NXP Semiconductors
Reference Manual

Document identifier: MCXW72RM
Rev. 4, 2025-12-11

MCX W72 Reference Manual

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Chapter 1
About This Manual

1.1 Audience

This reference manual (RM) is intended for system software, hardware developers, and applications programmers who need to develop products using this chip. It assumes that its users understand operating systems, microprocessor system design, and basic principles of software and hardware.

1.2 Organization

This manual has two main sets of chapters.

- Chapters in the first set contain information that applies to all components on the chip.
- Chapters in the second set are organized into functional groupings that detail particular areas of functionality.
  - Examples of these groupings are clocking, timers, and communication interfaces.
  - Each grouping includes chapters that provide a technical description of individual modules.

1.2.1 Attachments

This manual includes key information in the files attached to it. For example, memory map and I/O details. Use the content in these attachments in conjunction with this manual's content.

NOTE

Select the paperclip icon on the left side of the PDF window to see the list of attachments.

1.3 Module descriptions

Each module chapter has two main parts:

- The first section, *chip-specific [module name]* information, provides details such as the number of module instances on the chip and connections between that module and the other ones. Read this section *first* because its content is crucial for understanding the information in the other sections of the chapter.
- The subsequent sections provide general information about the module, including its signals, registers, and functional description.

The following figure shows you an example of this demarcation.

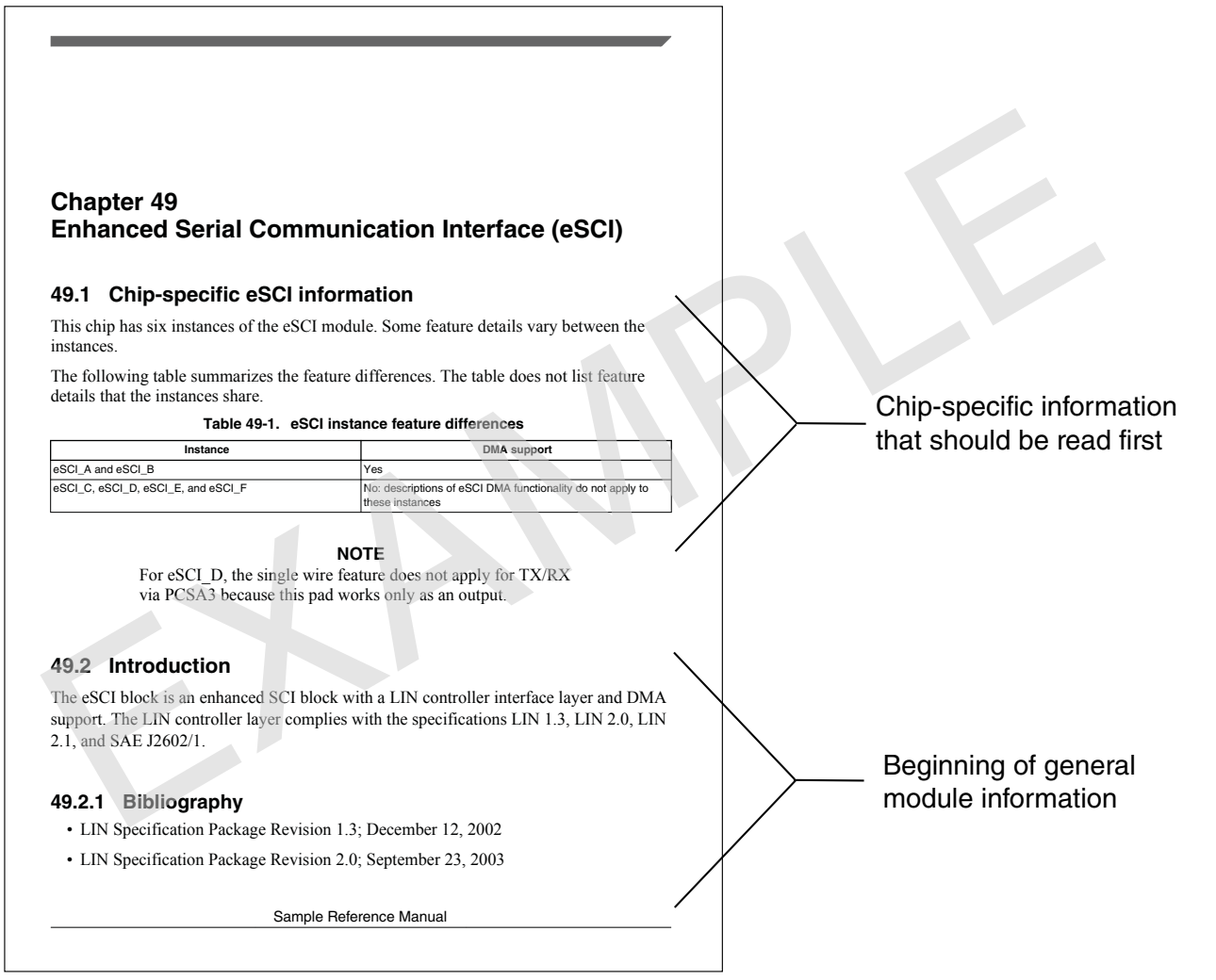

Figure 1. Example of chapter chip-specific information and general module information

1.3.1 Chip-specific information that clarifies content in the same chapter

The following figure shows an example of chip-specific information that clarifies general module information presented later in the chapter. In this case, the chip-specific register reset values supersede the reset values that appear in the register diagram.

System Integration Unit Lite2 (SIUL2)

Chapter 9
System Integration Unit Lite2 (SIUL2)

9.1 Chip-specific SIUL2 information

9.1.1 Feature configurations

In this device, the SIUL2_0 module instance does not support the following features described in the generic description:

- Interrupts
- DMA channels

9.1.2 Notes for IMCR

Out of reset, PA_00, PA_04, and PA_05 pads have JTAG input functionality selected by default. It should be disabled in the corresponding IMCR registers (IMCR61, IMCR60, and IMCR50 respectively) in order to use other functionality such as GPIO.

9.2 Introduction

9.2.1 Overview

The System Integration Unit Lite2 provides control over all the electrical pin controls and ports with 16 bits of bidirectional, general-purpose input and output signals. One of the most important functions of the SIUL2 is to enable the user to select the functions and electrical characteristics that appear on external device pins. It also controls the multiplexing of internal signals from one module to another and controls chip I/O. It supports as many as 32 external interrupts with trigger event configuration. The following figure is the block diagram of SIUL2 and its interfaces to other system components.

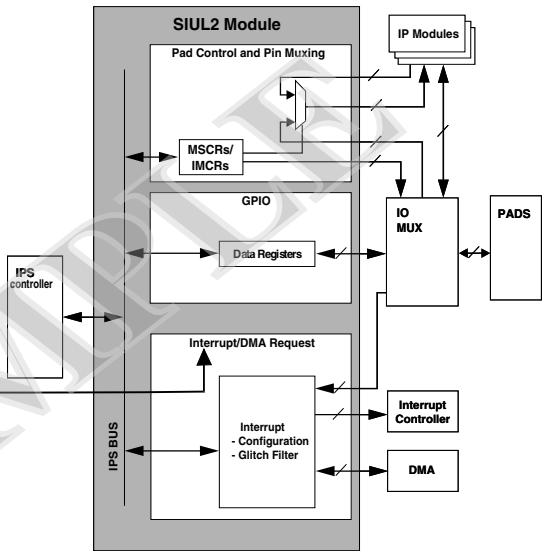

Figure 23. System Integration Unit Lite2 block diagram

This module provides dedicated pad control to general-purpose pads that can be configured as either inputs or outputs. The SIUL2 module provides registers that enable user software to read values from GPIO pads configured as inputs, and write values to GPIO pads configured as outputs:

- When configured as output, you can write to an internal register to control the state driven on the associated output pad.
- When configured as input, you can detect the state of the associated pad by reading the value from an internal register.
- When configured as input and output, the pad value can be read back, which can be used as a method of checking if the written value appeared on the pad.

To assist software development, GPIO data registers can be accessed using various mechanisms. These differing mechanisms allow support for port access or for bit manipulation without the need to use read-modify-write operations:

- Access to two 16-bit ports in one access
- Read/write access to a single bit
- A 16-bit port write with a bit mask, using single 32-bit access.

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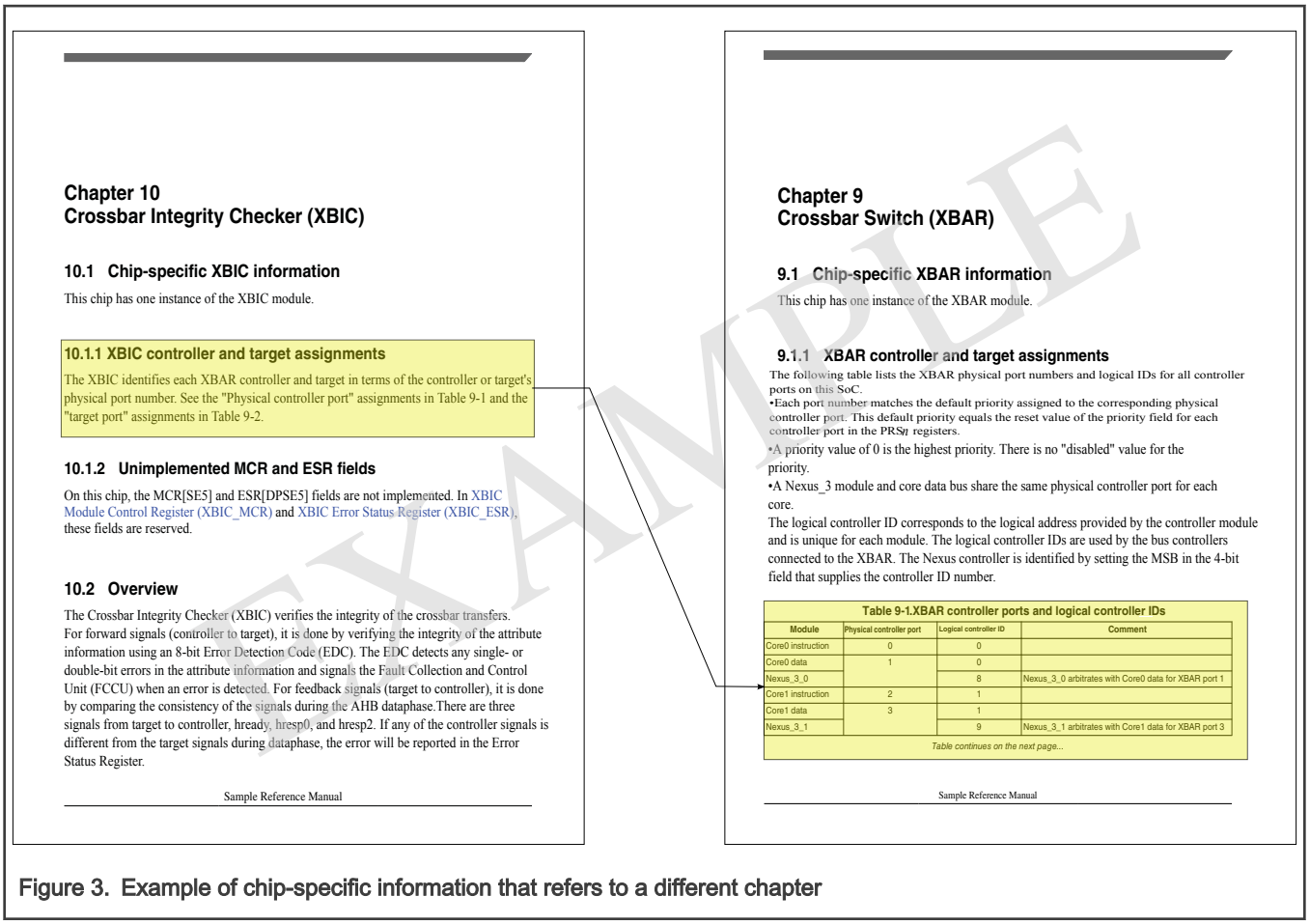
Figure 2. Example of chip-specific information that clarifies content in the same chapter

1.3.2 Chip-specific information that refers to a different chapter

Related chip-specific information may be provided in different chapters of the manual. The following figure shows an example of two such connected pieces of information. In this case, read both before you proceed.



Chapter 10
Crossbar Integrity Checker (XBIC)

10.1 Chip-specific XBIC information

This chip has one instance of the XBIC module.

10.1.1 XBIC controller and target assignments

The XBIC identifies each XBAR controller and target in terms of the controller or target's physical port number. See the "Physical controller port" assignments in Table 9-1 and the "target port" assignments in Table 9-2.

10.1.2 Unimplemented MCR and ESR fields

On this chip, the MCR[SE5] and ESR[DPSE5] fields are not implemented. In XBIC Module Control Register (XBIC_MCR) and XBIC Error Status Register (XBIC_ESR), these fields are reserved.

10.2 Overview

The Crossbar Integrity Checker (XBIC) verifies the integrity of the crossbar transfers. For forward signals (controller to target), it is done by verifying the integrity of the attribute information using an 8-bit Error Detection Code (EDC). The EDC detects any single- or double-bit errors in the attribute information and signals the Fault Collection and Control Unit (FCCU) when an error is detected. For feedback signals (target to controller), it is done by comparing the consistency of the signals during the AHB dataphase.There are three signals from target to controller, hready, hresp0, and hresp2. If any of the controller signals is different from the target signals during dataphase, the error will be reported in the Error Status Register.

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Chapter 9
Crossbar Switch (XBAR)

9.1 Chip-specific XBAR information

This chip has one instance of the XBAR module.

9.1.1 XBAR controller and target assignments

The following table lists the XBAR physical port numbers and logical IDs for all controller ports on this SoC.

- Each port number matches the default priority assigned to the corresponding physical controller port. This default priority equals the reset value of the priority field for each controller port in the PRSn registers.
- A priority value of 0 is the highest priority. There is no "disabled" value for the priority.
- A Nexus_3 module and core data bus share the same physical controller port for each core.

The logical controller ID corresponds to the logical address provided by the controller module and is unique for each module. The logical controller IDs are used by the bus controllers connected to the XBAR. The Nexus controller is identified by setting the MSB in the 4-bit field that supplies the controller ID number.

Table 9-1.XBAR controller ports and logical controller IDs

Module	Physical controller port	Logical controller ID	Comment
Core0 instruction	0	0	
Core0 data	1	0	
Nexus_3_0		8	Nexus_3_0 arbitrates with Core0 data for XBAR port 1
Core1 instruction	2	1	
Core1 data	3	1	
Nexus_3_1		9	Nexus_3_1 arbitrates with Core1 data for XBAR port 3

Table continues on the next page...

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EXAMPLE

Figure 3. Example of chip-specific information that refers to a different chapter

1.4 Register descriptions

Module chapters present register information in the following:

- Memory maps, which contain:
  - An offset from the module's base address
  - The mnemonic and name of each register
  - The width of each register (in bits)
  - The reset value of each register
- Register figures
- Field-description tables
- Associated text

The following figure shows register figure conventions used throughout the manual.

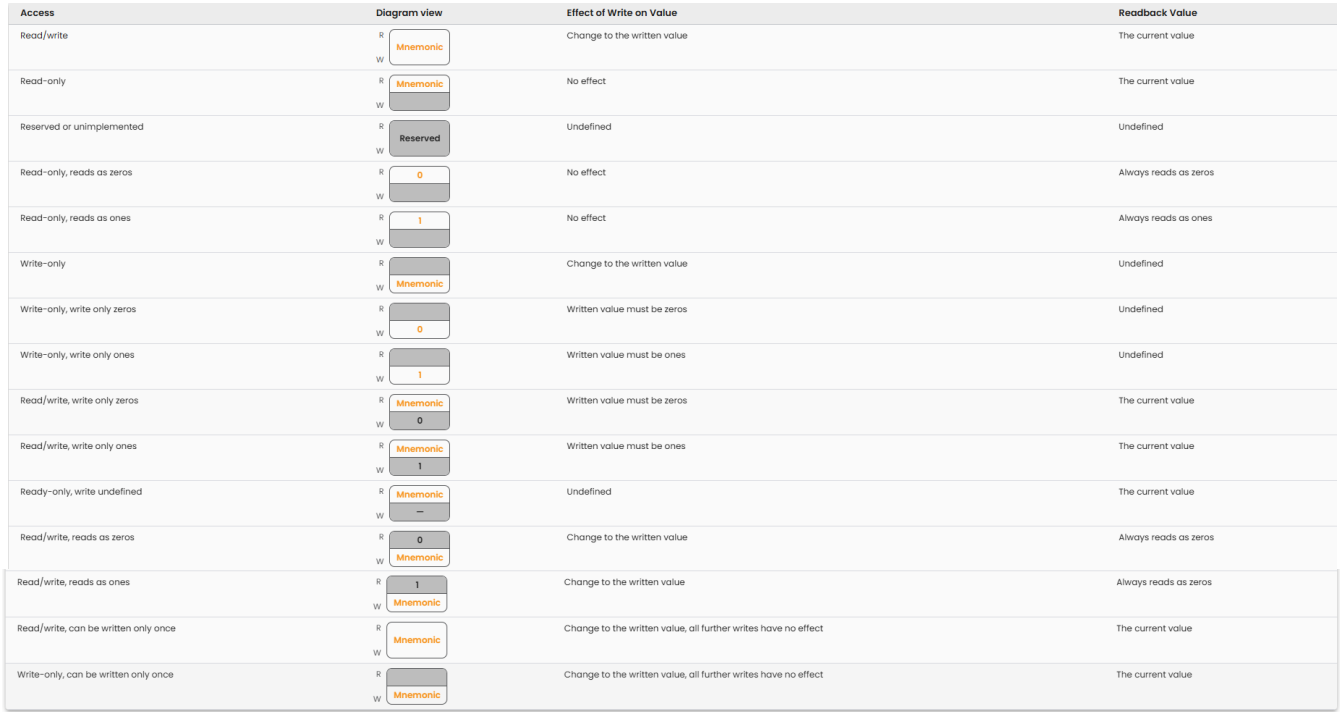


Figure 4. Register access types

NOTE

Reset values of reserved locations documented in this manual are subject to change and must not be used for diagnostic purposes.

Table 1. Modified write values

Modified write values	Description
Write one to clear	Writing a 1 clears the corresponding bit in the field to zero. Writting 0 has no effect.
Write one to set	Writing a 1 sets the corresponding bit in the field to one. Writting 0 has no effect.
Write one to toggle	Writing a 1 toggles the corresponding bit in the field. Writting 0 has no effect.
Write zero to clear	Writing a 0 clears the corresponding bit in the field to zero. Writting 1 has no effect.
Write zero to set	Writing a 0 sets to one the corresponding bit in the field to one. Writting 1 has no effect.
Write zero to toggle	Writing a 0 toggles the corresponding bit in the field. Writting 1 has no effect.
Write always clears	Writing any value clears all bits in the field to zeros.
Write always sets	Writing any value sets all bits in the field to ones.
Modification in an unspecified way	Writing any value modifies all bits in the field in an unspecified way.

Table continues on the next page...

Table 1. Modified write values (continued)

Modified write values	Description
Write the value as is	The written value is stored in the field as-is. The most common behavior for control and data registers.

Table 2. Read action

Read action	Description
Read to clear	The field is cleared to zeros after the read operation.
Read to set	The field is set to ones after the read operation.
Read to modify	The field is modified in an unspecified way after the read operation.
Read to modify external	The field, and possibly fields in other registers, are modified in an unspecified way after the read operation.
Read without any side effect	The field is not modified after the read operation. The most common behavior for control and data registers.

1.5 Conventions

1.5.1 Notes and cautions

Specific information is provided as part of notes and cautions throughout this manual.

NOTE

Emphasizes information that deserves extra attention.

CAUTION

Informs you of situations that could lead to highly undesirable outcomes—such as damage to the chip or irreversible malfunction.

1.5.2 Numbering systems

The following suffixes identify different numbering systems:

Table 3. Numbering systems

This suffix	Identifies a
b	Binary number. For example, the binary equivalent of the number 5 is mentioned as 101b. In some cases, *0b* is prefixed to binary numbers.
d	Decimal number. Decimal numbers are followed by this suffix only when there is a possibility of confusion. In general, decimal numbers are used without a suffix.
h	Hexadecimal number. For example, the hexadecimal equivalent of the number 60 is mentioned as 3Ch. In some cases, *0x* is prefixed to hexadecimal numbers.

1.5.3 Typographic notation

The following typographic notations are used throughout this document:

Table 4. Typographic notation

Example	Description
x and other italicized text	The italicized, lowercase *x* is used as a placeholder for replaceable numbers. In general, italicized text is used for titles of publications and for emphasis. Additionally, italics could be used for metasymbols in syntax descriptions. Plain lowercase letters are used as placeholders for single letters and numbers.
`code font`	Fixed-width font (such as Courier) used for code. It is used for a letter, word, or phrase that you want the user to type. For example, "Type `Read` and press Enter." This type of font is also used for instruction mnemonics, directives, symbols, subcommands, parameters, operators, computer-language elements, code listings, commands that appear in running text, and for sample code. Instruction mnemonics and directives in text and tables are mentioned in all caps; for example, BSR.
SR[SCM]	A mnemonic in square brackets represents the name of a register field. This example refers to the Scaling Mode (SCM) field in the Status Register (SR).
REVNO[6:4], XAD[7:0]	Numbers in brackets that are separated by a colon represent either: • A subset of a register's named field For example, REVNO[6:4] refers to bits 6-4 that are part of the COREREV field occupying bits 6-0 of the REVNO register. • A continuous range of individual signals of a bus For example, XAD[7:0] refers to signals 7-0 of the XAD bus.
MOD.REG	A period separates the elements of a hierarchy: subsystem.module.register. For example: • SWT.TO means that the TO register is located in the SWT module. • SMU.XRDC.CR means that the CR register is located in the XRDC module within the SMU subsystem.

1.5.4 Special terms

The following terms have special meanings.

Table 5. Special terms

Term	Meaning
Asserted	Refers to the state of a signal as follows: • An active-high signal is asserted when high (1). • An active-low signal is asserted when low (0).
Deasserted	Refers to the state of a signal as follows: • An active-high signal is deasserted when low (0). • An active-low signal is deasserted when high (1). In some cases, deasserted signals are described as *negated*.
Reserved	Refers to memory space, register, field, or programming setting. Writes to a reserved location can result in unpredictable functionality or behavior. You must:

Table continues on the next page...

Table 5. Special terms (continued)

Term	Meaning
	• Before writing to a location which contain reserved bits user must make sure the write operation will write the reserved bit with value specified as the reset value in NXP reference manual. • Consider undefined locations in memory to be reserved as reset value 0 shall be assumed. You might get a BERR(transfer error) response on access to undefined locations in memory. • If user reads data from memory area containing reserved bit, the value of reserved bits should be ignored and not used for any functional purposes. **NOTE** BootROM could modify the reserved bit values after reset. Please refer to the BootROM settings attachment.
Write 1 to clear (w1c)	Refers to the access type of a register field that is used to clear the field by writing the value 1 to it.
Undefined (u)	Refers to undefined reset values

1.6 Editorial changes

Each new release of this document includes editorial improvements such as:

- Spelling
- Grammar
- Punctuation
- Voice
- Tense
- Capitalization
- Formatting
- Presentation
- Navigation

Chapter 2
Introduction

2.1 Introduction

The MCX W72 microcontroller is a low-power, highly secure, Arm® Cortex-M33-based wireless device targeting these applications:

- Smart Home IoT
  - Smart Home environmental, occupancy and security sensors
  - Home Gateways and Bridges
  - Smart Lighting
  - Smart Plugs
  - Access Control
  - HVACs and Thermostats
  - Window Shades
- Industrial/IoT
  - Positioning/Localization
  - Building Control and Monitoring
  - Process/Factory Automation
  - Access Control

The device includes these key features:

Highly secure	• Arm Trustzone-M • Trusted resource domain controller (TRDC) providing access policies for embedded memory and peripherals • NXP's EdgeLock® Secure Enclave providing secure key management and storage plus hardware acceleration of cryptographic algorithms • Internal flash memory with on-the-fly encryption and decryption using a PRINCE XEX block cipher mode • Factory Root of Trust programming • Secure boot, debug and firmware updates
Power-efficient operating modes	• Less than 35 µA/MHz active current at 96 MHz • Less than 2 µA in Power Down mode with FRO32K active and 32 KB SRAM retention • Less than 1 µA in Deep Power Down mode with FRO32K active

2.2 Functional overview

The following figure shows a top-level organization of the modules within the device organized by functional category.

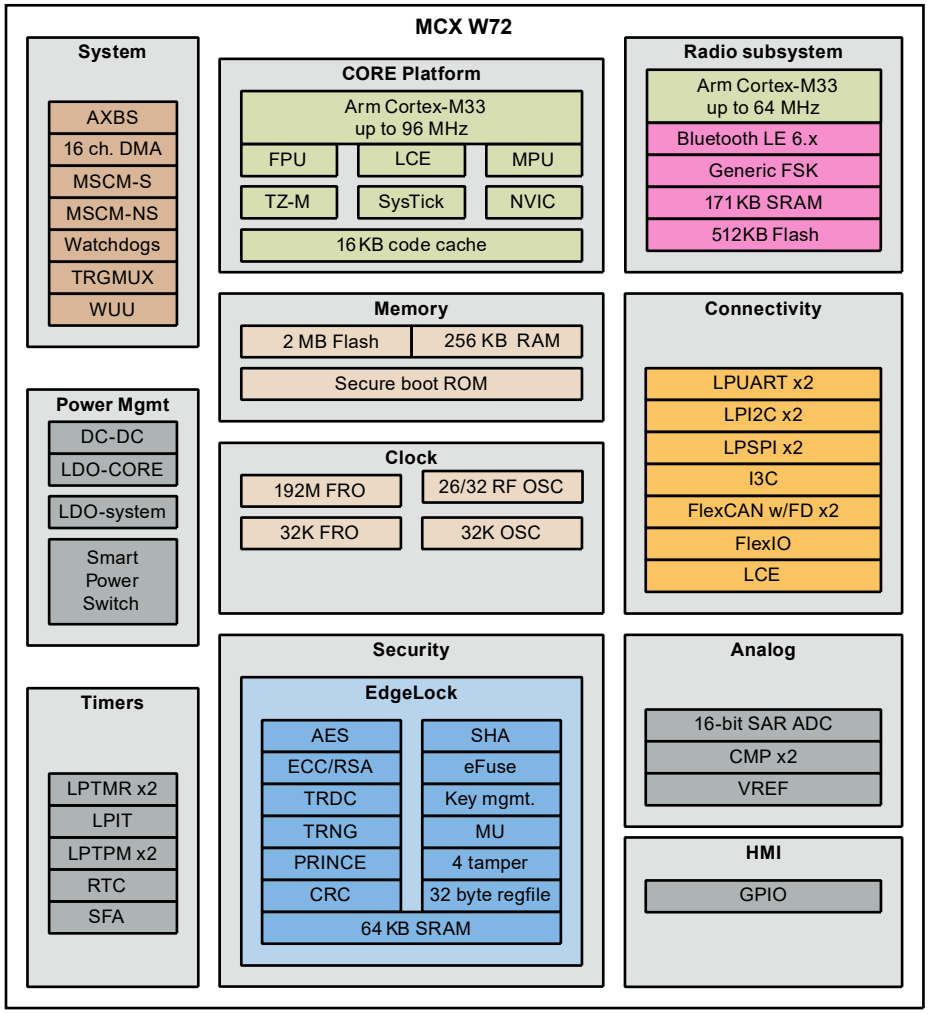


Figure 5. Features block diagram

Table 6. Module functional categories

Module category	Description
Core	The Arm® Cortex®-M33 is a member of the Cortex® M Series of processors targeting microcontroller cores focused on cost sensitive, deterministic, interrupt driven environments. The Cortex® M33 processor is based on the Arm®v8-M Architecture and ThumbR-2 ISA and is upward compatible with the Cortex® M7, M4, M3, M1 and M0/M0+. **LCE Accelerator** - LCE is a SIMD processor with 32-bit data path supporting 4x8-bit, 2x16-bit and 1x32-bit SIMD operations. Most C/C++ integer math, floating-point math and logical operations are supported in SIMD form Special Arithmetic Unit (SAU) supporting efficient 1/x, sqrt(x), 1/sqrt(x) and exp(j*w*n+p) operations.
System	• AHB Cross-Bar Switch (AXBS)

Table continues on the next page...

Table 6. Module functional categories (continued)

Module category	Description
	• Core Mode Controller (CMC) • Direct Current / Direct Current Converter - Low Voltage (DCDC-LV) • Direct Memory Access (DMA) controller • External Watchdog Monitor (EWM) • Low Drop Out Regulator - Core (LDO_CORE) • Low Drop Out Regulator - System (LDO_SYS) • Miscellaneous System Control Module (MSCM) • Secure Miscellaneous System Control Module (SMSCM) • Semaphore Module (SEMA42) • System Power Controller (SPC) • Trigger Multiplexer (TRGMUX) • Wake-Up Unit (WUU) • Watchdog (WDOG)
Memory	• Flash Management Unit (FMU) • Read Only Memory - Boot (ROM_BOOT) • Register File - REGFILE • Static Random Access Memory (SRAM)
Clock	• Crystal Oscillator - Real Time Clock (OSC_RTC) • Free Running Oscillator - 32 kHz (FRO_32K) • Free Running Oscillator - 16 kHz (FRO_16K) • Free Running Oscillator - 192 MHz (FRO_192M) • Radio Free Running Oscillator - 192 MHz (RFRO_192M) • Module Reset and Clock Control (MRCC) • System Clock Generator (SCG) • Signal Frequency Analyzer (SFA)
Security	• EdgeLock Secure Enclave • Trusted Resource Domain Controller (TRDC) • Cyclic Redundancy Check (CRC) • Non-Volatile Memory PRINCE XEX (NPX) encryption/decryption • Up to 4 digital tamper pins
Timer	• Real Time Clock (RTC) • Low-Power Timer (LPTMR)

Table continues on the next page...

Table 6. Module functional categories (continued)

Module category	Description
	• Low Power Periodic Interrupt Timers (LPIT) • Timer/PWM Module (TPM)
Communication	• Flexible Input/Output (FlexIO) • Low Power Inter-Integrated Circuit (LPI2C) • Improved Inter-Integrated Circuit (I3C) • Low Power Serial Peripheral Interface (LPSPI) • Low Power Universal Asynchronous Receive/Transmit (LPUART)
HMI	• General Purpose Input/Output (GPIO) • Port Control (PORT)
Analog	• Analog-to-Digital Converter - General Purpose (ADC) • Low Power Comparator (LPCMP) • Voltage Reference (VREF)
Radio	• Radio Frequency - 2.4 GHz (RF-2.4G)

2.2.1 Core

The following core modules are available on this device.

Table 7. Core modules

Module	Description
CPU0	CPU0 is an Arm® Cortex®-M33, a member of the Cortex® M Series of processors targeting microcontroller cores focused on cost-sensitive, deterministic, interrupt-driven environments. **LCE Accelerator** - LCE is a SIMD processor with 32-bit data path supporting 4x8-bit, 2x16-bit and 1x32-bit SIMD operations. Most C/C++ integer math, floating-point math and logical operations are supported in SIMD form Special Arithmetic Unit (SAU) supporting efficient 1/x, sqrt(x), 1/sqrt(x) and exp(j*w*n+p) operations.
Code Cache Memory (CACHE-CODE)	The CACHE-CODE is an 16-KB cache for memory attached to the Code bus.
Digital Signal Processing Extensions (DSP)	The Cortex-M33 processor features extended single-cycle Multiply Accumulate (MAC) instructions, optimized Single Instruction Multiple Data (SIMD) arithmetic, and saturating arithmetic instructions.
Floating Point Unit (FPU)	The FPU provides single-precision floating point computation compliant to the IEEE Standard for Floating-Point Arithmetic (IEEE 754).
Memory Protection Unit (MPU)	The MPU provides support for eight unified protection regions, overlapping protection regions with ascending region priority, and access permissions. MPU mismatches and permission violations

Table continues on the next page...

Table 7. Core modules (continued)

Module	Description
	invoke the HardFault handler. See the Armv8-M Architecture Reference Manual for more information.
Nested Vectored Interrupt Controller (NVIC)	The Armv8-M exception model and Nested-Vectored Interrupt Controller (NVIC) implement a relocatable vector table supporting many external interrupts, a single non-maskable interrupt (NMI), and priority levels.
System Timer (SysTick)	See the Armv8-M Architecture Reference Manual for more information about this system timer.
TrustZone - M (TZM)	The TZM is an Arm security feature related to hardware-enforced access control mechanisms.

2.2.2 Debug

The following Debug (DBG) modules are available on this device:

Table 8. Debug modules

Module	Description
Cross Trigger Interface (CTI)	The CTI enables the device's debug logic to interact with (cross trigger) each other.
Data Watchpoint and Trace (DWT)	The DWT is a generic name for several modules that allow debug access of the Cortex-M33. The DWT is composed of the Debug Watchpoint and Trace (DWT) module and the Flash Patch and Breakpoint (FPB) unit.
Debug Access Port (DAP)	The DAP enables real-time access to the device registers from an external debugger without halting the processor cores.
Instruction Trace Macrocell (ITM)	The ITM provides a memory-mapped register interface that applications can use to write logging or event words for profiling software.
Serial Wire Debug (SWD)	The SWD is a serial communication interface used for debugging devices with multiple cores while only requiring a single external interface.
Trace Port Interface Unit (TPIU)	The TPIU acts as a bridge between the on-chip trace data from the modules such as the Embedded Trace Macrocell (ETM) or the Instrumentation Trace Macrocell (ITM), which have separate system IDs, to the external world.

2.2.3 System

The following System (SYS) modules are available on this device:

Table 9. System modules

Module	Description
AHB Cross-Bar Switch (AXBS)	The AXBS connects bus masters and bus slaves, allowing all bus masters to access different bus slaves simultaneously and providing arbitration among the bus masters when they access the same slave.
Core Mode Controller (CMC)	The CMC provides control and protection on entry and exit to each power mode, control for the System Power Controller (SPC), and reset entry and exit for the complete device.
Direct Current / Direct Current Converter - Low Voltage (DCDC-LV)	An efficient voltage converter for generating the low voltage supply for internal Low Drop Out (LDO) regulators.
Direct Memory Access 3 (DMA3) controller	The DMA3 controller provides programmable channels with transfer control descriptors for data movement via dual-address transfers for 8-, 16-, 32- and 128-bit data values.
External Watchdog Monitor (EWM)	Similar to the Watchdog timer, the EWM monitors internal and external system operations and forces a reset in case of failure.
Low Drop Out Regulator - Core (LDO-CORE)	A voltage regulator for generating the core voltage for the device.
Low Drop Out Regulator - System (LDO-SYS)	A voltage regulator for generating the system voltage for the device.
Miscellaneous System Control Module (MSCM)	The MSCM contains CPU configuration registers and on-chip memory controller registers.
Secure Miscellaneous System Control Module (SMSCM).	The SMSCM contains configuration registers related to security.
Semaphore Module (SEMA42)	The SEMA42 is a memory-mapped module that provides robust hardware support needed in multi-core systems for implementing semaphores and provides a simple mechanism to achieve "lock and unlock" operations via a single write access. The hardware semaphore module provides hardware-enforced gates as well as other useful system functions related to the gating mechanisms.
System Power Controller (SPC)	The SPC provides control over the operation and configuration of the system power generation modules to optimize power consumption for the level of functionality needed.
Trigger Multiplexer (TRGMUX)	The TRGMUX allows the trigger output of one peripheral to be connected to the trigger input of a second peripheral.
Wake-Up Unit (WUU)	The WUU provides a mechanism for external or internal sources to initiate the exit of certain low-power modes.
Watchdog (WDOG)	The WDOG monitors internal system operation and forces a reset in case of failure. It can run from multiple clocks with a programmable refresh window to detect deviations in program flow or system frequency.

2.2.4 Clocks

The following Clock (CLK) modules are available on this device:

Table 10. Clock sources

Module	Description
Crystal Oscillator - Radio Frequency (OSC-RF)	The OSC-RF, in conjunction with an external crystal or resonator, generates a reference clock for the Radio that can also be used by the device.
Crystal Oscillator - Real Time Clock (OSC-RTC)	The OSC-RTC oscillator, in conjunction with an external 32 kHz crystal, generates a 32 kHz reference clock for the RTC that can also be used by the radio and other modules of the device.
Free Running Oscillator - 32 kHz (FRO-32K)	The FRO-32K is an internal clock source that generates a 32 kHz reference clock for the RTC that can also be used by the radio and other modules of the device.
Free Running Oscillator - 16 kHz (FRO-16K)	The FRO-16K is an internal clock source that generates a 16 kHz reference clock that is used by the Smart Power Switch domain.
Free Running Oscillator - 192 MHz (FRO-192M)	The FRO-192M is an internal clock source that generates a 192 MHz frequency for use by the modules other than the radio of the device.
Radio Free Running Oscillator - 192 MHz (RFRO-192M)	The RFRO-192M is an internal clock source that generates a 192 MHz frequency for use by the radio module of the device.
Module Reset and Clock Control (MRCC)	The MRCC provides the user with access to the configuration control registers for the peripherals of the device.
System Clock Generator (SCG)	The SCG provides the user with access to the configuration control registers for the system level clock sources.
Signal Frequency Analyzer (SFA)	The SFA provides facilities for measurement of clock period/frequency as well as time between triggers.

2.2.5 Memory

The following Memory and Memory Interface (MEM) modules are available on this device:

Table 11. Memory modules

Module	Description
Flash Memory	Programmable flash memory — non-volatile flash memory that can store executable program code or data.
Flash Management Unit (FMU)	The FMU manages the interface between the device and the on-chip flash memory.
Read Only Memory - Boot (ROM-BOOT)	Provisions the internal flash with an embedded firmware image during manufacturing or at any time during the life of the device.
Register File - REGFILE	32-byte register file that can be retained in all power modes.
Static Random Access Memory (SRAM)	Internal system SRAM memory. Each individual block of SRAM can be configured to be retained in low-power modes.

2.2.6 Security

The following Security modules are available on this device:

Table 12. Security modules

Module	Description
Cyclic Redundancy Check (CRC)	Hardware CRC generator provides error detection for all single, double, and many multi-bit errors.
Non-Volatile Memory PRINCE XEX (NPX)	Provides on-the-fly encryption/decryption of the embedded flash contents using a PRINCE XEX block cipher.
Trusted Resource Domain Controller (TRDC)	Provides programmable access control mechanisms for independent processing domains. Unique isolation and access mechanisms for memory and peripheral resources are configured on a domain basis.

2.2.7 Timers

The following Timer (TMR) modules are available on this device:

Table 13. Timer modules

Module	Description
Real Time Clock (RTC)	32-bit seconds counter with 32-bit Alarm Independent power supply
Low-Power Timer (LPTMR)	32-bit time or pulse counter with compare feature
Low Power Periodic Interrupt Timers (LPIT)	Four general purpose interrupt timers with 32-bit counter resolution and DMA support
Timer/PWM Module (TPM)	Six channel timer with DMA support for electric motor and power management applications. Clocked by an asynchronous clock that can remain enabled in low power modes.

2.2.8 Communications

The following Communication (COM) modules are available on this device:

Table 14. Communication modules

Module	Description
Flexible Input/Output (FlexIO)	Functions in Sleep/Deep Sleep modes. DMA support
Low Power Inter-Integrated Circuit (LPI2C)	Allows communication between a number of devices. Also supports the System Management Bus (SMBus) Specification, version 2.
Improved Inter-Integrated Circuit (I3C)	I3C is an extension of the I2C bus protocol supporting higher speeds.

Table continues on the next page...

Table 14. Communication modules (continued)

Module	Description
Low Power Serial Peripheral Interface (LPSPI)	Synchronous serial bus for communication to an external device.
Low Power Universal Asynchronous Receive/ Transmit (LPUART)	Asynchronous serial bus communication interface with programmable 8- or 9-bit data format.

2.2.9 Radio

The following are Radio Frequency (RF) modules.

Table 15. Radio modules

Module	Description
Radio Frequency - 2.4 GHz (RF-2.4G)	The 2.4 GHz band radio covers 2.36-2.4835 GHz and is built to support multiple protocols: • Bluetooth Low Energy V6.0 • Generic 2-level FSK/GFSK/MSK/GMSK • IEEE 802.15.4-2015

2.2.10 Human Machine Interface

The following Human Machine Interfaces (HMI) modules are available on this device:

Table 16. HMI modules

Module	Description
General Purpose Input/Output (GPIO)	All General Purpose Input / Output (GPIO) pins are capable of interrupt and DMA request generation.
Port Control	The Port Control (PORT) module provides support for pad control functions.

2.2.11 Analog

The following Analog (ANA) modules are available on this device:

Table 17. Analog modules

Module	Description
Dual Single End Analog-to-Digital Converter (ADC)	A Dual 16-bit Single End Successive-Approximation Register (SAR) Analog-to-Digital Converter (ADC)
Low Power Comparator (LPCMP)	Compares two analog input voltages across the full range of the supply voltage.
Voltage Reference (VREF)	The VREF module supplies an accurate voltage output that can be used by internal or external peripherals.

2.3 Block diagram

The following figure shows a detailed block diagram of the device.

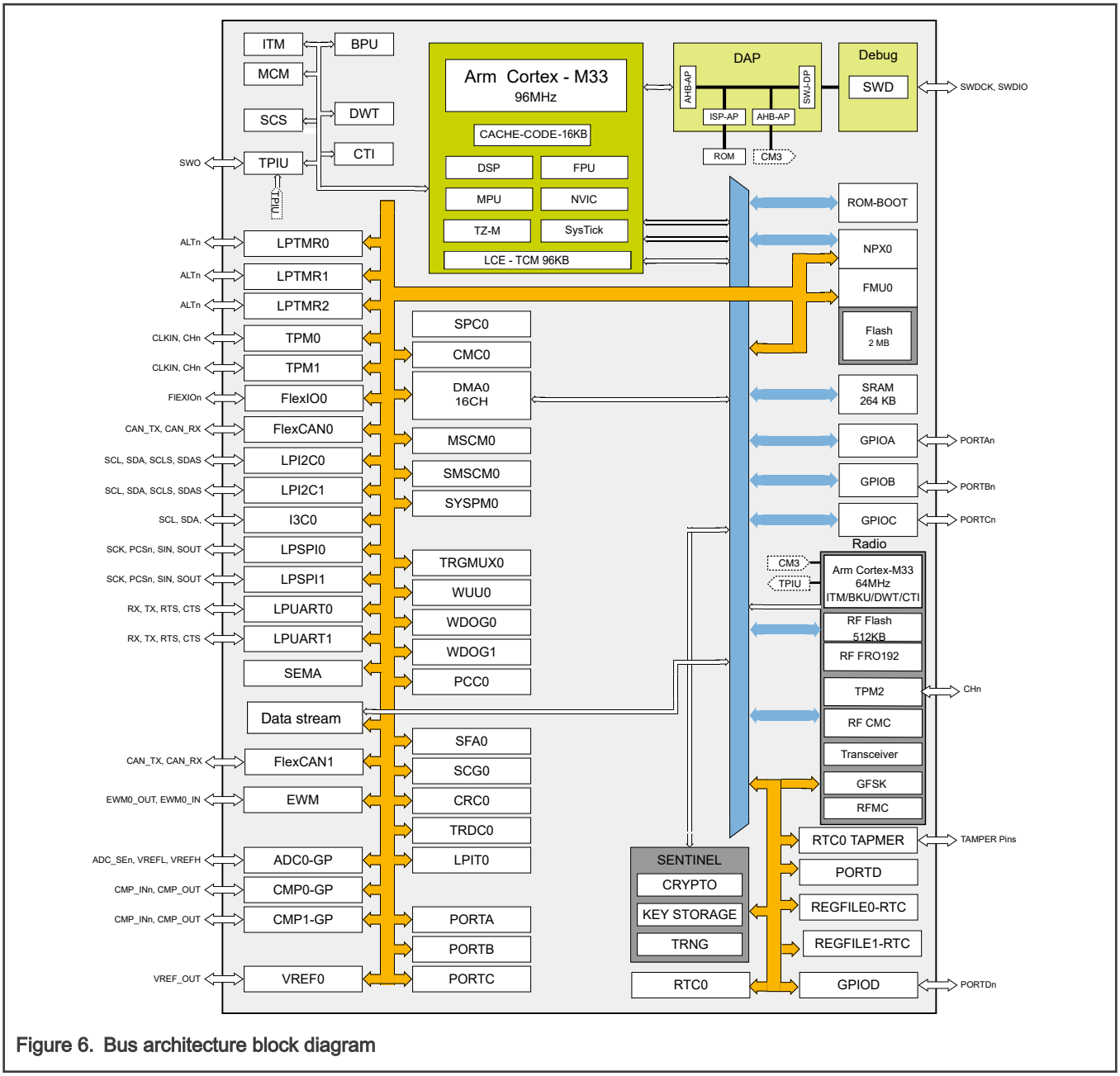


Figure 6. Bus architecture block diagram

2.4 Ordering information

The following table summarizes the part numbers of the devices covered by this document.

Table 18. Ordering information [1]

Part number	Marking	Core Speed (MHz)	Flash	SRAM	GPIOs	Pin Count	Package	Packing	LCE	CAN
MCXW727DMFTBT	MCXW727DMFTB	96MHz	2 MB + 512 KB	264 KB + 171 KB	29	48	HVQFN	Tray	Yes	No
MCXW727AMFTBT	MCXW727AMFTB	96MHz	2 MB + 512 KB	264 KB + 171 KB	29	48	HVQFN	Tray	No	No
MCXW727CMFTBT	MCXW727CMFTB	96MHz	2 MB + 512 KB	264 KB + 171 KB	29	48	HVQFN	Tray	Yes	Yes
MCXW727DMFTBR	MCXW727DMFTB	96MHz	2 MB + 512 KB	264 KB + 171 KB	29	48	HVQFN	Tape and Reel	Yes	No
MCXW727AMFTBR	MCXW727AMFTB	96MHz	2 MB + 512 KB	264 KB + 171 KB	29	48	HVQFN	Tape and Reel	No	No
MCXW727CMFTBR	MCXW727CMFTB	96MHz	2 MB + 512 KB	264 KB + 171 KB	29	48	HVQFN	Tape and Reel	Yes	Yes

1. To confirm current availability of orderable part numbers, go to http://www.nxp.com and perform a part number search.

Chapter 3
Core Overview

3.1 Introduction

This section covers the core modules included in this device.

3.2 Cortex-M33 Code and System Buses

The Cortex-M33 processor implements a modified Harvard memory architecture using two 32-bit bus interfaces: the Code and System buses. The bus interfaces are activated by address range and can include both instruction fetches and operand data references on a given bus port. (A traditional Harvard architecture strictly separates instruction fetches and operand data references onto specific bus ports regardless of access address.)

The Code bus is typically used for instruction fetching and data accesses of PC-relative data, while the system bus is typically used for operand data references to the on- and off-chip memories and peripheral accesses. The bus structure fully supports concurrent instruction fetch and data accesses, but the Cortex-M33 implementations can generate both types of references on each bus.

NOTE

It is recommended that performance critical code be located such that it fetches from the Code bus interface as defined by addresses < 0x2000_0000.

3.2.1 Code Bus access

Code Bus accesses are routed to the Code TCM if they are mapped to that space. All other Code Bus accesses are routed to the Code Cache Controller. This controller then processes the cacheable accesses as needed, while bypassing the non-cacheable accesses or forwarding the cache write-through and cache miss accesses to the downstream memories through the master port of this cache controller.

3.2.2 System bus access

System Bus accesses are routed to the System TCM if they are mapped to that space. All other System Bus accesses are routed to the target address in destination memories through S1 port.

3.2.3 Access control

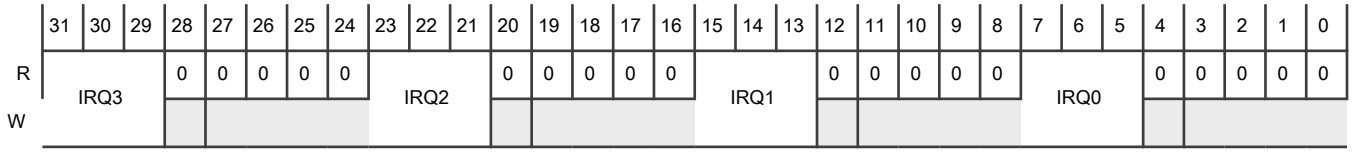
All core Code and System Bus accesses are checked by the core access control logic, that is, IDAU/SAU and MPU. All requests that miss or bypass the cache are checked by downstream TRDC logic. The caches include protection control signals (HPROT[3:0]) and processing domain bits as part of the tags. If a fetch address hits the cache but the protection control and/or domain bits are different, the cache controller forces a miss with the allocate location the same as the address hit location in the cache. This policy allows all the downstream checks to take place, and this new miss is loaded in the cache with the updated protection control and domain bits overwriting the line with the same address. This keeps the cache coherent while always checking accesses that need to see the downstream checks.

All requests are checked by normal platform slave bus checks in the corresponding Memory Block Controller (MBC).

3.3 Nested Vectored Interrupt Controller (NVIC)

3.3.1 Interrupt priority levels

This device supports 8 priority levels for interrupts. Therefore, in the NVIC each source in the IPR registers contains 3 bits. For example, IPR0 is shown below:



3.3.2 Non-Maskable Interrupt (NMI) configuration

The Non-Maskable Interrupt (NMI) request to the NVIC is controlled by the external NMI_b signal. The pin the NMI_b signal is multiplexed on, must be configured for the Non-Maskable Interrupt function to generate the non-maskable interrupt request.

3.3.3 Interrupt channel assignments

The interrupt source assignments are defined in the following table.

- Vector number — the value stored on the stack when an interrupt is serviced.
- IRQ number — non-core interrupt source count, which is the vector number minus 16.

The IRQ number is used within Arm's NVIC documentation.

Table 20. Interrupt Vector Assignments

Address	Vector	IRQ	NVIC non-IPR register number	NVIC IPR register number	Alias	Source Description
0000_0000	0	-	-	-	Cortex-M33	Initial Stack Pointer
0000_0004	1	-	-	-	Cortex-M33	Initial Program Counter
0000_0008	2	-	-	-	Cortex-M33	Non-Maskable Interrupt (NMI)
0000_000C	3	-	-	-	Cortex-M33	Hard Fault
0000_0010	4	-	-	-	Cortex-M33	MemManage Fault
0000_0014	5	-	-	-	Cortex-M33	Bus Fault / TRDC
0000_0018	6	-	-	-	Cortex-M33	Usage Fault
0000_001C	7	-	-	-	Cortex-M33	Secure Fault
0000_0020	8	-	-	-	Reserved	-
0000_0024	9	-	-	-	Reserved	-
0000_0028	10	-	-	-	Reserved	-
0000_002C	11	-	-	-	Cortex-M33	Supervisor Call (SVCall)
0000_0030	12	-	-	-	Cortex-M33	Debug Monitor
0000_0034	13	-	-	-	Reserved	-
0000_0038	14	-	-	-	Cortex-M33	Pendable request for system service (Penable SrvReq)
0000_003C	15	-	-	-	Cortex-M33	System Tick Timer
0000_0040	16	0	0	0	Cortex-M33	Cross Trigger Interface interrupt

Table continues on the next page...

Table 20. Interrupt Vector Assignments (continued)

Address	Vector	IRQ	NVIC non-IPR register number	NVIC IPR register number	Alias	Source Description
0000_0044	17	1	0	0	CMC0	Core Mode Controller interrupt
0000_0048	18	2	0	0	DMA0	DMA0 channel 0 error or transfer complete
0000_004C	19	3	0	0	DMA0	DMA0 channel 1 error or transfer complete
0000_0050	20	4	0	1	DMA0	DMA0 channel 2 error or transfer complete
0000_0054	21	5	0	1	DMA0	DMA0 channel 3 error or transfer complete
0000_0058	22	6	0	1	DMA0	DMA0 channel 4 error or transfer complete
0000_005C	23	7	0	1	DMA0	DMA0 channel 5 error or transfer complete
0000_0060	24	8	0	2	DMA0	DMA0 channel 6 error or transfer complete
0000_0064	25	9	0	2	DMA0	DMA0 channel 7 error or transfer complete
0000_0068	26	10	0	2	DMA0	DMA0 channel 8 error or transfer complete
0000_006C	27	11	0	2	DMA0	DMA0 channel 9 error or transfer complete
0000_0070	28	12	0	3	DMA0	DMA0 channel 10 error or transfer complete
0000_0074	29	13	0	3	DMA0	DMA0 channel 11 error or transfer complete
0000_0078	30	14	0	3	DMA0	DMA0 channel 12 error or transfer complete
0000_007C	31	15	0	3	DMA0	DMA0 channel 13 error or transfer complete
0000_0080	32	16	0	4	DMA0	DMA0 channel 14 error or transfer complete
0000_0084	33	17	0	4	DMA0	DMA0 channel 15 error or transfer complete
0000_0088	34	18	0	4	EWM0	External Watchdog Monitor interrupt
0000_008C	35	19	0	4	MCM0	Miscellaneous Control Module0 interrupt
0000_0090	36	20	0	5	MSCM0	Miscellaneous System Control Module0 interrupt
0000_0094	37	21	0	5	SPC0	System Power Controller0 interrupt
0000_0098	38	22	0	5	WUU0	Wake Up Unit0 interrupt
0000_009C	39	23	0	5	WDOG0	Watchdog0 interrupt
0000_00A0	40	24	0	6	WDOG1	Watchdog1 interrupt
0000_00A4	41	25	0	6	SCG0	System Clock Generator0 interrupt
0000_00A8	42	26	0	6	SFA0	System Frequency Analyzer0 interrupt
0000_00AC	43	27	0	6	FMU0	Flash Memory Unit0 interrupt
0000_00B0	44	28	0	7	SNT0	Sentinel command interface interrupt
0000_00B4	45	29	0	7	SNT0	Sentinel secure interrupt
0000_00B8	46	30	0	7	SNT0	Sentinel non-secure interrupt

Table continues on the next page...

Table 20. Interrupt Vector Assignments (continued)

Address	Vector	IRQ	NVIC non-IPR register number	NVIC IPR register number	Alias	Source Description
0000_00BC	47	31	0	7	TRDC0	Trusted Resource Domain Controller0 interrupt
0000_00C0	48	32	1	8	RTC0	Real Time Clock0 alarm interrupt
0000_00C4	49	33	1	8	RTC0	Real Time Clock0 seconds interrupt
0000_00C8	50	34	1	8	LPTMR0	Low Power Timer0 interrupt
0000_00CC	51	35	1	8	LPTMR1	Low Power Timer1 interrupt
0000_00D0	52	36	1	9	LPIT0	Low-Power Periodic Interrupt Timer0 interrupt
0000_00D4	53	37	1	9	TPM0	Timer / PWM Module0 interrupt
0000_00D8	54	38	1	9	TPM1	Timer / PWM Module1 interrupt
0000_00DC	55	39	1	9	LPI2C0	Low-Power Inter Integrated Circuit0 interrupt
0000_00E0	56	40	1	10	LPI2C1	Low-Power Inter Integrated Circuit1 interrupt
0000_00E4	57	41	1	10	I3C0	Improved Inter Integrated Circuit0 interrupt
0000_00E8	58	42	1	10	LPSPI0	Low-Power Serial Peripheral Interface0 interrupt
0000_00EC	59	43	1	10	LPSPI1	Low-Power Serial Peripheral Interface1 interrupt
0000_00F0	60	44	1	11	LPUART0	Low-Power Universal Asynchronous Receive/ Transmit0 interrupt
0000_00F4	61	45	1	11	LPUART1	Low-Power Universal Asynchronous Receive/ Transmit1 interrupt
0000_00F8	62	46	1	11	FLEXIO0	Flexible Input/Output interrupt
0000_00FC	63	47	1	11	CAN0	Controller Area Network interrupt
0000_0100	64	48	1	12	RF-2.4G	Radio IMU interrupt0 (msg_rdy_imu)
0000_0104	65	49	1	12	RF-2.4G	Radio IMU interrupt1(msg_space_avail_imu)
0000_0108	66	50	1	12	RF-2.4G	Radio NBU timeout interrupt
0000_010C	67	51	1	12	RF-2.4G	Radio FMU interrupt
0000_0110	68	52	1	13	RF-2.4G	Radio WOR RX FAIL interrupt
0000_0114	69	53	1	13	RF-2.4G	Radio Frequency 2.4GHz - 802.15.4 Link Layer interrupt
0000_0118	70	54	1	13	RF-2.4G	Radio Frequency 2.4GHz - Generic Link Layer interrupt
0000_011C	71	55	1	13	RF-2.4G	Radio Frequency 2.4GHz - BRIC interrupt
0000_0120	72	56	1	14	RF-2.4G	Radio Transceiver - Radio LANT_SW interrupt
0000_0124	73	57	1	14	RF-2.4G	RFMC interrupt
0000_0128	74	58	1	14	DSB	Data Stream Buffer interrupt

Table continues on the next page...

Table 20. Interrupt Vector Assignments (continued)

Address	Vector	IRQ	NVIC non-IPR register number	NVIC IPR register number	Alias	Source Description
0000_012C	75	59	1	14	GPIOA	General Purpose Input/Output A interrupt 0
0000_0130	76	60	1	15	GPIOA	General Purpose Input/Output A interrupt 1
0000_0134	77	61	1	15	GPIOB	General Purpose Input/Output B interrupt 0
0000_0138	78	62	1	15	GPIOB	General Purpose Input/Output B interrupt 1
0000_013C	79	63	1	15	GPIOC	General Purpose Input/Output C interrupt 0
0000_0140	80	64	2	16	GPIOC	General Purpose Input/Output C interrupt 1
0000_0144	81	65	2	16	GPIOD	General Purpose Input/Output D interrupt 0
0000_0148	82	66	2	16	GPIOD	General Purpose Input/Output D interrupt 1
0000_014C	83	67	2	16	PORTA	PortA EFT interrupt
0000_0150	84	68	2	17	PORTB	PortB EFT interrupt
0000_0154	85	69	2	17	PORTC	PortC EFT interrupt
0000_0158	86	70	2	17	PORTD	PortD EFT interrupt
0000_015C	87	71	2	17	ADC-GP0	Analog-to-Digital Converter - General Purpose0 interrupt
0000_0160	88	72	2	18	CMP-GP0	Comparator - General Purpose0 interrupt
0000_0164	89	73	2	18	CMP-GP1	Comparator - General Purpose1 interrupt
0000_0168	90	74	2	18	PSD	Smart Power Switch Domain interrupt
0000_016C	91	75	2	18	Reserved	-
0000_0170	92	76	2	19	CAN1	Controller Area Network interrupt
0000_0174	93	77	2	19	DSP0	LCE interrupt
0000_0178	94	78	2	19	Reserved	-

3.4 System memory map

The following table shows the device's high-level memory map. Additionally, the various sections are split into "Secure" and "Non-Secure" apertures for each IP. Although these apertures address the same IP, access through the "Secure" aperture can only be performed by code with the appropriate security settings.

Table 21. CPU0 memory map

Start address	Default [1]	Description	Alias	Size	Access	Cached
0000_0000	Non-Secure	Program Flash	FLASH	2 MB	All Masters except data stream and RF	Code Cache

Table continues on the next page...

Table 21. CPU0 memory map (continued)

Start address	Default [1]	Description	Alias	Size	Access	Cached
0020_0000		Reserved	—	—	—	—
0100_0000		Flash Logical Window	FLW	2 MB	All Masters except data stream and RF	Code Cache
0120_0000		Reserved	—	—	—	—
0200_0000		IFR0	IFR0	32 KB	All Masters except data stream and RF	No
0200_8000		Reserved	—	—	—	—
0210_0000		IFR1	IFR1	8 KB	All Masters except data stream and RF	No
0210_2000		Reserved	—	—	—	—
0400_0000		Tightly Coupled Memory - Code	TCM-CODE	32 KB	All Masters except data stream and RF	No
0400_8000		Reserved	—	—	—	—
0480_0000		Read Only Memory - Boot	ROM-BOOT	96 KB	All Masters except data stream and RF	No
0481_8000		Reserved	—	—	—	—
1000_0000	Secure	Program Flash	FLASH	2 MB	All Masters except data stream and RF	Code Cache
1020_0000		Reserved	—	—	—	—
1100_0000		Flash Logical Window	FLW	2 MB	All Masters except data stream and RF	Code Cache
1120_0000		Reserved	—	—	—	—
1200_0000		IFR0	IFR0	32 KB	All Masters except data stream and RF	No

Table continues on the next page...

Table 21. CPU0 memory map (continued)

Start address	Default [1]	Description	Alias	Size	Access	Cached
1200_8000		Reserved	—	—	—	—
1210_0000		IFR1	IFR1	8 KB	All Masters except data stream and RF	No
1210_2000		Reserved	—	—	—	—
1400_0000		Tightly Coupled Memory - Code	TCM-CODE	32 KB	All Masters except data stream and RF	No
1400_8000		Reserved	—	—	—	—
1480_0000		Read Only Memory - Boot	ROM-BOOT	96 KB	All Masters except data stream and RF	No
1481_8000		Reserved	—	—	—	—
2000_0000	Non-Secure	Tightly Coupled Memory - System	TCM-SYS	232 KB	All Masters except RF	No
2003_A000		Reserved	—	—	—	—
3000_0000	Secure	Tightly Coupled Memory - System	TCM-SYS	232 KB	All Masters except RF	No
3003_A000		Reserved	—	—	—	—
4000_0000	Non-Secure	Peripheral Bridge 0	PBRG0	512 KB	All Masters	No
4008_0000		Reserved	—	—	—	—
4800_0000		Fast Peripherals 0	FASTP0	8 MB	All Masters except RF	No
4880_0000		Fast Peripherals 1	FASTP1	8 MB	All Masters except data stream and RF	No
4900_0000		Reserved	—	—	—	—
5000_0000	Secure	Peripheral Bridge 0	PBRG0	512 KB	All Masters	No
5008_0000		Reserved	—	—	—	—
5800_0000		Fast Peripherals 0	FASTP0	8 MB	All Masters except RF	No
5880_0000		Fast Peripherals 1	FASTP1	8 MB	All Masters except data	No

Table continues on the next page...

Table 21. CPU0 memory map (continued)

Start address	Default [1]	Description	Alias	Size	Access	Cached
					stream and RF	
5900_0000		Reserved	—	—	—	—
6000_0000	Non-Secure	Reserved	—	—	—	—
7000_0000	Secure	Reserved	—	—	—	—
8000_0000	Non-Secure	Reserved	—	—	—	—
9000_0000	Secure	Reserved	—	—	—	—
A000_0000	Non-Secure	Reserved	—	—	—	—
B000_0000	Secure	Reserved	—	—	—	—
C000_0000	Non-Secure	Reserved	—	—	—	—
D000_0000	Secure	Reserved	—	—	—	—
E000_0000	Mixed	Private Peripheral Bus - Internal	PPB	256 KB	Core	No
E004_0000		Private Peripheral Bus - External	EPPB	768 KB	Core	No
E010_0000	Non-Secure	Reserved	—	—	—	—

1. This is the default Targeted Security Attribute for the memory region at reset. It is set by the IDAU and the SAU configuration. The attribute listed is the intended use case for users of TrustZone-M (TZM) security function.

3.5 Peripheral bridge2 (PBRIDGE2)

The Peripheral Bridge2 (PBRIDGE2) is the portion of the bus fabric that connects the peripherals to the processor elements. Each peripheral has a base address where the processor elements can access them. The following sections provide the memory map of the peripherals connected to the PBRIDGE2.

3.5.1 Peripheral Bridge2 (PBRIDGE2) memory map

Table 22. Peripheral Bridge 0

Base address (non-secure)	Base address (secure)	Slot	Module	Alias
SYS Modules				
4000_0000	5000_0000	0	AHB Crossbar Switch 0	AXBS0
4000_1000	5000_1000	1	Core Mode Controller 0	CMC0
4000_2000	5000_2000	2	Direct Memory Access - Management Page 0	DMA0-MP
4000_3000	5000_3000	3	Direct Memory Access - Channel 0 0	DMA0-CH0

Table continues on the next page...

Table 22. Peripheral Bridge 0 (continued)

Base address (non-secure)	Base address (secure)	Slot	Module	Alias
4000_4000	5000_4000	4	Direct Memory Access - Channel 1 0	DMA0-CH1
4000_5000	5000_5000	5	Direct Memory Access - Channel 2 0	DMA0-CH2
4000_6000	5000_6000	6	Direct Memory Access - Channel 3 0	DMA0-CH3
4000_7000	5000_7000	7	Direct Memory Access - Channel 4 0	DMA0-CH4
4000_8000	5000_8000	8	Direct Memory Access - Channel 5 0	DMA0-CH5
4000_9000	5000_9000	9	Direct Memory Access - Channel 6 0	DMA0-CH6
4000_A000	5000_A000	10	Direct Memory Access - Channel 7 0	DMA0-CH7
4000_B000	5000_B000	11	Direct Memory Access - Channel 8 0	DMA0-CH8
4000_C000	5000_C000	12	Direct Memory Access - Channel 9 0	DMA0-CH9
4000_D000	5000_D000	13	Direct Memory Access - Channel 10 0	DMA0-CH10
4000_E000	5000_E000	14	Direct Memory Access - Channel 11 0	DMA0-CH11
4000_F000	5000_F000	15	Direct Memory Access - Channel 12 0	DMA0-CH12
4001_0000	5001_0000	16	Direct Memory Access - Channel 13 0	DMA0-CH13
4001_1000	5001_1000	17	Direct Memory Access - Channel 14 0	DMA0-CH14
4001_2000	5001_2000	18	Direct Memory Access - Channel 15 0	DMA0-CH15
4001_3000	5001_3000	19	External Watchdog Monitor 0	EWM0
4001_4000	5001_4000	20	Miscellaneous System Control Module 0 0	MSCM0
4001_5000	5001_5000	21	Secure Miscellaneous System Control Module 0 0	SMSCM0
4001_6000	5001_6000	22	System Power Controller 0	SPC0
4001_7000	5001_7000	23	System Performance Monitor 0	SYSPM0
4001_8000	5001_8000	24	Trigger Multiplexer 0	TRGMUX0
4001_9000	5001_9000	25	Wake Up Unit 0	WUU0
4001_A000	5001_A000	26	Watchdog 0	WDOG0
4001_B000	5001_B000	27	Watchdog 1	WDOG1
CLK Modules				
4001_C000	5001_C000	28	Peripheral Clock Controller 0	PCC0
4001_D000	5001_D000	29	Signal Frequency Analyzer 0	SFA0
4001_E000	5001_E000	30	System Clock Generator 0	SCG0
4001_F000	5001_F000	31	Real Time Clock Domain 0 0	RTCD0
MEM Modules				
4002_0000	5002_0000	32	Flash Memory Unit 0	FMU0
4002_1000	5002_1000	33	Register File 0 0	REGFILE0

Table continues on the next page...

Table 22. Peripheral Bridge 0 (continued)

Base address (non-secure)	Base address (secure)	Slot	Module	Alias
4002_2000	5002_2000	34	Register File 1 0	REGFILE1
SEC Modules				
4002_3000	5002_3000	35	Cyclic Redundancy Check 0	CRC0
4002_4000	5002_4000	36	Sentinel Command Interface 0	SCI0
4002_5000	5002_5000	37	Non-Volatile Memory Prince XOR-Encrypt-XOR 0	NPX0
4002_6000	5002_6000	38	Trusted Resource Domain Controller - Manager 0	TRDC0-MGR
4002_7000	5002_7000	39	Trusted Resource Domain Controller - MBC 0	TRDC0-MBC0
4002_8000	5002_8000	40	Trusted Resource Domain Controller - MBC 1	TRDC0-MBC1
4002_9000	5002_9000	41	Trusted Resource Domain Controller - MBC 2	TRDC0-MBC2
4002_A000	5002_A000	42	Trusted Resource Domain Controller - Memory Region Control 0	TRDC0-MRC0
SYS Modules				
4002_B000	5002_B000	43	Smart Power Switch Domain Controller 0	VBAT0
TMR Modules				
4002_C000	5002_C000	44	Real Time Clock 0	RTC0
4002_D000	5002_D000	45	Low-Power Timer 0	LPTMR0
4002_E000	5002_E000	46	Low-Power Timer 1	LPTMR1
4002_F000	5002_F000	47	Low-Power Periodic Interrupt Timer 0	LPIT0
4003_1000	5003_1000	49	Timer/PWM Module 0	TPM0
4003_2000	5003_2000	50	Timer/PWM Module 1	TPM1
COM Modules				
4003_3000	5003_3000	51	Low-Power Inter Integrated Circuit 0	LPI2C0
4003_4000	5003_4000	52	Low-Power Inter Integrated Circuit 1	LPI2C1
4003_5000	5003_5000	53	Improved Inter Integrated Circuit 0	I3C0
4003_6000	5003_6000	54	Low-Power Serial Peripheral Interface 0	LPSPI0
4003_7000	5003_7000	55	Low-Power Serial Peripheral Interface 1	LPSPI1
4003_8000	5003_8000	56	Low-Power Universal Asynchronous Receive/Transmit 0	LPUART0
4003_9000	5003_9000	57	Low-Power Universal Asynchronous Receive/Transmit 1	LPUART1
4003_A000	5003_A000	58	Flexible Input/Output 0	FlexIO0
4003_B000	5003_B000	59 - 62	Controller Area Network 0	CAN0
4003_F000	5003_F000	63	Semaphore 0	SEMA0
RF Modules				

Table continues on the next page...

Table 22. Peripheral Bridge 0 (continued)

Base address (non-secure)	Base address (secure)	Slot	Module	Alias
4004_0000	5004_0000	64	Radio Frequency Mode Controller 0	RFMC
4004_1000	5004_1000	65	Data Stream Buffer 0	DSB0
HMI Modules				
4004_2000	5004_2000	66	Port Control and Interrupts A	PORTA
4004_3000	5004_3000	67	Port Control and Interrupts B	PORTB
4004_4000	5004_4000	68	Port Control and Interrupts C	PORTC
4004_5000	5004_5000	69	Port Control and Interrupts D	PORTD
4004_6000	5004_6000	70	General Purpose Input/Output D	GPIOD
ANA Modules				
4004_7000	5004_7000	71	Analog-to-Digital Converter - General Purpose 0	ADC-GP0
4004_8000	5004_8000	72	Comparator - General Purpose 0	CMP-GP0
4004_9000	5004_9000	73	Comparator - General Purpose 1	CMP-GP1
4004_A000	5004_A000	74	Voltage Reference 0	VREF0
COM Modules				
4004_F000	5004_F000	79-82	Controller Area Network 1	CAN1
SYS Modules				
4005_3000	5005_3000	83	LCE	DSP0
4005_4000	5005_4000	84 - 127	Reserved	—

3.6 Fast peripherals

3.6.1 Fast peripherals 0 memory map

The following table shows the memory map of the fast peripherals in this device.

Table 23. Fast Peripherals 0 Non-Secure

Base	Slot	Module	Alias
DBG Modules			
4800_0000	0	ISP-AP Debug Module 0	ISP-AP0
HMI Modules			
4801_0000	1	General Purpose Input/Output A	GPIOA
4802_0000	2	General Purpose Input/Output B	GPIOB
4803_0000	3	General Purpose Input/Output C	GPIOC
4804_0000	4-127	Reserved	—

3.6.2 Fast peripherals 1 memory map

The following table shows the memory map of the fast peripherals in this device.

Table 24. Fast Peripherals 1 Non-Secure

Base	Slot	Module	Alias
RF Modules			
4880_0000	0	Radio Flash/IFR 0	RF-NBU-Flash
4890_0000	1	Reserved	RF-2.4G
4894_0000	2	Radio NBU CIU2 0	RF-NBU-CIU2
4898_0000	0	Radio FRO192M 0	RF-FRO192M
4898_1000	1	Radio Flash Memory Unit 0	RF-FMU
4898_2000	2	Radio FMC CFG 0	RF-FMCCFG
4898_3000	3	Radio CMC 0	RF-CMC
4898_4000	4	Radio Low-Power Timer 0	RF-LPTPM2
4898_5000	5	Radio Flash Memory Unit - Test 0	RF-FMU-TST
4898_6000	6	Low-Power Timer 2	LPTMR2
4898_7000	7 - 63	Reserved	RF-NBU-PRB
489C_0000	40 - 47	Radio NBU SMU2 0	RF-NBU-SMU2
48A0_0000	0	Reserved	RF-2.4G
48A0_1000	1	Radio Zigbee Link Layer 0	RF-ZigbeeLL
48A0_2000	2	Radio Generic LinkLayer 0	RF-GENLL
48A0_3000	3	Radio Generic LinkLayer Remapping 0 0	RF-GENLL-REMAP0
48A0_4000	4	Radio Generic LinkLayer Remapping 1 0	RF-GENLL-REMAP1
48A0_5000	5	Radio Generic LinkLayer Remapping 2 0	RF-GENLL-REMAP2
48A0_6000	6	Rdio Control 0	RF-CTRL
48A0_7000	7	Radio Transceiver 0	RF-XCVR
48A0_8000	8 - 9	Radio Packet RAM 0	RF-Packet-RAM
48A0_A000	10 - 15	Reserved	RF-2.4G
48A1_0000	0	Reserved	—

3.7 PPB memory map

The following table shows the memory map of the Private Peripheral Bus (PPB) in this device.

Table 25. Private Peripheral Bus - Internal

Base	Slot	Module	Alias
DBG Modules			
E000_0000	0	Instrumentation Trace Macrocell 0	ITM
E000_1000	1	Data Watchpoint and Trace 0	DWT
E000_2000	2	Breakpoint Unit 0	BPU
E000_3000	3-13	Reserved	—
E000_E000	14	Secure System Control Space 0	Secure SCS
E000_F000	15-45	Reserved	—
E002_E000	46	Non-secure System Control Space 0	Non-secure SCS
E002_F000	47-63	Reserved	—

Table 26. Private Peripheral Bus - External

Base	Slot	Module	Alias
DBG Modules			
E004_0000	0	Trace Port Interface Unit 0	TPIU
E004_1000	1	Reserved	—
E004_2000	2	Cross Trigger Interface -	CTI
E004_3000	3	Reserved	—
E004_4000	4	CoreSight Funnel 0	CSF
E004_5000	5-63	Reserved	—
E008_0000	64	Miscellaneous Control Module 0	MCM
E008_1000	65-190	Reserved	—
E00F_F000	191	ROM Table 0	ROM

Chapter 4
Localization Compute Engine (LCE)

4.1 Overview

LCE is a platform that provides the digital signal processing unit (LPU ZV2117) and support modules around it as depicted in Block diagram.

4.1.1 Block diagram

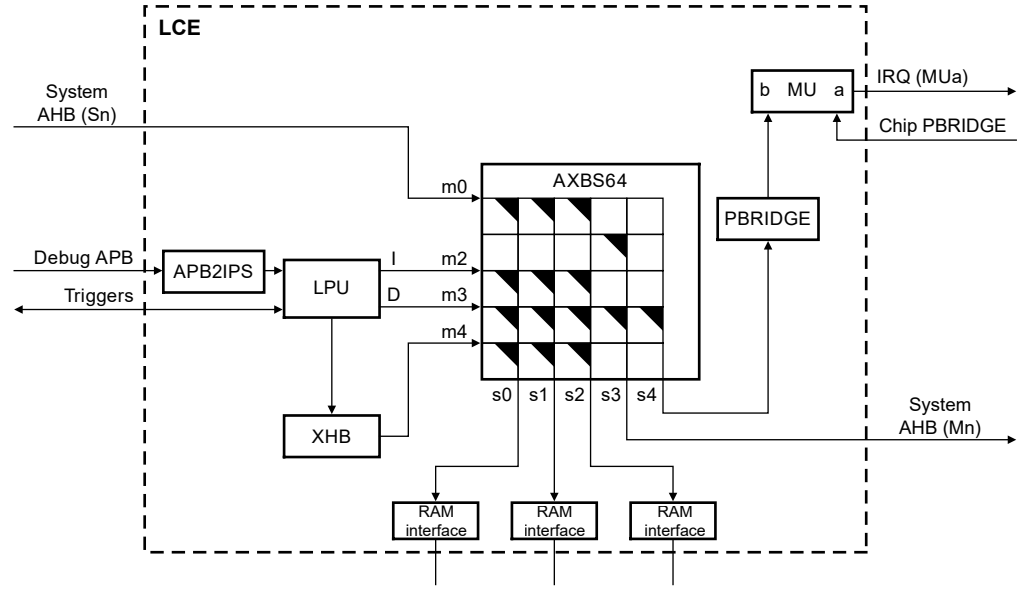


Figure 7. LCE overview diagram

4.1.2 Features

The following features are included in LPU ZV2117:

- 32-bit data path supporting 4 × 8-bit, 2 × 16-bit and 1 × 32-bit SIMD operations
- Most C/C++ integer math, floating-point math and logical operations are supported in SIMD form
- Special arithmetic unit (SAU) supporting efficient 1/x, sqrt(x), 1/sqrt(x) & exp(j*w*n+p) operations
- Instructions for efficient FFT computation
- Dedicated 64-bit AXI bus for SIMD operations
- 16 entry × 64-bit integrated SIMD data cache
- Memory page address size 17 bits
- Direct support for 16-bit complex multiplication and accumulation
- Double precision SIMD accumulator
- Support for all C/C++ {8,16,32}-bit data types
- Support for AI/ML 8-bit and 16-bit floating point data types
- Support for 2^n scaling factor for input and output operands
- Fixed size 32-bit vector instructions

4.2 Functional description

4.2.1 LPU

LPU has a single-instruction multiple-data (SIMD) data path. SIMD operations can be introduced in C/C++ software through the use of special SIMD data types. SIMD data types can be mixed with other integer or floating-point data types and the compiler will choose the proper instructions to make sure the variables are processed using the appropriate data path.

It is important to note that the LPU has a dedicated, 64-bit, AXI data path for its vector data.

Code for the LPU is loaded through the 32-bit AHB I bus and, similarly, data is accessed through the 32-bit AHB D bus.

4.2.1.1 LPU configuration

LPU configuration information is provided by a set of user registers.

LPU has an AXI3 master interface to retrieve data to process and to write computation results. The LPU AXI3 bus has a data width of 64 bits. See the AXI documentation for standard signal definitions and operation of the protocol.

LPU also contains a small smart cache (SC) to assist in maintaining a local working set. Various pointer configurations are available to assist in vector processing.

4.2.2 Integrated system

4.2.2.1 Memory and buses

The platform is integrated with the necessary components to access local memory.

The AXBS64 bus fabric provides arbitration to the 3 available memories. It is natively 64-bit to preserve the bandwidth of the LPU vector memory interface. All three memories are considered equivalent to provide the user with the ability to allocate as needed. A typical configuration might be code in RAM0 and ping-pong data buffers in RAM1 and RAM2.

Furthermore, ports are provided for the chip to access the memories (Sn) and for the LPU to access the chip (Mn).

All necessary width and protocol conversions are performed within the platform.

4.2.2.2 Messaging Unit (MU) block

The platform also integrates an MU block to assist with software abstraction with a host core. See MU chapter for details.

It can be accessed by the LPU through the integrated PBRIDGE or from the chip on the PBRIDGE bus.

Chapter 5
Low Power Cache Controller (LPCAC)

5.1 Chip-specific LPCAC information

Table 27. Reference links to related information

Topic	Related module	Reference
Full description	LPCAC	LPCAC
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing
Additional Cache Control and Status	MCM	Miscellaneous Control Module (MCM)
	SMSCM	Secure Miscellaneous System Control Module (SMSCM)
	MSCM	Miscellaneous System Control Module (MSCM)

5.1.1 Module instances

This device has one instance of the LPCAC module.

5.1.2 Additional cache control and status

In this device, the primary controls for the cache from outside the LPCAC include :

- Miscellaneous Control Module (MCM):
  - ISCR[CWBEE] - Should always set as 0 to disable the interrupt for cache write buffer error
  - ISCR[CWBER] - This field indicates whether the cache write buffer error is received.
  - FATR register - This register indicates the faulting attributes, when a properly-enabled cache write buffer error interrupt event is detected.
  - FADR register - This register captures the faulting address when a properly-enabled cache write buffer error interrupt event is detected.
  - FDR register - This register indicates the captured faulting data, when a properly-enabled cache write buffer error interrupt event is detected.
  - CPCR2 register - This register controls several code cache features like cache buffering, bus size, and bus control bitfields.
- Secure Miscellaneous System Control Module (SMSCM):
  - OCMDR0[OCMCF2] bitfields provides control bits to enable flash cache and options for instruction and data fetch.
  - **NOTE**

    Flash cache is enabled by default and can be disabled or configured in a different way through SMSCM : OCMDR0[OCMCF2] bitfield.
- Miscellaneous System Control Module (MSCM):
  - There are status registers related to cache
    - CPxCFG0- This register provides read-only instruction and data cache size info, if it is valid.
    - CPxCFG1- This register provides read-only instruction cache info, if it is valid.

5.2 Overview

LPCAC provides low-latency access to instructions or data. This decouples processor performance from system memory performance, increasing bus availability for other modules and improving system performance.

LPCAC has a 32-bit data path AMBA-AHB input bus and a 32-bit data path AMBA-AHB output bus.

5.2.1 Block diagram

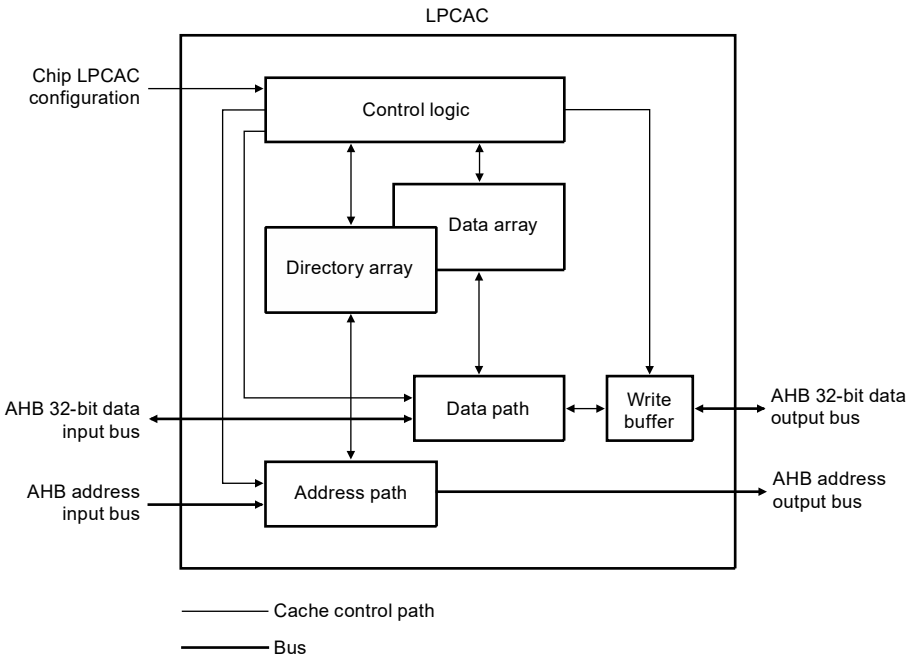


Figure 8. Block diagram

5.2.2 Features

LPCAC supports the following features:

- Nonblocking and write-through cache mode
- 16 KB total cache size
- Cache organization as an 8-way, 8-set-associative design based on 256-byte superpages
- Each way or superpage contains up to sixteen sequential 16-byte pages

5.3 Functional description

This section provides further information on the LPCAC module operation.

A reset signal clears and enables this module.

LPCAC examines every valid AHB input access. If the access hits the cache memory region and the cache is enabled, the access goes to the cache portion of the module. If the access is not cacheable, the access is passed directly to the AHB output bus.

The LPCAC cache has a 256-byte line subdivided into sixteen 16-byte sublines:

- Cache read accesses that are cache misses perform an aligned 16-byte subline-size burst cache read miss to the module's AHB output bus. Then the cache loads the needed data in the cache’s data storage. The cache miss uses a 4-beat (32 bits per beat), wrapped burst bus access to fetch the cache miss data.

- Cache read accesses that are cache hits return the desired read data from the cache.
- Cache write accesses that are cache misses perform the desired write operation only to the module's AHB output bus (for write-through mode accesses, LPCAC has a no allocation on write-miss policy).
- Cache write accesses that are cache hits perform the desired write operation to the cache and the module's AHB output bus.

LPCAC has a one entry write buffer. When LPCAC is enabled and available, cache write accesses with a bufferable attribute use the buffer, which allows write from the processor to receive an immediate (zero wait state) bus termination.

5.3.1 Cache functional description

The LPCAC cache is an 8-way, 8-set-associative, 256-byte per line write-through design. It supports a total cache capacity of 16 KB for a 32-bit wide cache miss data path.

5.3.1.1 Cache controls

This module has controls to enable, disable, and clear the cache.

The cache control inputs are as follows:

- clr_lpcac: clear lpcac
- dis_lpcac: disable lpcac
- dis_lpcac_wtbf: disable write buffer
- lim_lpcac_wtbf: limit write buffer
- frc_no_alloc: force no allocation
- mode_ctl_hprot: ignore LPCAC Memory Regions

See chip-specific section for more information on how these signals are connected or controlled on a given device.

5.3.2 Clocks

The core clock domain defines the module's clock domain.

5.3.3 Reset

A reset signal clears and enables this module. See the chip-integration information for the resets that affect LPCAC.

5.3.4 Interrupts

This module has no interrupts.

5.4 Signal descriptions

This module has no external signals.

5.5 Memory regions and input control description

5.5.1 Memory regions

LPCAC decodes cacheable address regions. The cache memory region may be composed of one or more disjointed memory regions and the total size may be larger than the cache storage.

Any address not in the cacheable memory region is in the pass-through memory region. All accesses to the pass-through memory regions are non-cacheable. For all accesses to the cacheable memory regions, the access is cacheable if the attributes of the access indicate that it can be cached, else the access is non-cacheable.

The following table defines the memory map.

Table 28. Memory map

Cache memory range	Cache memory range	Cache total memory address space
0000_0000h–07FF_FFFFh (128 MB)	1000_0000h–1FFF_FFFFh (256 MB)	384 MB

5.5.2 Input controls

The LPCAC does not have a module-resident programming model. An external block supplies the needed LPCAC control inputs.

Table 29. Control inputs for LPCAC

Function	Control input	Description
clear lpcac	clr_lpcac	One cycle active-high pulse clears the lpcac.
disable lpcac	dis_lpcac	• 0 = lpcac enabled (reset configuration) • 1 = lpcac disabled, all cacheable accesses pass from LPCAC input to output bus
disable write buffer	dis_lpcac_wtbf	• 0 = write buffer enabled • 1 = write buffer disabled
limit write buffer	lim_lpcac_wtbf	• 0 = If write buffer is enabled, buffer all writes to spaces that are bufferable • 1 = If write buffer is enabled, buffer all writes to spaces that are both bufferable and cacheable
force no allocation	frc_no_alloc	When frc_no_alloc is asserted and the cache is enabled, all accesses to the cache search the cache. If they hit a valid entry that was loaded before frc_no_alloc was asserted, they operate normally. That is, read hits return cache data without going through the cache and write hits update cache data and write through the cache. If they miss, they bypass the cache (that is, even though a read access is to a cacheable space, it does not allocate on a cache miss). This control input is useful for debug. If there is a software breakpoint, halting the processor. Then, using the debug port, cacheable memory and other address spaces are accessed. These debug accesses go through the processor, through the cache, and to the rest of the system. The idea is during the debug accesses the cache is placed on frc_no_alloc mode. In this way, debug access through the core and then through the cache do not disturb the state of the cache. Before restarting the processor, frc_no_alloc mode is negated. When the processor restarts, the cache state is the same or at least very similar as the cache state when the breakpoint was hit. • 0 = normal allocation on cache miss • 1 = no allocation on cache miss
ignore CACHE_MAP	mode_ctl_hprot	• 0 = use LPCAC Memory Regions to determine if an access to a given address may be cached. Then, if the attributes of the access indicate it can be cached, the access is cached. • 1 = Use only the attributes of the access to indicate it can be cached.

Chapter 6
Peripheral Bridge2 (PBRIDGE2)

6.1 Chip-specific PBRIDGE2 information

Table 30. Reference links to related information

Topic	Related module	Reference
Full description	PBRIDGE	PBRIDGE
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

6.1.1 Module instances

This device has one PBRIDGE2.

6.2 Overview

PBRIDGE2 converts an AMBA AHB interface to a peripheral interface, which includes peripheral module enables that allow the controller to interface with multiple peripherals.

PBRIDGE2 includes:

- A configurable data path width (32-bit or 64-bit) for the AMBA AHB input bus.
- 8-, 16-, and 32-bit data path peripheral output buses.

Each peripheral bridge occupies a configurable amount of the address space, which is divided into either 128 slots of 4 KB or 64 KB. It is possible that not all expansion slots are used. See the "Memory Map" chapter for details on slot assignments.

6.2.1 Features

- Supports expansion slots with 8-, 16-, and 32-bit data path width
- Includes separate clock enable inputs for each of the slots to accommodate slower peripherals
- Includes separate powered down inputs for each of the slots to accommodate powering down individual peripherals

6.2.2 Number of peripheral bridges

This chip contains 1 peripheral bridge(s).

6.3 Functional description

This section provides further information on the PBRIDGE2 operation.

The peripheral bridge functions as a bus protocol translator between an AMBA AHB bus and the subordinate peripheral bus. The peripheral bridge manages all transactions destined for the attached subordinate devices and generates select signals for modules on the peripheral bus by decoding accesses within the attached address space.

PBRIDGE2 examines every valid AHB input access. If the access hits an expansion slot that is configured but not powered down and the access width is less than or equal to the slot data width, the access goes to that slot peripheral bus. If access to the slot is error-free on the slot peripheral bus, the AHB access is error-free too. If the AHB accesses an expansion slot that is not configured, is powered down, has a width greater than the slot data width, or the access to the slot completes with an error on the slot peripheral bus, the AHB access terminates with a bus error.

6.3.1 Access support

PBRIDGE2 supports the following accesses:

- Aligned 32-bit, 16-bit, and byte accesses for 32-bit peripherals
- Aligned 16-bit and byte accesses for 16-bit peripherals
- Byte accesses for 8-bit peripherals

PBRIDGE2 performs all accesses to the peripherals with a single peripheral bus transfer. Resize all accesses to the expansion slots to be less than or equal to the designated expansion slot size. If the access attempt is larger than the targeted expansion slot size, PBRIDGE2 generates an AHB bus error response.

6.3.2 Clocking

This module has no clocking considerations.

6.3.3 Interrupts

This module has no interrupts.

6.4 External signals

This module has no external signals.

6.5 Initialization

This module does not require initialization.

6.6 Memory maps

Use peripheral bridges to access most of the peripheral module registers on this chip. See the "Memory Map" chapter for the memory slot assignment for each module.

Chapter 7
Crossbar Switch (AXBS)

7.1 Chip-specific AXBS information

Table 31. Reference links to related information

Topic	Related module	Reference
Full description	AXBS	AXBS
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

7.1.1 Module instances

This device has one instance of the AXBS module, AXBS0.

7.1.2 Crossbar switch assignment

The masters connected to the crossbar switch are assigned as follows:

Table 32. Crossbar master assignment

Master port number	Master module
M0	CM33 Code Cache
M1	CM33 Data Cache
M2	eDMA
M3	EdgeLock secure enclave
M4	Data steam
M5	NBU
M6	DSP

Table 33. Crossbar slave assignment

Slave port number	Slave module
S0	FMC, FMU
S1	CTCM
S2	STCM2, STCM3
S3	STCM0, STCM1, STCM4
S4	STCM5
S5	PBRIDGE2
S6	GPIOA, GPIOB, GPIOC
S7	Radio

7.2 Overview

This section provides information on the layout, configuration, and programming of the crossbar switch.

The crossbar switch connects bus initiators and bus targets using a crossbar switch structure. This structure allows all bus initiators to access different bus targets simultaneously, while providing arbitration among the bus initiators when they access the same target. A variety of bus arbitration methods and attributes may be programmed on a target-by-target basis.

7.2.1 Features

- Symmetric crossbar bus switch implementation
  - Allows concurrent access from different Initiators to different Targets
  - Target arbitration attributes configured on a Target-by-Target basis
- Single-clock 32-bit transfer
- Support for burst transfers of 64 bits of data
- Support for low-power park mode
- 32-bit AHB crossbar bus switch compatible with ARM's AMBA Specification v2.0

7.3 Memory map and register definition

Each target port of the crossbar switch contains configuration registers. Read- and write transfers require two bus clock cycles. The registers can be read from and written to only in supervisor mode. Additionally, these registers can be read from or written to only by 32-bit accesses.

A bus error response is returned if an unimplemented location is accessed within the crossbar switch.

The CRS*n* and PRS*n* registers can be programmed as read-only to prevent changes to their configuration. After being read-only protected, future writes to them terminate with a data storage error.

NOTE

This section shows the registers for all eight initiator and target ports. If a initiator or target is not used on this particular chip, then unexpected results occur when writing to its registers. See the chip configuration details for the exact initiator and target assignments for your chip.

All references to the crossbar switch registers are based on the physical port connections.

7.3.1 AXBS register descriptions

7.3.1.1 AXBS memory map

AXBS0 base address: 4000_0000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Priority Target Registers (PRS0)	32	RW	0654_3210h
10h	Control Register (CRS0)	32	RW	0000_0110h
100h	Priority Target Registers (PRS1)	32	RW	0654_3210h
110h	Control Register (CRS1)	32	RW	0000_0110h
200h	Priority Target Registers (PRS2)	32	RW	0654_3210h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
210h	Control Register (CRS2)	32	RW	0000_0110h
300h	Priority Target Registers (PRS3)	32	RW	0654_3210h
310h	Control Register (CRS3)	32	RW	0000_0110h
400h	Priority Target Registers (PRS4)	32	RW	0654_3210h
410h	Control Register (CRS4)	32	RW	0000_0110h
500h	Priority Target Registers (PRS5)	32	RW	0654_3210h
510h	Control Register (CRS5)	32	RW	0000_0110h
600h	Priority Target Registers (PRS6)	32	RW	0654_3210h
610h	Control Register (CRS6)	32	RW	0000_0110h
700h	Priority Target Registers (PRS7)	32	RW	0654_3210h
710h	Control Register (CRS7)	32	RW	0000_0110h
800h	Initiator General Purpose Control Register (MGPCR0)	32	RW	0000_0001h
900h	Initiator General Purpose Control Register (MGPCR1)	32	RW	0000_0001h
A00h	Initiator General Purpose Control Register (MGPCR2)	32	RW	0000_0001h
B00h	Initiator General Purpose Control Register (MGPCR3)	32	RW	0000_0001h
C00h	Initiator General Purpose Control Register (MGPCR4)	32	RW	0000_0001h
D00h	Initiator General Purpose Control Register (MGPCR5)	32	RW	0000_0001h
E00h	Initiator General Purpose Control Register (MGPCR6)	32	RW	0000_0001h

7.3.1.2 Priority Target Registers (PRS0 - PRS7)

Offset

Register	Offset
PRS0	0h
PRS1	100h
PRS2	200h
PRS3	300h
PRS4	400h
PRS5	500h
PRS6	600h
PRS7	700h

Function

The priority target registers(PRS*n*) set the priority of each initiator port on a per target port basis and reside in each target port. The priority register can be accessed only with 32-bit access. After the CRS*n*[RO] bit is set, the PRS*n* register can only be read; attempts to write to it have no effect on PRS*n* and result in a bus-error response to the initiator initiating the write.

Two available initiators must not be programmed with the same priority level. Attempts to program two or more initiators with the same priority level result in a bus-error response and the PRS*n* is not updated.

NOTE

Valid values for the M*n* priority fields depend on which initiators are available on the chip. This information can be found in the chip-specific information for the crossbar.

- If the chip contains fewer than three initiators, only one bit is valid.
- If the chip contains fewer than five initiators, only two bits are valid.
- If five or more initiators are present, all three bits of the priority field are used.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	Reserved			0	M6			0	M5			0	M4		
W		-														
Reset	0	0	0	0	0	1	1	0	0	1	0	1	0	1	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	M3			0	M2			0	M1			0	M0		
W																
Reset	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0

Fields

Field	Function
31 —	Reserved
30-28 —	Reserved
27 —	Reserved
26-24 M6	Initiator 6 Priority This field sets the arbitration priority for this port on the associated target port. 000b - This initiator has level 1 or highest priority when accessing the target port. 001b - This initiator has level 2 priority when accessing the target port.

Table continues on the next page...

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Field	Function
	010b - This initiator has level 3 priority when accessing the target port. 011b - This initiator has level 4 priority when accessing the target port. 100b - This initiator has level 5 priority when accessing the target port. 101b - This initiator has level 6 priority when accessing the target port. 110b - This initiator has level 7 priority when accessing the target port. 111b - This initiator has level 8the or lowest priority when accessing the target port.
23 —	Reserved
22-20 M5	Initiator 5 Priority This field sets the arbitration priority for this port on the associated target port. 000b - This initiator has level 1 or highest priority when accessing the target port. 001b - This initiator has level 2 priority when accessing the target port. 010b - This initiator has level 3 priority when accessing the target port. 011b - This initiator has level 4 priority when accessing the target port. 100b - This initiator has level 5 priority when accessing the target port. 101b - This initiator has level 6 priority when accessing the target port. 110b - This initiator has level 7 priority when accessing the target port. 111b - This initiator has level 8 or lowest priority when accessing the target port.
19 —	Reserved
18-16 M4	Initiator 4 Priority This field sets the arbitration priority for this port on the associated target port. 000b - This initiator has level 1 or highest priority when accessing the target port. 001b - This initiator has level 2 priority when accessing the target port. 010b - This initiator has level 3 priority when accessing the target port. 011b - This initiator has level 4 priority when accessing the target port. 100b - This initiator has level 5 priority when accessing the target port. 101b - This initiator has level 6 priority when accessing the target port. 110b - This initiator has level 7 priority when accessing the target port. 111b - This initiator has level 8 or lowest priority when accessing the target port.
15 —	Reserved

Table continues on the next page...

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Field	Function
14-12 M3	Initiator 3 Priority This field sets the arbitration priority for this port on the associated target port. 000b - This initiator has level 1 or highest priority when accessing the target port. 001b - This initiator has level 2 priority when accessing the target port. 010b - This initiator has level 3 priority when accessing the target port. 011b - This initiator has level 4 priority when accessing the target port. 100b - This initiator has level 5 priority when accessing the target port. 101b - This initiator has level 6 priority when accessing the target port. 110b - This initiator has level 7 priority when accessing the target port. 111b - This initiator has level 8the or lowest priority when accessing the target port.
11 —	Reserved
10-8 M2	Initiator 2 Priority This field sets the arbitration priority for this port on the associated target port. 000b - This initiator has level 1 or highest priority when accessing the target port. 001b - This initiator has level 2 priority when accessing the target port. 010b - This initiator has level 3 priority when accessing the target port. 011b - This initiator has level 4 priority when accessing the target port. 100b - This initiator has level 5 priority when accessing the target port. 101b - This initiator has level 6 priority when accessing the target port. 110b - This initiator has level 7 priority when accessing the target port. 111b - This initiator has level 8the or lowest priority when accessing the target port.
7 —	Reserved
6-4 M1	Initiator 1 Priority This field sets the arbitration priority for this port on the associated target port. 000b - This initiator has level 1 or highest priority when accessing the target port. 001b - This initiator has level 2 priority when accessing the target port. 010b - This initiator has level 3 priority when accessing the target port. 011b - This initiator has level 4 priority when accessing the target port. 100b - This initiator has level 5 priority when accessing the target port. 101b - This initiator has level 6 priority when accessing the target port.

Table continues on the next page...

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Field	Function
	110b - This initiator has level 7 priority when accessing the target port. 111b - This initiator has level 8 or lowest priority when accessing the target port.
3 —	Reserved
2-0 M0	Initiator 0 Priority This field sets the arbitration priority for this port on the associated target port. 000b - This initiator has level 1 or highest priority when accessing the target port. 001b - This initiator has level 2 priority when accessing the target port. 010b - This initiator has level 3 priority when accessing the target port. 011b - This initiator has level 4 priority when accessing the target port. 100b - This initiator has level 5 priority when accessing the target port. 101b - This initiator has level 6 priority when accessing the target port. 110b - This initiator has level 7 priority when accessing the target port. 111b - This initiator has level 8 or the lowest priority when accessing the target port.

7.3.1.3 Control Register (CRS0 - CRS7)

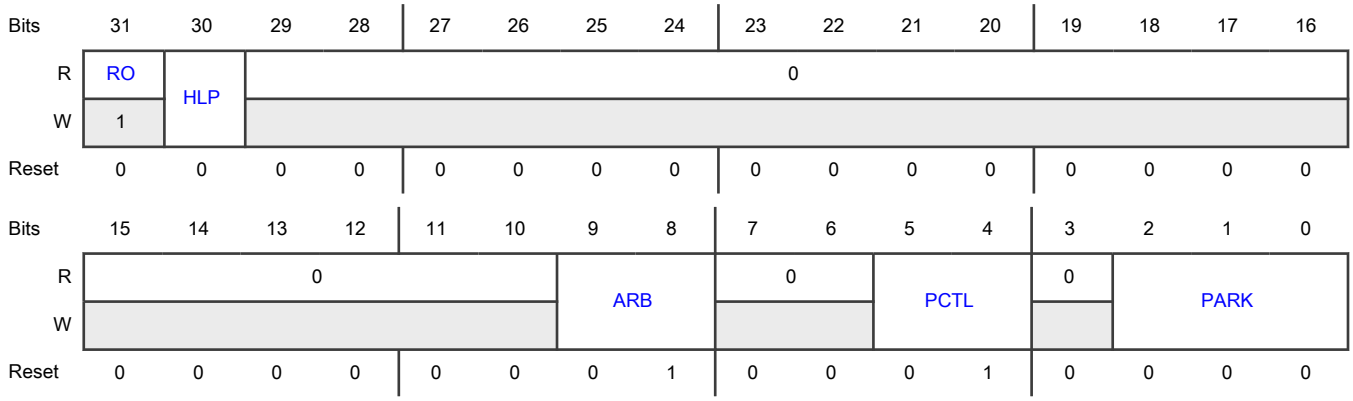
Offset

Register	Offset
CRS0	10h
CRS1	110h
CRS2	210h
CRS3	310h
CRS4	410h
CRS5	510h
CRS6	610h
CRS7	710h

Function

These registers control several features of each target port and must be accessed using 32-bit accesses. After CRS*n*[RO] is set, the PRS*n* can only be read; attempts to write to it have no effect and result in an error response.

Diagram



Fields

Field	Function
31 RO	Read Only This field forces the target port's CSR*n* and PRS*n* registers to be read-only. After setting, only a hardware reset clears it. 0b - The target port's registers are writeable. 1b - The target port's registers are read-only and cannot be written. Attempted writes do not affect the registers and result in a bus error response.
30 HLP	Halt Low Priority This field sets the initial arbitration priority for low-power mode requests. Setting this bit will not affect the request for low-power mode from attaining the highest priority after it has control of the target ports. 0b - The low-power mode request has the highest priority for arbitration on this target port. 1b - The low-power mode request has the lowest initial priority for arbitration on this target port.
29-10 —	Reserved
9-8 ARB	Arbitration Mode This field selects the arbitration policy for the target port. 00b - Fixed priority 01b - Round-robin(RR) or rotating priority 10b - Reserved 11b - Reserved
7-6 —	Reserved
5-4	Parking Control

Table continues on the next page...

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Field	Function
PCTL	This field determines the target port's parking control. The low-power park feature results in overall power saving if the target port is not saturated. However, this forces an extra latency clock when a initiator tries to access the target port when not in use because it is not parked on any initiator. 00b - When no initiator makes a request, the arbiter parks the target port on the initiator port defined by the PARK field. 01b - When no initiator makes a request, the arbiter parks the target port on the last initiator to be in control of the target port. 10b - When no initiator makes a request, the target port is not parked on a initiator and the arbiter drives all outputs to a constant safe state. 11b - Reserved
3 —	Reserved
2-0 PARK	Park This field determines which initiator port the current target port parks on when no initiators are actively making requests and the PCTL bits are cleared. **NOTE** Select only those initiator ports that are present on the chip. Otherwise, undefined behavior may occur. 000b - Park on initiator port M0. 001b - Park on initiator port M1. 010b - Park on initiator port M2. 011b - Park on initiator port M3. 100b - Park on initiator port M4. 101b - Park on initiator port M5. 110b - Park on initiator port M6. 111b - Park on initiator port M7.

7.3.1.4 Initiator General Purpose Control Register (MGPCR0 - MGPCR6)

Offset

Register	Offset
MGPCR0	800h
MGPCR1	900h
MGPCR2	A00h

Table continues on the next page...

Table continued from the previous page...

Register	Offset
MGPCR3	B00h
MGPCR4	C00h
MGPCR5	D00h
MGPCR6	E00h

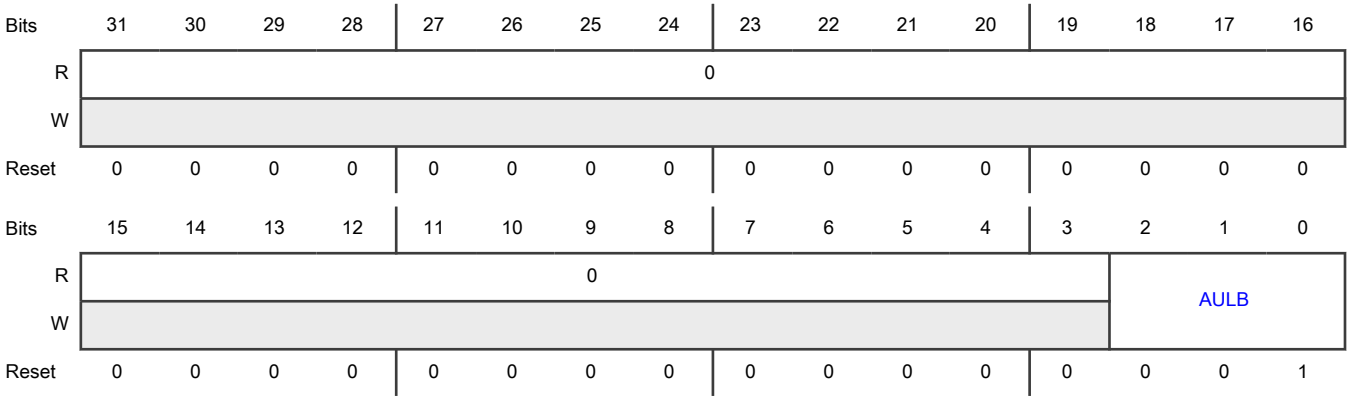
Function

The MGPCR controls only whether the initiator's undefined length burst accesses are allowed to complete uninterrupted or whether they can be broken by requests from higher priority initiators. The MGPCR can be accessed only in supervisor mode with 32-bit accesses.

NOTE

If there are fewer than eight initiator ports, only the registers associated with those initiators are present. Register addresses associated with initiator ports that are not present are reserved. See the module's chip-specific information for which initiator ports are present on this module.

Diagram



Fields

Field	Function
31-3 —	Reserved
2-0 AULB	Arbitrates On Undefined Length Bursts This field determines whether, and when, the crossbar switch arbitrates away the target port the initiator owns when the initiator is performing undefined length burst accesses. 000b - No arbitration is allowed during an undefined length burst. 001b - Arbitration is allowed at any time during an undefined length burst.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	010b - Arbitration is allowed after four beats of an undefined length burst. 011b - Arbitration is allowed after eight beats of an undefined length burst. 100b - Arbitration is allowed after 16 beats of an undefined length burst. 101b - Reserved 110b - Reserved 111b - Reserved

7.4 Functional description

Information about general operation and arbitration are provided in this section.

7.4.1 General operation

When a Initiator accesses the crossbar switch, the access is immediately taken. If the targeted target port of the access is available, then the access is immediately presented on the target port. Single-clock or zero-wait-state accesses are possible through the crossbar. If the targeted target port of the access is busy or parked on a different Initiator port, the requesting Initiator sees wait states inserted until the targeted target port can service the Initiator's request. The latency in servicing the request depends on each Initiator's priority level and the responding target's access time.

Because the crossbar switch appears to be just another target to the Initiator device, the Initiator device does not know whether it owns the target port it is targeting. The Initiator waits while it does not have control of the target port it is targeting.

After the Initiator acquires control of the target port, it controls the port until it relinquishes the port by running an IDLE cycle or by targeting a different target port for its next access.

The Initiator can also lose control of the target port if another higher-priority Initiator makes a request to the target port. However, if the Initiator is running a fixed- or undefined-length burst transfer, it retains control of the target port until that transfer completes. Based on MGPCR[AULB], the Initiator either retains control of the target port when doing undefined-length, incrementing burst transfers or loses the bus to a higher-priority Initiator.

The crossbar terminates all Initiator IDLE transfers, as opposed to allowing the termination to come from one of the target buses. Additionally, when no Initiator is requesting access to a target port, the crossbar drives IDLE transfers onto the target bus, even though a default Initiator may be granted access to the target port.

When a target bus is being idled by the crossbar, it can park the target port on the Initiator port indicated by CRS*n*[PARK]. This is done to save the initial clock of arbitration delay that otherwise would be seen if the same Initiator had to arbitrate to gain control of the target port. The target port can also be put into low-power park mode to save power, by using CRS*n*[PCTL].

7.4.2 Register coherency

The operation of the crossbar is affected as soon as a register is written. The values of the registers do not track with target-port-related Initiator accesses, but instead track only with target accesses.

The MGPCRx[AULB] bits are the exception to this rule. The update of these bits is only recognized when the Initiator on that Initiator port runs an IDLE cycle, even though the target bus cycle to write them will have already terminated successfully. If the MGPCRx[AULB] bits are written between two burst accesses, the new AULB encodings do not take effect until an IDLE cycle is initiated by the Initiator on that Initiator port.

7.4.3 Arbitration

The crossbar switch supports the following arbitration algorithms:

- Fixed priority

- Round-robin

The arbitration scheme is independently programmable for each target port.

7.4.3.1 Arbitration during undefined length bursts

Arbitration points during an undefined length burst are defined by the current master's MGPCR[AULB] field setting. When a defined length is imposed on the burst via the AULB bits, the undefined length burst is treated as a single or series of single back-to-back fixed-length burst accesses.

The following figure illustrates an example:

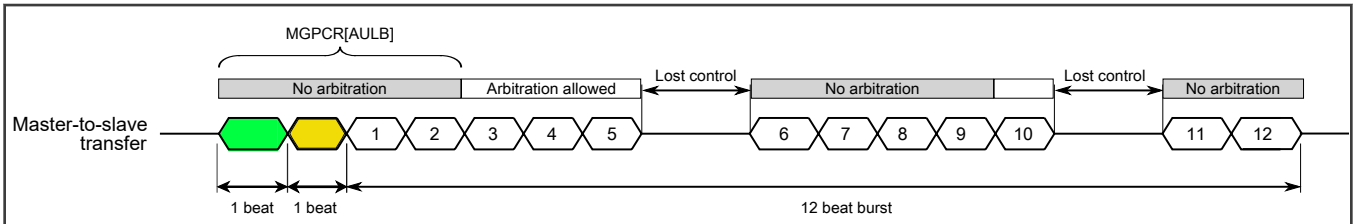


Figure 9. Undefined length burst example

In this example, a master runs an undefined length burst and the MGPCR[AULB] bits indicate arbitration occurs after the fourth beat of the burst. The master runs two sequential beats and then starts what will be a 12-beat undefined length burst access to a new address within the same slave port region as the previous access. The crossbar does not allow an arbitration point until the fourth overall access, or the second beat of the second burst. At that point, all remaining accesses are open for arbitration until the master loses control of the slave port.

Assume the master loses control of the slave port after the fifth beat of the second burst. After the master regains control of the slave port no arbitration point is available until after the master has run four more beats of its burst. After the fourth beat of the now continued burst, or the ninth beat of the second burst from the master's perspective, is taken, all beats of the burst are once again open for arbitration until the master loses control of the slave port.

Assume the master again loses control of the slave port on the fifth beat of the third now continued burst, or the 10th beat of the second burst from the master's perspective. After the master regains control of the slave port, it is allowed to complete its final two beats of its burst without facing arbitration.

NOTE

Fixed-length burst accesses are not affected by the AULB bits. All fixed-length burst accesses lockout arbitration until the last beat of the fixed-length burst.

7.4.3.2 Fixed-priority operation

When operating in fixed-priority mode, each initiator is assigned a unique priority level in the priority registers (PRS*n*). If two initiators request access to the same target port, the initiator with the highest priority in the selected priority register gains control over the target port.

NOTE

In this arbitration mode, a higher-priority initiator can monopolize a target port, preventing access from any lower-priority initiator to the port.

When a initiator makes a request to a target port, the target port checks whether the new requesting initiator's priority level is higher than that of the initiator that currently has control over the target port, unless the target port is in a parked state. The target port performs an arbitration check at every clock edge to ensure that the initiator, if any, has control of the target port.

The following table describes possible scenarios based on the requesting initiator port.

Table 34. Methods of how the crossbar switch grants control of a target port to a initiator

When	Then the crossbar switch grants control to the requesting initiator
Both of the following are true: • The current initiator is not running a transfer. • The new requesting initiator's priority level is higher than that of the current initiator.	At the next clock edge
Both of the following are true: • The current initiator is running a fixed-length burst transfer or a locked transfer. • The requesting initiator's priority level is higher than that of the current initiator.	At the end of the burst transfer or locked transfer
Both of the following are true: • The current initiator is running an undefined length burst transfer. • The requesting initiator's priority level is higher than that of the current initiator.	At the next arbitration point for the undefined length burst transfer **NOTE** Arbitration points for an undefined length burst are defined in the MGPCR for each initiator.
The requesting initiator's priority level is lower than the current initiator.	At the conclusion of one of the following cycles: • An IDLE cycle • A non-IDLE cycle to a location other than the current target port

7.4.3.3 Round-robin priority operation

When operating in round-robin mode, each initiator is assigned a relative priority based on the initiator port number. This relative priority is compared to the initiator port number (ID) of the last initiator to perform a transfer on the target bus. The highest priority requests the initiator owns the target bus at the next transfer boundary, accounting for locked and fixed-length burst transfers. Priority is based on how far ahead the ID of the requesting initiator is of the ID of the last initiator.

After a initiator is granted access to a target port, a initiator may perform as many transfers as desired to that port until another initiator requests the same target port. The next initiator in line is granted access to the target port at the next transfer boundary, or possibly on the next clock cycle, if the current initiator has no pending access request.

As an example of arbitration in round-robin mode, assume that the crossbar is implemented with initiator ports 0, 1, 4, and 5. If the last initiator of the target port was initiator 1, and initiators 0, 4, and 5 make simultaneous requests, they are serviced in this order: 4,5, and then 0.

Parking may continue to be used in a round-robin mode, but does not affect the round-robin pointer unless the parked initiator performs a transfer. Handoff occurs to the next initiator in line after one cycle of arbitration. If the target port is put into low-power park mode, the round-robin pointer is reset to point at initiator port 0, giving it the highest priority.

7.4.3.4 Clocking

This module has no clocking considerations.

7.4.3.5 Interrupts

This module has no interrupts.

7.4.3.6 Priority assignment

Each initiator port must be assigned a unique 3-bit priority level. If an attempt is made to program multiple initiator ports with the same priority level within the priority registers (PRS*n*), the crossbar switch responds with a bus error and the registers are not updated.

7.5 External signals

This module has no external signals.

7.6 Initialization/application information

No initialization is required for the crossbar switch.

Hardware reset ensures that all the register bits used by the crossbar switch are properly initialized to a valid state. However, the following settings and priorities may be programmed to achieve the maximum system performance:

- During the configuration of the crossbar switch, all other initiators must be IDLE.
- To prevent reconfiguration of the crossbar switch, write 1 to CRS*n*[RO].

7.7 Glossary

AMBA	Advanced Microcontroller Bus Architecture
IDLE	A type of transfer that a initiator uses when it does not want to perform a data transfer
ID	Initiator port number

Chapter 8
Flash Memory Controller (FMC)

8.1 Chip-specific FMC information

Table 35. Reference links to related information

Topic	Related module	Reference
Full description	FMC	FMC
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

See SMSCM_OCMDR0 for details on flash speculation and flash cache control, refer to the Security RM.

NOTE

The FMC module includes an optional PRINCE encryption/decryption features that is not described here. For details on this feature, refer to the Security RM.

8.1.1 Module instances

This device has two instance of the FMC module.

Table 36. FMC module instances and configuration info

Instance	For information about flash configuration and controls.
Main subsystem flash	See "Secure Miscellaneous System Control Module" in the Security RM.
Radio subsystem flash	See "Radio Flash."

8.1.2 PRINCE

The FMC module includes an optional PRINCE encryption and decryption feature not described in this reference manual. For details on this feature, see the Security RM.

8.2 Overview

The Flash Memory Controller (FMC) is a memory interface and acceleration unit providing:

- An interface between the device and the nonvolatile memory
- Buffers that can accelerate flash memory transfers
  - A flash-phrase-sized(128 bits) single-entry buffer holds the most recently accessed flash phrase.
  - An optional flash-phrase-sized(128 bits) speculation buffer can prefetch the next flash phrase.
  - An optional 4-way,1-set, 128-bit line size flash cache can store previously accessed flash phrases.

The FMC manages the interface between the device and the flash memory. The FMC receives status information describing the configuration of the memory and uses this information to ensure a proper interface. The following table shows the supported read and write operations.

Flash memory type	Read	Write
Program, IFR0, IFR1 flash memory	8-bit, 16-bit, and 32-bit reads	16-byte and 128-byte writes

The FMC is controlled by a programmer's model external to the FMC module; see the chip-specific FMC information for details. The FMC's programming model provides a very configurable, high performance flexible memory controller, which can be optimized for the runtime characteristics of specific applications.

NOTE

Program the FMC's controls only while the flash controller is idle. Changing the configuration settings while a flash access is in progress can cause non-deterministic, unpredictable behavior.

8.2.1 Features

- Interface between the device and the flash memory:
  - The FMC's input bus supports 8-bit, 16-bit, and 32-bit read operations to flash memory.
  - The FMC's flash memory interface fetches a 128-bit flash phrase.
  - For input read requests, the FMC fetches a flash phrase with the desired read data from flash memory.
  - The flash memory interface can write aligned 16-byte flash write phrases or aligned 128-byte flash write pages to flash memory.
  - The FMC has a 16-byte aligned write buffer. This buffer is used once for aligned 16-byte flash write phrases or eight times for aligned 128-byte flash write pages.
  - The FMC's input bus supports 32-bit write operations for flash memory writes to fill the FMC's write buffer.
  - For input write requests, the FMC must receive the 4-word(16-byte) write of an aligned phrase in order.
  - For input write requests, the FMC supports write cancel.
  - Program flash and IFR0 support read and write requests, IFR1 only supports read requests.
- Acceleration of data transfer from flash memory to the device:
  - A flash-phrase-sized single-entry buffer that holds the current decrypted flash phrase fetched due to a FMC read request. Subsequent FMC read requests *that hit in the single-entry buffer* return data with no wait states.
  - A flash-phrase-sized prefetch speculation buffer with controls for prefetching on instructions and/or data reads. When prefetching is enabled, idle FMC-to-flash interface cycles are used to fetch the next sequential flash phrase and hold it in the prefetch buffer. Subsequent FMC read requests *that hit in the speculation buffer* return data with no wait states.
  - Input controls:
    - To disable data type speculation
    - To disable all speculation
    - To clear the flash cache,single-entry buffer and speculation buffer
    - To disable the flash cache,single-entry buffer and speculation buffer
    - To enable AHB bus stall on flash busy
    - To lock access to IFR1
    - To disable AHB bus error on flash multibit ECC error for data
    - To disable AHB bus error on flash multibit ECC error for instruction

    To enable flash speculation, enable AHB bus error on flash multibit ECC error for data and instruction. See the chip-specific section for details about controls.
  - Flash cache

- Program flash and IFR0 are cacheable, IFR1 is not cacheable.

— The flash cache has input controls:

- To disable instruction caching(disable cache loads)
- To disable data caching(disable cache loads)
- To disable all caching(disable cache loads and hits)
- To clear the cache(tag, data and valid)

See the chip-specific section for details about controls.

— The size of the flash cache in bytes is calculated as follows:

flash cache size = [number of ways] × [number of sets] × [flash phrase size (in bytes)]

For example, a flash cache with 4 ways, 1 set, and a 128-bit flash phrase (= 16 bytes) has a total flash cache size = 64 bytes

(4 ways) × (1 set) × (16 bytes per flash phrase) = 64 bytes, the size of the flash cache

NOTE

Clear the speculation buffer and flash cache before accessing recently modified flash addresses. The flash cache has a specific clear control bit. To clear the speculation buffer, first disable then re-enable the speculation via other modules.

8.3 Functional description

The FMC is a flash interface and acceleration unit, with flexible buffers for user configuration.

- The FMC's input bus can operate faster than the flash memory.
- The FMC-to-flash interface has flow control to add wait states as needed (for input bus reads that need flash accesses).
- The FMC also contains various configurable buffers that hold recent flash accesses. If an input bus read hits a valid buffer, then that access will complete with no wait states.

8.3.1 Modes of operation

The FMC only operates when a bus master accesses the flash memory.

For any device power mode where the flash memory cannot be accessed, FMC is disabled automatically.

8.3.2 Default configuration

After system reset, the FMC is configured to provide a significant level of buffering for transfers from the flash memory. For all banks:

- The single-entry and speculation buffers are cleared by reset.
- Prefetch support by speculation buffer for data and instructions is enabled.
- The flash cache is cleared by reset.
- The flash cache is configured for data or instruction replacement.

8.3.3 Configuration options

The default configuration provides a high degree of flash acceleration, but advanced users may want to customize the FMC buffer configurations to maximize throughput for their use cases. When reconfiguring the FMC for custom use cases, do not program the FMC's control registers while the flash memory is being accessed. Instead, change the control registers with a routine executing from RAM in Supervisor mode.

The FMC's flash cache and buffering controls allow other modules to tune resources to suit specific application requirements. The flash cache and buffer are each controlled individually. The controls enable caching and prefetching per access type (instruction fetch or data reference).

See the chip-specific section for details about the registers used to configure FMC.

As an application example: if both instruction fetches and data references are accessing flash memory, then control is available to send instruction fetches, data references, or both to the flash cache or the single-entry buffer. Likewise, speculation can be enabled or disabled for either type of access.

For best performance, the FMC flash cache and speculation buffering should be enabled for instruction, data fetching, or both. The following is recommended for best performance:

- If the speculation buffer is enabled for both instruction and data speculation, enable the flash cache for both instruction and data caching.
- If the speculation buffer is enabled for instruction speculation only, enable the flash cache for at least instruction caching.

8.3.4 Wait states

Because the core, crossbar switch, and bus masters can be clocked at a higher frequency than the flash clock, flash memory accesses that do not hit in the speculation buffer or cache usually require wait states.

FMC does not allow the configuration of wait states directly. Wait states can be controlled via FMU FCTRL[RWSC].

8.3.5 Speculative reads

The FMC has a speculation buffer that reads ahead to the next phrase in the flash memory if there is an idle cycle. Speculative prefetching is programmable for instruction and data accesses. Because many code accesses are sequential, using the speculative prefetch buffer improves performance in most cases.

Program flash and IFR0 support speculation reads, IFR1 doesn't support speculation reads. See the chip-specific section for information about controlling speculative reads.

When speculative reads are enabled, the FMC immediately requests the next sequential phrase address after a read completes. By requesting the next phrase immediately, speculative reads can help to reduce or even eliminate wait states when accessing sequential code and/or data.

8.3.6 Interrupts

This module has no interrupts.

8.4 External signals

The FMC has no external signals.

8.5 Initialization and application information

The FMC does not require user initialization. Flash acceleration features are enabled by default.

The FMC has no visibility into flash memory erase and program cycles because the Flash Memory module manages them directly. To prevent the possibility of returning stale data after an application executes flash memory commands, disable and/or clear FMC's single-entry buffer, speculation buffer, and cache. If you want to disable the speculation buffer and cache in certain specific cases, we recommend disabling them all.

See the chip-specific section for details about the registers used to disable and/or clear flash cache, speculation buffer and single-entry buffer.

Chapter 9
System Performance Monitor (SYSPM)

9.1 Chip-specific SYSPM information

Table 37. Reference links to related information

Topic	Related module	Reference
Full description	SYSPM	SYSPM
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

9.1.1 Module instances

SYSPM does not support FlexSPI and supports CM33 PC and CM33 PS PERFMON monitors.

9.1.2 Perfmon Counters

The following table describes the countable events for the LPCAC and FlexSPI performance monitors in MCX W72.

Table 38. Perfmon Counters

Event Encoding	Mnemonic	CMX_PERFMON Note: Same event encodings are used for CMX_PERFMON0 and CMX_PERFMON1 except cac_wb_push.	Notes
AHB nonTCM ("cache") Transfers			
0b100_0000	cac_if	YES	Cached instruction fetches
0b100_0100	cac_if_stalls	YES	Stalled cached instruction fetches
0b100_0001	cac_opr	YES	Cached operand reads
0b100_0101	cac_opr_stalls	YES	Stalled cached operand reads
0b100_0010	cac_opw	YES	Cached operand writes
0b100_0110	cac_opw_stalls	YES	Stalled cached operand writes
0b100_0011	cac_opx	YES	Cached operand reads plus writes
0b100_0111	cac_opx_stalls	YES	Stalled cached operand reads plus writes
0b100_1000	cac_wt_opw	YES	Cache writethrough operand writes

Table continues on the next page...

Table 38. Perfmon Counters (continued)

Event Encoding	Mnemonic	CMX_PERFMON Note: Same event encodings are used for CMX_PERFMON0 and CMX_PERFMON1 except cac_wb_push.	Notes
0b100_1100	cac_wt_opw_stalls	YES	Stalled writethrough operand writes
0b101_0000	cac_if_miss	YES	Instruction fetch miss (for CMX_PERFMON1 - number of times FlexSPI signalled miss)
0b101_0001	cac_opr_miss	YES	Operand read miss
0b101_0010	cac_opw_miss	YES	Operand write miss
0b101_0011	cac_opx_miss	YES	Operand read plus write miss
0b101_1000	cac_wb_push	YES for CMX_PERFMON1, NO for CMX_PERFMON0	Cache writeback line pushes

9.2 Overview

System Performance Monitor (SYSPM) is a memory mapped peripheral that enables the user to monitor system and/or CPU events. The SYSPM consists of sixteen 256 Byte sub-slots (SS). The first subslot is the configuration slot. The registers in the configuration SS0 describe the number of monitors, types of monitors and number of counters per monitor. Subsequent sub-slots are occupied by Performance Monitors (PERFMON) registers.

9.2.1 Features

The SYSPM includes the following features:

- Three 40-bit event counters
- Programmable event select
- Countable events that include cache, branch fetches, and stalls

Memory mapped performance monitor that counts instructions, cache, branch, IPS, and TCM stats

9.2.2 Block diagram

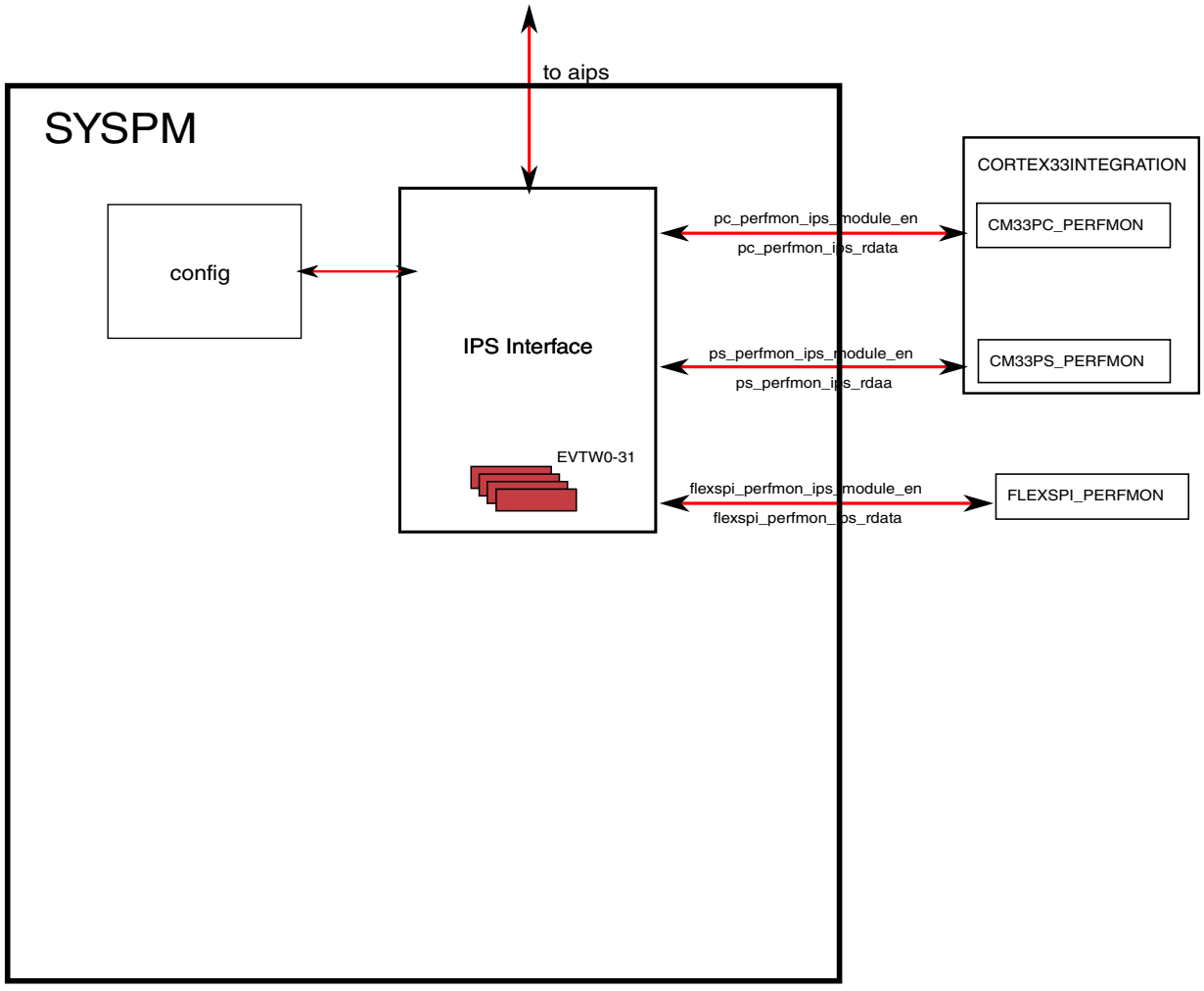


Figure 10. SYSPM Block Diagram

9.3 Functional description

9.3.1 Operating modes

There are no special operating modes for the SYSPM.

9.3.2 Operations

SYSPM routes transaction to CMX_PERFMON. See the chip-specific SYSPM information for details on the performance monitors. SYSPM also provides read-only identification registers that describe the types of monitors in each sub-slot.

9.3.3 Clocking

This module has no clocking considerations.

9.3.4 Interrupts

This module has no interrupts.

9.3.5 External signals

This module has no external signals.

9.3.6 Initialization

Initialization is not required for this module.

9.4 Memory Map and register definition

This section includes the SYSPM module memory map and detailed descriptions of all registers.

9.4.1 SYSPM register descriptions

9.4.1.1 SYSPM memory map

SYSPM base address: 4001_7000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Configuration 0 (CFGSS0)	32	R	FF00_00FFh
4h	Configuration 1 (CFGSS1)	32	R	0000_0000h
8h	Configuration 2 (CFGSS2)	32	R	0103_0002h
Ch	Configuration 3 (CFGSS3)	32	R	0203_0002h
200h	Performance Monitor Control Register (PMCR0)	32	RW	0000_0000h
218h	Performance Monitor Event Counter (PMECTR1_HI_0)	8	R	00h
21Ch	Performance Monitor Event Counter (PMECTR1_LO_0)	32	R	0000_0000h
220h	Performance Monitor Event Counter (PMECTR2_HI_0)	8	R	00h
224h	Performance Monitor Event Counter (PMECTR2_LO_0)	32	R	0000_0000h
228h	Performance Monitor Event Counter (PMECTR3_HI_0)	8	R	00h
22Ch	Performance Monitor Event Counter (PMECTR3_LO_0)	32	R	0000_0000h
300h	Performance Monitor Control Register (PMCR1)	32	RW	0000_0000h
318h	Performance Monitor Event Counter (PMECTR1_HI_1)	8	R	00h
31Ch	Performance Monitor Event Counter (PMECTR1_LO_1)	32	R	0000_0000h
320h	Performance Monitor Event Counter (PMECTR2_HI_1)	8	R	00h
324h	Performance Monitor Event Counter (PMECTR2_LO_1)	32	R	0000_0000h
328h	Performance Monitor Event Counter (PMECTR3_HI_1)	8	R	00h
32Ch	Performance Monitor Event Counter (PMECTR3_LO_1)	32	R	0000_0000h

9.4.1.2 Configuration 0 (CFGSS0)

Offset

Register	Offset
CFGSS0	0h

Function

This register describes the type of monitor, its hardware revision level, number of implemented counters in the monitor.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	MSC								NCTRS							
W																
Reset	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	HRL								ID							
W																
Reset	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 MSC	Miscellaneous • If ID = 0000_0001b, MSC = number of events • If ID = 0000_0010b, — MSC = location identifier — MSC = 00b - CM0+ — MSC = 01b - CMx Code — MSC = 10b - CMx Sys — MSC = 11b- FlexSPI • If ID 0000_0011b, MSC = 11b = Configuration slot • If ID = 0000_0011b, MSC = 11b • For any other ID value, MSC = 00b
23-16 NCTRS	Number of Counters
15-8	Hardware revision level

Table continues on the next page...

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Field	Function
HRL	
7-0 ID	Identifier 0000_0000b - CFGSS not present 0000_0001b - Reserved 0000_0010b - CFGSS PERFMON configuration 0000_0011b - CFGSS Configuration

9.4.1.3 Configuration 1 (CFGSS1)

Offset

Register	Offset
CFGSS1	4h

Function

This register describes the type of monitor, its hardware revision level, number of implemented counters in the monitor and the location of the monitor (if it is a PERFMON).

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	MSC								NCTRS							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	HRL								ID							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 MSC	Miscellaneous • If ID = 0000_0001b, MSC = number of events • If ID = 0000_0010b,

Table continues on the next page...

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Field	Function
	— MSC = location identifier — MSC = 00b - CM0+ — MSC = 01b - CMx Code — MSC = 10b - CMx Sys — MSC = 11b- FlexSPI • If ID 0000_0011b, MSC = 11b = Configuration slot • If ID = 0000_0011b, MSC = 11b • For any other ID value, MSC = 00b
23-16 NCTRS	Number of Counters
15-8 HRL	Hardware revision level
7-0 ID	Identifier 0000_0000b - CFGSS not present 0000_0001b - Reserved 0000_0010b - CFGSS PERFMON configuration 0000_0011b - CFGSS Configuration

9.4.1.4 Configuration 2 (CFGSS2)

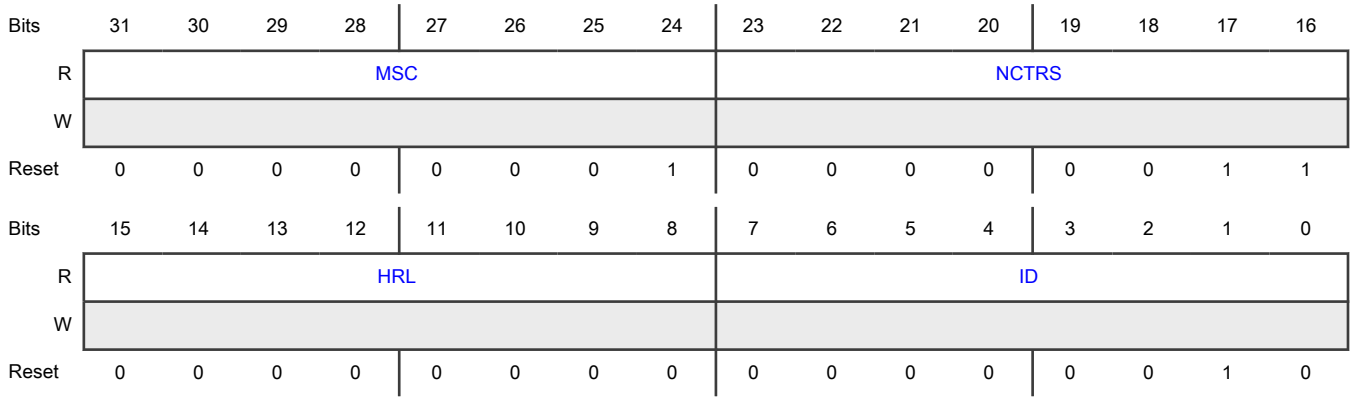
Offset

Register	Offset
CFGSS2	8h

Function

This register describes the type of monitor, its hardware revision level, number of implemented counters in the monitor.

Diagram



Fields

Field	Function
31-24 MSC	Miscellaneous • If ID = 0000_0001b, MSC = number of events • If ID = 0000_0010b, — MSC = location identifier — MSC = 00b - CM0+ — MSC = 01b - CMx Code — MSC = 10b - CMx Sys — MSC = 11b- FlexSPI • If ID 0000_0011b, MSC = 11b = Configuration slot • If ID = 0000_0011b, MSC = 11b • For any other ID value, MSC = 00b
23-16 NCTRS	Number of Counters
15-8 HRL	Hardware revision level
7-0 ID	Identifier 0000_0000b - CFGSS not present 0000_0001b - Reserved 0000_0010b - CFGSS PERFMON configuration 0000_0011b - CFGSS Configuration

9.4.1.5 Configuration 3 (CFGSS3)

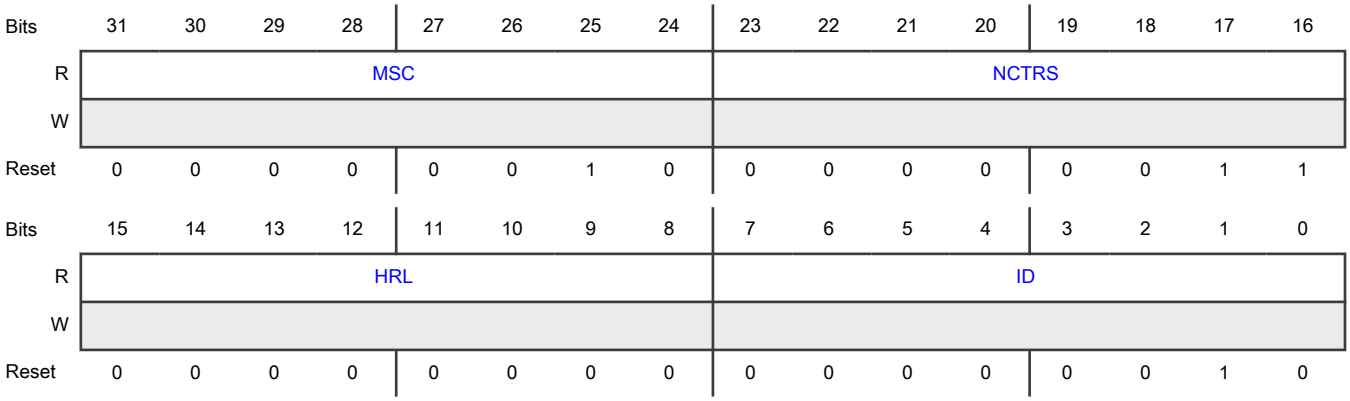
Offset

Register	Offset
CFGSS3	Ch

Function

This register describes the type of monitor, its hardware revision level, number of implemented counters in the monitor.

Diagram



Fields

Field	Function
31-24 MSC	Miscellaneous • If ID = 0000_0001b, MSC = number of events • If ID = 0000_0010b, — MSC = location identifier — MSC = 00b - CM0+ — MSC = 01b - CMx Code — MSC = 10b - CMx Sys — MSC = 11b- FlexSPI • If ID 0000_0011b, MSC = 11b = Configuration slot • If ID = 0000_0011b, MSC = 11b • For any other ID value, MSC = 00b
23-16 NCTRS	Number of Counters
15-8	Hardware revision level

Table continues on the next page...

Table continued from the previous page...

Field	Function
HRL	
7-0 ID	Identifier 0000_0000b - CFGSS not present 0000_0001b - Reserved 0000_0010b - CFGSS PERFMON configuration 0000_0011b - CFGSS Configuration

9.4.1.6 Performance Monitor Control Register (PMCR0 - PMCR1)

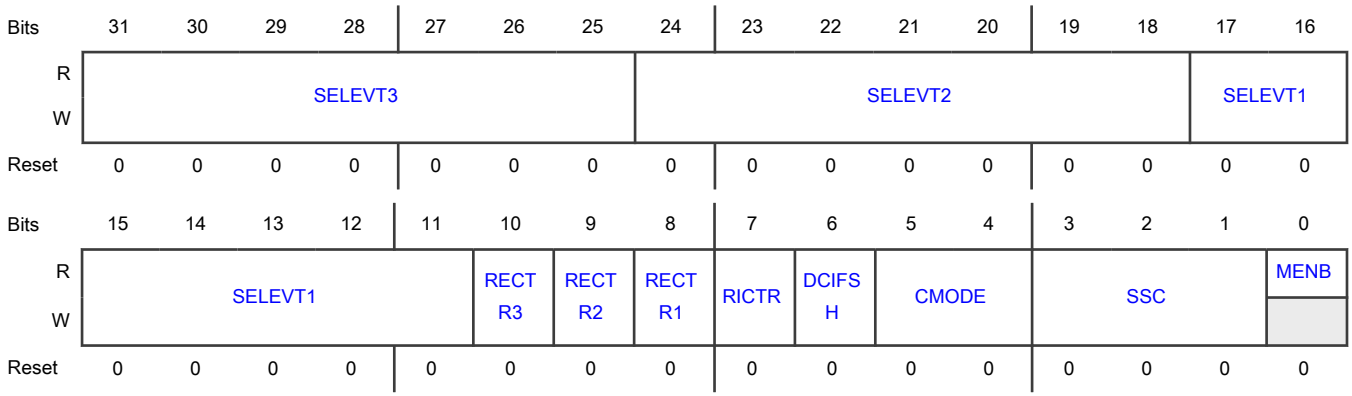
Offset

Register	Offset
PMCR0	200h
PMCR1	300h

Function

The performance monitor control register is used to select which events will be counted in PMCRn register, the count mode, start/stop control and the enables for the counters. See the chip-specific SYSPM information for detailed events.

Diagram



Fields

Field	Function
31-25 SELEVT3	Select Event 3 See Operations to select which event to be counted in PMECTR3.
24-18	Select Event 2

Table continues on the next page...

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Field	Function
SELEVT2	See Operations to select which event to be counted in PMECTR2.
17-11 SELEVT1	Select Event 1 See Operations to select which event to be counted in PMECTR1.
10 RECTR3	Reset Event Counter 3 Write a one to clear event counter 3. This field must be zero to restart event counter 3. 0b - Counter runs normally 1b - Counter value resets at the end of the cycle
9 RECTR2	Reset Event Counter 2 Write a one to clear event counter 2. This field must be zero to restart event counter 2.
8 RECTR1	Reset Event Counter 1 Write a one to clear event counter 1. This field must be zero to restart event counter 1.
7 RICTR	Resets the Instruction Counter Write a one to clear the instruction counter. This field must be zero to restart the instruction counter. 0b - do not reset the instruction counter 1b - clear the instruction counter
6 DCIFSH	Disable Counters if Stopped or Halted 0b - Continue counting 1b - Stops counting when the CPU is halted
5-4 CMODE	Count Mode Determines if events are counted for privileged mode, user mode, or both privileged and user. This setting affects the operation of all three of the event counters. 00b - count in both user and privileged modes 01b - Reserved 10b - count only in user mode 11b - count only in privileged mode
3-1 SSC	Start/Stop Control This 3-bit field provides a three-phase mechanism to start/stop the counters. It includes a prioritized scheme with local start > local stop > global start > global stop > conditional TSTART > TSTOP. The global and conditional start/stop affect all configured PM module concurrently so counters are "coherent". 000b - Idle 001b - local stop

Table continues on the next page...

Table continued from the previous page...

Field	Function
	010b - local start 011b - local start 100b - Reserved 101b - Reserved 110b - Reserved 111b - Reserved
0 MENB	Module is Enabled This bit signals the performance monitor is enabled. Write a non-zero value to the SSC bit field to start the counter. 0b - Disable the performance monitor. 1b - Enable the performance monitor.

9.4.1.7 Performance Monitor Event Counter (PMECTR1_HI_0)

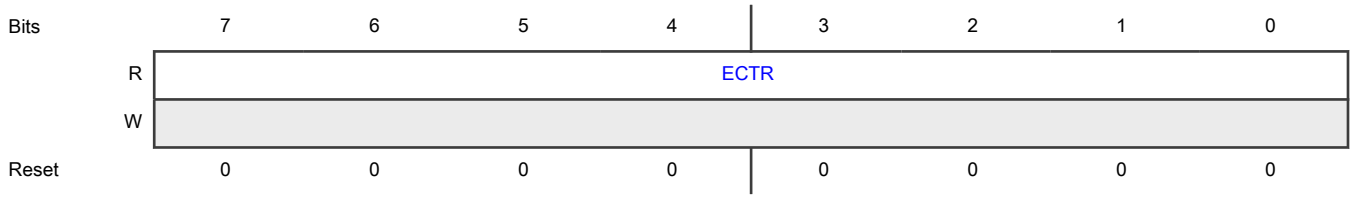
Offset

Register	Offset
PMECTR1_HI_0	218h

Function

{PMECTR1_HI, PMECTR1_LO} is the 40-bit counter that counts the event selected by the PMCR0[SELEVT1] configuration.

Diagram



Fields

Field	Function
7-0 ECTR	Event Counter This is the upper 8-bits of event1 counter. The value in this register increments each time the event selected in PMCR0[SELEVT1] occurs.

9.4.1.8 Performance Monitor Event Counter (PMECTR1_LO_0)

Offset

Register	Offset
PMECTR1_LO_0	21Ch

Function

{PMECTR1_HI, PMECTR1_LO} is the 40-bit counter that counts the event selected by the PMCR0[SELEVT1] configuration.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	ECTR															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	ECTR															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 ECTR	Event Counter This is the lower 32-bits of event1 counter. The 40-bit value increments each time the event selected in PMCR0[SELEVT1] occurs.

9.4.1.9 Performance Monitor Event Counter (PMECTR2_HI_0)

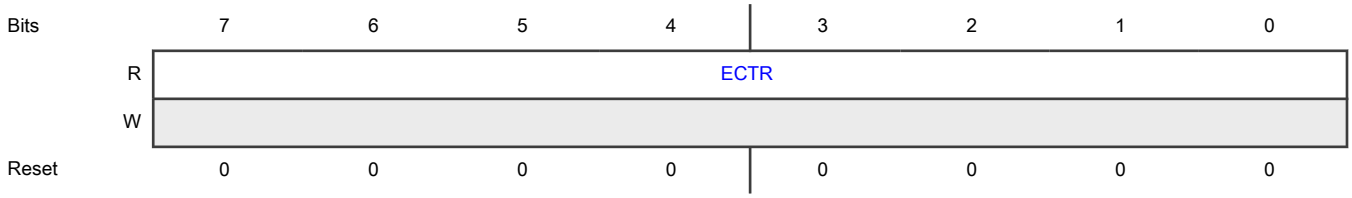
Offset

Register	Offset
PMECTR2_HI_0	220h

Function

{PMECTR2_HI, PMECTR2_LO} is the 40-bit counter that counts the event selected by the PMCR0[SELEVT2] configuration.

Diagram



Fields

Field	Function
7-0 ECTR	Event Counter This is the upper 8-bits of event1 counter. The value in this register increments each time the event selected in PMCR0[SELEVT2] occurs.

9.4.1.10 Performance Monitor Event Counter (PMECTR2_LO_0)

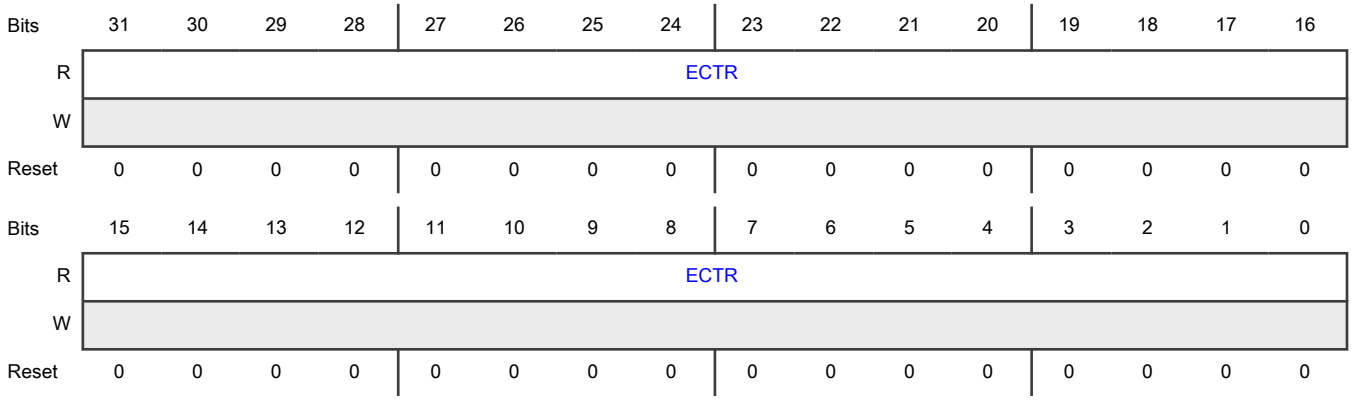
Offset

Register	Offset
PMECTR2_LO_0	224h

Function

{PMECTR2_HI, PMECTR2_LO} is the 40-bit counter that counts the event selected by the PMCR0[SELEVT2] configuration.

Diagram



Fields

Field	Function
31-0 ECTR	Event Counter This is the lower 32-bits of event1 counter. The 40-bit value increments each time the event selected in PMCR0[SELEVT2] occurs.

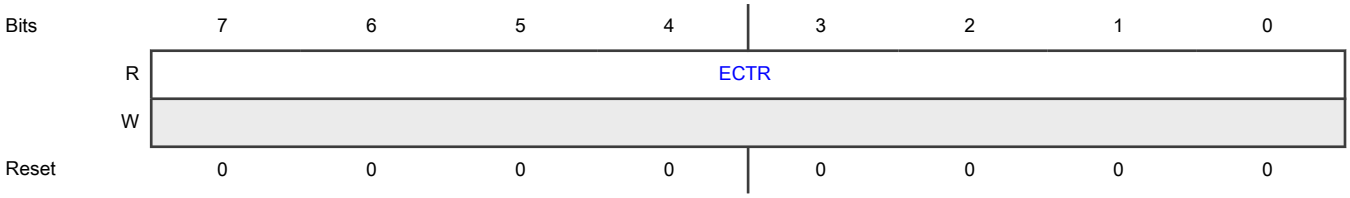
9.4.1.11 Performance Monitor Event Counter (PMECTR3_HI_0)

Offset

Register	Offset
PMECTR3_HI_0	228h

Function
{PMECTR3_HI, PMECTR3_LO} is the 40-bit counter that counts the event selected by the PMCR0[SELEVT3] configuration.

Diagram



Fields

Field	Function
7-0 ECTR	Event Counter This is the upper 8-bits of event1 counter. The value in this register increments each time the event selected in PMCR0[SELEVT3] occurs.

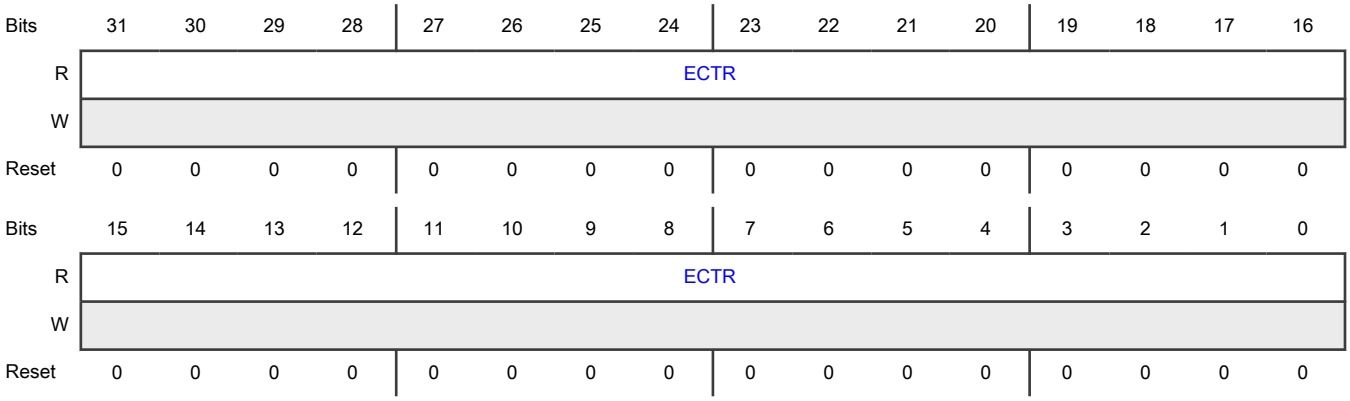
9.4.1.12 Performance Monitor Event Counter (PMECTR3_LO_0)

Offset

Register	Offset
PMECTR3_LO_0	22Ch

Function
{PMECTR3_HI, PMECTR3_LO} is the 40-bit counter that counts the event selected by the PMCR0[SELEVT3] configuration.

Diagram



Fields

Field	Function
31-0 ECTR	Event Counter This is the lower 32-bits of event1 counter. The 40-bit value increments each time the event selected in PMCR0[SELEVT3] occurs.

9.4.1.13 Performance Monitor Event Counter (PMECTR1_HI_1)

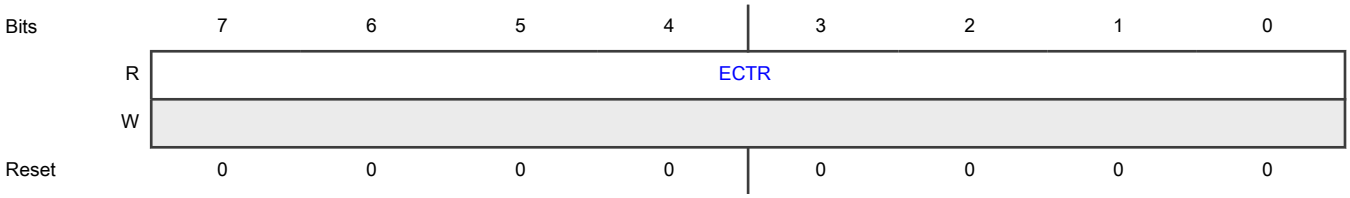
Offset

Register	Offset
PMECTR1_HI_1	318h

Function

{PMECTR1_HI, PMECTR1_LO} is the 40-bit counter that counts the event selected by the PMCR1[SELEVT1] configuration.

Diagram



Fields

Field	Function
7-0 ECTR	Event Counter This is the upper 8-bits of event1 counter. The value in this register increments each time the event selected in PMCR1[SELEVT1] occurs.

9.4.1.14 Performance Monitor Event Counter (PMECTR1_LO_1)

Offset

Register	Offset
PMECTR1_LO_1	31Ch

Function

{PMECTR1_HI, PMECTR1_LO} is the 40-bit counter that counts the event selected by the PMCR1[SELEVT1] configuration.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	ECTR															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	ECTR															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 ECTR	Event Counter This is the lower 32-bits of event1 counter. The 40-bit value increments each time the event selected in PMCR1[SELEVT1] occurs.

9.4.1.15 Performance Monitor Event Counter (PMECTR2_HI_1)

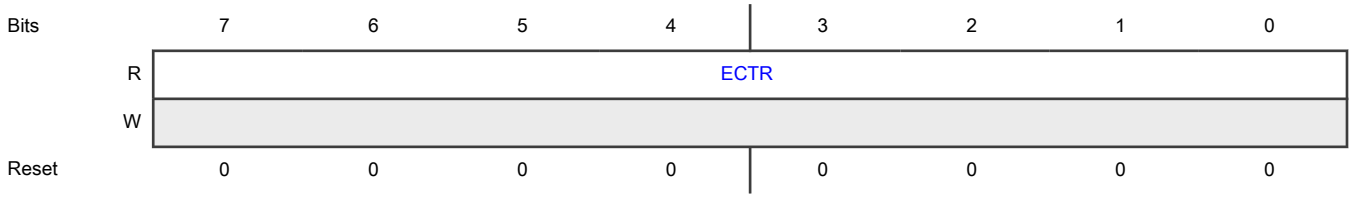
Offset

Register	Offset
PMECTR2_HI_1	320h

Function

{PMECTR2_HI, PMECTR2_LO} is the 40-bit counter that counts the event selected by the PMCR1[SELEVT2] configuration.

Diagram



Fields

Field	Function
7-0 ECTR	Event Counter This is the upper 8-bits of event1 counter. The value in this register increments each time the event selected in PMCR1[SELEVT2] occurs.

9.4.1.16 Performance Monitor Event Counter (PMECTR2_LO_1)

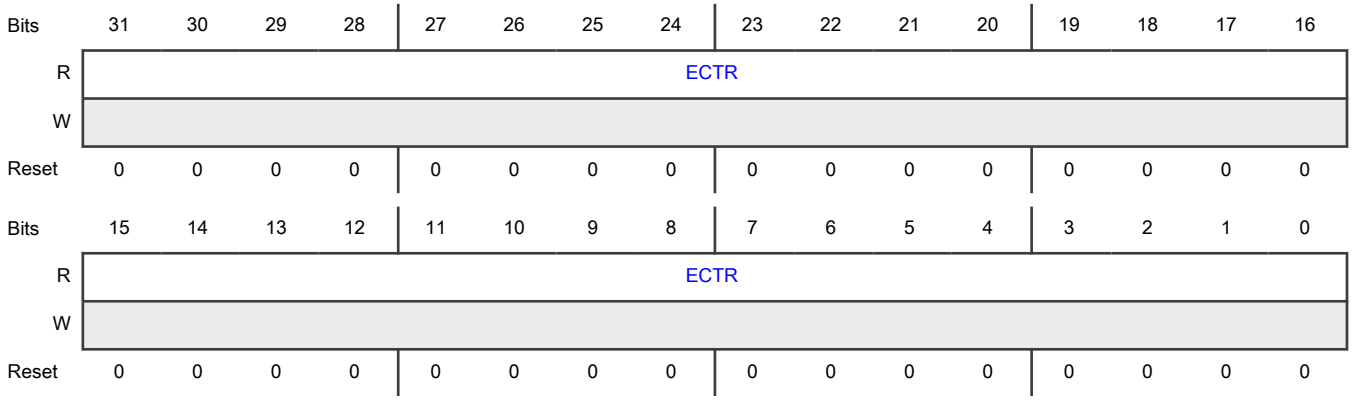
Offset

Register	Offset
PMECTR2_LO_1	324h

Function

{PMECTR2_HI, PMECTR2_LO} is the 40-bit counter that counts the event selected by the PMCR1[SELEVT2] configuration.

Diagram



Fields

Field	Function
31-0 ECTR	Event Counter This is the lower 32-bits of event1 counter. The 40-bit value increments each time the event selected in PMCR1[SELEVT2] occurs.

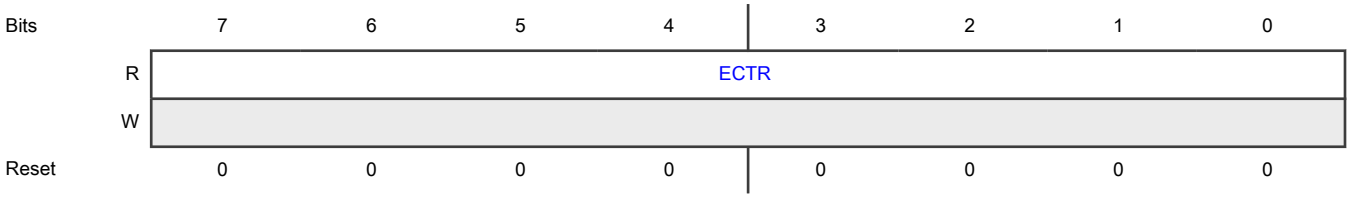
9.4.1.17 Performance Monitor Event Counter (PMECTR3_HI_1)

Offset

Register	Offset
PMECTR3_HI_1	328h

Function
{PMECTR3_HI, PMECTR3_LO} is the 40-bit counter that counts the event selected by the PMCR1[SELEVT3] configuration.

Diagram



Fields

Field	Function
7-0 ECTR	Event Counter This is the upper 8-bits of event1 counter. The value in this register increments each time the event selected in PMCR1[SELEVT3] occurs.

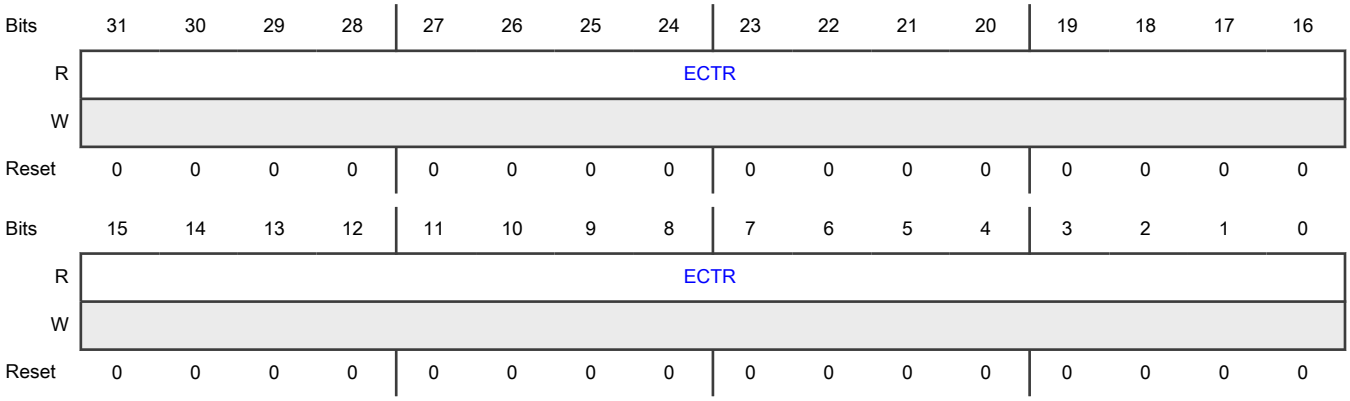
9.4.1.18 Performance Monitor Event Counter (PMECTR3_LO_1)

Offset

Register	Offset
PMECTR3_LO_1	32Ch

Function
{PMECTR3_HI, PMECTR3_LO} is the 40-bit counter that counts the event selected by the PMCR1[SELEVT3] configuration.

Diagram



Fields

Field	Function
31-0 ECTR	Event Counter This is the lower 32-bits of event1 counter. The 40-bit value increments each time the event selected in PMCR1[SELEVT3] occurs.

Chapter 10
Trusted Resource Domain Controller (TRDC)

10.1 Chip-specific TRDC information

Table 39. Reference links to related information

Topic	Related module	Reference
Full description	TRDC	TRDC
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

10.1.1 Module instances

This device has one instance of the TRDC module.

10.1.2 TRDC configuration

Table 40. TRDC slave port configuration

No.	Domain[1]	Slave port No.	Slave memory	Number of block x block size / Regions	Non-secure address
MBC0	Domain0 Domain1 Domain2	SLV0	Flash – 2 MB p System memory map	64 x 32 KB	0000_0000 – 001F_FFFF
		SLV1	Flash IFR0 – 32 KB	4 x 8 KB	0200_0000 – 0200_7FFF
		SLV2	Flash IFR1 – 8 KB	1 x 8 KB	0210_0000 – 0210_1FFF
		SLV3	ROM – 96 KB	12 x 8 KB	0480_0000 – 0481_7FFF
MBC1	Domain0 Domain1 Domain2	SLV0	(Code TCM) CTCM0 – 16 KB (with ECC)	4 x 8 KB	0400_0000 – 0400_7FFF
			CTCM1 – 16 KB (with ECC)		
		SLV1	(System TCM) STCM0 – 16 KB (with ECC) STCM1 – 16 KB (with ECC) STCM2 – 32 KB (with ECC) STCM3 - 32KB (No ECC) STMC4 - 32KB (No ECC)	16 x 8 KB	2000_0000 – 2001_FFFF
		SLV2	STCM5 – 32 KB STCM6 – 32 KB STCM7 – 32 KB	12 x 8 KB	2002_0000 – 2003_7FFF

Table continues on the next page...

Table 40. TRDC slave port configuration (continued)

No.	Domain[1]	Slave port No.	Slave memory	Number of block x block size / Regions	Non-secure address
		SLV3	STCM8 – 8 KB (with ECC)	2 x 4 KB	2003_8000 – 2003_9FFF
MBC2	Domain0 Domain1 Domain2	SLV0	PBRIDGE2	84[2] x 4 KB	4000_0000 – 4007_FFFF
		SLV1	Radio Pbridge in Fast Peripheral 1#unique_190/ unique_190_Connect_42_fn2	4 x 64 KB	4800_0000 – 487F_FFFF
		SLV2	NBU map in Fast Peripheral 1	16 x 4 KB	48A0_0000 – 48A0_FFFF
MRC	Domain0 Domain1 Domain2		NBU map	8 regions	4880_0000 – 489F_FFFF

1. The address ranges for each domain are identical. The different domains provide a mechanism for different masters to have different access permissions when accessing a given memory space. The MDA_Wr_m[DID] configures the domain ID for a given master and this is used to select which set of domain access registers to use.
2. See Peripheral Bridge2 (PBRIDGE2) memory map for details.

Refer Domain Assignment Controller (TRDC_DAC) section

Table 41. TRDC master port configuration

MDAC#	Master
MDAC0	CM33
MDAC1	DMA3
MDAC2	Data stream buffer
MDAC3	Radio NBU
MDAC4	LCE

10.2 Overview

TRDC provides an integrated and scalable architectural framework for access control, system memory protection, and peripheral isolation. It allows software to assign chip resources including processor cores, non-core bus initiators, memory regions, and peripherals to processing domains to support enforcement of robust operational environments.

- First, each bus initiating resource is assigned to a domain identifier (domainID, DID). Typically, each processor is assigned to a unique domainID and all remaining non-processor bus initiators assigned to a different domainID.
- Next, the access control policies for the individual domains are programmed into any number of registers implemented in the target memory block and region checkers.
- Finally, all accesses throughout the device are monitored concurrently to determine the validity of each access. If a reference from a given domain has sufficient access rights, it is allowed to continue, else the access is aborted and error information captured.

The access control scheme that TRDC defines supports a 4-level model, combining the traditional privileged (also known as supervisor) and user modes with an additional signal defining the secure, nonsecure attributes of each memory reference. The result is a 4-level hierarchical access control mechanism with different access control policies based on read, write, and execute references, where:

SecurePriv > SecureUser > NonsecurePriv > NonsecureUser

Combined with the secure/nonsecure and privileged/user attributes, a domainID is associated with every system bus transaction and forms the hardware basis for the implementation of TRDC's access control mechanisms.

NOTE

The terminology in this chapter has been updated to align with NXP's inclusive language standards, as shown in the table below.

Table 42. Updated terms

Updated term	Deprecated term
Initiator	Master
Target	Slave

10.2.1 Block diagram

As previously noted, the TRDC implementation is distributed across multiple submodules instantiated throughout the device. The TRDC submodules include:

- TRDC_MGR
  - The Manager (MGR) submodule coordinates all programming model reads and writes.
- TRDC_DAC
  - The Domain Assignment Controller (DAC) submodule handles resource assignments and generation of the domain identifiers.
- TRDC_MBC
  - The Memory Block Checker (MBC) submodule implements access controls for on-chip internal memories and peripherals based on a fixed-sized block format.
- TRDC_MRC
  - The Memory Region Checker (MRC) submodule implements the access controls for external off-chip memories and peripherals based on the pre-programmed region descriptor registers.

See Figure 11 for a simplified TRDC block diagram focusing on topology and connections.

NOTE

TRDC typically consists of various submodules like DAC, MGR, MBC, and MRC. However, all the submodules as shown in the block diagram below may not be present for this configuration. For chip-specific implementation details of this module's instances, see the chip-specific information.

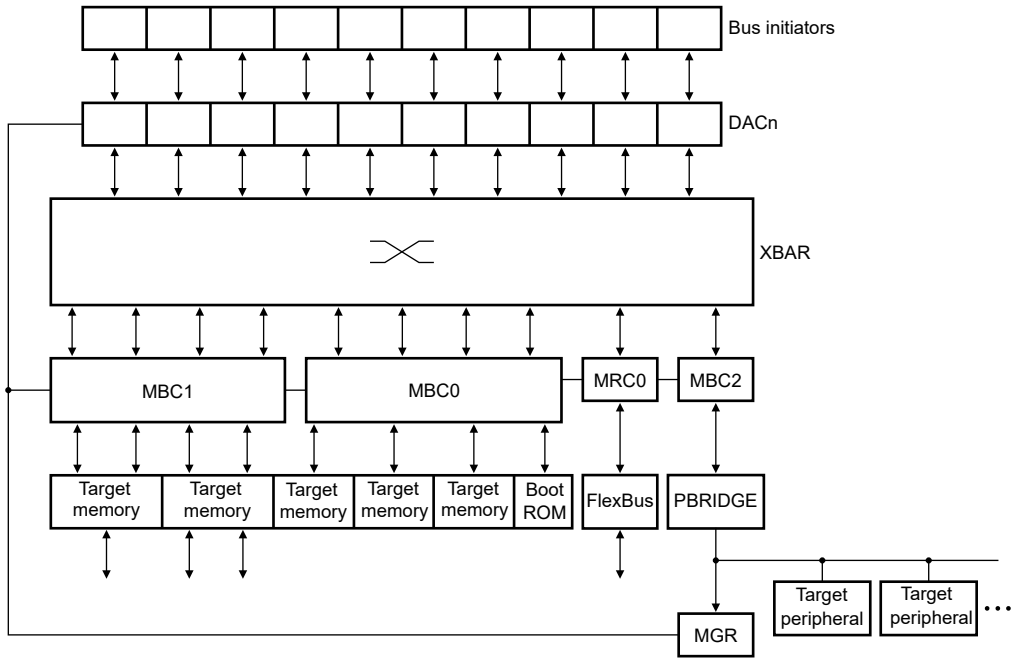


Figure 11. Block diagram

10.2.2 Features

- Ability to assign chip resources to processing "domains":
  - Processor cores, non-core bus initiators, target memories, and target peripherals
  - Each processing domain is assigned a unique domain identifier (domainID, DID)
  - DomainID is an attribute associated with every system bus transaction
  - Used in conjunction with secure/nonsecure, privileged/user attributes
- Generates known physical address (KPA) bus transaction attribute
- Defines access rights to targets in MBCs for on-chip memories and peripherals and in MRCs for external memories and peripherals
- Built upon a 4-level hierarchical access control model:
  - SecurePriv > SecureUser > NonsecurePriv > NonsecureUser
  - Defined by multiple sets of user-programmable R/W/X (Read, Write, Execute) flags per access state
- Distributes programming model and hardware implementation across multiple submodules:
  - Supports a broad, highly-configurable architecture definition
  - Supports efficient mechanisms for memory space context switch state changes using nonsecure enables (NSE) for memory blocks and regions

10.3 Functional description

This section provides more details on the operation and implementation of the TRDC submodules.

10.3.1 Modes of operation

TRDC does not support any special modes of operation. As a memory-mapped device located in the core platform's clock domain, it responds strictly on the basis of memory addresses of the connected system buses. TRDC evaluates domain assignment

and access control functions on a reference-by-reference basis using the addresses and attributes connected to the system bus port(s).

10.3.2 Flash logical window (FLW)

The FLW logic provides a logical window (remapping) between a fixed physical address window and a programmable flash array window.

NOTE

The whole flash image is also available at the normal flash array addresses.

The fixed physical address base and maximum window size is determined per project:

- The fixed physical address base is available in the read-only FLW Physical Base register.
- Program the window size in the number of 32KByte blocks in the FLW Logical Block Count register to configure the functional size of the window.
- Configure the flash array address base in the FLW Array Base register.

When FLW is disabled, the physical address window is not mapped to any memory storage and all accesses to the window result in fault. When FLW is enabled, the physical address window, up to the size that you configure using the Logical Block Count, is mapped to the flash array window. The access to the window beyond the size configured by the Logical Block Count results in fault.

10.3.3 Manager (TRDC_MGR)

The MGR submodule is responsible for coordinating TRDC's programming model reads and writes.

The complete programming model is large. Additionally, the programming model is distributed across the various submodule instances (DAC, MBC, MRC).

MGR provides:

- The required hardware management for all programming model accesses.
- Generating and distributing the appropriate address decodes and write data to the DAC, MBC, and MRC submodule instances.
- Collecting and combining all the register read data buses and responses.

MGR implements:

- The Control Register
- All the read-only hardware configuration registers (HWCFG[0-1], DACFGn, MBCFG, MRCFG)
- The program-visible versions of the domain error capture registers.

To support the domain error reporting functionality, MGR collects the individual captured error indicator output signals from all the submodule instances and remaps them so that they are organized into an instance bitmap by domain that the DERRLOCn register array specifies.

10.3.4 Domain Assignment Controller (TRDC_DAC)

The DAC submodule is responsible for the generation of the domainID on every memory transaction for every bus initiator in the device. The resulting domainID, KPA, and {nonsecure, privileged} signals are generated and then treated as address attributes and associated with each transaction as it moves through the system. KPA indicates whether the address is physical or non-physical. You can use it to bypass SMMU.

As a simple example, assume a system with two domainIDs.

- domainID 0 is for critical tasks.
- domainID 1 is for non-critical tasks.
- Two domainIDs require two MDA_Wm_n registers, MDA_W0 and MDA_W1.

During startup, software initializes the MDA_W[0-1] registers.

1. MDA_W0 = 0x8000_0F81
   - VLD = 1
   - DIDS = 0
   - DID = 1
2. MDA_W1 = 0x8000_0FC2
   - VLD = 1
   - DIDS = 0
   - DID = 2

A special mode is provided for driving the DID of non-processor initiators. This is enabled with the DID bypass (DIDB) bit. The DAC has a DID input that can be driven by a initiator and used directly as the DID output. This allows variability in the DID as dictated by the initiator and is intended to be used by DMA initiators that masquerade as, (that is, drive the DID of) the initiator that programmed it.

10.3.5 Access evaluation

Fundamental to the TRDC's operation is the actual access violation check performed by the memory block checker (MBC) and memory region (MRC).

Previous descriptions have detailed the domain assignment mechanisms and the tracking of the domain identifier as an address attribute through the system bus switching fabric(s). As transactions reach the target memory and peripheral controllers, the address is used to select the appropriate memory region descriptor or block configuration register. Once the appropriate register has been selected, the next function is the actual access evaluation.

For this step, the 3-bit M{B,R}ACSEL field of the selected RGD or BLK_CFG register selects the appropriate GLBAC (global access control policy). The GLBAC register defines the access rights for the domain based on the 4-level model combined with the transaction's access attributes (read = 0/write = 1, secure = 0/nonsecure = 1, execute =1/non-execute=0, user = 0/privileged = 1).

The 4-level model is defined by the concatenation of two address attributes: secure/nonsecure and user/privileged attributes. These two attribute signals (nonsecure, privileged) and the resulting access levels are defined as:

```
if {nonsecure, privileged} == 0b00, then level = SecureUser
if {nonsecure, privileged} == 0b01, then level = SecurePriv(ileged)
if {nonsecure, privileged} == 0b10, then level = NonsecureUser
if {nonsecure, privileged} == 0b11, then level = NonsecurePriv(ileged)
```

The resulting hierarchical access control model specifies:

```
SecurePriv , SecureUser , NonsecurePriv , NonsecureUser
```

After the access evaluation is complete and the access error signal generated, the transaction is allowed to continue if it has sufficient access rights, else the access is aborted with the address and attribute information captured in the appropriate error registers.

10.3.6 Memory Block Checker (TRDC_MBC)

The TRDC's Memory Block Checker provides domain-based access control for all system bus references targeted to on-chip internal memories and peripherals. Using programmed block configuration registers which define the access rights per domain and block, the MBC concurrently monitors system bus transactions and evaluates the appropriateness of each transfer. Memory references that have sufficient access rights are allowed to complete, while references that have insufficient rights are terminated with an access error response.

The TRDC architectural framework supports up to 8 MBC instances where each MBC can support up to 4 sub-regions (MEM[s]). Note monitoring of an AXI memory counts as 2 sub-regions since there are independent read and write channels per AXI memory. Conversely, an AHB connection counts as a single subregion.

Each sub-memory is divided up in equal sized consecutive blocks. Sub-memory 0 (MEM0) can support up to 512 blocks while sub-memory 1-3 (MEM1-MEM3) can each support up to 64 blocks. The number of blocks and size of the block is defined in MBCm_MEMs_GLBCFG[NBLKS,SIZE_LOG2] register fields, where m is the MBC instance number, and s is the sub-memory number. For example, Sub-memory 0 (MEM0) may have 16 consecutive blocks, each of size 64 KB, and corresponding MBCm_DOMd_BLK_CFG_W register to a block will control access to that block.

Each MBCm_DOMd_BLK_CFG_W contains eight access control structures. Each structure is comprised of a 1-bit NSE (NonSecure Enable) plus a 3-bit MBACSEL (Memory Block Access Control Select). The NSE controls secure/nonsecure access to the corresponding block, while the MBACSEL field selects a MBCm_MEMN_GLBACr register which controls the read/write/execute access to the corresponding block. There are 8 programmable MBCm_MEMn_GLBACr registers per block checker, each containing contain read-write-execute control flags for each of the four operating modes:

```
SPR, SPW, SPX - Secure    Privileged {Read, Write, Execute}
SUR, SUW, SUX - Secure    User       {Read, Write, Execute}
NPR, NPW, NPX - Nonsecure Privileged {Read, Write, Execute}
NUR, NUW, NUX - Nonsecure User       {Read, Write, Execute}
```

GLBAC1-7 also have a lock bit MBCm_MEMn_GLBACr[LK]. When LK=1, the GLBACr register is read-only until the next reset. Furthermore, if MBCm_DOMd_BLK_CFG_W[MBACSEL] selects a GLBAC that is locked, the 3-bit MBCACSEL field is also locked until the next reset. GLBAC0 cannot be locked.

The MBC also has MBCm_DOMd_MEMs_BLK_NSE_W registers. These registers are a bit map of the block NSE bits. Each word supports up to 32 blocks.

```
MBCm_DOMd_MEM0_BLK_NSE_W[0-15] has a maximum of 16 words to support 512 blocks
MBCm_DOMd_MEM[1-3]_BLK_NSE_W[0-1] has a maximum of 2 words to support 64 blocks.
```

The block NSE bits can be programmed by writing these registers or by writing the MBCm_MEMN_BLK_{INDEX, SET, CLR, CLR_ALL} registers.

The MBCm_MEMn_NSE_BLK_{INDEX, SET, CLR, CLR_ALL} registers provide a mechanism to efficiently and quickly manipulate the NSE bitmap with bitmasks to set or clear individual blocks within the bitmap and a single operation to perform a clear all across multiple DIDs. The BLK_INDEX register provides the control definition for the BLK_SET and BLK_CLR operations.

10.3.6.1 Memory block hit determination

MBCm_MEMs_GLBCFG[NBLK, SIZE_LOG2] is used to determine which bits of the address correspond to block number.

```
block_n_hit = (addr[MSB:LSB] == n)
where LSB=SIZE_LOG2
MSB=f{NBLKS,LSB}
```

Note that the block hit determination is based only on the address comparison of the first byte being accessed; that is, the MBC does not check the size of the access to make sure it entirely fits within the region.

10.3.6.2 Memory block access evaluation

For a block n hit, the MBC logic evaluates the access rights defined by the MBCm_DOMd_BLK_CFG_Ww registers. The domainID attribute and block number hit selects the appropriate MBCm_DOMd_BLK_CFG_Ww register to use in the access evaluation. The {R,W,X}, nonsecure and privilege attributes of the access are compared with the MBC global access control policy defined in MBCm_DOMd_BLK_CFG_W[MBACSEL, NSE] fields.

While TRDC_CR[GVLDB] = 1, and for each sub-memory being monitored, the MBC performs a reduction-AND of all the individual error terms from each access evaluation.

Unlike the MRC access evaluation and termination, the MBC access evaluation terminates the access with a bus error and reports an access error for only one condition - when the access doesn't have sufficient access rights. By nature, the block checker can only hit in ONE block, and by implementation, there are no "miss" accesses. Accesses outside of the range covered by the MBC

are not sent to the MBC. There also aren't any individual block valid bits. When TRDC_CR[GVLDB] = 1, checking on all blocks is always enabled.

10.3.7 Memory Region Checker (TRDC_MRC)

The TRDC's Memory Region Controller provides domain-based, hardware access control for all system bus references targeted at non-peripheral memory spaces. Using pre-programmed *region descriptors* which define memory spaces and their associated access rights per domain identifier, the MRC concurrently monitors system bus transactions and evaluates the appropriateness of each transfer. Memory references that have sufficient access control rights are allowed to complete, while references that are not mapped to any region descriptor or have insufficient rights are terminated with an access error response.

The TRDC architectural framework supports up to 16 MRC instances, where each MRC instance can support [1-16] region descriptors, concurrently monitoring up to 8 target memory ports. Note, monitoring an AXI protocol port counts as two ports since there are independent read address and write address channels. Conversely, an AHB connection counts as a single port.

A partial, simplified one-dimensional block diagram of an instance of the MRC module is shown in Figure 12. In this figure, a single target bus port is shown. When the remaining target ports are considered, the MRC hardware's two-dimensional connection matrix, broadcasting each system bus target port access across the implemented memory region descriptors, is the resulting structure with the basic access evaluation macro shown as the replicated submodule block. In Figure 12, the system bus fabric target port is shown on the left, the memory region descriptor registers are in the middle, and the peripheral bus interface on the right side. The evaluation macro contains two magnitude comparators connected to the start and end address registers from each region descriptor as well as the combinational logic blocks to determine the region hit and, based on the domainID associated with the reference, access violations.

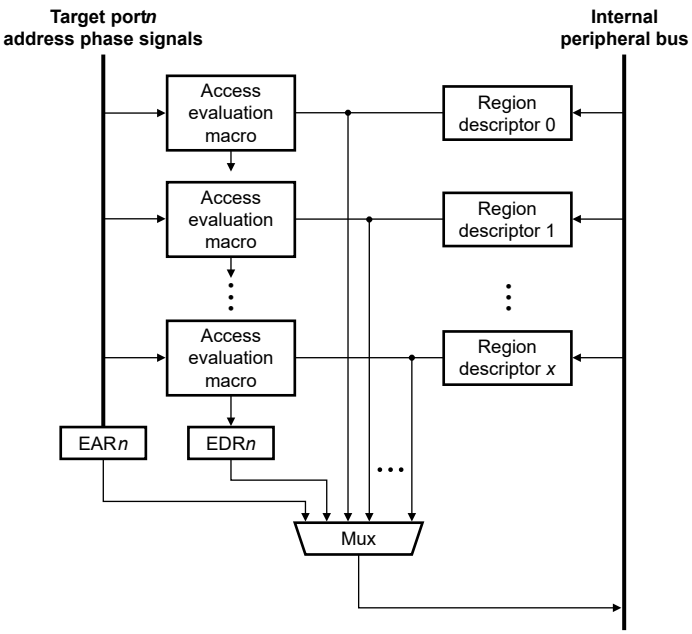


Figure 12. MRC access evaluation macro hardware structure

For each access, the MRC hardware performs a two-step evaluation process. First, the access is compared to all memory region descriptors to determine hit/miss status, and then, using the domainID associated with the reference plus the address attributes {write, nonsecure, privileged}, the access rights are examined using the method detailed in Access evaluation.

10.3.7.1 Memory region descriptor hit determination

To determine if the current reference hits in a given region, two magnitude comparators are used in conjunction with the region's start and end addresses. The boolean equation for this portion of the hit determination is defined as:

```
region_hit_n =
```

```
((addr >= start_addr) & (addr <= end_addr)) & valid
```

where `addr` is the current system reference address, `start_addr` and `end_addr` are the start and end addresses, and `valid` is the valid bit, all from memory region descriptor n.

Note there are *no hardware checks* to verify that `end_addr ≥ start_addr`, and it is software's responsibility to properly load appropriate values into these fields of the region descriptor.

Also, the region hit determination is based only on an address comparison of the first byte being accessed; that is, the MRC does *not* check the size of the access to make sure it entirely fits within the region.

10.3.7.2 Memory region access evaluation

For each region descriptor hit, the MRC logic evaluates the access rights defined by the MRCm_DOMd_RGDr_Ww registers. Specifically, the domainID attribute selects the appropriate MRCm_DOMd_RGDr_Ww register to use in the access evaluation. The {R,W,X}, nonsecure and privilege attributes of the access are compared with the MRC global access control policy defined in MRCm_DOMd_RGDr_W0[MRACSEL] and MRCm_DOMd_RGDr_W1[NSE] fields. See Access evaluation for additional details on this function.

While TRDC_CR[GVLDR] = 1, and for each bus target port being monitored, the MRC performs a **reduction-AND** of all the individual *(no_hit | error)* terms from each access evaluation macro. Recall as specified in Memory region descriptor hit determination, an *invalid* MRC_DOMd_RGDr_Ww (MRCm_DOMd_RGDr_W1[VLD] = 0) forces the region_hit_n evaluation to be negated.

This expression then terminates the bus cycle with an error and reports an access error for three conditions:

1. If the access does not hit in *any* region descriptor, an access error is reported.
2. If the access hits in a single region descriptor and that region signals a domain violation, then an access error is reported.
3. If the access hits in multiple (overlapping) regions and one region signals a violation, then an access error is reported.

The third condition reflects that priority is given to access denying over access allowing for overlapping regions.

Unimplemented domain IDs (DIDs) do not have any associated region descriptors and therefore have no access rights.

10.3.8 Interrupts

This module outputs an interrupt signal which can be connected to the system's interrupt controller. Please check chip-specific interrupt assignment for details. Interrupt is asserted on detection of access violation by any checker, and it remains asserted until DERRLOCn registers are cleared. This interrupt is in addition to interrupt generated by initiator after receiving bus error due to access violation by memory block checker or memory region checker. So, system may receive interrupt through different channels but from the same access violation at checker.

10.4 External signals

The TRDC module does not directly support any external interfaces.

The *internal* interfaces include a standard 32-bit target bus for all programming model accesses, connections to the address phase signals associated with AHB and/or AXI system buses and connections to the target peripheral buses as shown in TRDC block diagram.

10.5 Initialization

Out of reset, TRDC_CR[GVLDR, GVLDB, GVLDM] bits are cleared, TRDC is disabled and in deny by default mode allowing secure privileged startup code to configure the entire programming model. In deny by default mode, only the DIDs that aren't denied by default are allowed to access memory and peripherals. The allowed DIDs are implementation defined. The initialization process typically is performed in 3 steps:

1. Read the various hardware configuration registers (HWCFG{0,1}, DACFGn, MBCm_MEMs_GLBCFG, MRC_GLBCFG) to obtain the implemented hardware capabilities for the device.

2. Using the information retrieved in Step 1 coupled with the desired domain architecture, program all the register data structures for domain assignment (MDA_Wm_n), memory block configuration (MBCm_DOMd_MEMs_BLK_CFG_Ww) and memory region descriptors (MRCm_DOMd_RGDr_Ww). There are individual valid bits included in these registers which typically would be asserted. Additionally, there are also lock mechanisms available if register settings need to be configured and marked as read-only.
3. Once the TRDC programming model is loaded, the TRDC_CR is written with GVLD {R, B, M} asserted. Upon the assertion of the 3 GVLD bits, deny by default mode is exited and at that point, the TRDC is fully operational. The TRDC remains enabled until the next reset.

10.6 Application information

As described in Overview, the TRDC architecture is intended to provide a broad, highly-capable framework for access control, system memory protection and peripheral isolation. The resulting microarchitecture implementation is distributed throughout the core platform, highly configurable via hardware design parameters and software programmability.

10.6.1 Initiator domain assignments

The typical use case related to initiator domain assignments is to include one (or more) processor core(s) in a single domain, possibly coupled with other bus initiator devices like DMA, etc. The definition of a domain may be static, based simply on the combination of a processor and other optional bus initiators. Alternatively, the processor's operation may be configured to dynamically select between a very small number of domains.

For example, "critical" tasks, whether safety-critical, performance-critical, etc. can be grouped together in one domain and all other tasks into a second domain. Non-processor bus initiators typically have a single MDA_Wm_n configuration register associated with them. The domainID and {nonsecure, privileged} attributes are usually statically assigned, unless the module can "inherit" attributes from a processor programming it (certain modules like DMAs).

The MDA_Wm_n registers, along with the memory region descriptors and the peripheral domain access control registers all have lock features that allow the register resources to be converted into read-only resources to protect the written configuration.

10.6.2 Memory region descriptor management

There are important concepts to consider in managing the memory region descriptors.

Recall that the association between each MRCn instance and the target memory regions it monitors is SoC-dependent. The device-specific configuration specifies the number of implemented memory region descriptors in a given instance and the specific port numbers associated with the target memories being monitored.

10.6.3 Domain error capture management

Recall when a domain access violation is detected by either a memory region checker or a memory block checker, address and attribute information of the offending access is captured. The DERRLOCn read-only registers provide additional information signaling the instance number of the submodule where the access violation(s) occurred. Since the resulting exception handler needs the submodule instance to retrieve the captured address and attribute information from DERR_W0_n and DERR_W1_n, the DERRLOCn registers provide the instance number details.

These registers are organized as a word array, *indexed by the faulting domain number*, with the contents of each register providing a bitmap signaling the instance number(s) associated with all submodules containing captured error information for that domain.

It is recommended that the exception handler begin by reading the HWCFG1 register to determine its domainID. Next, it uses the just-retrieved domainID to index into the DERRLOCn array. The resulting DERRLOCn value is then examined to determine the instance number of the reporting MBC and/or MRC submodule.

There may be multiple access violations, across multiple instances, pending for a given domain. It is suggested that exception handler use a "find first one" instruction (alternatively known as "count leading zeroes") to quickly and efficiently find the instance number containing access violation details. Once the instance number has been determined, the captured error address and attribute information can easily be retrieved from the domain error registers. For 32 bits address, the captured error address can be retrieved from DERR_W0_n and the attribute information can be retrieved from DERR_W1_n. For 36 bits address, the captured error address can be retrieved from DERR_W0_n and DERR_W1_n and the attribute information can be retrieved from

DERR_W2_n. The 2-bit DERR_W1_n[EST] or DERR_W2_n[EST] field provides information signaling whether one or more errors have been detected by the submodule instance. A special write to DERR_W3_n is required to reset (and rearm) the EST error capture state machine.

This process is repeated until all errors associated with a given domainID have been processed.

A graphical representation of this 2-step retrieval of the domain error address and attributes is shown in Figure 13.

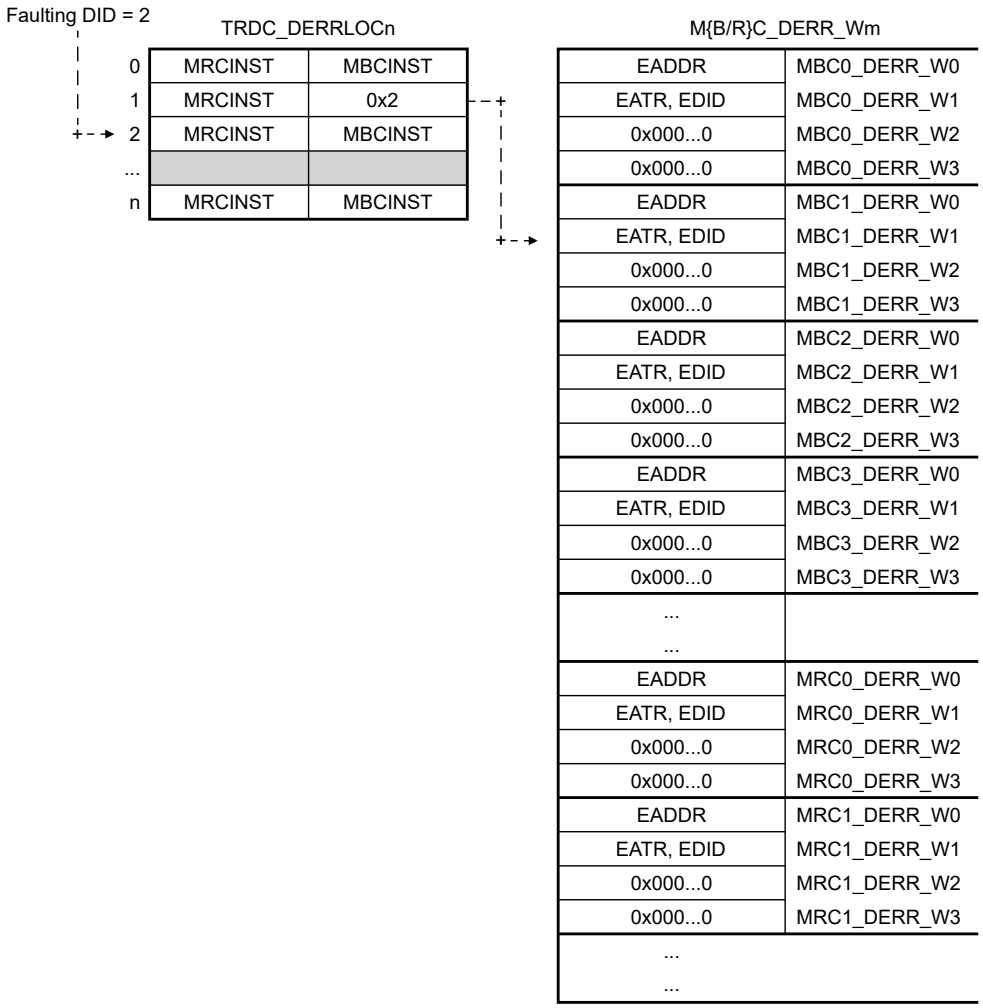


Figure 13. Two-step retrieval of domain error address and attributes

10.7 Register descriptions

The MBCm_NSE_BLK_SET, MBCm_NSE_BLK_CLR and MBCm_NSE_BLK_CLR_ALL registers exist at offset for only domain ID value 0 even when more than 1 domains exist, and address offsets for non-zero domain ID value should be considered reserved space. So, this reserved address space in MBC space does not return transfer error: 0xn14 to 0xn1C where n = (1 to NUM_DID-1) * 2 for each MBC.

If TZ-M is enabled, the TRDC programming model can only be accessed in SecurePrivileged mode. If TZ-M is disabled, it can only be accessed in Privileged mode regardless of Secure or NonSecure; that is it can't be accessed in User mode. Unless noted otherwise, the programming model registers can be accessed via 8-, 16- or 32-bit reads and 32-bit write references. Attempted accesses in a different operating mode, using unsupported write data sizes, writes to read-only resources, or access to reserved spaces are terminated with an error unless noted otherwise. The TRDC programming model is partitioned into these groups of registers:

- Basic hardware control and configuration
- Domain errors: location and details
- Initiator domain assignments
- Memory block and region checkers

It should be noted that many of the programming model registers in TRDC are organized as 2-, 3- or 4- dimensional data structures. For the 2-dimensional structures, the generic arrays contain "m" words representing the "columns" and "n" instances of the structure representing the "rows". These may be described as `structure[n][m]`. They appear in the address space of the programming model memory map in the standard C language row-major layout, that is, the "m" words representing the "column" appear sequentially with the entire row replicated "n" times. The TRDC register structure uses the naming convention of *TRDC_<regname>_Wm_n*, where the column number "m" appears as a numeric suffix on the W (32-bit word) identifier, and the row identifier "n" appears as the final numerical suffix.

For the 4-dimensional structures, the generic arrays contain "m", "d", "s" or "r", and "w" indices corresponding to MBC/MRC instance, domain index, sub-memory or region index and word index. The naming convention for the MBC block configuration and MRC region descriptor word registers are: *MBCm_DOMd_MEMs_BLK_CFG_Ww* and *MRCm_DOMd_RGDr_Ww*

For the reset values in this section, a "*" indicates an initial value determined by the hardware configuration.

10.7.1 TRDC register descriptions

10.7.1.1 TRDC memory map

TRDC base address: 4002_6000h

Offset	Register	Width (In bits)	Access	Reset value
0h	TRDC Register (TRDC_CR)	32	RW	0000_0010h
F0h	Hardware Configuration Register 0 (TRDC_HWCFG0)	32	R	2103_0503h
F4h	TRDC Hardware Configuration Register 1 (TRDC_HWCFG1)	32	R	See section
100h - 104h	Domain Assignment Configuration Register (DACFG0 - DACFG4)	8	R	See section
140h	Memory Block Configuration Register (MBC0_CFG0)	32	R	3404_3C40h
144h	Memory Block Configuration Register (MBC0_CFG1)	32	R	340C_3401h
148h	Memory Block Configuration Register (MBC1_CFG0)	32	R	3410_3404h
14Ch	Memory Block Configuration Register (MBC1_CFG1)	32	R	3002_340Ch
150h	Memory Block Configuration Register (MBC2_CFG0)	32	R	4004_3054h
154h	Memory Block Configuration Register (MBC2_CFG1)	32	R	0000_3010h
158h	Memory Block Configuration Register (MBC3_CFG0)	32	R	0000_0000h
15Ch	Memory Block Configuration Register (MBC3_CFG1)	32	R	0000_0000h
160h - 167h	Memory Region Configuration Register (MRCFG0 - MRCFG7)	8	R	See section
1C0h	TRDC IDAU Control Register (TRDC_IDAU_CR)	32	RW	0000_0009h
1E0h	TRDC FLW Control (TRDC_FLW_CTL)	32	RW	0000_0000h
1E4h	TRDC FLW Physical Base (TRDC_FLW_PBASE)	32	R	0100_0000h

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Offset	Register	Width (In bits)	Access	Reset value
1E8h	TRDC FLW Array Base (TRDC_FLW_ABASE)	32	RW	0000_0000h
1ECh	TRDC FLW Block Count (TRDC_FLW_BCNT)	32	RW	0000_0000h
1FCh	TRDC Fault Domain ID (TRDC_FDID)	32	RW	0000_0000h
200h - 208h	TRDC Domain Error Location Register (TRDC_DERRLOC0 - TRDC_DERRLOC2)	32	R	0000_0000h
400h	MBC Domain Error Word0 Register (MBC0_DERR_W0)	32	R	0000_0000h
404h	MBC Domain Error Word1 Register (MBC0_DERR_W1)	32	R	0000_0000h
40Ch	MBC Domain Error Word3 Register (MBC0_DERR_W3)	32	RW	0000_0000h
410h	MBC Domain Error Word0 Register (MBC1_DERR_W0)	32	R	0000_0000h
414h	MBC Domain Error Word1 Register (MBC1_DERR_W1)	32	R	0000_0000h
41Ch	MBC Domain Error Word3 Register (MBC1_DERR_W3)	32	RW	0000_0000h
420h	MBC Domain Error Word0 Register (MBC2_DERR_W0)	32	R	0000_0000h
424h	MBC Domain Error Word1 Register (MBC2_DERR_W1)	32	R	0000_0000h
42Ch	MBC Domain Error Word3 Register (MBC2_DERR_W3)	32	RW	0000_0000h
480h	MRC Domain Error Word0 Register (MRC0_DERR_W0)	32	R	0000_0000h
484h	MRC Domain Error Word1 Register (MRC0_DERR_W1)	32	R	0000_0000h
48Ch	MRC Domain Error Word3 Register (MRC0_DERR_W3)	32	RW	0000_0000h
800h	DAC Initiator Domain Assignment Register (MDA_W0_0_DFMT0)	32	RW	0000_0000h
820h	DAC Initiator Domain Assignment Register (MDA_W0_1_DFMT1)	32	RW	2000_0000h
840h	DAC Initiator Domain Assignment Register (MDA_W0_2_DFMT1)	32	RW	2000_0000h
860h	DAC Initiator Domain Assignment Register (MDA_W0_3_DFMT1)	32	RW	2000_0000h
880h	DAC Initiator Domain Assignment Register (MDA_W0_4_DFMT1)	32	RW	2000_0000h
1000h	MBC Global Configuration Register (MBC0_MEM0_GLBCFG)	32	R	000F_0040h
1004h	MBC Global Configuration Register (MBC0_MEM1_GLBCFG)	32	R	000D_0004h
1008h	MBC Global Configuration Register (MBC0_MEM2_GLBCFG)	32	R	000D_0001h
100Ch	MBC Global Configuration Register (MBC0_MEM3_GLBCFG)	32	R	000D_000Ch
1010h	MBC NonSecure Enable Block Index (MBC0_NSE_BLK_INDEX)	32	RW	0000_0000h
1014h	MBC NonSecure Enable Block Set (MBC0_NSE_BLK_SET)	32	RW	0000_0000h
1018h	MBC NonSecure Enable Block Clear (MBC0_NSE_BLK_CLR)	32	RW	0000_0000h
101Ch	MBC NonSecure Enable Block Clear All (MBC0_NSE_BLK_CLR_ALL)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
1020h	MBC Global Access Control (MBC0_MEMN_GLBAC0)	32	RW	0000_0000h
1024h	MBC Global Access Control (MBC0_MEMN_GLBAC1)	32	RW	0000_0000h
1028h	MBC Global Access Control (MBC0_MEMN_GLBAC2)	32	RW	0000_0000h
102Ch	MBC Global Access Control (MBC0_MEMN_GLBAC3)	32	RW	0000_0000h
1030h	MBC Global Access Control (MBC0_MEMN_GLBAC4)	32	RW	0000_0000h
1034h	MBC Global Access Control (MBC0_MEMN_GLBAC5)	32	RW	0000_0000h
1038h	MBC Global Access Control (MBC0_MEMN_GLBAC6)	32	RW	0000_0000h
103Ch	MBC Global Access Control (MBC0_MEMN_GLBAC7)	32	RW	0000_0000h
1040h	MBC Memory Block Configuration Word (MBC0_DOM0_MEM0_BLK_CFG_W0)	32	RW	0000_0000h
1044h	MBC Memory Block Configuration Word (MBC0_DOM0_MEM0_BLK_CFG_W1)	32	RW	0000_0000h
1048h	MBC Memory Block Configuration Word (MBC0_DOM0_MEM0_BLK_CFG_W2)	32	RW	0000_0000h
104Ch	MBC Memory Block Configuration Word (MBC0_DOM0_MEM0_BLK_CFG_W3)	32	RW	0000_0000h
1050h	MBC Memory Block Configuration Word (MBC0_DOM0_MEM0_BLK_CFG_W4)	32	RW	0000_0000h
1054h	MBC Memory Block Configuration Word (MBC0_DOM0_MEM0_BLK_CFG_W5)	32	RW	0000_0000h
1058h	MBC Memory Block Configuration Word (MBC0_DOM0_MEM0_BLK_CFG_W6)	32	RW	0000_0000h
105Ch	MBC Memory Block Configuration Word (MBC0_DOM0_MEM0_BLK_CFG_W7)	32	RW	0000_0000h
1140h	MBC Memory Block NonSecure Enable Word (MBC0_DOM0_MEM0_BLK_NSE_W0)	32	RW	0000_0000h
1144h	MBC Memory Block NonSecure Enable Word (MBC0_DOM0_MEM0_BLK_NSE_W1)	32	RW	0000_0000h
1180h	MBC Memory Block Configuration Word (MBC0_DOM0_MEM1_BLK_CFG_W0)	32	RW	0000_0000h
11A0h	MBC Memory Block NonSecure Enable Word (MBC0_DOM0_MEM1_BLK_NSE_W0)	32	RW	0000_0000h
11A8h	MBC Memory Block Configuration Word (MBC0_DOM0_MEM2_BLK_CFG_W0)	32	RW	0000_0000h
11C8h	MBC Memory Block NonSecure Enable Word (MBC0_DOM0_MEM2_BLK_NSE_W0)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
11D0h	MBC Memory Block Configuration Word (MBC0_DOM0_MEM3_BLK_CFG_W0)	32	RW	0000_0000h
11D4h	MBC Memory Block Configuration Word (MBC0_DOM0_MEM3_BLK_CFG_W1)	32	RW	0000_0000h
11F0h	MBC Memory Block NonSecure Enable Word (MBC0_DOM0_MEM3_BLK_NSE_W0)	32	RW	0000_0000h
1240h	MBC Memory Block Configuration Word (MBC0_DOM1_MEM0_BLK_CFG_W0)	32	RW	0000_0000h
1244h	MBC Memory Block Configuration Word (MBC0_DOM1_MEM0_BLK_CFG_W1)	32	RW	0000_0000h
1248h	MBC Memory Block Configuration Word (MBC0_DOM1_MEM0_BLK_CFG_W2)	32	RW	0000_0000h
124Ch	MBC Memory Block Configuration Word (MBC0_DOM1_MEM0_BLK_CFG_W3)	32	RW	0000_0000h
1250h	MBC Memory Block Configuration Word (MBC0_DOM1_MEM0_BLK_CFG_W4)	32	RW	0000_0000h
1254h	MBC Memory Block Configuration Word (MBC0_DOM1_MEM0_BLK_CFG_W5)	32	RW	0000_0000h
1258h	MBC Memory Block Configuration Word (MBC0_DOM1_MEM0_BLK_CFG_W6)	32	RW	0000_0000h
125Ch	MBC Memory Block Configuration Word (MBC0_DOM1_MEM0_BLK_CFG_W7)	32	RW	0000_0000h
1340h	MBC Memory Block NonSecure Enable Word (MBC0_DOM1_MEM0_BLK_NSE_W0)	32	RW	0000_0000h
1344h	MBC Memory Block NonSecure Enable Word (MBC0_DOM1_MEM0_BLK_NSE_W1)	32	RW	0000_0000h
1380h	MBC Memory Block Configuration Word (MBC0_DOM1_MEM1_BLK_CFG_W0)	32	RW	0000_0000h
13A0h	MBC Memory Block NonSecure Enable Word (MBC0_DOM1_MEM1_BLK_NSE_W0)	32	RW	0000_0000h
13A8h	MBC Memory Block Configuration Word (MBC0_DOM1_MEM2_BLK_CFG_W0)	32	RW	0000_0000h
13C8h	MBC Memory Block NonSecure Enable Word (MBC0_DOM1_MEM2_BLK_NSE_W0)	32	RW	0000_0000h
13D0h	MBC Memory Block Configuration Word (MBC0_DOM1_MEM3_BLK_CFG_W0)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
13D4h	MBC Memory Block Configuration Word (MBC0_DOM1_MEM3_BLK_CFG_W1)	32	RW	0000_0000h
13F0h	MBC Memory Block NonSecure Enable Word (MBC0_DOM1_MEM3_BLK_NSE_W0)	32	RW	0000_0000h
1440h	MBC Memory Block Configuration Word (MBC0_DOM2_MEM0_BLK_CFG_W0)	32	RW	0000_0000h
1444h	MBC Memory Block Configuration Word (MBC0_DOM2_MEM0_BLK_CFG_W1)	32	RW	0000_0000h
1448h	MBC Memory Block Configuration Word (MBC0_DOM2_MEM0_BLK_CFG_W2)	32	RW	0000_0000h
144Ch	MBC Memory Block Configuration Word (MBC0_DOM2_MEM0_BLK_CFG_W3)	32	RW	0000_0000h
1450h	MBC Memory Block Configuration Word (MBC0_DOM2_MEM0_BLK_CFG_W4)	32	RW	0000_0000h
1454h	MBC Memory Block Configuration Word (MBC0_DOM2_MEM0_BLK_CFG_W5)	32	RW	0000_0000h
1458h	MBC Memory Block Configuration Word (MBC0_DOM2_MEM0_BLK_CFG_W6)	32	RW	0000_0000h
145Ch	MBC Memory Block Configuration Word (MBC0_DOM2_MEM0_BLK_CFG_W7)	32	RW	0000_0000h
1540h	MBC Memory Block NonSecure Enable Word (MBC0_DOM2_MEM0_BLK_NSE_W0)	32	RW	0000_0000h
1544h	MBC Memory Block NonSecure Enable Word (MBC0_DOM2_MEM0_BLK_NSE_W1)	32	RW	0000_0000h
1580h	MBC Memory Block Configuration Word (MBC0_DOM2_MEM1_BLK_CFG_W0)	32	RW	0000_0000h
15A0h	MBC Memory Block NonSecure Enable Word (MBC0_DOM2_MEM1_BLK_NSE_W0)	32	RW	0000_0000h
15A8h	MBC Memory Block Configuration Word (MBC0_DOM2_MEM2_BLK_CFG_W0)	32	RW	0000_0000h
15C8h	MBC Memory Block NonSecure Enable Word (MBC0_DOM2_MEM2_BLK_NSE_W0)	32	RW	0000_0000h
15D0h	MBC Memory Block Configuration Word (MBC0_DOM2_MEM3_BLK_CFG_W0)	32	RW	0000_0000h
15D4h	MBC Memory Block Configuration Word (MBC0_DOM2_MEM3_BLK_CFG_W1)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
15F0h	MBC Memory Block NonSecure Enable Word (MBC0_DOM2_MEM3_BLK_NSE_W0)	32	RW	0000_0000h
2000h	MBC Global Configuration Register (MBC1_MEM0_GLBCFG)	32	R	000D_0004h
2004h	MBC Global Configuration Register (MBC1_MEM1_GLBCFG)	32	R	000D_0010h
2008h	MBC Global Configuration Register (MBC1_MEM2_GLBCFG)	32	R	000D_000Ch
200Ch	MBC Global Configuration Register (MBC1_MEM3_GLBCFG)	32	R	000C_0002h
2010h	MBC NonSecure Enable Block Index (MBC1_NSE_BLK_INDEX)	32	RW	0000_0000h
2014h	MBC NonSecure Enable Block Set (MBC1_NSE_BLK_SET)	32	RW	0000_0000h
2018h	MBC NonSecure Enable Block Clear (MBC1_NSE_BLK_CLR)	32	RW	0000_0000h
201Ch	MBC NonSecure Enable Block Clear All (MBC1_NSE_BLK_CLR_ALL)	32	RW	0000_0000h
2020h	MBC Global Access Control (MBC1_MEMN_GLBAC0)	32	RW	0000_0000h
2024h	MBC Global Access Control (MBC1_MEMN_GLBAC1)	32	RW	0000_0000h
2028h	MBC Global Access Control (MBC1_MEMN_GLBAC2)	32	RW	0000_0000h
202Ch	MBC Global Access Control (MBC1_MEMN_GLBAC3)	32	RW	0000_0000h
2030h	MBC Global Access Control (MBC1_MEMN_GLBAC4)	32	RW	0000_0000h
2034h	MBC Global Access Control (MBC1_MEMN_GLBAC5)	32	RW	0000_0000h
2038h	MBC Global Access Control (MBC1_MEMN_GLBAC6)	32	RW	0000_0000h
203Ch	MBC Global Access Control (MBC1_MEMN_GLBAC7)	32	RW	0000_0000h
2040h	MBC Memory Block Configuration Word (MBC1_DOM0_MEM0_BLK_CFG_W0)	32	RW	0000_0000h
2140h	MBC Memory Block NonSecure Enable Word (MBC1_DOM0_MEM0_BLK_NSE_W0)	32	RW	0000_0000h
2180h	MBC Memory Block Configuration Word (MBC1_DOM0_MEM1_BLK_CFG_W0)	32	RW	0000_0000h
2184h	MBC Memory Block Configuration Word (MBC1_DOM0_MEM1_BLK_CFG_W1)	32	RW	0000_0000h
21A0h	MBC Memory Block NonSecure Enable Word (MBC1_DOM0_MEM1_BLK_NSE_W0)	32	RW	0000_0000h
21A8h	MBC Memory Block Configuration Word (MBC1_DOM0_MEM2_BLK_CFG_W0)	32	RW	0000_0000h
21ACh	MBC Memory Block Configuration Word (MBC1_DOM0_MEM2_BLK_CFG_W1)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
21C8h	MBC Memory Block NonSecure Enable Word (MBC1_DOM0_MEM2_BLK_NSE_W0)	32	RW	0000_0000h
21D0h	MBC Memory Block Configuration Word (MBC1_DOM0_MEM3_BLK_CFG_W0)	32	RW	0000_0000h
21F0h	MBC Memory Block NonSecure Enable Word (MBC1_DOM0_MEM3_BLK_NSE_W0)	32	RW	0000_0000h
2240h	MBC Memory Block Configuration Word (MBC1_DOM1_MEM0_BLK_CFG_W0)	32	RW	0000_0000h
2340h	MBC Memory Block NonSecure Enable Word (MBC1_DOM1_MEM0_BLK_NSE_W0)	32	RW	0000_0000h
2380h	MBC Memory Block Configuration Word (MBC1_DOM1_MEM1_BLK_CFG_W0)	32	RW	0000_0000h
2384h	MBC Memory Block Configuration Word (MBC1_DOM1_MEM1_BLK_CFG_W1)	32	RW	0000_0000h
23A0h	MBC Memory Block NonSecure Enable Word (MBC1_DOM1_MEM1_BLK_NSE_W0)	32	RW	0000_0000h
23A8h	MBC Memory Block Configuration Word (MBC1_DOM1_MEM2_BLK_CFG_W0)	32	RW	0000_0000h
23ACh	MBC Memory Block Configuration Word (MBC1_DOM1_MEM2_BLK_CFG_W1)	32	RW	0000_0000h
23C8h	MBC Memory Block NonSecure Enable Word (MBC1_DOM1_MEM2_BLK_NSE_W0)	32	RW	0000_0000h
23D0h	MBC Memory Block Configuration Word (MBC1_DOM1_MEM3_BLK_CFG_W0)	32	RW	0000_0000h
23F0h	MBC Memory Block NonSecure Enable Word (MBC1_DOM1_MEM3_BLK_NSE_W0)	32	RW	0000_0000h
2440h	MBC Memory Block Configuration Word (MBC1_DOM2_MEM0_BLK_CFG_W0)	32	RW	0000_0000h
2540h	MBC Memory Block NonSecure Enable Word (MBC1_DOM2_MEM0_BLK_NSE_W0)	32	RW	0000_0000h
2580h	MBC Memory Block Configuration Word (MBC1_DOM2_MEM1_BLK_CFG_W0)	32	RW	0000_0000h
2584h	MBC Memory Block Configuration Word (MBC1_DOM2_MEM1_BLK_CFG_W1)	32	RW	0000_0000h
25A0h	MBC Memory Block NonSecure Enable Word (MBC1_DOM2_MEM1_BLK_NSE_W0)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
25A8h	MBC Memory Block Configuration Word (MBC1_DOM2_MEM2_BLK_CFG_W0)	32	RW	0000_0000h
25ACh	MBC Memory Block Configuration Word (MBC1_DOM2_MEM2_BLK_CFG_W1)	32	RW	0000_0000h
25C8h	MBC Memory Block NonSecure Enable Word (MBC1_DOM2_MEM2_BLK_NSE_W0)	32	RW	0000_0000h
25D0h	MBC Memory Block Configuration Word (MBC1_DOM2_MEM3_BLK_CFG_W0)	32	RW	0000_0000h
25F0h	MBC Memory Block NonSecure Enable Word (MBC1_DOM2_MEM3_BLK_NSE_W0)	32	RW	0000_0000h
3000h	MBC Global Configuration Register (MBC2_MEM0_GLBCFG)	32	R	000C_0054h
3004h	MBC Global Configuration Register (MBC2_MEM1_GLBCFG)	32	R	0010_0004h
3008h	MBC Global Configuration Register (MBC2_MEM2_GLBCFG)	32	R	000C_0010h
300Ch	MBC Global Configuration Register (MBC2_MEM3_GLBCFG)	32	R	0000_0000h
3010h	MBC NonSecure Enable Block Index (MBC2_NSE_BLK_INDEX)	32	RW	0000_0000h
3014h	MBC NonSecure Enable Block Set (MBC2_NSE_BLK_SET)	32	RW	0000_0000h
3018h	MBC NonSecure Enable Block Clear (MBC2_NSE_BLK_CLR)	32	RW	0000_0000h
301Ch	MBC NonSecure Enable Block Clear All (MBC2_NSE_BLK_CLR_ALL)	32	RW	0000_0000h
3020h	MBC Global Access Control (MBC2_MEMN_GLBAC0)	32	RW	0000_0000h
3024h	MBC Global Access Control (MBC2_MEMN_GLBAC1)	32	RW	0000_0000h
3028h	MBC Global Access Control (MBC2_MEMN_GLBAC2)	32	RW	0000_0000h
302Ch	MBC Global Access Control (MBC2_MEMN_GLBAC3)	32	RW	0000_0000h
3030h	MBC Global Access Control (MBC2_MEMN_GLBAC4)	32	RW	0000_0000h
3034h	MBC Global Access Control (MBC2_MEMN_GLBAC5)	32	RW	0000_0000h
3038h	MBC Global Access Control (MBC2_MEMN_GLBAC6)	32	RW	0000_0000h
303Ch	MBC Global Access Control (MBC2_MEMN_GLBAC7)	32	RW	0000_0000h
3040h	MBC Memory Block Configuration Word (MBC2_DOM0_MEM0_BLK_CFG_W0)	32	RW	0000_0000h
3044h	MBC Memory Block Configuration Word (MBC2_DOM0_MEM0_BLK_CFG_W1)	32	RW	0000_0000h
3048h	MBC Memory Block Configuration Word (MBC2_DOM0_MEM0_BLK_CFG_W2)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
304Ch	MBC Memory Block Configuration Word (MBC2_DOM0_MEM0_BLK_CFG_W3)	32	RW	0000_0000h
3050h	MBC Memory Block Configuration Word (MBC2_DOM0_MEM0_BLK_CFG_W4)	32	RW	0000_0000h
3054h	MBC Memory Block Configuration Word (MBC2_DOM0_MEM0_BLK_CFG_W5)	32	RW	0000_0000h
3058h	MBC Memory Block Configuration Word (MBC2_DOM0_MEM0_BLK_CFG_W6)	32	RW	0000_0000h
305Ch	MBC Memory Block Configuration Word (MBC2_DOM0_MEM0_BLK_CFG_W7)	32	RW	0000_0000h
3060h	MBC Memory Block Configuration Word (MBC2_DOM0_MEM0_BLK_CFG_W8)	32	RW	0000_0000h
3064h	MBC Memory Block Configuration Word (MBC2_DOM0_MEM0_BLK_CFG_W9)	32	RW	0000_0000h
3068h	MBC Memory Block Configuration Word (MBC2_DOM0_MEM0_BLK_CFG_W10)	32	RW	0000_0000h
3140h	MBC Memory Block NonSecure Enable Word (MBC2_DOM0_MEM0_BLK_NSE_W0)	32	RW	0000_0000h
3144h	MBC Memory Block NonSecure Enable Word (MBC2_DOM0_MEM0_BLK_NSE_W1)	32	RW	0000_0000h
3148h	MBC Memory Block NonSecure Enable Word (MBC2_DOM0_MEM0_BLK_NSE_W2)	32	RW	0000_0000h
3180h	MBC Memory Block Configuration Word (MBC2_DOM0_MEM1_BLK_CFG_W0)	32	RW	0000_0000h
31A0h	MBC Memory Block NonSecure Enable Word (MBC2_DOM0_MEM1_BLK_NSE_W0)	32	RW	0000_0000h
31A8h	MBC Memory Block Configuration Word (MBC2_DOM0_MEM2_BLK_CFG_W0)	32	RW	0000_0000h
31ACh	MBC Memory Block Configuration Word (MBC2_DOM0_MEM2_BLK_CFG_W1)	32	RW	0000_0000h
31C8h	MBC Memory Block NonSecure Enable Word (MBC2_DOM0_MEM2_BLK_NSE_W0)	32	RW	0000_0000h
3240h	MBC Memory Block Configuration Word (MBC2_DOM1_MEM0_BLK_CFG_W0)	32	RW	0000_0000h
3244h	MBC Memory Block Configuration Word (MBC2_DOM1_MEM0_BLK_CFG_W1)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
3248h	MBC Memory Block Configuration Word (MBC2_DOM1_MEM0_BLK_CFG_W2)	32	RW	0000_0000h
324Ch	MBC Memory Block Configuration Word (MBC2_DOM1_MEM0_BLK_CFG_W3)	32	RW	0000_0000h
3250h	MBC Memory Block Configuration Word (MBC2_DOM1_MEM0_BLK_CFG_W4)	32	RW	0000_0000h
3254h	MBC Memory Block Configuration Word (MBC2_DOM1_MEM0_BLK_CFG_W5)	32	RW	0000_0000h
3258h	MBC Memory Block Configuration Word (MBC2_DOM1_MEM0_BLK_CFG_W6)	32	RW	0000_0000h
325Ch	MBC Memory Block Configuration Word (MBC2_DOM1_MEM0_BLK_CFG_W7)	32	RW	0000_0000h
3260h	MBC Memory Block Configuration Word (MBC2_DOM1_MEM0_BLK_CFG_W8)	32	RW	0000_0000h
3264h	MBC Memory Block Configuration Word (MBC2_DOM1_MEM0_BLK_CFG_W9)	32	RW	0000_0000h
3268h	MBC Memory Block Configuration Word (MBC2_DOM1_MEM0_BLK_CFG_W10)	32	RW	0000_0000h
3340h	MBC Memory Block NonSecure Enable Word (MBC2_DOM1_MEM0_BLK_NSE_W0)	32	RW	0000_0000h
3344h	MBC Memory Block NonSecure Enable Word (MBC2_DOM1_MEM0_BLK_NSE_W1)	32	RW	0000_0000h
3348h	MBC Memory Block NonSecure Enable Word (MBC2_DOM1_MEM0_BLK_NSE_W2)	32	RW	0000_0000h
3380h	MBC Memory Block Configuration Word (MBC2_DOM1_MEM1_BLK_CFG_W0)	32	RW	0000_0000h
33A0h	MBC Memory Block NonSecure Enable Word (MBC2_DOM1_MEM1_BLK_NSE_W0)	32	RW	0000_0000h
33A8h	MBC Memory Block Configuration Word (MBC2_DOM1_MEM2_BLK_CFG_W0)	32	RW	0000_0000h
33ACh	MBC Memory Block Configuration Word (MBC2_DOM1_MEM2_BLK_CFG_W1)	32	RW	0000_0000h
33C8h	MBC Memory Block NonSecure Enable Word (MBC2_DOM1_MEM2_BLK_NSE_W0)	32	RW	0000_0000h
3440h	MBC Memory Block Configuration Word (MBC2_DOM2_MEM0_BLK_CFG_W0)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
3444h	MBC Memory Block Configuration Word (MBC2_DOM2_MEM0_BLK_CFG_W1)	32	RW	0000_0000h
3448h	MBC Memory Block Configuration Word (MBC2_DOM2_MEM0_BLK_CFG_W2)	32	RW	0000_0000h
344Ch	MBC Memory Block Configuration Word (MBC2_DOM2_MEM0_BLK_CFG_W3)	32	RW	0000_0000h
3450h	MBC Memory Block Configuration Word (MBC2_DOM2_MEM0_BLK_CFG_W4)	32	RW	0000_0000h
3454h	MBC Memory Block Configuration Word (MBC2_DOM2_MEM0_BLK_CFG_W5)	32	RW	0000_0000h
3458h	MBC Memory Block Configuration Word (MBC2_DOM2_MEM0_BLK_CFG_W6)	32	RW	0000_0000h
345Ch	MBC Memory Block Configuration Word (MBC2_DOM2_MEM0_BLK_CFG_W7)	32	RW	0000_0000h
3460h	MBC Memory Block Configuration Word (MBC2_DOM2_MEM0_BLK_CFG_W8)	32	RW	0000_0000h
3464h	MBC Memory Block Configuration Word (MBC2_DOM2_MEM0_BLK_CFG_W9)	32	RW	0000_0000h
3468h	MBC Memory Block Configuration Word (MBC2_DOM2_MEM0_BLK_CFG_W10)	32	RW	0000_0000h
3540h	MBC Memory Block NonSecure Enable Word (MBC2_DOM2_MEM0_BLK_NSE_W0)	32	RW	0000_0000h
3544h	MBC Memory Block NonSecure Enable Word (MBC2_DOM2_MEM0_BLK_NSE_W1)	32	RW	0000_0000h
3548h	MBC Memory Block NonSecure Enable Word (MBC2_DOM2_MEM0_BLK_NSE_W2)	32	RW	0000_0000h
3580h	MBC Memory Block Configuration Word (MBC2_DOM2_MEM1_BLK_CFG_W0)	32	RW	0000_0000h
35A0h	MBC Memory Block NonSecure Enable Word (MBC2_DOM2_MEM1_BLK_NSE_W0)	32	RW	0000_0000h
35A8h	MBC Memory Block Configuration Word (MBC2_DOM2_MEM2_BLK_CFG_W0)	32	RW	0000_0000h
35ACh	MBC Memory Block Configuration Word (MBC2_DOM2_MEM2_BLK_CFG_W1)	32	RW	0000_0000h
35C8h	MBC Memory Block NonSecure Enable Word (MBC2_DOM2_MEM2_BLK_NSE_W0)	32	RW	0000_0000h
4000h	MRC Global Configuration Register (MRC0_GLBCFG)	32	R	0000_0008h

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Offset	Register	Width (In bits)	Access	Reset value
4010h	MRC NonSecure Enable Region Indirect (MRC0_NSE_RGN_INDIRECT)	32	RW	0000_0000h
4014h	MRC NonSecure Enable Region Set (MRC0_NSE_RGN_SET)	32	RW	0000_0000h
4018h	MRC NonSecure Enable Region Clear (MRC0_NSE_RGN_CLR)	32	RW	0000_0000h
401Ch	MRC NonSecure Enable Region Clear All (MRC0_NSE_RGN_CLR_ALL)	32	RW	0000_0000h
4020h	MRC Global Access Control (MRC0_GLBAC0)	32	RW	0000_0000h
4024h	MRC Global Access Control (MRC0_GLBAC1)	32	RW	0000_0000h
4028h	MRC Global Access Control (MRC0_GLBAC2)	32	RW	0000_0000h
402Ch	MRC Global Access Control (MRC0_GLBAC3)	32	RW	0000_0000h
4030h	MRC Global Access Control (MRC0_GLBAC4)	32	RW	0000_0000h
4034h	MRC Global Access Control (MRC0_GLBAC5)	32	RW	0000_0000h
4038h	MRC Global Access Control (MRC0_GLBAC6)	32	RW	0000_0000h
403Ch	MRC Global Access Control (MRC0_GLBAC7)	32	RW	0000_0000h
4040h	MRC Region Descriptor Word 0 (MRC0_DOM0_RGD0_W0)	32	RW	0000_0000h
4044h	MRC Region Descriptor Word 1 (MRC0_DOM0_RGD0_W1)	32	RW	0000_0000h
4048h	MRC Region Descriptor Word 0 (MRC0_DOM0_RGD1_W0)	32	RW	0000_0000h
404Ch	MRC Region Descriptor Word 1 (MRC0_DOM0_RGD1_W1)	32	RW	0000_0000h
4050h	MRC Region Descriptor Word 0 (MRC0_DOM0_RGD2_W0)	32	RW	0000_0000h
4054h	MRC Region Descriptor Word 1 (MRC0_DOM0_RGD2_W1)	32	RW	0000_0000h
4058h	MRC Region Descriptor Word 0 (MRC0_DOM0_RGD3_W0)	32	RW	0000_0000h
405Ch	MRC Region Descriptor Word 1 (MRC0_DOM0_RGD3_W1)	32	RW	0000_0000h
4060h	MRC Region Descriptor Word 0 (MRC0_DOM0_RGD4_W0)	32	RW	0000_0000h
4064h	MRC Region Descriptor Word 1 (MRC0_DOM0_RGD4_W1)	32	RW	0000_0000h
4068h	MRC Region Descriptor Word 0 (MRC0_DOM0_RGD5_W0)	32	RW	0000_0000h
406Ch	MRC Region Descriptor Word 1 (MRC0_DOM0_RGD5_W1)	32	RW	0000_0000h
4070h	MRC Region Descriptor Word 0 (MRC0_DOM0_RGD6_W0)	32	RW	0000_0000h
4074h	MRC Region Descriptor Word 1 (MRC0_DOM0_RGD6_W1)	32	RW	0000_0000h
4078h	MRC Region Descriptor Word 0 (MRC0_DOM0_RGD7_W0)	32	RW	0000_0000h
407Ch	MRC Region Descriptor Word 1 (MRC0_DOM0_RGD7_W1)	32	RW	0000_0000h
40C0h	MRC Region Descriptor NonSecure Enable (MRC0_DOM0_RGD_NSE)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
4140h	MRC Region Descriptor Word 0 (MRC0_DOM1_RGD0_W0)	32	RW	0000_0000h
4144h	MRC Region Descriptor Word 1 (MRC0_DOM1_RGD0_W1)	32	RW	0000_0000h
4148h	MRC Region Descriptor Word 0 (MRC0_DOM1_RGD1_W0)	32	RW	0000_0000h
414Ch	MRC Region Descriptor Word 1 (MRC0_DOM1_RGD1_W1)	32	RW	0000_0000h
4150h	MRC Region Descriptor Word 0 (MRC0_DOM1_RGD2_W0)	32	RW	0000_0000h
4154h	MRC Region Descriptor Word 1 (MRC0_DOM1_RGD2_W1)	32	RW	0000_0000h
4158h	MRC Region Descriptor Word 0 (MRC0_DOM1_RGD3_W0)	32	RW	0000_0000h
415Ch	MRC Region Descriptor Word 1 (MRC0_DOM1_RGD3_W1)	32	RW	0000_0000h
4160h	MRC Region Descriptor Word 0 (MRC0_DOM1_RGD4_W0)	32	RW	0000_0000h
4164h	MRC Region Descriptor Word 1 (MRC0_DOM1_RGD4_W1)	32	RW	0000_0000h
4168h	MRC Region Descriptor Word 0 (MRC0_DOM1_RGD5_W0)	32	RW	0000_0000h
416Ch	MRC Region Descriptor Word 1 (MRC0_DOM1_RGD5_W1)	32	RW	0000_0000h
4170h	MRC Region Descriptor Word 0 (MRC0_DOM1_RGD6_W0)	32	RW	0000_0000h
4174h	MRC Region Descriptor Word 1 (MRC0_DOM1_RGD6_W1)	32	RW	0000_0000h
4178h	MRC Region Descriptor Word 0 (MRC0_DOM1_RGD7_W0)	32	RW	0000_0000h
417Ch	MRC Region Descriptor Word 1 (MRC0_DOM1_RGD7_W1)	32	RW	0000_0000h
41C0h	MRC Region Descriptor NonSecure Enable (MRC0_DOM1_RGD_NSE)	32	RW	0000_0000h
4240h	MRC Region Descriptor Word 0 (MRC0_DOM2_RGD0_W0)	32	RW	0000_0000h
4244h	MRC Region Descriptor Word 1 (MRC0_DOM2_RGD0_W1)	32	RW	0000_0000h
4248h	MRC Region Descriptor Word 0 (MRC0_DOM2_RGD1_W0)	32	RW	0000_0000h
424Ch	MRC Region Descriptor Word 1 (MRC0_DOM2_RGD1_W1)	32	RW	0000_0000h
4250h	MRC Region Descriptor Word 0 (MRC0_DOM2_RGD2_W0)	32	RW	0000_0000h
4254h	MRC Region Descriptor Word 1 (MRC0_DOM2_RGD2_W1)	32	RW	0000_0000h
4258h	MRC Region Descriptor Word 0 (MRC0_DOM2_RGD3_W0)	32	RW	0000_0000h
425Ch	MRC Region Descriptor Word 1 (MRC0_DOM2_RGD3_W1)	32	RW	0000_0000h
4260h	MRC Region Descriptor Word 0 (MRC0_DOM2_RGD4_W0)	32	RW	0000_0000h
4264h	MRC Region Descriptor Word 1 (MRC0_DOM2_RGD4_W1)	32	RW	0000_0000h
4268h	MRC Region Descriptor Word 0 (MRC0_DOM2_RGD5_W0)	32	RW	0000_0000h
426Ch	MRC Region Descriptor Word 1 (MRC0_DOM2_RGD5_W1)	32	RW	0000_0000h
4270h	MRC Region Descriptor Word 0 (MRC0_DOM2_RGD6_W0)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
4274h	MRC Region Descriptor Word 1 (MRC0_DOM2_RGD6_W1)	32	RW	0000_0000h
4278h	MRC Region Descriptor Word 0 (MRC0_DOM2_RGD7_W0)	32	RW	0000_0000h
427Ch	MRC Region Descriptor Word 1 (MRC0_DOM2_RGD7_W1)	32	RW	0000_0000h
42C0h	MRC Region Descriptor NonSecure Enable (MRC0_DOM2_RGD_NSE)	32	RW	0000_0000h

10.7.1.2 TRDC Register (TRDC_CR)

Offset

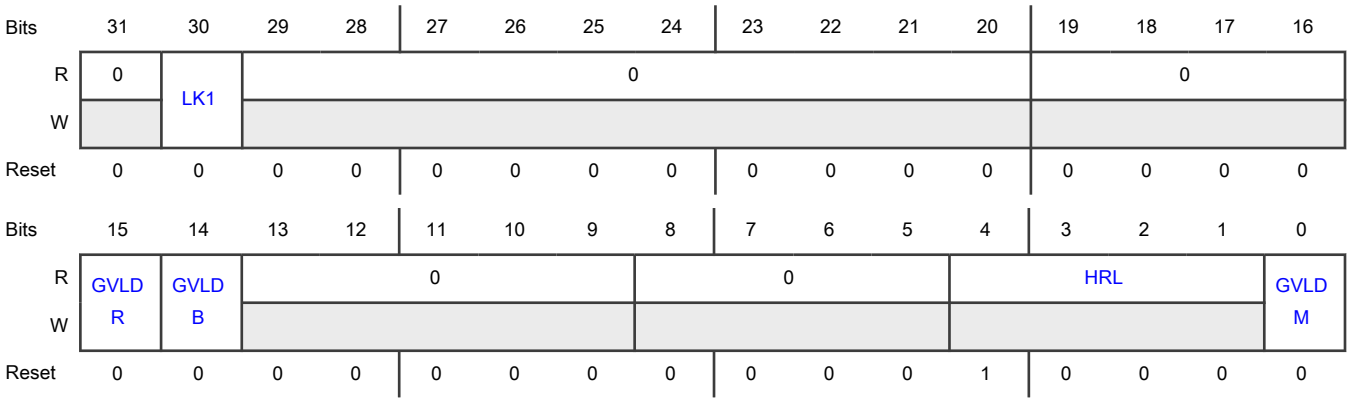
Register	Offset
TRDC_CR	0h

Function

This register provides status about the TRDC and global enable bits for the entire module's operation. A fully operational TRDC requires all global bits GVLD {R,B,M} to be asserted. Undefined behavior results if they are not all asserted. If there are no region checkers (MRCs) present in the configuration, GVLDR need not be asserted for a fully operational TRDC.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read/Write

Diagram



Fields

Field	Function
31 —	Reserved

Table continues on the next page...

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Field	Function
30 LK1	Lock Status This field is the lock status of the TRDC_CR. This field is set when all GVLD bits are set; GVLDR=GVLDB=GVLDM=1b1. Once set, this bit remains asserted until the next reset. 0b - The CR can be written by any secure privileged write. 1b - The CR is locked (read-only) until the next reset.
29-20 —	Reserved
19-16 —	Reserved
15 GVLDR	Global Valid for Memory Region Checkers TRDC global MRC enable/disable. Once set, this bit remains set until the next reset. 0b - TRDC MRCs are disabled. 1b - TRDC MRCs are enabled.
14 GVLDB	Global Valid for Memory Block Checkers TRDC global MBC enable/disable. Once set, this bit remains set until the next reset. 0b - TRDC MBCs are disabled. 1b - TRDC MBCs are enabled.
13-9 —	Reserved
8-5 —	Reserved
4-1 HRL	Hardware Revision Level This read-only field specifies the TRDC’s hardware and definition revision level. It can be read by software to determine the functional definition of the module.
0 GVLDM	Global Valid for Domain Assignment Controllers TRDC global DAC enable/disable. Once set, this bit remains set until the next reset. 0b - TRDC DACs are disabled. 1b - TRDC DACs are enabled.

10.7.1.3 Hardware Configuration Register 0 (TRDC_HWCFG0)

Offset

Register	Offset
TRDC_HWCFG0	F0h

Function

This read-only register contains information on the TRDC's hardware configuration. Specifically, it defines the number of implemented domains and bus initiators along with the number of instances of memory block checkers (MBCs) and memory region checkers (MRCs). The register value at reset is device-specific. Attempted writes are error terminated.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	MID				NMRC				0				NMBC			
W																
Reset	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	NMSTR								0				NDID			
W																
Reset	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	1

Fields

Field	Function
31-28 MID	Module ID This field defines major version ID of this module.
27-24 NMRC	Number of MRCs This field defines the number of Memory Region Checkers on the device [1-8].
23-19 —	Reserved
18-16 NMBC	Number of MBCs This field defines the number of Memory Block Checkers on the device [1-4].
15-8 NMSTR	Number of bus initiators This read-only field defines the number of bus initiators.

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Field	Function
7-4 —	Reserved
3-0 NDID	Number of domains This read-only field defines the number of domains on the device [1-8].

10.7.1.4 TRDC Hardware Configuration Register 1 (TRDC_HWCFG1)

Offset

Register	Offset
TRDC_HWCFG1	F4h

Function

This register contains information on the TRDC's hardware configuration. It provides a mechanism for software to determine its domain number by simply reading the register. See Domain error capture management for more details on typical usage. Attempted writes are error terminated.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0													DID		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	u	u	u

Fields

Field	Function
31-3 —	Reserved
2-0 DID	Domain identifier number This field provides the domain number [0-7] of the requesting bus initiator.

10.7.1.5 Domain Assignment Configuration Register (DACFG0 - DACFG4)

Offset

Register	Offset
DACFG0	100h
DACFG1	101h
DACFG2	102h
DACFG3	103h
DACFG4	104h

Function

This register defines the number of implemented domain assignment registers for bus initiator m, where m+1 can specify from 1 to 64 bus initiators. These registers are organized as a byte-sized data array and can be read using 8-, 16- or 32-bit accesses. An all-zero value (NCM = 0, NMDAR = 0) indicates a non-existent bus initiator. Attempted writes are error terminated.

Register read will not return transfer error when DACFG for a initiator doesn't exist but it is in the same 32-bit group as DACFG for an existing initiator. For example, when there are only 2 DACFG0-1 registers for 2 initiator, and initiators for DACFG2-3 don't exist, then access to DACFG2-3 won't return transfer error.

Typically, processor bus initiators have one or more domain assignment registers, while non-processor initiators have a single domain assignment register.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read

Diagram

Bits	7	6	5	4	3	2	1	0
R	NCM	0			NMDAR			
W								
Reset	See Register reset values.							

Register reset values

Register	Reset value
DACFG0	01h
DACFG1–DACFG4	81h

Fields

Field	Function
7 NCM	Non-CPU Initiator

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Table continued from the previous page...

Field	Function
	This read-only field signals that bus initiator m is a non-CPU initiator. It specifies that the format of the associated MDA_Wr_m register defines a non-processor domain assignment. This field is zero for a non-existent bus initiator. 0b - Bus initiator is a processor. 1b - Bus initiator is a non-processor.
6-4 —	Reserved
3-0 NMDAR	Number of initiator domain assignment registers for bus initiator m This read-only field specifies the number of registers associated with the initiator domain assignment register for a given bus initiator. The value is limited to the range [0-8], where zero indicates a non-existent bus initiator and non-zero values indicate the number of implemented registers associated with this MDAm.

10.7.1.6 Memory Block Configuration Register (MBC0_CFG0)

Offset

Register	Offset
MBC0_CFG0	140h

Function

This register defines the hardware configuration of two of the sub-blocks within a memory block checker.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv read-only

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	SLV1_BLKSZL2					SLV1_NMBLK									
W																
Reset	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	SLV0_BLKSZL2					SLV0_NMBLK									
W																
Reset	0	0	1	1	1	1	0	0	0	1	0	0	0	0	0	0

Fields

Field	Function
31 —	Reserved
30-26 SLV1_BLKSZL2	Block size log2 in target 1.
25-16 SLV1_NMBLK	Number of blocks in target 1.
15 —	Reserved
14-10 SLV0_BLKSZL2	Block size log2 in target 0.
9-0 SLV0_NMBLK	Number of blocks in target 0.

10.7.1.7 Memory Block Configuration Register (MBC0_CFG1)

Offset

Register	Offset
MBC0_CFG1	144h

Function

This register defines the hardware configuration of two of the sub-blocks within a memory block checker.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv read-only

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	SLV3_BLKSZL2					SLV3_NMBLK									
W																
Reset	0	0	1	1	0	1	0	0	0	0	0	0	1	1	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	SLV2_BLKSZL2					SLV2_NMBLK									
W																
Reset	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1

Fields

Field	Function
31 —	Reserved
30-26 SLV3_BLKSZL2	Block size log2 in target 3.
25-16 SLV3_NMBLK	Number of blocks in target 3.
15 —	Reserved
14-10 SLV2_BLKSZL2	Block size log2 in target 2.
9-0 SLV2_NMBLK	Number of blocks in target 2.

10.7.1.8 Memory Block Configuration Register (MBC1_CFG0)

Offset

Register	Offset
MBC1_CFG0	148h

Function

This register defines the hardware configuration of two of the sub-blocks within a memory block checker.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv read-only

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	SLV1_BLKSZL2							SLV1_NMBLK							
W																
Reset	0	0	1	1	0	1	0	0	0	0	0	1	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	SLV0_BLKSZL2							SLV0_NMBLK							
W																
Reset	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0

Fields

Field	Function
31 —	Reserved
30-26 SLV1_BLKSZL2	Block size log2 in target 1.
25-16 SLV1_NMBLK	Number of blocks in target 1.
15 —	Reserved
14-10 SLV0_BLKSZL2	Block size log2 in target 0.
9-0 SLV0_NMBLK	Number of blocks in target 0.

10.7.1.9 Memory Block Configuration Register (MBC1_CFG1)

Offset

Register	Offset
MBC1_CFG1	14Ch

Function

This register defines the hardware configuration of two of the sub-blocks within a memory block checker.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv read-only

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	SLV3_BLKSZL2					SLV3_NMBLK									
W																
Reset	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	SLV2_BLKSZL2					SLV2_NMBLK									
W																
Reset	0	0	1	1	0	1	0	0	0	0	0	0	1	1	0	0

Fields

Field	Function
31 —	Reserved
30-26 SLV3_BLKSZL2	Block size log2 in target 3.
25-16 SLV3_NMBLK	Number of blocks in target 3.
15 —	Reserved
14-10 SLV2_BLKSZL2	Block size log2 in target 2.
9-0 SLV2_NMBLK	Number of blocks in target 2.

10.7.1.10 Memory Block Configuration Register (MBC2_CFG0)

Offset

Register	Offset
MBC2_CFG0	150h

Function

This register defines the hardware configuration of two of the sub-blocks within a memory block checker.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv read-only

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	SLV1_BLKSZL2							SLV1_NMBLK							
W																
Reset	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	SLV0_BLKSZL2							SLV0_NMBLK							
W																
Reset	0	0	1	1	0	0	0	0	0	1	0	1	0	1	0	0

Fields

Field	Function
31 —	Reserved
30-26 SLV1_BLKSZL2	Block size log2 in target 1.
25-16 SLV1_NMBLK	Number of blocks in target 1.
15 —	Reserved
14-10 SLV0_BLKSZL2	Block size log2 in target 0.
9-0 SLV0_NMBLK	Number of blocks in target 0.

10.7.1.11 Memory Block Configuration Register (MBC2_CFG1)

Offset

Register	Offset
MBC2_CFG1	154h

Function

This register defines the hardware configuration of two of the sub-blocks within a memory block checker.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv read-only

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	SLV3_BLKSZL2							SLV3_NMBLK							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	SLV2_BLKSZL2							SLV2_NMBLK							
W																
Reset	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0

Fields

Field	Function
31 —	Reserved
30-26 SLV3_BLKSZL2	Block size log2 in target 3.
25-16 SLV3_NMBLK	Number of blocks in target 3.
15 —	Reserved
14-10 SLV2_BLKSZL2	Block size log2 in target 2.
9-0 SLV2_NMBLK	Number of blocks in target 2.

10.7.1.12 Memory Block Configuration Register (MBC3_CFG0)

Offset

Register	Offset
MBC3_CFG0	158h

Function

This register defines the hardware configuration of two of the sub-blocks within a memory block checker.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv read-only

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	SLV1_BLKSZL2							SLV1_NMBLK							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	SLV0_BLKSZL2							SLV0_NMBLK							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 —	Reserved
30-26 SLV1_BLKSZL2	Block size log2 in target 1.
25-16 SLV1_NMBLK	Number of blocks in target 1.
15 —	Reserved
14-10 SLV0_BLKSZL2	Block size log2 in target 0.
9-0 SLV0_NMBLK	Number of blocks in target 0.

10.7.1.13 Memory Block Configuration Register (MBC3_CFG1)

Offset

Register	Offset
MBC3_CFG1	15Ch

Function

This register defines the hardware configuration of two of the sub-blocks within a memory block checker.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv read-only

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	SLV3_BLKSZL2					SLV3_NMBLK									
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	SLV2_BLKSZL2					SLV2_NMBLK									
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 —	Reserved
30-26 SLV3_BLKSZL2	Block size log2 in target 3.
25-16 SLV3_NMBLK	Number of blocks in target 3.
15 —	Reserved
14-10 SLV2_BLKSZL2	Block size log2 in target 2.
9-0 SLV2_NMBLK	Number of blocks in target 2.

10.7.1.14 Memory Region Configuration Register (MRCFG0 - MRCFG7)

Offset

For r = 0 to 7:

Register	Offset
MRCFGr	160h + (r × 1h)

Function

This read-only register defines the number of implemented memory region descriptors for each MRCr, where r+1 can specify up to 16 instances. These registers are organized as a byte-sized data array and can be read using 8-, 16- or 32-bit accesses. A zero value indicates a non-existent memory region checker instance. Attempted writes are error terminated.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read

Diagram

Bits	7	6	5	4	3	2	1	0
R	0				NMRGD			
W								
Reset	See Register reset values.							

Register reset values

Register	Reset value
MRCFG0	08h
MRCFG1–MRCFG7	00h

Fields

Field	Function
7-5 —	Reserved
4-0 NMRGD	Number of memory region descriptors for memory region checker n Number of memory region descriptors for MRCr. This field specifies the number of memory region descriptors associated with a given memory region checker instance. The value is limited to the range [0-16], where zero indicates a non-existent MRC instance and non-zero values indicate the number of implemented memory region descriptors [0-16] associated with the TRDC_MRCm submodule.

10.7.1.15 TRDC IDAU Control Register (TRDC_IDAU_CR)

Offset

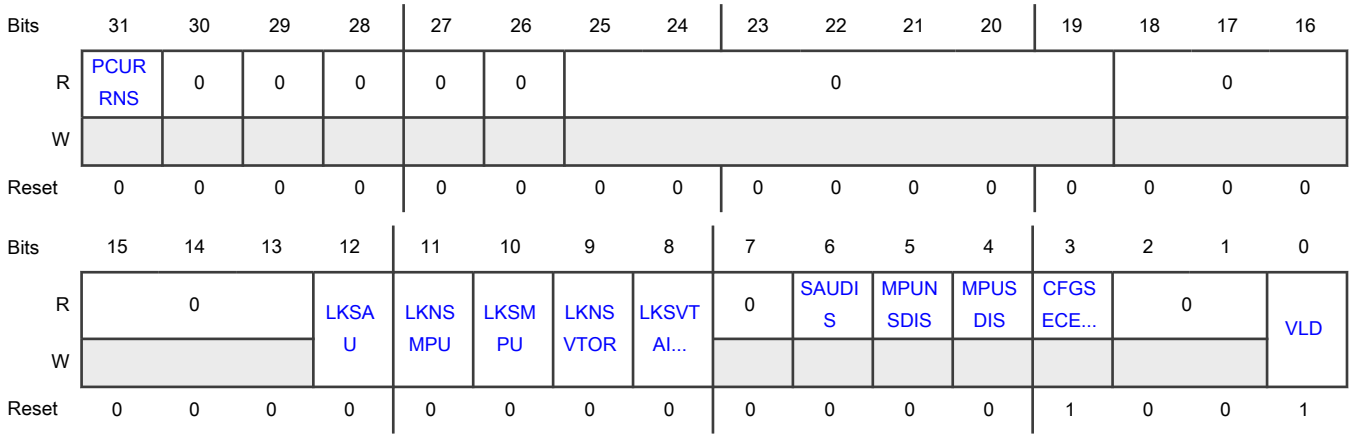
Register	Offset
TRDC_IDAU_CR	1C0h

Function

This register defines the configuration for the Implementation-Defined Attribution Unit which is tightly-coupled to the TZ-M extensions in the processor core. Many of the fields in this register explicitly control processor TZ-M functions.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read/Write

Diagram



Fields

Field	Function
31 PCURRNS	Processor current security Current security state of the processor. 0b - Processor is in Secure state 1b - Processor is in Nonsecure state
30 —	Reserved
29 —	Reserved
28 —	Reserved
27 —	Reserved
26 —	Reserved
25-19 —	Reserved
18-16 —	Reserved
15-13 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
12 LKSAU	Lock SAU Asserting this bit prevents changes to the processor's Secure SAU memory regions already programmed. All processor writes to the registers are ignored. This bit is sticky, once set, it can only be cleared with a reset. 0b - Unlock these registers 1b - Disable writes to the SAU_CTRL, SAU_RNR, SAU_RBAR and SAU_RLAR registers from software or from a debug agent connected to the processor
11 LKNSMPU	Lock Nonsecure MPU Asserting this bit prevents changes to the processor's Nonsecure MPU memory regions already programmed. All processor writes to the registers are ignored. This bit is sticky, once set, it can only be cleared with a reset. 0b - Unlock these registers 1b - Disable writes to the MPU_CTRL_NS, MPU_RNR_NS, MPU_RBAR_NS, MPU_RLAR_NS, MPU_RBAR_A_NSn and MPU_RLAR_A_NSn from software or from a debug agent connected to the processor
10 LKSMPU	Lock Secure MPU Asserting this signal prevents changes to the processor's programmed Secure MPU memory regions and all processor writes to the registers are ignored. This bit is sticky, once set, it can only be cleared with a reset. 0b - Unlock these registers 1b - Disable writes to the MPU_CTRL, MPU_RNR, MPU_RBAR, MPU_RLAR, MPU_RBAR_An and MPU_RLAR_An from software or from a debug agent connected to the processor in Secure state
9 LKNSVTOR	Lock Nonsecure Vector Table Offset Register Asserting this signal prevents changes to the processor's Nonsecure vector table base address. This bit is sticky, once set, it can only be cleared with a reset. 0b - Unlock this register 1b - Disable writes to the VTOR_NS register
8 LKSVTAIRCR	Lock Secure VTOR, Application interrupt and Reset Control Registers This bit is sticky, once set, it can only be cleared with a reset. Asserting this signal prevents processor changes to: • The Secure vector table base address. • Handling of Secure interrupt priority. • BusFault, HardFault, and NMI security target settings in the processor. 0b - Unlock these registers 1b - Disable writes to the VTOR_S, AIRCR[PRIS], and AIRCR[BFHFNMINS] registers
7	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
6 SAUDIS	Security Attribution Unit Disable 0b - SAU is enabled 1b - SAU is disabled
5 MPUNSDIS	NonSecure Memory Protection Unit Disabled 0b - Nonsecure MPU is enabled 1b - Nonsecure MPU is disabled
4 MPUSDIS	Secure Memory Protection Unit Disabled 0b - Secure MPU is enabled 1b - Secure MPU is disabled
3 CFGSECEXT	Configure Security Extension 0b - Armv8M Security Extension is disabled 1b - Armv8-M Security Extension is enabled
2-1 —	Reserved
0 VLD	Valid When VLD =0, all address attribute from IDAU is nonSecure. When VLD=1, values in other fields of this register are valid.

10.7.1.16 TRDC FLW Control (TRDC_FLW_CTL)

Offset

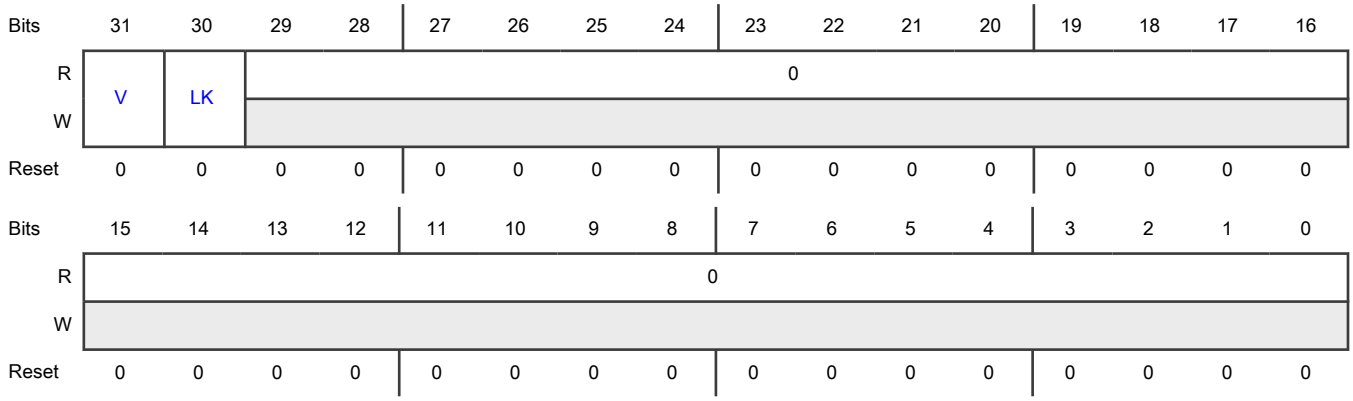
Register	Offset
TRDC_FLW_CTL	1E0h

Function

This register provides control of the FLW = Flash Logical Window operation.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read/Write

Diagram



Fields

Field	Function
31 V	Valid bit 0b - FLW function is disabled. 1b - FLW function is enabled.
30 LK	Lock bit 0b - FLW registers may be modified. 1b - FLW registers are locked until the next reset.
29-0 —	Reserved

10.7.1.17 TRDC FLW Physical Base (TRDC_FLW_PBASE)

Offset

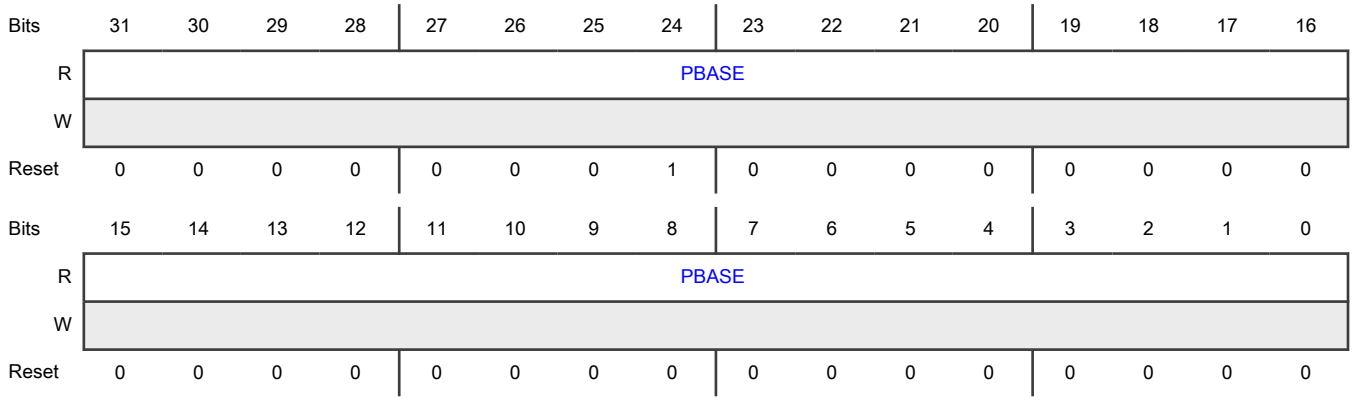
Register	Offset
TRDC_FLW_PBASE	1E4h

Function

This read-only register gives the physical base address of the Flash Logical Window.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read

Diagram



Fields

Field	Function
31-0 PBASE	Physical base address Physical address of the base of the FLW (mod 32KBytes).

10.7.1.18 TRDC FLW Array Base (TRDC_FLW_ABASE)

Offset

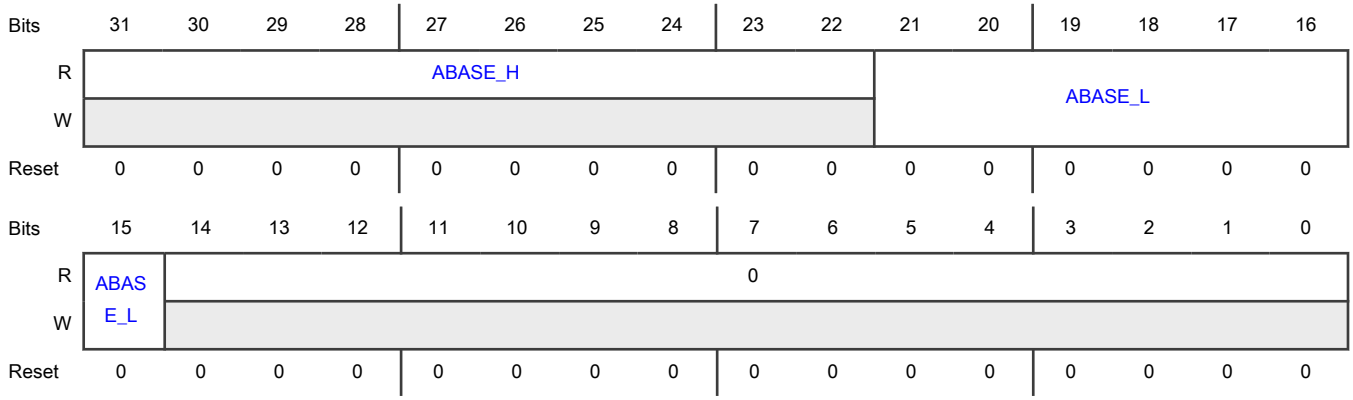
Register	Offset
TRDC_FLW_ABASE	1E8h

Function

This register gives the flash array base address of the Flash Logical Window.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read/Write. This register is not writable if TRDC_FLW_CTL[LK]=1.

Diagram



Fields

Field	Function
31-22 ABASE_H	Array base address high Flash array address upper bits of the base of the FLW (mod 32KBytes).
21-15 ABASE_L	Array base address low Flash array address lower bits of the base of the FLW (mod 32KBytes).
14-0 —	Reserved

10.7.1.19 TRDC FLW Block Count (TRDC_FLW_BCNT)

Offset

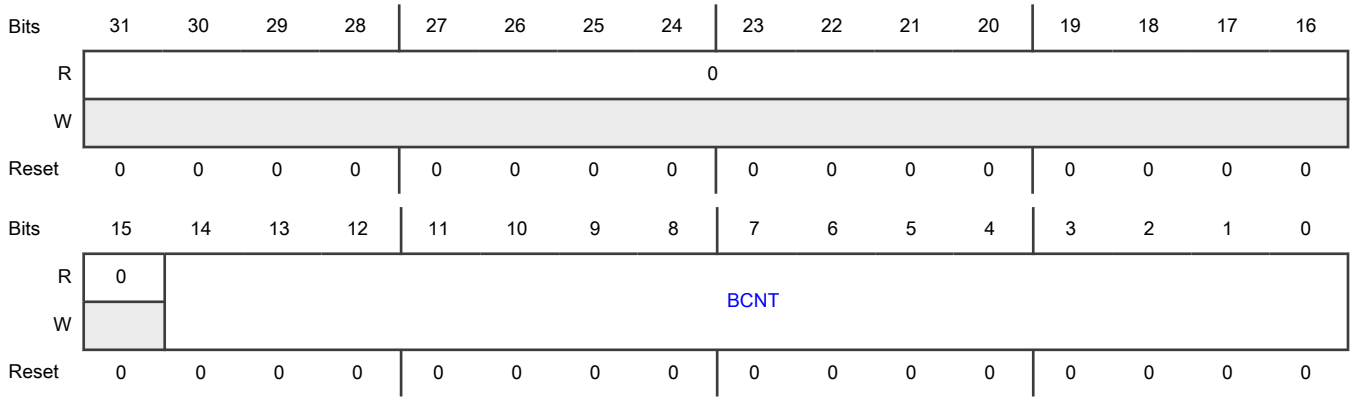
Register	Offset
TRDC_FLW_BCNT	1ECh

Function

This register gives the size of the Flash Logic Window in 32KByte blocks.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read/Write. This register is not writable if TRDC_FLW_CTL[LK]=1.

Diagram



Fields

Field	Function
31-15 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
14-0 BCNT	Block Count Size of FLW in number of 32KByte blocks.

10.7.1.20 TRDC Fault Domain ID (TRDC_FDID)

Offset

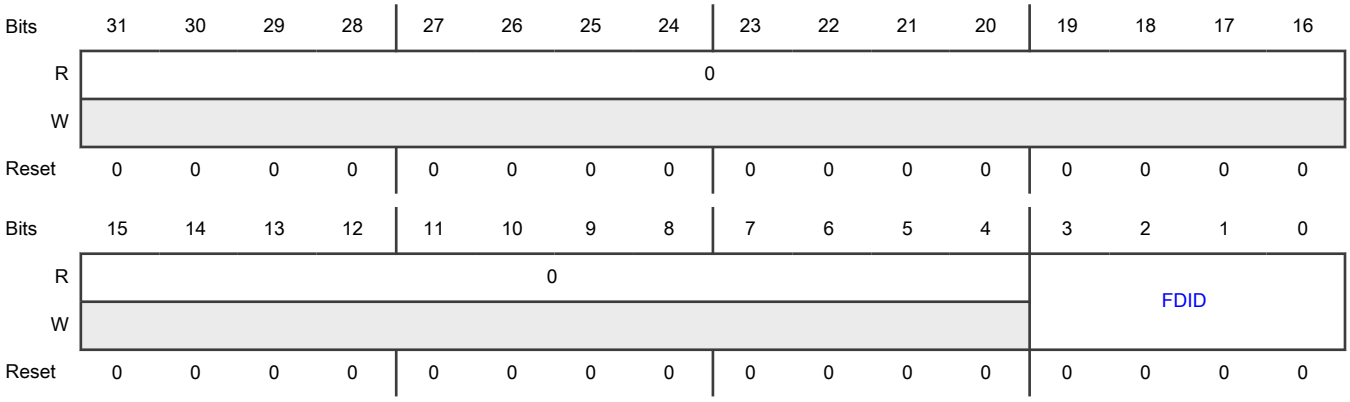
Register	Offset
TRDC_FDID	1FCh

Function

In the event of an access error, this register is used to specify the domainID of the faulting reference before indexing into the Domain Error registers.

If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read/Write

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 FDID	Domain ID of Faulted Access This field indicates the domainID of the fault used to index the array of domain error information. The user queries the DERRLOCx registers to find the DomainID of the faulting access and must write this register with the domain ID before reading the Domain Error registers.

10.7.1.21 TRDC Domain Error Location Register (TRDC_DERRLOC0 - TRDC_DERRLOC2)

Offset

Register	Offset
TRDC_DERRLOC0	200h
TRDC_DERRLOC1	204h
TRDC_DERRLOC2	208h

Function

This array of read-only registers provide the instance number of the submodule where (an) access violation(s) occurred. These registers are organized as a word array, indexed by the faulting domain number, d. The two fields of this register provide a bitmap of instances associated with all submodules containing captured error information for that domain. These instance numbers are then used as indices into the DERR_W0_*i*, DERR_W1_*i*, and DERR_W3_*i*register arrays. See Domain error capture management for more details.

When an access violation is detected by either a Memory Region Checker (MRC) or a Memory Block Checker (MBC), address and attribute information of the offending access is captured. Using the faulting domainID number as the index, d, this array of read-only registers provide additional information signaling the instance number of the submodule where the access violation(s) occurred. Since the resulting exception handler needs the submodule instance to retrieve the captured address and attribute information from DERR_W0_*i* and DERR_W1_*i*, these registers provide the instance number details.

Attempted writes are error terminated.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0								MRCINST							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	mbc3_err_slv				mbc2_err_slv				mbc1_err_slv				mbc0_err_slv			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 —	Reserved
23-16	MRC instance

Table continues on the next page...

Table continued from the previous page...

Field	Function
MRCINST	This field is a bitmap indicating the presence of a detected access violation for domain d in the implemented instances of the MRC. The least-significant bit of this field (bit 16) corresponds to MRC instance 0. The most-significant bit of this field (bit 23) corresponds to MRC instance 7 (MRC instance = i-16 where i is the register bit number), and so on. Multiple bits can be set at any time indicating access violations for this domain have been detected across multiple instances of the MRCs. For each bit in this field: • 0 - The memory region checker has not detected an access violation or is not physically present. • 1 - The memory region checker has detected one or more access violations for this domain.
15-12 mbc3_err_slv	MBC3 ERROR SLAVE • 0001b - Error in Slave memory 0 • 0010b - Error in Slave memory 1 • 0100b - Error in Slave memory 2 • 1000b - Error in Slave memory 3
11-8 mbc2_err_slv	MBC2 ERROR SLAVE • 0001b - Error in Slave memory 0 • 0010b - Error in Slave memory 1 • 0100b - Error in Slave memory 2 • 1000b - Error in Slave memory 3
7-4 mbc1_err_slv	MBC1 ERROR SLAVE • 0001b - Error in Slave memory 0 • 0010b - Error in Slave memory 1 • 0100b - Error in Slave memory 2 • 1000b - Error in Slave memory 3
3-0 mbc0_err_slv	MBC0 ERROR SLAVE • 0001b - Error in Slave memory 0 • 0010b - Error in Slave memory 1 • 0100b - Error in Slave memory 2 • 1000b - Error in Slave memory 3

10.7.1.22 MBC Domain Error Word0 Register (MBC0_DERR_W0 - MBC2_DERR_W0)

Offset

Register	Offset
MBC0_DERR_W0	400h
MBC1_DERR_W0	410h
MBC2_DERR_W0	420h

Function

This read-only register array provides the address of an access violation detected by memory block checker (MBC). These registers are organized as a word array, which is indexed by the MBC instance number. That is, the index, i, of this array is the instance number of MBC with the access violation. The submodule instance numbers are provided by the DERRLOC registers. The memory mapped error capture detail registers are organized as 24 sequential 16 byte entries.

When an access violation is detected and the offending information captured, subsequent updates to this register are disabled until the required data pattern is written to the DERR_W3_i register. At that time, this register is cleared and re-enabled to capture the next access violation.

Attempted writes are error terminated as are attempted reads of an MBC instance that is not physically present.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	EADDR															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	EADDR															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 EADDR	Error address This is the unaliased virtual address of the access that generated the access violation.

10.7.1.23 MBC Domain Error Word1 Register (MBC0_DERR_W1 - MBC2_DERR_W1)

Offset

Register	Offset
MBC0_DERR_W1	404h
MBC1_DERR_W1	414h
MBC2_DERR_W1	424h

Function

This read-only register array provides the attributes of an access violation detected by Memory Block Checker (MBC). These registers are organized as a word array, which is indexed by the violating submodule instance number. Refer to register Domain Error Location(DERRLOCd), Domain Error Word0 Register(DERR_W0_i), and Domain error capture management for more information.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	EST		0		EPORT				0							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				ERW	EATR			SLV_ABO...	SLV_SA_...	SLV_PA_...	SLV_DID...	EDID			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 EST	Error state This field signals the state of access violations for this domain in this instance of the block checker or region checker. Once an access violation has been detected and the faulting address and attribute information stored, subsequent errors are simply recorded as an overrun condition without any data captured. After retrieving the faulting address and attributes, the error capture mechanism must be rearmed by performing a write to DERR_W3_i. 00b - No access violation has been detected. 01b - No access violation has been detected. 10b - A single access violation has been detected.

Table continues on the next page...

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Field	Function
	11b - Multiple access violations for this domain have been detected by this submodule instance. Only the address and attribute information for the first error have been captured in DERR_W0_i and DERR_W1_i.
29-27 —	Reserved
26-24 EPORT	Error port This field identifies the encoded port number of the MBC that detected the access violation. The MBC port number connection is device-specific. See the chip configuration details for more information. This is the MBC target that has the violation. 000b - mbcxslv0 001b - mbcxslv1 010b - mbcxslv2 011b - mbcxslv3
23-12 —	Reserved
11 ERW	Error read/write This field signals whether the captured access violation occurred on a read or write reference. 0b - Read access 1b - Write access
10-8 EATR	Error attributes This field captures attributes of the access violation. 000b - Secure user mode, instruction fetch access. 001b - Secure user mode, data access. 010b - Secure privileged mode, instruction fetch access. 011b - Secure privileged mode, data access. 100b - Nonsecure user mode, instruction fetch access. 101b - Nonsecure user mode, data access. 110b - Nonsecure privileged mode, instruction fetch access. 111b - Nonsecure privileged mode, data access.
7 SLV_ABORT	Bus protect error This field captures the bus protect error from target which cause access abort.
6	Secure attribute check error

Table continues on the next page...

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Field	Function
SLV_SA_ERR	This field captures the secure attribute check error from target.
5 SLV_PA_ERR	Privilege attribute check error This field captures the privilege attribute check error from target.
4 SLV_DID_ERR	DID check error This field captures the DID check error from target.
3-0 EDID	Error domain identifier This field captures the domain identifier of the access violation.

10.7.1.24 MBC Domain Error Word3 Register (MBC0_DERR_W3 - MBC2_DERR_W3)

Offset

Register	Offset
MBC0_DERR_W3	40Ch
MBC1_DERR_W3	41Ch
MBC2_DERR_W3	42Ch

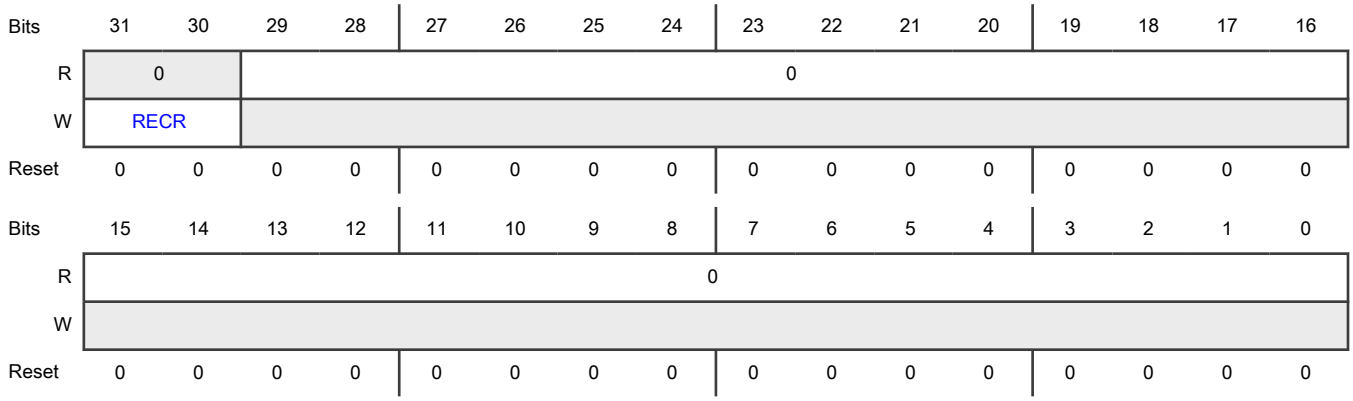
Function

This register is used to rearm the error capture logic and clear the DERR_W0_i and DERR_W1_i registers. After the domain access violation error details have been read, typically in an exception service routine, a 32-bit word write to this register is required to rearm the error capture logic.

A read of this location returns zeroes. Attempted reads of a Memory Region Checker (MRC) or Memory Block Checker (MBC) instance that is not physically present are error terminated.

See Domain error capture management for more details.

Diagram



Fields

Field	Function
31-30 RECR	Rearm Error Capture Registers This 2-bit, write-only field controls the rearming of the domain error capture registers. Once an access violation has been detected with the faulting address and attribute information stored, subsequent errors are simply recorded as an overrun condition without any data captured. Writing 01b to this field rearms the error capture mechanism and clears the DERR_W0_i and DERR_W1_i registers. A write of any value other than 01b has no effect.
29-0 —	Reserved

10.7.1.25 MRC Domain Error Word0 Register (MRC0_DERR_W0)

Offset

Register	Offset
MRC0_DERR_W0	480h

Function

This read-only register array provides the address of an access violation detected by memory region checker (MRC). These registers are organized as a word array, which is indexed by the MRC instance number. That is, the index, i, of this array is the instance number of MRC with the access violation. The submodule instance numbers are provided by the DERRLOC registers. The memory mapped error capture detail registers are organized as 24 sequential 16 byte entries.

When an access violation is detected and the offending information captured, subsequent updates to this register are disabled until the required data pattern is written to the DERR_W3_i register. At that time, this register is cleared and re-enabled to capture the next access violation.

Attempted writes are error terminated as are attempted reads of an MRC instance that is not physically present.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	EADDR															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	EADDR															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 EADDR	Error address This is the unaliased virtual address of the access that generated the access violation.

10.7.1.26 MRC Domain Error Word1 Register (MRC0_DERR_W1)

Offset

Register	Offset
MRC0_DERR_W1	484h

Function

This read-only register array provides the attributes of an access violation detected by memory region checker (MRC). These registers are organized as a word array, which is indexed by the violating submodule instance number. Refer to register Domain Error Location(DERRLOCd), Domain Error Word0 Register(DERR_W0_i), and Domain error capture management for more information.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	EST		0		EPORT				0							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				ERW	EATR			SLV_ABO...	SLV_SA_...	SLV_PA_...	SLV_DID...	EDID			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 EST	Error state This field signals the state of access violations for this domain in this instance of the block checker or region checker. Once an access violation has been detected and the faulting address and attribute information stored, subsequent errors are simply recorded as an overrun condition without any data captured. After retrieving the faulting address and attributes, the error capture mechanism must be rearmed by performing a write to DERR_W3_i.

Table continues on the next page...

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Field	Function
	00b - No access violation has been detected. 01b - No access violation has been detected. 10b - A single access violation has been detected. 11b - Multiple access violations for this domain have been detected by this submodule instance. Only the address and attribute information for the first error have been captured in DERR_W0_i and DERR_W1_i.
29-27 —	Reserved
26-24 EPORT	Error port This field identifies the encoded port number of the MRC that detected the access violation. The MRC port number connection is device-specific. See the chip configuration details for more information.
23-12 —	Reserved
11 ERW	Error read/write This field signals whether the captured access violation occurred on a read or write reference. 0b - Read access 1b - Write access
10-8 EATR	Error attributes This field captures certain attributes of the access violation. 000b - Secure user mode, instruction fetch access. 001b - Secure user mode, data access. 010b - Secure privileged mode, instruction fetch access. 011b - Secure privileged mode, data access. 100b - Nonsecure user mode, instruction fetch access. 101b - Nonsecure user mode, data access. 110b - Nonsecure privileged mode, instruction fetch access. 111b - Nonsecure privileged mode, data access.
7 SLV_ABORT	Bus protect error This field captures the bus protect error from target which cause access abort.
6 SLV_SA_ERR	Secure attribute check error This field captures the secure attribute check error from target.
5	Privilege attribute check error

Table continues on the next page...

Table continued from the previous page...

Field	Function
SLV_PA_ERR	This field captures the privilege attribute check error from target.
4 SLV_DID_ERR	DID check error This field captures the DID check error from target.
3-0 EDID	Error domain identifier This field captures the domain identifier of the access violation.

10.7.1.27 MRC Domain Error Word3 Register (MRC0_DERR_W3)

Offset

Register	Offset
MRC0_DERR_W3	48Ch

Function

This register is used to rearm the error capture logic and clear the DERR_W0_i and DERR_W1_i registers. After the domain access violation error details have been read, typically in an exception service routine, a 32-bit word write to this register is required to rearm the error capture logic.

A read of this location returns zeroes. Attempted reads of a memory region checker (MRC) or Memory Block Checker (MBC) instance that is not physically present are error terminated.

See Domain error capture management for more details.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read/Write

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				0											
W	RECR															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 RECR	Rearm Error Capture Registers This 2-bit, write-only field controls the rearming of the domain error capture registers. Once an access violation has been detected with the faulting address and attribute information stored, subsequent errors are simply recorded as an overrun condition without any data captured. Writing 01b to this field rearms the error capture mechanism and clears the DERR_W0_i and DERR_W1_i registers. A write of any value other than 01b has no effect.
29-0 —	Reserved

10.7.1.28 DAC Initiator Domain Assignment Register (MDA_W0_0_DFMT0)

Offset

Register	Offset
MDA_W0_0_DFMT0	800h

Function

The MDA_Wr_m registers provide a 2-dimensional data structure for assigning bus initiators to domains. The number of implemented registers is defined by DACFGm[NMDAR]. This per-initiator domain assignment is then repeated for each bus initiator (MDAm). Thus, m specifies the initiator number and r refers to the specific MDA register for a given bus initiator.

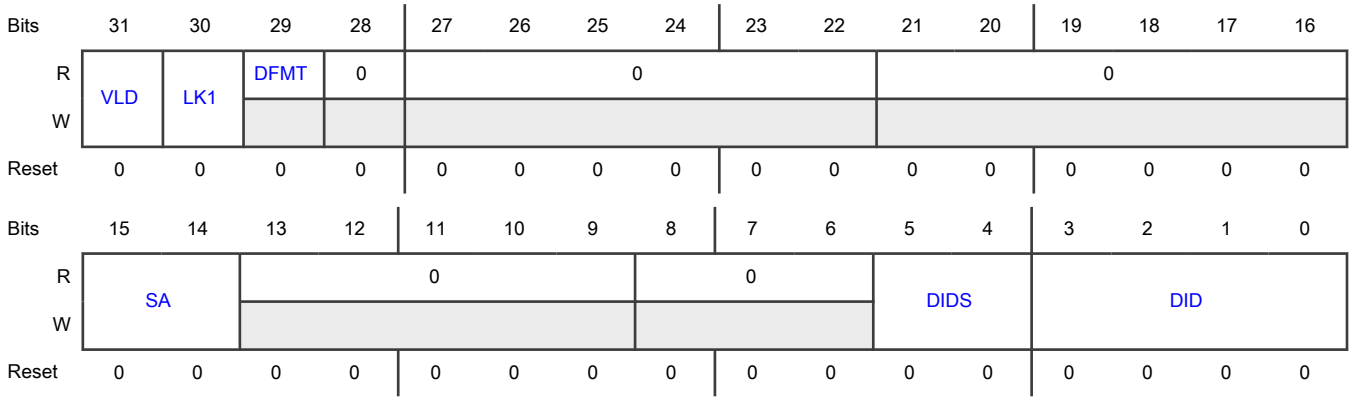
Each Wr within the MDAm structure is a word-sized definition; there are two formats supported, one for processor cores and another for non-processors. Processor initiators typically support one or more Wr domain definitions, while non-processor initiators support a single Wr. Processor initiators Domain Assignment register names use a _DFMT0 suffix. Non-processor initiators Domain Assignment register names use a _DFMT1 suffix.

The DAC submodule is responsible for the generation of domain identifiers for every transaction from every bus initiator. If there is a single Wr for a given initiator, then the specified domain identifier is used directly. If there are multiple Wr values for a given initiator, then the DAC evaluates the conditional terms to determine a “hit”. For all Wr hits, their corresponding domain identifiers are simply logically summed together (boolean OR). Use cases are typically expected to *hit in a single Wr* for a processor initiator. Special care is needed if *none* of the conditional terms hit in any Wr evaluation; for this case, the generated DID = 0 and software needs to be aware of any potential access rights granted for this DID.

Each MDA_Wr_m register has one of two programming models depending on the state of the domain format field, DFMT. The model described in this section is for DFMT = 0. This definition allows three different specifications of the DID for processors. The DFMT = 1 model is described in Initiator Domain Assignment (MDA_Wr_m_DFMT1) register.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read/write.

Diagram



Fields

Field	Function
31 VLD	Valid This field indicates the domain assignment is valid. It is further qualified by TRDC_CR[GVLDM] = 1. If TRDC_CR[GVLDM] is cleared, the DID output is defined by the SoC-specific *default DID* value. See the TRDC chip configuration section for more details. If both MDA_Wr_m[VLD] and TRDC_CR[GVLDM] are asserted, the DID output is defined by the remaining contents of this register. 0b - The Wr domain assignment is invalid. 1b - The Wr domain assignment is valid.
30 LK1	1-bit Lock This field provides a locking mechanism that can be used to limit the ability to write the register. Once set, this bit remains asserted until the next reset. 0b - Register can be written by any secure privileged write. 1b - Register is locked (read-only) until the next reset.
29 DFMT	Domain format Identifies this register's domain assignment format. **NOTE** This bitfield access is ROZ 0b - Processor-core domain assignment 1b - Non-processor domain assignment
28 —	Reserved
27-22 —	Reserved
21-16	Reserved

Table continues on the next page...

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Field	Function
—	
15-14 SA	Secure attribute This field defines the secure/nonsecure attribute for processor cores. **NOTE** The bus initiator's input secure/nonsecure attribute is used if SA = 1X, or this VLD = 0. If TZM_ENB = 0, the initiator attribute is forced to nonsecure. A nonsecure write cannot program this field to 2'b00, which is a security level higher than the mode of the process that is writing it. Reset value of SA: • if TZM_ENB=0, SA reset value = 2'b01 • if TZM_ENB=1, SA reset value = 2'b00 00b - Force the bus attribute for this initiator to secure. 01b - Force the bus attribute for this initiator to nonsecure. 10b - Use the bus initiator's secure/nonsecure attribute directly. 11b - Use the bus initiator's secure/nonsecure attribute directly.
13-9 —	Reserved
8-6 —	Reserved
5-4 DIDS	DID Select This field selects the source of the domain identifier. 00b - Use MDAm[3:0] as the domain identifier. 01b - Use the input DID as the domain identifier. 10b - Use MDAm[3:2] concatenated with the low-order 2 bits of the input DID (DID_in[1:0]) as the domain identifier. 11b - Reserved for future use.
3-0 DID	Domain identifier This 4-bit field is the domain ID attribute that is sent on the accesses from the bus initiator connected to the DAC when DIDS=00b. DID[3:2] is used when DIDS=10b. Write a value greater than the number of DIDs is illegal.

10.7.1.29 DAC Initiator Domain Assignment Register (MDA_W0_1_DFMT1 - MDA_W0_4_DFMT1)

Offset

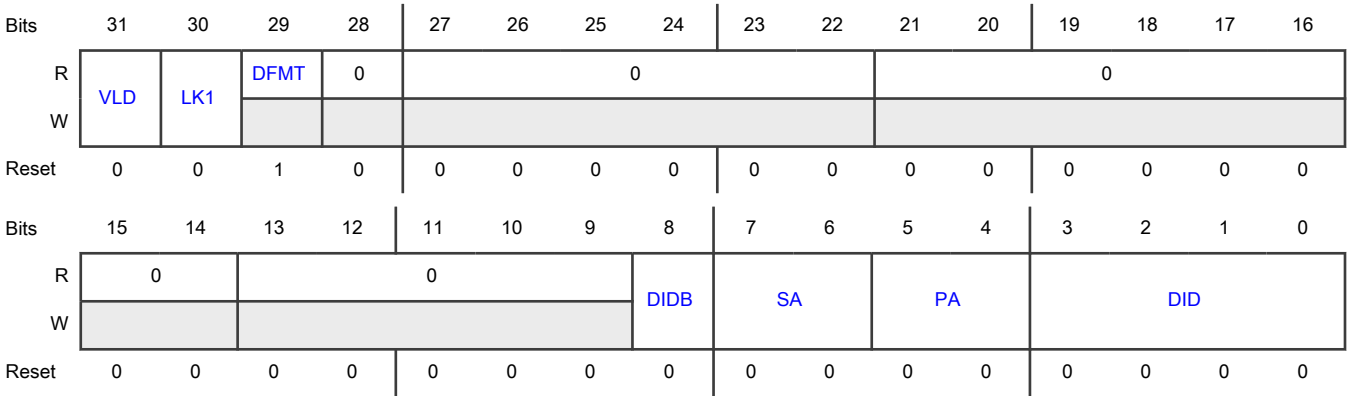
Register	Offset
MDA_W0_1_DFMT1	820h
MDA_W0_2_DFMT1	840h
MDA_W0_3_DFMT1	860h
MDA_W0_4_DFMT1	880h

Function

This register is identical to Initiator Domain Assignment (MDA_Wr_m_DFMT0) register except that the domain format field, DFMT, is 1 and the PID field is not used. This format supports two different specifications of the DID for non-core bus initiators.

Access: If TZ-M is enabled, then SecurePrivileged, else NonsecurePriv Read/write.

Diagram



Fields

Field	Function
31 VLD	Valid This field indicates the domain assignment is valid. It is further qualified by TRDC_CR[GVLDM] = 1. If TRDC_CR[GVLDM] is cleared, the DID output is defined by the SoC-specific *default DID* value. See the TRDC chip configuration section for more details. If both MDA_Wr_m[VLD] and TRDC_CR[GVLDM] are asserted, the DID output is defined by the remaining contents of this register. 0b - The Wr domain assignment is invalid. 1b - The Wr domain assignment is valid.
30 LK1	1-bit Lock This field provides a locking mechanism that can be used to limit the ability to write the register. Once set, this bit remains asserted until the next reset.

Table continues on the next page...

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Field	Function
	0b - Register can be written by any secure privileged write. 1b - Register is locked (read-only) until the next reset.
29 DFMT	Domain format Identifies this register's domain assignment format. **NOTE** This bitfield access is ROO 0b - Processor-core domain assignment 1b - Non-processor domain assignment
28 —	Reserved
27-22 —	Reserved
21-16 —	Reserved
15-14 —	Reserved
13-9 —	Reserved
8 DIDB	DID Bypass If asserted, this bit enables the bypassing of an input DID value as the domain identifier for this non-processor bus initiator. This capability allows non-processor bus initiators, for example, a DMA to masquerade as a processor. Once set, this field is “sticky” and remains set until the next reset. **DAC** / **DID Input** 0 / 0 1 / DMA Domain ID 2 / USB Domain ID 0b - Use MDAn[3:0] as the domain identifier. 1b - Use the DID input as the domain identifier.
7-6	Secure attribute

Table continues on the next page...

Table continued from the previous page...

Field	Function
SA	This field defines the secure/nonsecure attribute for non-processor cores. **NOTE** The bus initiator's input secure/nonsecure attribute is used if SA = 1X, or this VLD = 0. If TZM_ENB = 0, the initiator attribute is forced to nonsecure. A nonsecure write cannot program this field to 2'b00, which is a security level higher than the mode of the process that is writing it. Reset value of SA: • if TZM_ENB=0, SA reset value = 2'b01 • if TZM_ENB=1, SA reset value = 2'b00 00b - Force the bus attribute for this initiator to secure. 01b - Force the bus attribute for this initiator to nonsecure. 10b - Use the bus initiator's secure/nonsecure attribute directly. 11b - Use the bus initiator's secure/nonsecure attribute directly.
5-4 PA	Privileged attribute This field defines the privileged/user attribute for non-processor cores. **NOTE** The bus initiator's input privileged/user attribute is used if PA = 1X, or this VLD = 0. 00b - Force the bus attribute for this initiator to user. 01b - Force the bus attribute for this initiator to privileged. 10b - Use the bus initiator's privileged/user attribute directly. 11b - Use the bus initiator's privileged/user attribute directly.
3-0 DID	Domain identifier This 4-bit field is the domain ID attribute that is sent on the accesses from the bus initiator connected to the DAC when DIDB=0. Write a value greater than the number of DIDs is illegal.

10.7.1.30 MBC Global Configuration Register (MBC0_MEM0_GLBCFG - MBC2_MEM3_GLBCFG)

Offset

For m = 0 to 2; r = 0 to 3:

Register	Offset
MBCm_MEMr_GLBCFG	1000h + (m × 1000h) + (r × 4h)

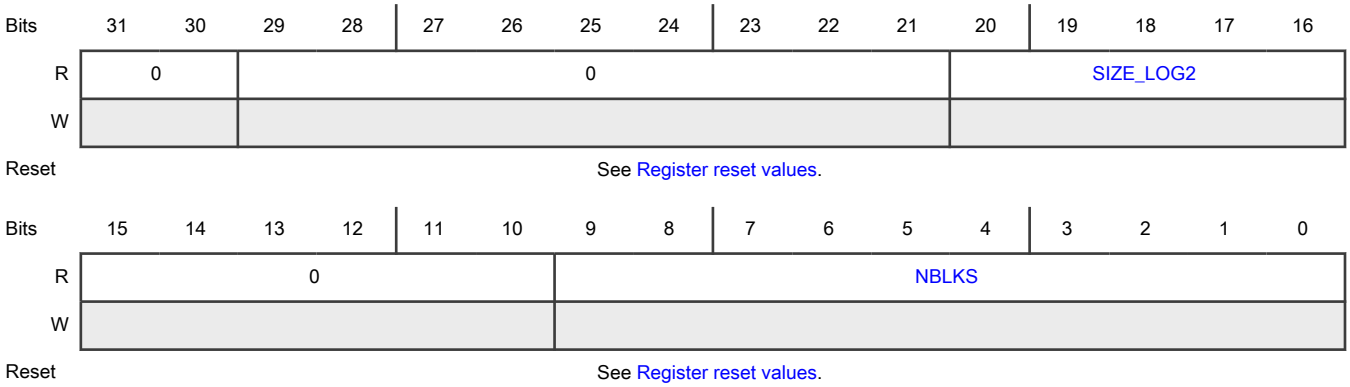
Function

These MBC global configuration read-only registers contain information on the MBC's hardware configuration. Specifically, it defines the number of memory blocks and the size of each block in each MBC mem (r).

NOTE

An all zero value (SIZE_LOG2 = 0, NBLKS = 0) indicates a non-existent memory. For the number of memories implemented in the MBCs, refer to chip-specific information

Diagram



Register reset values

Register	Reset value
MBC0_MEM0_GLBCFG	000F_0040h
MBC0_MEM1_GLBCFG	000D_0004h
MBC0_MEM2_GLBCFG	000D_0001h
MBC0_MEM3_GLBCFG	000D_000Ch
MBC1_MEM0_GLBCFG	000D_0004h
MBC1_MEM1_GLBCFG	000D_0010h
MBC1_MEM2_GLBCFG	000D_000Ch
MBC1_MEM3_GLBCFG	000C_0002h
MBC2_MEM0_GLBCFG	000C_0054h
MBC2_MEM1_GLBCFG	0010_0004h
MBC2_MEM2_GLBCFG	000C_0010h
MBC2_MEM3_GLBCFG	0000_0000h

Fields

Field	Function
31-30	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
29-21 —	Reserved
20-16 SIZE_LOG2	Log2 size per block For example SIZE_LOG2=0x0C is 2^12=4 KB blocks.
15-10 —	Reserved
9-0 NBLKS	Number of blocks in this memory

10.7.1.31 MBC NonSecure Enable Block Index (MBC0_NSE_BLK_INDEX - MBC2_NSE_BLK_INDEX)

Offset

Register	Offset
MBC0_NSE_BLK_INDEX	1010h
MBC1_NSE_BLK_INDEX	2010h
MBC2_NSE_BLK_INDEX	3010h

Function

This R/W register defines the selected memories that are affected by the writes to the NSE_BLK_SET and NSE_BLK_CLR registers.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	AI	0												DID_SEL2	DID_SEL1	DID_SEL0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				MEM_SEL				0				WNDX		0	0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 AI	Auto Increment 0b - No effect. 1b - Add 1 to the WNDX field after the register write.
30-19 —	Reserved
18-16 DID_SELn	DID Select Destination domain bitmap select. 0b - No effect. 1b - Selects NSE bits for this domain.
15-12 —	Reserved
11-8 MEM_SEL	Memory Select Destination memory bitmap select. • Bit [11] - MBC MEM 3 • Bit [10] - MBC MEM 2 • Bit [9] - MBC MEM 1 • Bit [8] - MBC MEM 0
7-6 —	Reserved
5-2 WNDX	Word index into the block NSE bitmap. It selects the BLK_NSE_Wn register, where WNDX determines the value of n.
1 —	Reserved
0 —	Reserved

10.7.1.32 MBC NonSecure Enable Block Set (MBC0_NSE_BLK_SET - MBC2_NSE_BLK_SET)

Offset

Register	Offset
MBC0_NSE_BLK_SET	1014h

Table continues on the next page...

Table continued from the previous page...

Register	Offset
MBC1_NSE_BLK_SET	2014h
MBC2_NSE_BLK_SET	3014h

Function

A write to this register sets the appropriate NSE Bits for the selected domains and memories defined at the word location NSE_BLK_INDEX[WDNX]. If NSE_BLK_INDEX[AI] = 1, then the NSE_BLK_INDEX[WDNX] field is incremented by 1 (modulo-16) after the write is completed. This register reads as zero.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W	W1SET															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W	W1SET															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 W1SET	Write-1 Set If set to 1, sets appropriate NSE bit for the selected domains and memories defined at the word location NSE_BLK_INDEX[WDNX]. Write with value 0 has no effect.

10.7.1.33 MBC NonSecure Enable Block Clear (MBC0_NSE_BLK_CLR - MBC2_NSE_BLK_CLR)

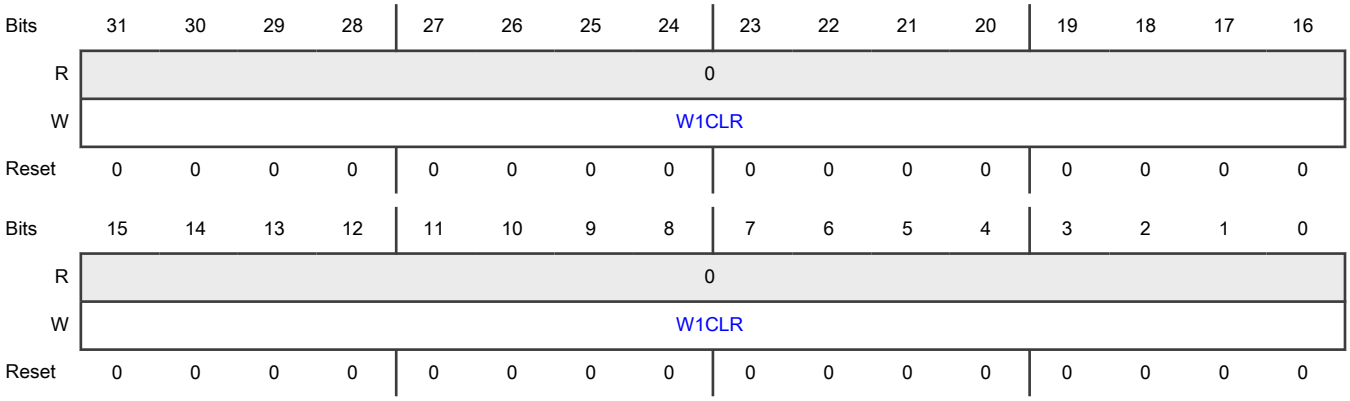
Offset

Register	Offset
MBC0_NSE_BLK_CLR	1018h
MBC1_NSE_BLK_CLR	2018h
MBC2_NSE_BLK_CLR	3018h

Function

A write to this location clears the appropriate NSE bits as defined by the W1CLR[n]=1 for the selected domains and memories Defined at the word location NSE_BLK_INDEX[WDNX]. If NSE_BLK_INDEX[AI] = 1, then the NSE_BLK_INDEX[WDNX] field is incremented by 1 (modulo-16) after the write is completed. This register reads as zero.

Diagram



Fields

Field	Function
31-0 W1CLR	Write-1 Clear If set to 1, Clear the appropriate NSE bit for the selected domains and memories defined at the word location NSE_BLK_INDEX[WDNX]. Write with value 0 has no effect.

10.7.1.34 MBC NonSecure Enable Block Clear All (MBC0_NSE_BLK_CLR_ALL - MBC2_NSE_BLK_CLR_ALL)

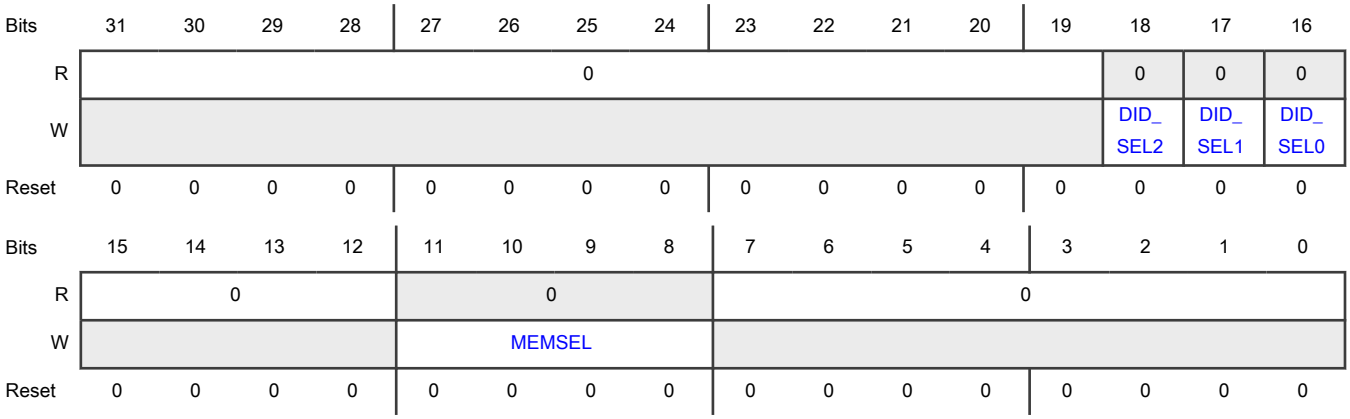
Offset

Register	Offset
MBC0_NSE_BLK_CLR_ALL	101Ch
MBC1_NSE_BLK_CLR_ALL	201Ch
MBC2_NSE_BLK_CLR_ALL	301Ch

Function

A write to this location clears all the block NSE bits for the selected domains and memories defined in the write data. This register reads as zero.

Diagram



Fields

Field	Function
31-19 —	Reserved
18-16 DID_SELn	DID Select Destination domain bitmap select. 0b - No effect. 1b - Clear all NSE bits for this domain.
15-12 —	Reserved
11-8 MEMSEL	Memory Select Destination memory bitmap select. • Bit [11] - clear all MEM 3 NSE bits • Bit [10] - clear all MEM 2 NSE bits • Bit [9] - clear all MEM 1 NSE bits • Bit [8] - clear all MEM 0 NSE bits
7-0 —	Reserved

10.7.1.35 MBC Global Access Control (MBC0_MEMN_GLBAC0)

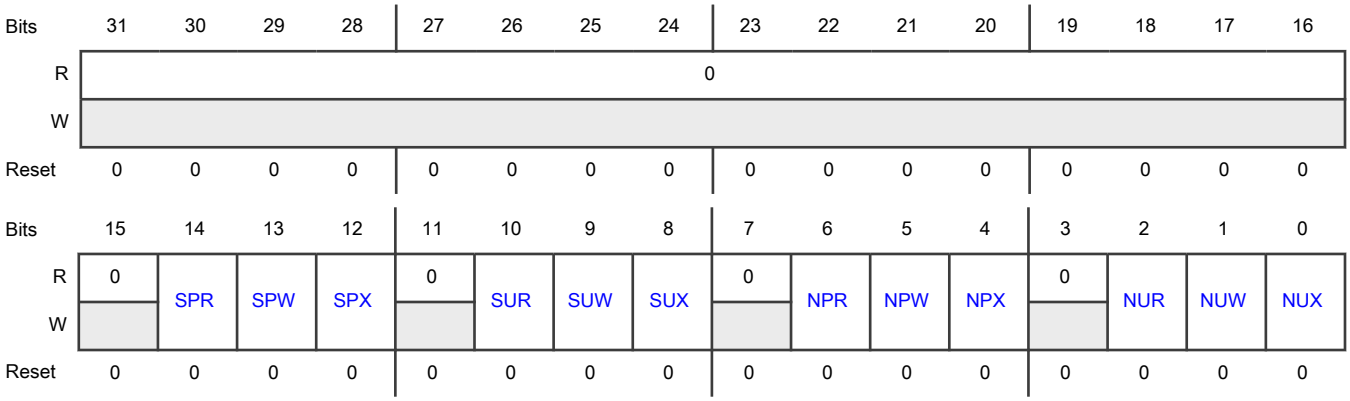
Offset

Register	Offset
MBC0_MEMN_GLBAC0	1020h

Function

These fully programmable R/W fields define the R/W/X (read/write/execute) access control flags with each of the 4 supported operating modes: SecurePriv, SecureUser, NonsecurePriv, Nonsecure User.

Diagram



Fields

Field	Function
31-15 —	Reserved
14 SPR	SecurePriv Read SecurePriv read access control flag 0b - Read access is not allowed in Secure Privilege mode. 1b - Read access is allowed in Secure Privilege mode.
13 SPW	SecurePriv Write SecurePriv write access control flag 0b - Write access is not allowed in Secure Privilege mode. 1b - Write access is allowed in Secure Privilege mode.
12 SPX	SecurePriv Execute SecurePriv execute access control flag 0b - Execute access is not allowed in Secure Privilege mode. 1b - Execute access is allowed in Secure Privilege mode.
11 —	Reserved
10 SUR	SecureUser Read SecureUser read access control flag

Table continues on the next page...

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Field	Function
	0b - Read access is not allowed in Secure User mode. 1b - Read access is allowed in Secure User mode.
9 SUW	SecureUser Write SecureUser write access control flag 0b - Write access is not allowed in Secure User mode. 1b - Write access is allowed in Secure User mode.
8 SUX	SecureUser Execute SecureUser execute access control flag 0b - Execute access is not allowed in Secure User mode. 1b - Execute access is allowed in Secure User mode.
7 —	Reserved
6 NPR	NonsecurePriv Read NonsecurePriv read access control flag 0b - Read access is not allowed in Nonsecure Privilege mode. 1b - Read access is allowed in Nonsecure Privilege mode.
5 NPW	NonsecurePriv Write NonsecurePriv write access control flag 0b - Write access is not allowed in Nonsecure Privilege mode. 1b - Write access is allowed in Nonsecure Privilege mode.
4 NPX	NonsecurePriv Execute NonsecurePriv execute access control flag 0b - Execute access is not allowed in Nonsecure Privilege mode. 1b - Execute access is allowed in Nonsecure Privilege mode.
3 —	Reserved
2 NUR	NonsecureUser Read NonsecureUser read access control flag 0b - Read access is not allowed in Nonsecure User mode. 1b - Read access is allowed in Nonsecure User mode.
1	NonsecureUser Write

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Field	Function
NUW	NonsecureUser write access control flag 0b - Write access is not allowed in Nonsecure User mode. 1b - Write access is allowed in Nonsecure User mode.
0 NUX	NonsecureUser Execute NonsecureUser execute access control flag 0b - Execute access is not allowed in Nonsecure User mode. 1b - Execute access is allowed in Nonsecure User mode.

10.7.1.36 MBC Global Access Control (MBC0_MEMN_GLBAC1 - MBC0_MEMN_GLBAC7)

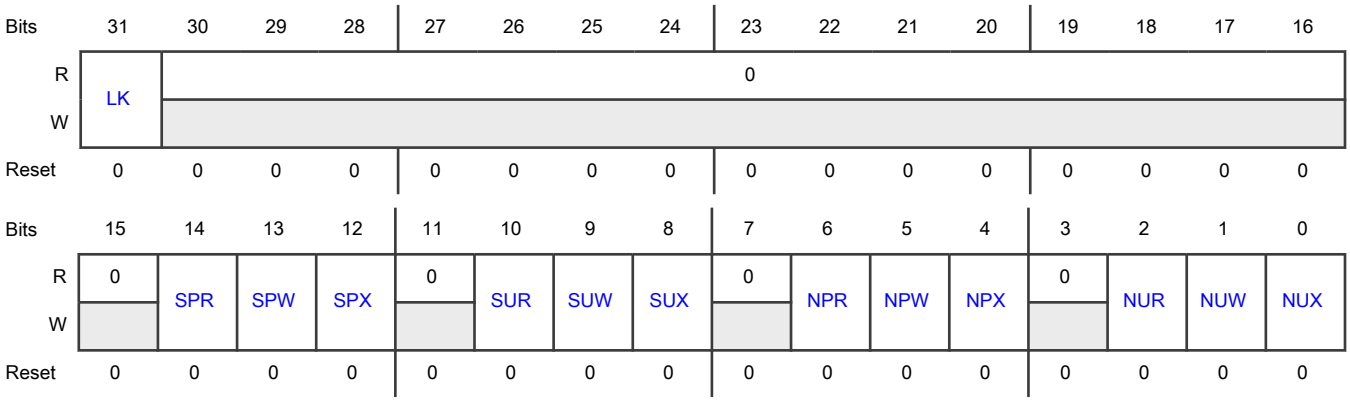
Offset

Register	Offset
MBC0_MEMN_GLBAC1	1024h
MBC0_MEMN_GLBAC2	1028h
MBC0_MEMN_GLBAC3	102Ch
MBC0_MEMN_GLBAC4	1030h
MBC0_MEMN_GLBAC5	1034h
MBC0_MEMN_GLBAC6	1038h
MBC0_MEMN_GLBAC7	103Ch

Function

These fully programmable R/W fields define the R/W/X (read/write/execute) access control flags with each of the 4 supported operating modes: SecurePriv, SecureUser, NonsecurePriv, Nonsecure User. The lock bit provides the ability to lock these control access flags and to lock the MBC_BLK_CFG[MBACSEL] field when a locked MBC_MEMN_GLBAC register is selected.

Diagram



Fields

Field	Function
31 LK	LOCK This 1-bit field provides a mechanism to limit writes to the this register to protect its contents. Once set, this bit remains asserted until the next reset. 0b - This register is not locked and can be altered. 1b - This register is locked and cannot be altered.
30-15 —	Reserved
14 SPR	SecurePriv Read SecurePriv read access control flag 0b - Read access is not allowed in Secure Privilege mode. 1b - Read access is allowed in Secure Privilege mode.
13 SPW	SecurePriv Write SecurePriv write access control flag 0b - Write access is not allowed in Secure Privilege mode. 1b - Write access is allowed in Secure Privilege mode.
12 SPX	SecurePriv Execute SecurePriv execute access control flag 0b - Execute access is not allowed in Secure Privilege mode. 1b - Execute access is allowed in Secure Privilege mode.
11 —	Reserved
10 SUR	SecureUser Read SecureUser read access control flag 0b - Read access is not allowed in Secure User mode. 1b - Read access is allowed in Secure User mode.
9 SUW	SecureUser Write SecureUser write access control flag 0b - Write access is not allowed in Secure User mode. 1b - Write access is allowed in Secure User mode.
8 SUX	SecureUser Execute SecureUser execute access control flag

Table continues on the next page...

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Field	Function
	0b - Execute access is not allowed in Secure User mode. 1b - Execute access is allowed in Secure User mode.
7 —	Reserved
6 NPR	NonsecurePriv Read NonsecurePriv read access control flag 0b - Read access is not allowed in Nonsecure Privilege mode. 1b - Read access is allowed in Nonsecure Privilege mode.
5 NPW	NonsecurePriv Write NonsecurePriv write access control flag 0b - Write access is not allowed in Nonsecure Privilege mode. 1b - Write access is allowed in Nonsecure Privilege mode.
4 NPX	NonsecurePriv Execute NonsecurePriv execute access control flag 0b - Execute access is not allowed in Nonsecure Privilege mode. 1b - Execute access is allowed in Nonsecure Privilege mode.
3 —	Reserved
2 NUR	NonsecureUser Read NonsecureUser read access control flag 0b - Read access is not allowed in Nonsecure User mode. 1b - Read access is allowed in Nonsecure User mode.
1 NUW	NonsecureUser Write NonsecureUser write access control flag 0b - Write access is not allowed in Nonsecure User mode. 1b - Write access is allowed in Nonsecure User mode.
0 NUX	NonsecureUser Execute NonsecureUser execute access control flag 0b - Execute access is not allowed in Nonsecure User mode. 1b - Execute access is allowed in Nonsecure User mode.

10.7.1.37 MBC Memory Block Configuration Word (MBC0_DOM0_MEM0_BLK_CFG_W0 - MBC0_DOM2_MEM3_BLK_CFG_W1)

Offset

Register	Offset
MBC0_DOM0_MEM0_BLK_CFG_W0	1040h
MBC0_DOM0_MEM0_BLK_CFG_W1	1044h
MBC0_DOM0_MEM0_BLK_CFG_W2	1048h
MBC0_DOM0_MEM0_BLK_CFG_W3	104Ch
MBC0_DOM0_MEM0_BLK_CFG_W4	1050h
MBC0_DOM0_MEM0_BLK_CFG_W5	1054h
MBC0_DOM0_MEM0_BLK_CFG_W6	1058h
MBC0_DOM0_MEM0_BLK_CFG_W7	105Ch
MBC0_DOM0_MEM1_BLK_CFG_W0	1180h
MBC0_DOM0_MEM2_BLK_CFG_W0	11A8h
MBC0_DOM0_MEM3_BLK_CFG_W0	11D0h
MBC0_DOM0_MEM3_BLK_CFG_W1	11D4h
MBC0_DOM1_MEM0_BLK_CFG_W0	1240h
MBC0_DOM1_MEM0_BLK_CFG_W1	1244h
MBC0_DOM1_MEM0_BLK_CFG_W2	1248h
MBC0_DOM1_MEM0_BLK_CFG_W3	124Ch
MBC0_DOM1_MEM0_BLK_CFG_W4	1250h
MBC0_DOM1_MEM0_BLK_CFG_W5	1254h

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Register	Offset
MBC0_DOM1_MEM0_BLK_CFG_W6	1258h
MBC0_DOM1_MEM0_BLK_CFG_W7	125Ch
MBC0_DOM1_MEM1_BLK_CFG_W0	1380h
MBC0_DOM1_MEM2_BLK_CFG_W0	13A8h
MBC0_DOM1_MEM3_BLK_CFG_W0	13D0h
MBC0_DOM1_MEM3_BLK_CFG_W1	13D4h
MBC0_DOM2_MEM0_BLK_CFG_W0	1440h
MBC0_DOM2_MEM0_BLK_CFG_W1	1444h
MBC0_DOM2_MEM0_BLK_CFG_W2	1448h
MBC0_DOM2_MEM0_BLK_CFG_W3	144Ch
MBC0_DOM2_MEM0_BLK_CFG_W4	1450h
MBC0_DOM2_MEM0_BLK_CFG_W5	1454h
MBC0_DOM2_MEM0_BLK_CFG_W6	1458h
MBC0_DOM2_MEM0_BLK_CFG_W7	145Ch
MBC0_DOM2_MEM1_BLK_CFG_W0	1580h
MBC0_DOM2_MEM2_BLK_CFG_W0	15A8h
MBC0_DOM2_MEM3_BLK_CFG_W0	15D0h
MBC0_DOM2_MEM3_BLK_CFG_W1	15D4h

Function

MBC[m]_DOM[d]_MEM[s]_BLK_CFG_W[w], where,

- m - mbc index

- d - domain index
- s - memory target index
- w - word index

These registers are read/write for both the alternate view of the NSE bit and the 3-bit MBACSEL field. This is an array of 4 bit fields defining the block configuration for the given submemory. Each 4-bit field includes an alternative view of the associated NSE bit plus a 3-bit access control select that selects the global access control value that applies to the referenced memory block.

For a given memory block, B, if the value programmed in the MBACSELn field selects a locked MBC_MEMN_GLBACr register, the MBACSEL field is locked until the next reset. Depending on BLK_CFG_W, the NSEn/MBASELn fields correspond to different blocks. The following table describes the relationship between W (word index) and B (block number).

MEM0 supports up to 512 blocks ; W0 - W63

MEM1-3 supports up to 64 block ; W0 - W7

NOTE

This register is shown with fields such that it covers entire 32 bit register. However, actual fields may be less if number of blocks are such that fields don't align to 32 bits. These absent fields may be shown but user can refer to table below to deduce actual fields and treat absent fields as reserved.

Table 43. Block Config Word to Block Number Relationship

Block Config Word	NSE7/ MBACSEL7	NSE6/ MBACSEL6	NSE5/ MBACSEL5	NSE4/ MBACSEL4	NSE3/ MBACSEL3	NSE2/ MBACSEL2	NSE1/ MBACSEL1	NSE0/ MBACSEL0
W0	block 7	block 6	block 5	block 4	block 3	block 2	block 1	block 0
W1	block 15	block 14	block 13	block 12	block 11	block 10	block 9	block 8
W2	block 23	block 22	block 21	block 20	block 19	block 18	block 17	block 16
W3	block 31	block 30	block 29	block 28	block 27	block 26	block 25	block 24
W4	block 39	block 38	block 37	block 36	block 35	block 34	block 33	block 32
W5	block 47	block 46	block 45	block 44	block 43	block 42	block 41	block 40
W6	block 55	block 54	block 53	block 52	block 51	block 50	block 49	block 48
W7	block 63	block 62	block 61	block 60	block 59	block 58	block 57	block 56
For MEM0, block 64 - block 511								
W8	block 71	block 70	block 69	block 68	block 67	block 66	block 65	block 64
. . .								
W63	block 511	block 510	block 509	block 508	block 507	block 506	block 505	block 504

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	NSE7	MBACSEL7			NSE6	MBACSEL6			NSE5	MBACSEL5			NSE4	MBACSEL4		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	NSE3	MBACSEL3			NSE2	MBACSEL2			NSE1	MBACSEL1			NSE0	MBACSEL0		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 NSE7	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure and nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
30-28 MBACSEL7	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL7 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B
27 NSE6	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure and nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
26-24	Memory Block Access Control Select for block B

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Field	Function
MBACSEL6	This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL6 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B
23 NSE5	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure and nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
22-20 MBACSEL5	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL5 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B
19 NSE4	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed.

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Field	Function
	1b - Secure and nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
18-16 MBACSEL4	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL4 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B
15 NSE3	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure and nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
14-12 MBACSEL3	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL3 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B
11	NonSecure Enable for block B

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Field	Function
NSE2	0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure and nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
10-8 MBACSEL2	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL2 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B
7 NSE1	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure and nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
6-4 MBACSEL1	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL1 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B

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Field	Function
	111b - select MBC_MEMN_GLBAC7 access control policy for block B
3 NSE0	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure and nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
2-0 MBACSEL0	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL0 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B

10.7.1.38 MBC Memory Block NonSecure Enable Word (MBC0_DOM0_MEM0_BLK_NSE_W0 - MBC0_DOM2_MEM3_BLK_NSE_W0)

Offset

Register	Offset
MBC0_DOM0_MEM0_BLK_NSE_W0	1140h
MBC0_DOM0_MEM0_BLK_NSE_W1	1144h
MBC0_DOM0_MEM1_BLK_NSE_W0	11A0h
MBC0_DOM0_MEM2_BLK_NSE_W0	11C8h
MBC0_DOM0_MEM3_BLK_NSE_W0	11F0h

Table continues on the next page...

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Register	Offset
MBC0_DOM1_MEM0_BLK_NSE_W0	1340h
MBC0_DOM1_MEM0_BLK_NSE_W1	1344h
MBC0_DOM1_MEM1_BLK_NSE_W0	13A0h
MBC0_DOM1_MEM2_BLK_NSE_W0	13C8h
MBC0_DOM1_MEM3_BLK_NSE_W0	13F0h
MBC0_DOM2_MEM0_BLK_NSE_W0	1540h
MBC0_DOM2_MEM0_BLK_NSE_W1	1544h
MBC0_DOM2_MEM1_BLK_NSE_W0	15A0h
MBC0_DOM2_MEM2_BLK_NSE_W0	15C8h
MBC0_DOM2_MEM3_BLK_NSE_W0	15F0h

Function

MBC[m]_DOM[d]_MEM[s]_BLK_NSE_W[w], where,

- m - mbc index
- d - domain index
- s - memory target index
- w - word index

This is the bitmap of the individual NSE bits for the memory block.

NOTE

This register is shown with fields such that it covers entire 32 bit register. However, actual fields may be less if number of blocks are such that fields don't align to 32 bits. These absent fields may be shown but user can refer to table below to deduce actual fields and treat absent fields as reserved.

The following table describes the relationship between W (word index) and B (block number).

Table 44. Block Config Word to Block Number Relationship

Block NSE Word	BIT31	BIT30-BIT1	BIT0
W0	block 31	block 30 - block 1	block 0

Table continues on the next page...

Table 44. Block Config Word to Block Number Relationship (continued)

Block NSE Word	BIT31	BIT30-BIT1	BIT0
W1	block 63	block 62 - block 33	block 32
For MEM0, block 64 - block 511			
W2	block 95	block 94 - block 65	block 64
. . .			
W15	block 511	block 510 - block 481	block 480

The NSE bitmap can be accessed directly by register reads and writes to these locations, or "indirectly" through writes to NSE_SET, NSE_CLR, NSE_CLR_ALL, and BLK_CFG[NSEn] registers.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	BIT31	BIT30	BIT29	BIT28	BIT27	BIT26	BIT25	BIT24	BIT23	BIT22	BIT21	BIT20	BIT19	BIT18	BIT17	BIT16
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	BIT15	BIT14	BIT13	BIT12	BIT11	BIT10	BIT9	BIT8	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 BITb	Bit b NonSecure Enable [b = 0 - 31] 0b - Secure accesses to block B are based on corresponding MBACSEL field in register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure and nonsecure accesses to block B are based on corresponding MBACSEL field in register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).

10.7.1.39 MBC Global Access Control (MBC1_MEMN_GLBAC0)

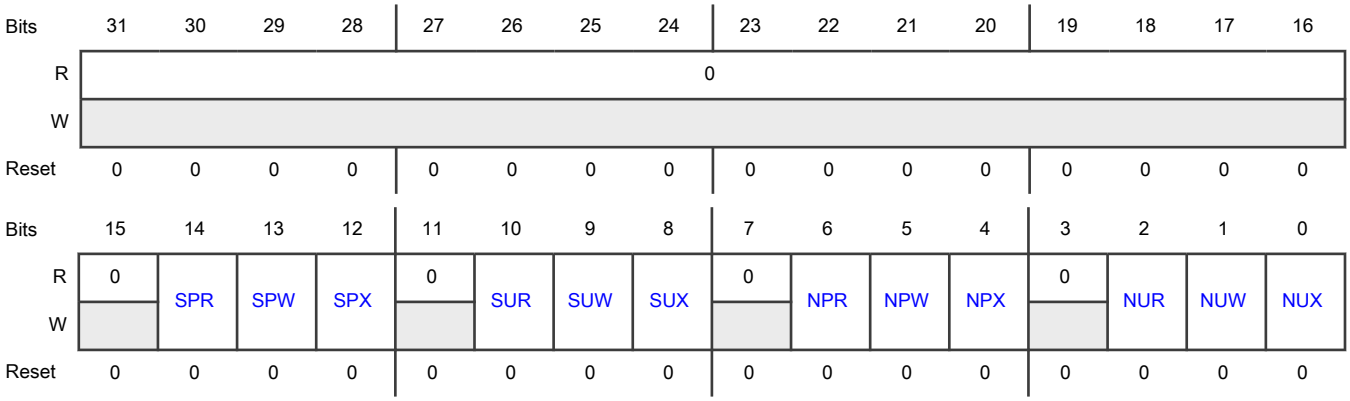
Offset

Register	Offset
MBC1_MEMN_GLBAC0	2020h

Function

These fully programmable R/W fields define the R/W/X (read/write/execute) access control flags with each of the 4 supported operating modes: SecurePriv, SecureUser, NonsecurePriv, Nonsecure User.

Diagram



Fields

Field	Function
31-15 —	Reserved
14 SPR	SecurePriv Read SecurePriv read access control flag 0b - Read access is not allowed in Secure Privilege mode. 1b - Read access is allowed in Secure Privilege mode.
13 SPW	SecurePriv Write SecurePriv write access control flag 0b - Write access is not allowed in Secure Privilege mode. 1b - Write access is allowed in Secure Privilege mode.
12 SPX	SecurePriv Execute SecurePriv execute access control flag

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Field	Function
	0b - Execute access is not allowed in Secure Privilege mode. 1b - Execute access is allowed in Secure Privilege mode.
11 —	Reserved
10 SUR	SecureUser Read SecureUser read access control flag 0b - Read access is not allowed in Secure User mode. 1b - Read access is allowed in Secure User mode.
9 SUW	SecureUser Write SecureUser write access control flag 0b - Write access is not allowed in Secure User mode. 1b - Write access is allowed in Secure User mode.
8 SUX	SecureUser Execute SecureUser execute access control flag 0b - Execute access is not allowed in Secure User mode. 1b - Execute access is allowed in Secure User mode.
7 —	Reserved
6 NPR	NonsecurePriv Read NonsecurePriv read access control flag 0b - Read access is not allowed in Nonsecure Privilege mode. 1b - Read access is allowed in Nonsecure Privilege mode.
5 NPW	NonsecurePriv Write NonsecurePriv write access control flag 0b - Write access is not allowed in Nonsecure Privilege mode. 1b - Write access is allowed in Nonsecure Privilege mode.
4 NPX	NonsecurePriv Execute NonsecurePriv execute access control flag 0b - Execute access is not allowed in Nonsecure Privilege mode. 1b - Execute access is allowed in Nonsecure Privilege mode.
3	Reserved

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Field	Function
—	
2 NUR	NonsecureUser Read NonsecureUser read access control flag 0b - Read access is not allowed in Nonsecure User mode. 1b - Read access is allowed in Nonsecure User mode.
1 NUW	NonsecureUser Write NonsecureUser write access control flag 0b - Write access is not allowed in Nonsecure User mode. 1b - Write access is allowed in Nonsecure User mode.
0 NUX	NonsecureUser Execute NonsecureUser execute access control flag 0b - Execute access is not allowed in Nonsecure User mode. 1b - Execute access is allowed in Nonsecure User mode.

10.7.1.40 MBC Global Access Control (MBC1_MEMN_GLBAC1 - MBC1_MEMN_GLBAC7)

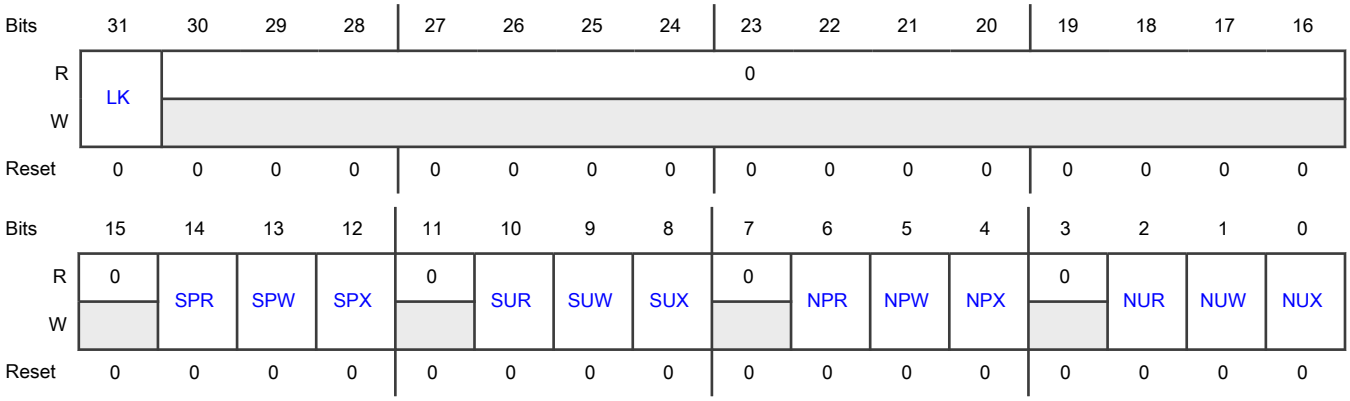
Offset

Register	Offset
MBC1_MEMN_GLBAC1	2024h
MBC1_MEMN_GLBAC2	2028h
MBC1_MEMN_GLBAC3	202Ch
MBC1_MEMN_GLBAC4	2030h
MBC1_MEMN_GLBAC5	2034h
MBC1_MEMN_GLBAC6	2038h
MBC1_MEMN_GLBAC7	203Ch

Function

These fully programmable R/W fields define the R/W/X (read/write/execute) access control flags with each of the 4 supported operating modes: SecurePriv, SecureUser, NonsecurePriv, Nonsecure User. The lock bit provides the ability to lock these control access flags and to lock the MBC_BLK_CFG[MBACSEL] field when a locked MBC_MEMN_GLBAC register is selected.

Diagram



Fields

Field	Function
31 LK	LOCK This 1-bit field provides a mechanism to limit writes to the this register to protect its contents. Once set, this bit remains asserted until the next reset. 0b - This register is not locked and can be altered. 1b - This register is locked and cannot be altered.
30-15 —	Reserved
14 SPR	SecurePriv Read SecurePriv read access control flag 0b - Read access is not allowed in Secure Privilege mode. 1b - Read access is allowed in Secure Privilege mode.
13 SPW	SecurePriv Write SecurePriv write access control flag 0b - Write access is not allowed in Secure Privilege mode. 1b - Write access is allowed in Secure Privilege mode.
12 SPX	SecurePriv Execute SecurePriv execute access control flag 0b - Execute access is not allowed in Secure Privilege mode. 1b - Execute access is allowed in Secure Privilege mode.
11 —	Reserved
10	SecureUser Read

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Field	Function
SUR	SecureUser read access control flag 0b - Read access is not allowed in Secure User mode. 1b - Read access is allowed in Secure User mode.
9 SUW	SecureUser Write SecureUser write access control flag 0b - Write access is not allowed in Secure User mode. 1b - Write access is allowed in Secure User mode.
8 SUX	SecureUser Execute SecureUser execute access control flag 0b - Execute access is not allowed in Secure User mode. 1b - Execute access is allowed in Secure User mode.
7 —	Reserved
6 NPR	NonsecurePriv Read NonsecurePriv read access control flag 0b - Read access is not allowed in Nonsecure Privilege mode. 1b - Read access is allowed in Nonsecure Privilege mode.
5 NPW	NonsecurePriv Write NonsecurePriv write access control flag 0b - Write access is not allowed in Nonsecure Privilege mode. 1b - Write access is allowed in Nonsecure Privilege mode.
4 NPX	NonsecurePriv Execute NonsecurePriv execute access control flag 0b - Execute access is not allowed in Nonsecure Privilege mode. 1b - Execute access is allowed in Nonsecure Privilege mode.
3 —	Reserved
2 NUR	NonsecureUser Read NonsecureUser read access control flag 0b - Read access is not allowed in Nonsecure User mode. 1b - Read access is allowed in Nonsecure User mode.

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Field	Function
1 NUW	NonsecureUser Write NonsecureUser write access control flag 0b - Write access is not allowed in Nonsecure User mode. 1b - Write access is allowed in Nonsecure User mode.
0 NUX	NonsecureUser Execute NonsecureUser execute access control flag 0b - Execute access is not allowed in Nonsecure User mode. 1b - Execute access is allowed in Nonsecure User mode.

10.7.1.41 MBC Memory Block Configuration Word (MBC1_DOM0_MEM0_BLK_CFG_W0 - MBC2_DOM2_MEM2_BLK_CFG_W1)

Offset

Register	Offset
MBC1_DOM0_MEM0_BLK_CFG_W0	2040h
MBC1_DOM0_MEM1_BLK_CFG_W0	2180h
MBC1_DOM0_MEM1_BLK_CFG_W1	2184h
MBC1_DOM0_MEM2_BLK_CFG_W0	21A8h
MBC1_DOM0_MEM2_BLK_CFG_W1	21ACh
MBC1_DOM0_MEM3_BLK_CFG_W0	21D0h
MBC1_DOM1_MEM0_BLK_CFG_W0	2240h
MBC1_DOM1_MEM1_BLK_CFG_W0	2380h
MBC1_DOM1_MEM1_BLK_CFG_W1	2384h
MBC1_DOM1_MEM2_BLK_CFG_W0	23A8h
MBC1_DOM1_MEM2_BLK_CFG_W1	23ACh

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Register	Offset
MBC1_DOM1_MEM3_BLK_CFG_W0	23D0h
MBC1_DOM2_MEM0_BLK_CFG_W0	2440h
MBC1_DOM2_MEM1_BLK_CFG_W0	2580h
MBC1_DOM2_MEM1_BLK_CFG_W1	2584h
MBC1_DOM2_MEM2_BLK_CFG_W0	25A8h
MBC1_DOM2_MEM2_BLK_CFG_W1	25ACh
MBC1_DOM2_MEM3_BLK_CFG_W0	25D0h
MBC2_DOM0_MEM0_BLK_CFG_W0	3040h
MBC2_DOM0_MEM0_BLK_CFG_W1	3044h
MBC2_DOM0_MEM0_BLK_CFG_W2	3048h
MBC2_DOM0_MEM0_BLK_CFG_W3	304Ch
MBC2_DOM0_MEM0_BLK_CFG_W4	3050h
MBC2_DOM0_MEM0_BLK_CFG_W5	3054h
MBC2_DOM0_MEM0_BLK_CFG_W6	3058h
MBC2_DOM0_MEM0_BLK_CFG_W7	305Ch
MBC2_DOM0_MEM0_BLK_CFG_W8	3060h
MBC2_DOM0_MEM0_BLK_CFG_W9	3064h
MBC2_DOM0_MEM0_BLK_CFG_W10	3068h
MBC2_DOM0_MEM1_BLK_CFG_W0	3180h

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Register	Offset
MBC2_DOM0_MEM2_BLK_CFG_W0	31A8h
MBC2_DOM0_MEM2_BLK_CFG_W1	31ACh
MBC2_DOM1_MEM0_BLK_CFG_W0	3240h
MBC2_DOM1_MEM0_BLK_CFG_W1	3244h
MBC2_DOM1_MEM0_BLK_CFG_W2	3248h
MBC2_DOM1_MEM0_BLK_CFG_W3	324Ch
MBC2_DOM1_MEM0_BLK_CFG_W4	3250h
MBC2_DOM1_MEM0_BLK_CFG_W5	3254h
MBC2_DOM1_MEM0_BLK_CFG_W6	3258h
MBC2_DOM1_MEM0_BLK_CFG_W7	325Ch
MBC2_DOM1_MEM0_BLK_CFG_W8	3260h
MBC2_DOM1_MEM0_BLK_CFG_W9	3264h
MBC2_DOM1_MEM0_BLK_CFG_W10	3268h
MBC2_DOM1_MEM1_BLK_CFG_W0	3380h
MBC2_DOM1_MEM2_BLK_CFG_W0	33A8h
MBC2_DOM1_MEM2_BLK_CFG_W1	33ACh
MBC2_DOM2_MEM0_BLK_CFG_W0	3440h
MBC2_DOM2_MEM0_BLK_CFG_W1	3444h
MBC2_DOM2_MEM0_BLK_CFG_W2	3448h

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Register	Offset
MBC2_DOM2_MEM0_BLK_CFG_W3	344Ch
MBC2_DOM2_MEM0_BLK_CFG_W4	3450h
MBC2_DOM2_MEM0_BLK_CFG_W5	3454h
MBC2_DOM2_MEM0_BLK_CFG_W6	3458h
MBC2_DOM2_MEM0_BLK_CFG_W7	345Ch
MBC2_DOM2_MEM0_BLK_CFG_W8	3460h
MBC2_DOM2_MEM0_BLK_CFG_W9	3464h
MBC2_DOM2_MEM0_BLK_CFG_W10	3468h
MBC2_DOM2_MEM1_BLK_CFG_W0	3580h
MBC2_DOM2_MEM2_BLK_CFG_W0	35A8h
MBC2_DOM2_MEM2_BLK_CFG_W1	35ACh

Function

MBC[m]_DOM[d]_MEM[s]_BLK_CFG_W[w], where,

- m - mbc index
- d - domain index
- s - memory target index
- w - word index

These registers are read/write for both the alternate view of the NSE bit and the 3-bit MBACSEL field. This is an array of 4 bit fields defining the block configuration for the given submemory. Each 4-bit field includes an alternative view of the associated NSE bit plus a 3-bit access control select that selects the global access control value that applies to the referenced memory block.

For a given memory block, B, if the value programmed in the MBACSELn field selects a locked MBC_MEMN_GLBACr register, the MBACSEL field is locked until the next reset. Depending on BLK_CFG_W, the NSEn/MBASELn fields correspond to different blocks. The following table describes the relationship between W (word index) and B (block number).

MEM0 supports up to 512 blocks ; W0 - W63

MEM1-3 supports up to 64 block ; W0 - W7

NOTE

This register is shown with fields such that it covers entire 32 bit register. However, actual fields may be less if number of blocks are such that fields don't align to 32 bits. These absent fields may be shown but user can refer to table below to deduce actual fields and treat absent fields as reserved.

Table 45. Block Config Word to Block Number Relationship

Block Config Word	NSE7/ MBACSEL7	NSE6/ MBACSEL6	NSE5/ MBACSEL5	NSE4/ MBACSEL4	NSE3/ MBACSEL3	NSE2/ MBACSEL2	NSE1/ MBACSEL1	NSE0/ MBACSEL0
W0	block 7	block 6	block 5	block 4	block 3	block 2	block 1	block 0
W1	block 15	block 14	block 13	block 12	block 11	block 10	block 9	block 8
W2	block 23	block 22	block 21	block 20	block 19	block 18	block 17	block 16
W3	block 31	block 30	block 29	block 28	block 27	block 26	block 25	block 24
W4	block 39	block 38	block 37	block 36	block 35	block 34	block 33	block 32
W5	block 47	block 46	block 45	block 44	block 43	block 42	block 41	block 40
W6	block 55	block 54	block 53	block 52	block 51	block 50	block 49	block 48
W7	block 63	block 62	block 61	block 60	block 59	block 58	block 57	block 56
For MEM0, block 64 - block 511								
W8	block 71	block 70	block 69	block 68	block 67	block 66	block 65	block 64
. . .								
W63	block 511	block 510	block 509	block 508	block 507	block 506	block 505	block 504

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	NSE7	MBACSEL7			NSE6	MBACSEL6			NSE5	MBACSEL5			NSE4	MBACSEL4		
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	NSE3	MBACSEL3			NSE2	MBACSEL2			NSE1	MBACSEL1			NSE0	MBACSEL0		
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 NSE7	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure accesses to block B are not allowed, nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
30-28 MBACSEL7	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL7 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B
27 NSE6	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure accesses to block B are not allowed, nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
26-24 MBACSEL6	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL6 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B

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Field	Function
	100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B
23 NSE5	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure accesses to block B are not allowed, nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
22-20 MBACSEL5	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL5 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B
19 NSE4	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure accesses to block B are not allowed, nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
18-16 MBACSEL4	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL4 = r and MBC_MEMN_GLBACr[LK] = 1.

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Field	Function
	000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B
15 NSE3	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure accesses to block B are not allowed, nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
14-12 MBACSEL3	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL3 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B
11 NSE2	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure accesses to block B are not allowed, nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
10-8	Memory Block Access Control Select for block B

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Field	Function
MBACSEL2	This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL2 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B
7 NSE1	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure accesses to block B are not allowed, nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
6-4 MBACSEL1	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL1 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B
3 NSE0	NonSecure Enable for block B 0b - Secure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed.

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Field	Function
	1b - Secure accesses to block B are not allowed, nonsecure accesses to block B are based on corresponding MBACSEL field in this register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).
2-0 MBACSEL0	Memory Block Access Control Select for block B This field selects the global access control associated with block B. **NOTE** This field is locked (read-only) if MBACSEL0 = r and MBC_MEMN_GLBACr[LK] = 1. 000b - select MBC_MEMN_GLBAC0 access control policy for block B 001b - select MBC_MEMN_GLBAC1 access control policy for block B 010b - select MBC_MEMN_GLBAC2 access control policy for block B 011b - select MBC_MEMN_GLBAC3 access control policy for block B 100b - select MBC_MEMN_GLBAC4 access control policy for block B 101b - select MBC_MEMN_GLBAC5 access control policy for block B 110b - select MBC_MEMN_GLBAC6 access control policy for block B 111b - select MBC_MEMN_GLBAC7 access control policy for block B

10.7.1.42 MBC Memory Block NonSecure Enable Word (MBC1_DOM0_MEM0_BLK_NSE_W0 - MBC2_DOM2_MEM2_BLK_NSE_W0)

Offset

Register	Offset
MBC1_DOM0_MEM0_BLK_NSE_W0	2140h
MBC1_DOM0_MEM1_BLK_NSE_W0	21A0h
MBC1_DOM0_MEM2_BLK_NSE_W0	21C8h
MBC1_DOM0_MEM3_BLK_NSE_W0	21F0h
MBC1_DOM1_MEM0_BLK_NSE_W0	2340h
MBC1_DOM1_MEM1_BLK_NSE_W0	23A0h
MBC1_DOM1_MEM2_BLK_NSE_W0	23C8h

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Register	Offset
MBC1_DOM1_MEM3_BLK_NSE_W0	23F0h
MBC1_DOM2_MEM0_BLK_NSE_W0	2540h
MBC1_DOM2_MEM1_BLK_NSE_W0	25A0h
MBC1_DOM2_MEM2_BLK_NSE_W0	25C8h
MBC1_DOM2_MEM3_BLK_NSE_W0	25F0h
MBC2_DOM0_MEM0_BLK_NSE_W0	3140h
MBC2_DOM0_MEM0_BLK_NSE_W1	3144h
MBC2_DOM0_MEM0_BLK_NSE_W2	3148h
MBC2_DOM0_MEM1_BLK_NSE_W0	31A0h
MBC2_DOM0_MEM2_BLK_NSE_W0	31C8h
MBC2_DOM1_MEM0_BLK_NSE_W0	3340h
MBC2_DOM1_MEM0_BLK_NSE_W1	3344h
MBC2_DOM1_MEM0_BLK_NSE_W2	3348h
MBC2_DOM1_MEM1_BLK_NSE_W0	33A0h
MBC2_DOM1_MEM2_BLK_NSE_W0	33C8h
MBC2_DOM2_MEM0_BLK_NSE_W0	3540h
MBC2_DOM2_MEM0_BLK_NSE_W1	3544h
MBC2_DOM2_MEM0_BLK_NSE_W2	3548h
MBC2_DOM2_MEM1_BLK_NSE_W0	35A0h

Table continues on the next page...

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Register	Offset
MBC2_DOM2_MEM2_BLK_NSE_W0	35C8h

Function

MBC[m]_DOM[d]_MEM[s]_BLK_NSE_W[w], where,

- m - mbc index
- d - domain index
- s - memory target index
- w - word index

This is the bitmap of the individual NSE bits for the memory block.

NOTE

This register is shown with fields such that it covers entire 32 bit register. However, actual fields may be less if number of blocks are such that fields don't align to 32 bits. These absent fields may be shown but user can refer to table below to deduce actual fields and treat absent fields as reserved.

The following table describes the relationship between W (word index) and B (block number).

Table 46. Block Config Word to Block Number Relationship

Block NSE Word	BIT31	BIT30-BIT1	BIT0
W0	block 31	block 30 - block 1	block 0
W1	block 63	block 62 - block 33	block 32
For MEM0, block 64 - block 511			
W2	block 95	block 94 - block 65	block 64
. . .			
W15	block 511	block 510 - block 481	block 480

The NSE bitmap can be accessed directly by register reads and writes to these locations, or "indirectly" through writes to NSE_SET, NSE_CLR, NSE_CLR_ALL, and BLK_CFG[NSEn] registers.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	BIT31	BIT30	BIT29	BIT28	BIT27	BIT26	BIT25	BIT24	BIT23	BIT22	BIT21	BIT20	BIT19	BIT18	BIT17	BIT16
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	BIT15	BIT14	BIT13	BIT12	BIT11	BIT10	BIT9	BIT8	BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 BITb	Bit b NonSecure Enable [b = 0 - 31] 0b - Secure accesses to block B are based on corresponding MBACSEL field in register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]), nonsecure accesses to block B are not allowed. 1b - Secure accesses to block B are not allowed, nonsecure accesses to block B are based on corresponding MBACSEL field in register (MBCm_DOMd_MEMs_BLK_CFG_Ww[MBACSEL]).

10.7.1.43 MBC Global Access Control (MBC2_MEMN_GLBAC0)

Offset

Register	Offset
MBC2_MEMN_GLBAC0	3020h

Function

These fully programmable R/W fields define the R/W/X (read/write/execute) access control flags with each of the 4 supported operating modes: SecurePriv, SecureUser, NonsecurePriv, Nonsecure User.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	SPR	SPW	SPX	0	SUR	SUW	SUX	0	NPR	NPW	NPX	0	NUR	NUW	NUX
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-15 —	Reserved
14 SPR	SecurePriv Read SecurePriv read access control flag 0b - Read access is not allowed in Secure Privilege mode. 1b - Read access is allowed in Secure Privilege mode.
13 SPW	SecurePriv Write SecurePriv write access control flag 0b - Write access is not allowed in Secure Privilege mode. 1b - Write access is allowed in Secure Privilege mode.
12 SPX	SecurePriv Execute SecurePriv execute access control flag 0b - Execute access is not allowed in Secure Privilege mode. 1b - Execute access is allowed in Secure Privilege mode.
11 —	Reserved
10 SUR	SecureUser Read SecureUser read access control flag 0b - Read access is not allowed in Secure User mode. 1b - Read access is allowed in Secure User mode.
9 SUW	SecureUser Write SecureUser write access control flag 0b - Write access is not allowed in Secure User mode. 1b - Write access is allowed in Secure User mode.
8 SUX	SecureUser Execute SecureUser execute access control flag 0b - Execute access is not allowed in Secure User mode. 1b - Execute access is allowed in Secure User mode.
7 —	Reserved
6	NonsecurePriv Read

Table continues on the next page...

Table continued from the previous page...

Field	Function
NPR	NonsecurePriv read access control flag 0b - Read access is not allowed in Nonsecure Privilege mode. 1b - Read access is allowed in Nonsecure Privilege mode.
5 NPW	NonsecurePriv Write NonsecurePriv write access control flag 0b - Write access is not allowed in Nonsecure Privilege mode. 1b - Write access is allowed in Nonsecure Privilege mode.
4 NPX	NonsecurePriv Execute NonsecurePriv execute access control flag 0b - Execute access is not allowed in Nonsecure Privilege mode. 1b - Execute access is allowed in Nonsecure Privilege mode.
3 —	Reserved
2 NUR	NonsecureUser Read NonsecureUser read access control flag 0b - Read access is not allowed in Nonsecure User mode. 1b - Read access is allowed in Nonsecure User mode.
1 NUW	NonsecureUser Write NonsecureUser write access control flag 0b - Write access is not allowed in Nonsecure User mode. 1b - Write access is allowed in Nonsecure User mode.
0 NUX	NonsecureUser Execute NonsecureUser execute access control flag 0b - Execute access is not allowed in Nonsecure User mode. 1b - Execute access is allowed in Nonsecure User mode.

10.7.1.44 MBC Global Access Control (MBC2_MEMN_GLBAC1 - MBC2_MEMN_GLBAC7)

Offset

Register	Offset
MBC2_MEMN_GLBAC1	3024h

Table continues on the next page...

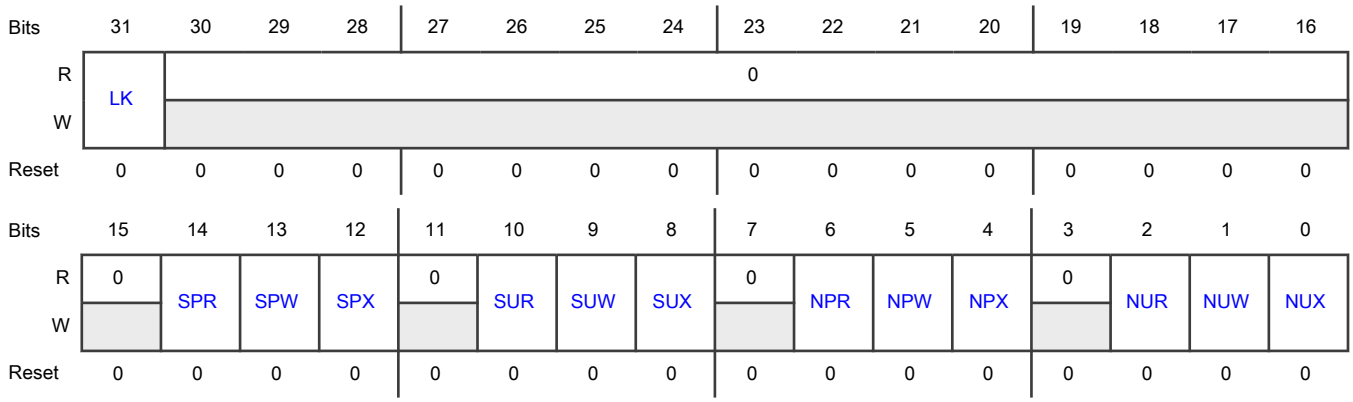
Table continued from the previous page...

Register	Offset
MBC2_MEMN_GLBAC2	3028h
MBC2_MEMN_GLBAC3	302Ch
MBC2_MEMN_GLBAC4	3030h
MBC2_MEMN_GLBAC5	3034h
MBC2_MEMN_GLBAC6	3038h
MBC2_MEMN_GLBAC7	303Ch

Function

These fully programmable R/W fields define the R/W/X (read/write/execute) access control flags with each of the 4 supported operating modes: SecurePriv, SecureUser, NonsecurePriv, Nonsecure User. The lock bit provides the ability to lock these control access flags and to lock the MBC_BLK_CFG[MBACSEL] field when a locked MBC_MEMN_GLBAC register is selected.

Diagram



Fields

Field	Function
31 LK	LOCK This 1-bit field provides a mechanism to limit writes to the this register to protect its contents. Once set, this bit remains asserted until the next reset. 0b - This register is not locked and can be altered. 1b - This register is locked and cannot be altered.
30-15 —	Reserved
14	SecurePriv Read

Table continues on the next page...

Table continued from the previous page...

Field	Function
SPR	SecurePriv read access control flag 0b - Read access is not allowed in Secure Privilege mode. 1b - Read access is allowed in Secure Privilege mode.
13 SPW	SecurePriv Write SecurePriv write access control flag 0b - Write access is not allowed in Secure Privilege mode. 1b - Write access is allowed in Secure Privilege mode.
12 SPX	SecurePriv Execute SecurePriv execute access control flag 0b - Execute access is not allowed in Secure Privilege mode. 1b - Execute access is allowed in Secure Privilege mode.
11 —	Reserved
10 SUR	SecureUser Read SecureUser read access control flag 0b - Read access is not allowed in Secure User mode. 1b - Read access is allowed in Secure User mode.
9 SUW	SecureUser Write SecureUser write access control flag 0b - Write access is not allowed in Secure User mode. 1b - Write access is allowed in Secure User mode.
8 SUX	SecureUser Execute SecureUser execute access control flag 0b - Execute access is not allowed in Secure User mode. 1b - Execute access is allowed in Secure User mode.
7 —	Reserved
6 NPR	NonsecurePriv Read NonsecurePriv read access control flag 0b - Read access is not allowed in Nonsecure Privilege mode. 1b - Read access is allowed in Nonsecure Privilege mode.

Table continues on the next page...

Table continued from the previous page...

Field	Function
5 NPW	NonsecurePriv Write NonsecurePriv write access control flag 0b - Write access is not allowed in Nonsecure Privilege mode. 1b - Write access is allowed in Nonsecure Privilege mode.
4 NPX	NonsecurePriv Execute NonsecurePriv execute access control flag 0b - Execute access is not allowed in Nonsecure Privilege mode. 1b - Execute access is allowed in Nonsecure Privilege mode.
3 —	Reserved
2 NUR	NonsecureUser Read NonsecureUser read access control flag 0b - Read access is not allowed in Nonsecure User mode. 1b - Read access is allowed in Nonsecure User mode.
1 NUW	NonsecureUser Write NonsecureUser write access control flag 0b - Write access is not allowed in Nonsecure User mode. 1b - Write access is allowed in Nonsecure User mode.
0 NUX	NonsecureUser Execute NonsecureUser execute access control flag 0b - Execute access is not allowed in Nonsecure User mode. 1b - Execute access is allowed in Nonsecure User mode.

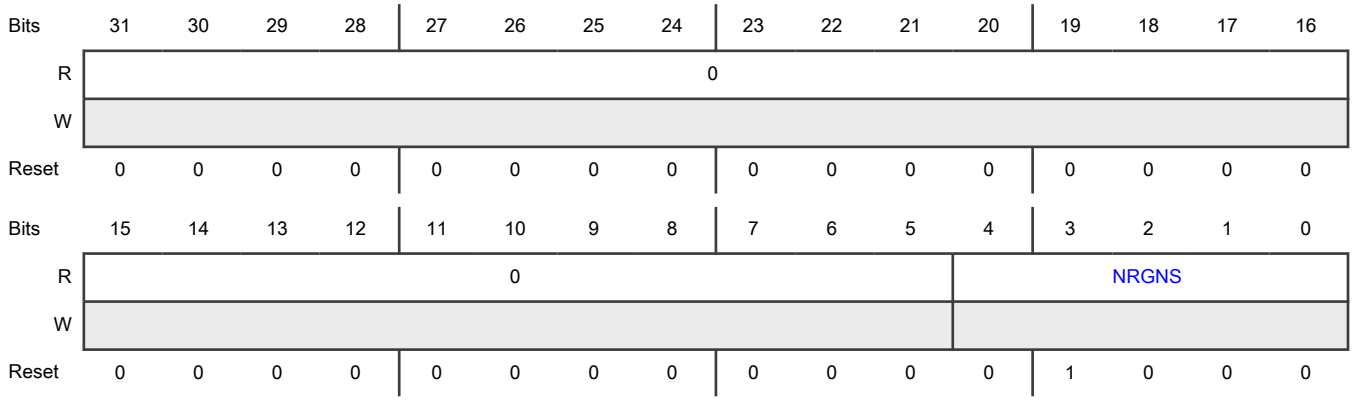
10.7.1.45 MRC Global Configuration Register (MRC0_GLBCFG)

Offset

Register	Offset
MRC0_GLBCFG	4000h

Function
This read-only register describes the number of region descriptors for this memory.

Diagram



Fields

Field	Function
31-5 —	Reserved
4-0 NRGNS	Number of regions [1-16]

10.7.1.46 MRC NonSecure Enable Region Indirect (MRC0_NSE_RGN_INDIRECT)

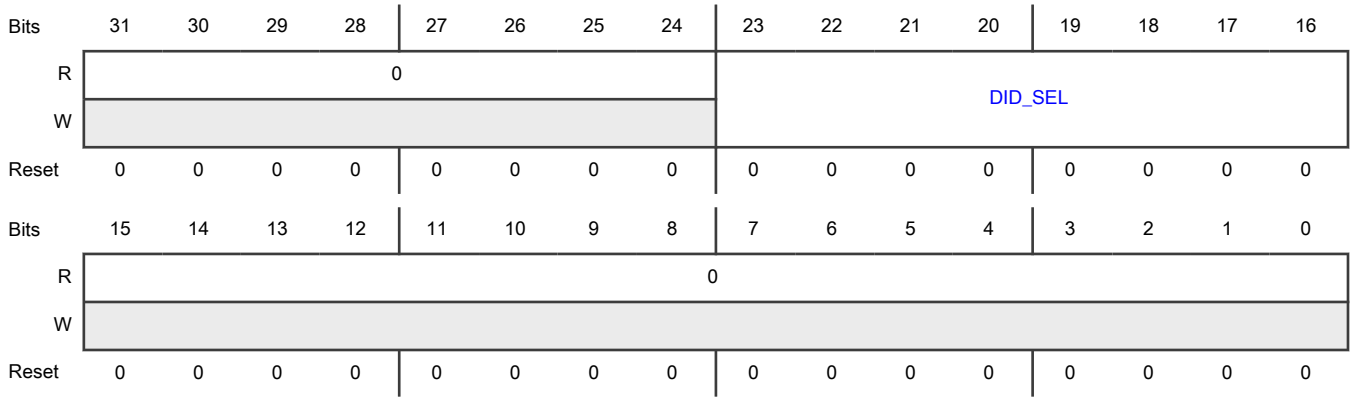
Offset

Register	Offset
MRC0_NSE_RGN_INDIRECT	4010h

Function

This R/W register defines the selected domains that are affected by writes to the NSE_RGN_SET and NSE_RGN_CLR registers.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 DID_SEL	DID Select Destination domain bitmap select. • Bit [23] = 1, update domain 7 • Bit [22] = 1, update domain 6 • Bit [21] = 1, update domain 5 • Bit [20] = 1, update domain 4 • Bit [19] = 1, update domain 3 • Bit [18] = 1, update domain 2 • Bit [17] = 1, update domain 1 • Bit [16] = 1, update domain 0
15-0 —	Reserved

10.7.1.47 MRC NonSecure Enable Region Set (MRC0_NSE_RGN_SET)

Offset

Register	Offset
MRC0_NSE_RGN_SET	4014h

Function

A write to this location sets the appropriate NSE bits in region descriptors for the selected domain in MRC NonSecure Enable Region Indirect register. This register reads as 0.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W	W1SET															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-16 —	Reserved
15-0 W1SET	Write-1 Set • Bit [15] = Set the NSE bits for RGD15 • Bit [14] = Set the NSE bits for RGD14 • Bit [13] = Set the NSE bits for RGD13 • Bit [12] = Set the NSE bits for RGD12 • Bit [11] = Set the NSE bits for RGD11 • Bit [10] = Set the NSE bits for RGD10 • Bit [9] = Set the NSE bits for RGD9 • Bit [8] = Set the NSE bits for RGD8 • Bit [7] = Set the NSE bits for RGD7 • Bit [6] = Set the NSE bits for RGD6 • Bit [5] = Set the NSE bits for RGD5 • Bit [4] = Set the NSE bits for RGD4 • Bit [3] = Set the NSE bits for RGD3 • Bit [2] = Set the NSE bits for RGD2 • Bit [1] = Set the NSE bits for RGD1 • Bit [0] = Set the NSE bits for RGD0

10.7.1.48 MRC NonSecure Enable Region Clear (MRC0_NSE_RGN_CLR)

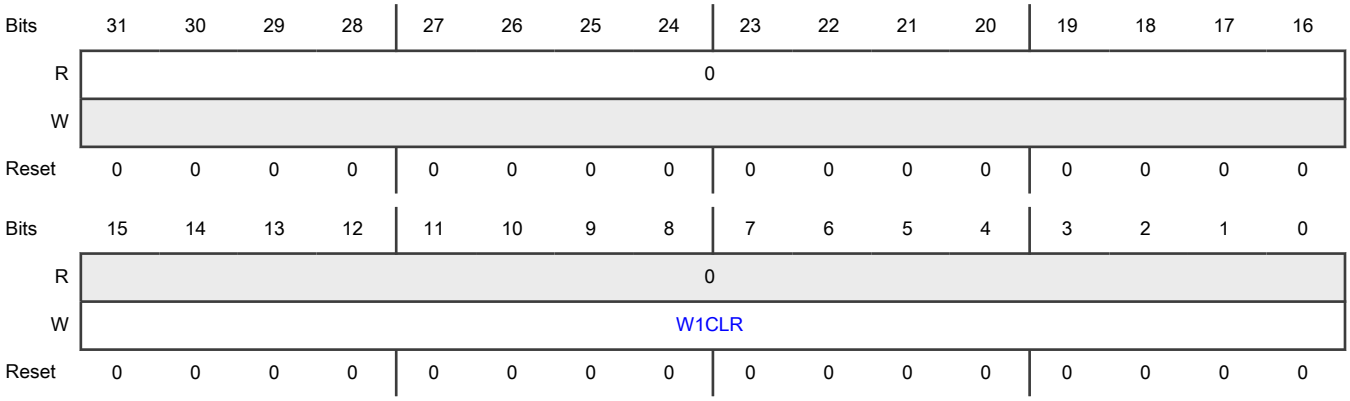
Offset

Register	Offset
MRC0_NSE_RGN_CLR	4018h

Function

A write to this location clears the appropriate NSE bits in region descriptors for the selected domain in MRC NonSecure Enable Region Indirect register. This register reads as 0.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 W1CLR	Write-1 Clear • Bit [15] = Clear the NSE bits for RGD15 • Bit [14] = Clear the NSE bits for RGD14 • Bit [13] = Clear the NSE bits for RGD13 • Bit [12] = Clear the NSE bits for RGD12 • Bit [11] = Clear the NSE bits for RGD11 • Bit [10] = Clear the NSE bits for RGD10 • Bit [9] = Clear the NSE bits for RGD9 • Bit [8] = Clear the NSE bits for RGD8 • Bit [7] = Clear the NSE bits for RGD7 • Bit [6] = Clear the NSE bits for RGD6 • Bit [5] = Clear the NSE bits for RGD5 • Bit [4] = Clear the NSE bits for RGD4 • Bit [3] = Clear the NSE bits for RGD3 • Bit [2] = Clear the NSE bits for RGD2 • Bit [1] = Clear the NSE bits for RGD1 • Bit [0] = Clear the NSE bits for RGD0

10.7.1.49 MRC NonSecure Enable Region Clear All (MRC0_NSE_RGN_CLR_ALL)

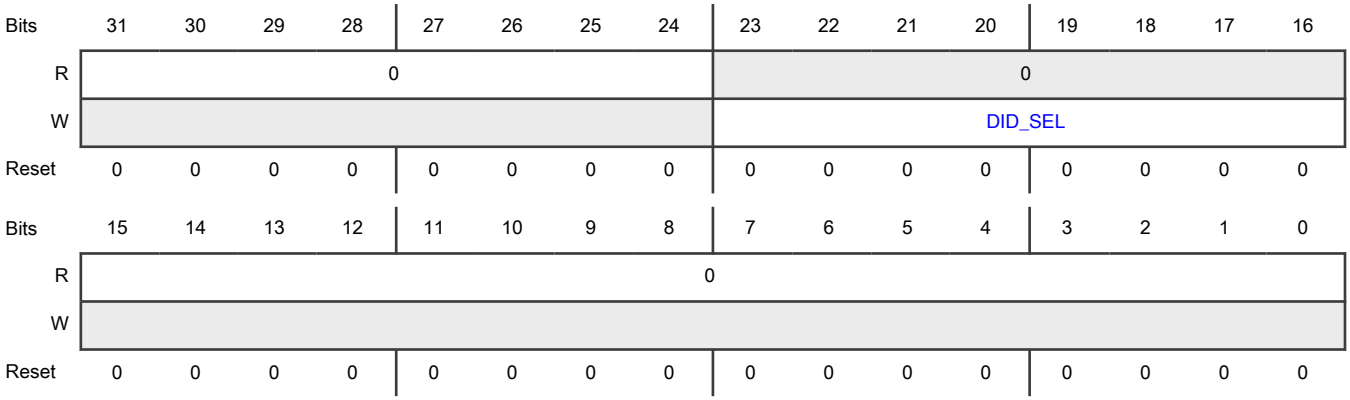
Offset

Register	Offset
MRC0_NSE_RGN_CLR_ALL	401Ch

Function

A write to this register clears all the region NSE bits for the selected domains defined in the write data.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 DID_SEL	DID Select Destination domain bitmap select. • Bit [23] = 1 clear NSE bits for domain 7 • Bit [22] = 1 clear NSE bits for domain 6 • Bit [21] = 1 clear NSE bits for domain 5 • Bit [20] = 1 clear NSE bits for domain 4 • Bit [19] = 1 clear NSE bits for domain 3 • Bit [18] = 1 clear NSE bits for domain 2 • Bit [17] = 1 clear NSE bits for domain 1 • Bit [16] = 1 clear NSE bits for domain 0
15-0 —	Reserved

10.7.1.50 MRC Global Access Control (MRC0_GLBAC0)

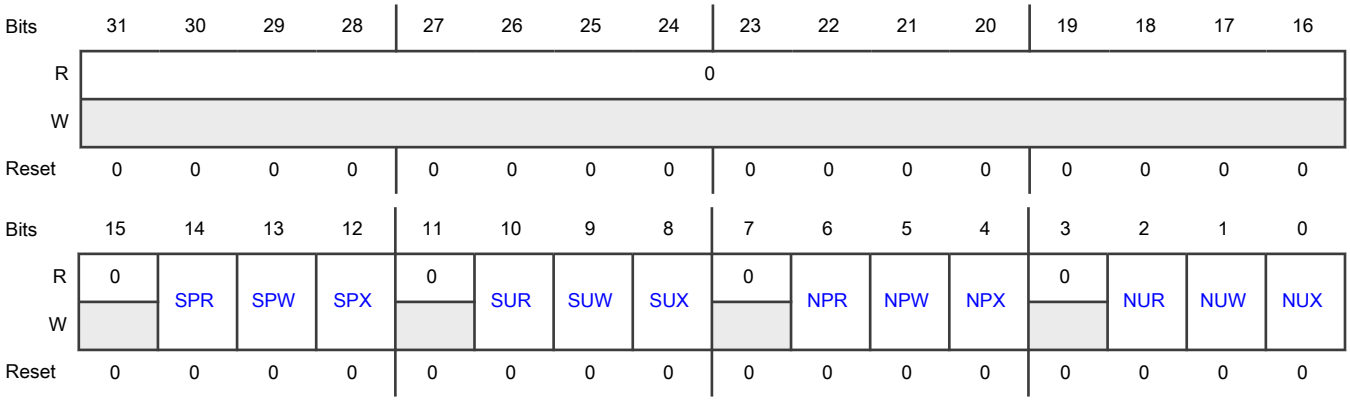
Offset

Register	Offset
MRC0_GLBAC0	4020h

Function

These fully programmable R/W fields define the R/W/X (read/write/execute) access control flags with each of the 4 supported operating modes: SecurePriv, SecureUser, NonsecurePriv, NonsecureUser. The lock bit provides the ability to lock these control access flags, to lock the MRC_BLK_CFG[MRACSEL] field, and to lock the MRC_RGD[STRT_ADDR, END_ADDR, VLD] fields when a locked MRC_GLBAC register is selected.

Diagram



Fields

Field	Function
31-15 —	Reserved
14 SPR	SecurePriv Read SecurePriv read access control flag 0b - Read access is not allowed in Secure Privilege mode. 1b - Read access is allowed in Secure Privilege mode.
13 SPW	SecurePriv Write SecurePriv write access control flag 0b - Write access is not allowed in Secure Privilege mode. 1b - Write access is allowed in Secure Privilege mode.
12	SecurePriv Execute

Table continues on the next page...

Table continued from the previous page...

Field	Function
SPX	SecurePriv execute access control flag 0b - Execute access is not allowed in Secure Privilege mode. 1b - Execute access is allowed in Secure Privilege mode.
11 —	Reserved
10 SUR	SecureUser Read SecureUser read access control flag 0b - Read access is not allowed in Secure User mode. 1b - Read access is allowed in Secure User mode.
9 SUW	SecureUser Write SecureUser write access control flag 0b - Write access is not allowed in Secure User mode. 1b - Write access is allowed in Secure User mode.
8 SUX	SecureUser Execute SecureUser execute access control flag 0b - Execute access is not allowed in Secure User mode. 1b - Execute access is allowed in Secure User mode.
7 —	Reserved
6 NPR	NonsecurePriv Read NonsecurePriv read access control flag 0b - Read access is not allowed in Nonsecure Privilege mode. 1b - Read access is allowed in Nonsecure Privilege mode.
5 NPW	NonsecurePriv Write NonsecurePriv write access control flag 0b - Write access is not allowed in Nonsecure Privilege mode. 1b - Write access is allowed in Nonsecure Privilege mode.
4 NPX	NonsecurePriv Execute NonsecurePriv execute access control flag 0b - Execute access is not allowed in Nonsecure Privilege mode. 1b - Execute access is allowed in Nonsecure Privilege mode.

Table continues on the next page...

Table continued from the previous page...

Field	Function
3 —	Reserved
2 NUR	NonsecureUser Read NonsecureUser read access control flag 0b - Read access is not allowed in Nonsecure User mode. 1b - Read access is allowed in Nonsecure User mode.
1 NUW	NonsecureUser Write NonsecureUser write access control flag 0b - Write access is not allowed in Nonsecure User mode. 1b - Write access is allowed in Nonsecure User mode.
0 NUX	NonsecureUser Execute NonsecureUser execute access control flag 0b - Execute access is not allowed in Nonsecure User mode. 1b - Execute access is allowed in Nonsecure User mode.

10.7.1.51 MRC Global Access Control (MRC0_GLBAC1 - MRC0_GLBAC7)

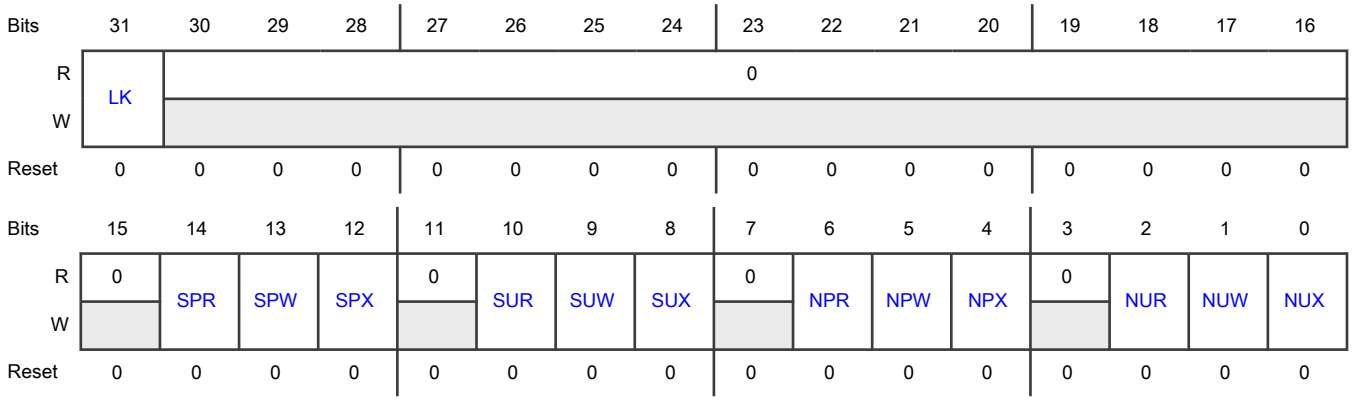
Offset

Register	Offset
MRC0_GLBAC1	4024h
MRC0_GLBAC2	4028h
MRC0_GLBAC3	402Ch
MRC0_GLBAC4	4030h
MRC0_GLBAC5	4034h
MRC0_GLBAC6	4038h
MRC0_GLBAC7	403Ch

Function

These fully programmable R/W fields define the R/W/X (read/write/execute) access control flags with each of the 4 supported operating modes: SecurePriv, SecureUser, NonsecurePriv, NonsecureUser. The lock bit provides the ability to lock these control access flags, to lock the MRC_BLK_CFG[MRACSEL] field, and to lock the MRC_RGD[STRT_ADDR, END_ADDR, VLD] fields when a locked MRC_GLBAC register is selected.

Diagram



Fields

Field	Function
31 LK	LOCK This 1-bit field provides a mechanism to limit writes to the this register to protect its contents. Once set, this bit remains asserted until the next reset. 0b - This register is not locked and can be altered. 1b - This register is locked (read-only) and cannot be altered.
30-15 —	Reserved
14 SPR	SecurePriv Read SecurePriv read access control flag 0b - Read access is not allowed in Secure Privilege mode. 1b - Read access is allowed in Secure Privilege mode.
13 SPW	SecurePriv Write SecurePriv write access control flag 0b - Write access is not allowed in Secure Privilege mode. 1b - Write access is allowed in Secure Privilege mode.
12 SPX	SecurePriv Execute SecurePriv execute access control flag 0b - Execute access is not allowed in Secure Privilege mode. 1b - Execute access is allowed in Secure Privilege mode.
11 —	Reserved
10	SecureUser Read

Table continues on the next page...

Table continued from the previous page...

Field	Function
SUR	SecureUser read access control flag 0b - Read access is not allowed in Secure User mode. 1b - Read access is allowed in Secure User mode.
9 SUW	SecureUser Write SecureUser write access control flag 0b - Write access is not allowed in Secure User mode. 1b - Write access is allowed in Secure User mode.
8 SUX	SecureUser Execute SecureUser execute access control flag 0b - Execute access is not allowed in Secure User mode. 1b - Execute access is allowed in Secure User mode.
7 —	Reserved
6 NPR	NonsecurePriv Read NonsecurePriv read access control flag 0b - Read access is not allowed in Nonsecure Privilege mode. 1b - Read access is allowed in Nonsecure Privilege mode.
5 NPW	NonsecurePriv Write NonsecurePriv write access control flag 0b - Write access is not allowed in Nonsecure Privilege mode. 1b - Write access is allowed in Nonsecure Privilege mode.
4 NPX	NonsecurePriv Execute NonsecurePriv execute access control flag 0b - Execute access is not allowed in Nonsecure Privilege mode. 1b - Execute access is allowed in Nonsecure Privilege mode.
3 —	Reserved
2 NUR	NonsecureUser Read NonsecureUser read access control flag 0b - Read access is not allowed in Nonsecure User mode. 1b - Read access is allowed in Nonsecure User mode.

Table continues on the next page...

Table continued from the previous page...

Field	Function
1 NUW	NonsecureUser Write NonsecureUser write access control flag 0b - Write access is not allowed in Nonsecure User mode. 1b - Write access is allowed in Nonsecure User mode.
0 NUX	NonsecureUser Execute NonsecureUser execute access control flag 0b - Execute access is not allowed in Nonsecure User mode. 1b - Execute access is allowed in Nonsecure User mode.

10.7.1.52 MRC Region Descriptor Word 0 (MRC0_DOM0_RGD0_W0 - MRC0_DOM2_RGD7_W0)

Offset

For d = 0 to 2; r = 0 to 7:

Register	Offset
MRC0_DOMd_RGDr_W0	4040h + (d × 100h) + (r × 8h)

Function

MRC[m]_DOM[d]_RGD[r]_W[w], where,

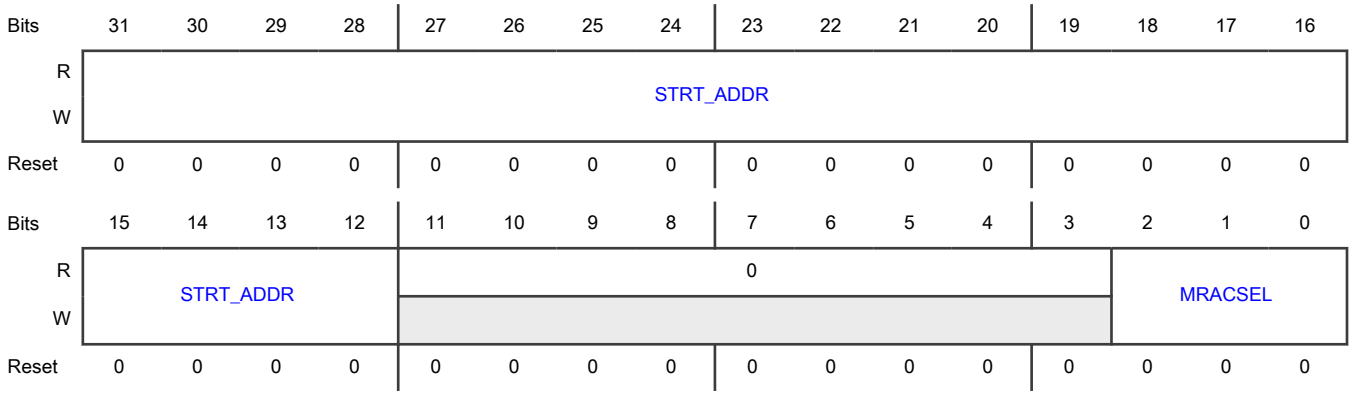
- m - mrc index
- d - domain index
- r - region descriptor index
- w - word index

The MRC[m]_DOM[d]_RGD[r]_W[w] registers provide a 3-dimensional data structure for defining access control policies per domain for each supported memory region.

Memory map/register definition:

There two word-size registers (W[w]) defined in each memory region. There are up to 8 memory region checkers (MRCs), m, each supporting up to 16 memory region descriptors (RGD), r. The number of MRCs is defined by HWCFG0[NMRC].

Diagram



Fields

Field	Function
31-12 STRT_ADDR	Start Address 0-mod-4K physical start address [31:12] of region r. **NOTE** This field is locked (read-only) if MRACSEL = r and MRC_GLBACr[LK] = 1.
11-3 —	Reserved
2-0 MRACSEL	Memory Region Access Control Select This field selects the global access control associated with region r. **NOTE** This field is locked (read-only) if MRACSEL = r and MRC_GLBACr[LK] = 1. 000b - Select MRC_GLBAC0 access control policy 001b - Select MRC_GLBAC1 access control policy 010b - Select MRC_GLBAC2 access control policy 011b - Select MRC_GLBAC3 access control policy 100b - Select MRC_GLBAC4 access control policy 101b - Select MRC_GLBAC5 access control policy 110b - Select MRC_GLBAC6 access control policy 111b - Select MRC_GLBAC7 access control policy

10.7.1.53 MRC Region Descriptor Word 1 (MRC0_DOM0_RGD0_W1 - MRC0_DOM2_RGD7_W1)

Offset

For d = 0 to 2; r = 0 to 7:

Register	Offset
MRC0_DOMd_RGDr_W1	4044h + (d × 100h) + (r × 8h)

Function

MRC[m]_DOM[d]_RGD[r]_W[w], where,

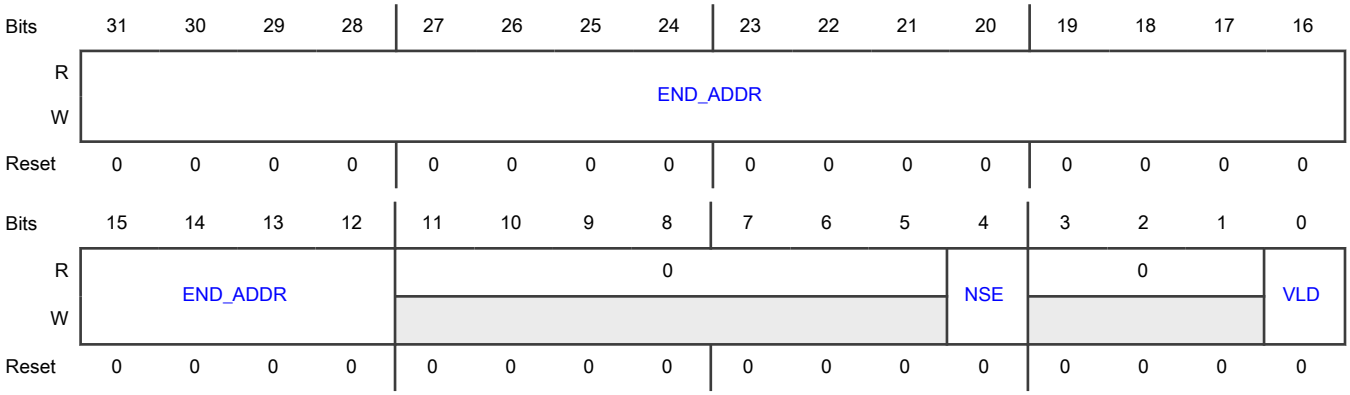
- m - mrc index
- d - domain index
- r - region descriptor index
- w - word index

The MRC[m]_[d]_rgd[r]_w[w] registers provide a 3-dimensional data structure for defining access control policies per domain for each supported memory region.

Memory map/register definition:

There two word-size registers (W[w]) defined in each memory region. There are up to 8 memory region checkers (MRCs), m, each supporting up to 16 region descriptors (RGD), r. The number of MRCs is defined by HWCFG0[NMRC].

Diagram



Fields

Field	Function
31-12 END_ADDR	End Address (4K-1)-mod-4K physical end address [31:12] of region r. **NOTE** This field is locked (read-only) if MRACSEL = r and MRC_GLBACr[LK] = 1.
11-5 —	Reserved
4	NonSecure Enable

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Table continued from the previous page...

Field	Function
NSE	Alternate view of NSE flag for Region r. 0b - Secure accesses to region r are based on corresponding MRACSEL field in this register (MRCm_DOMd_RGDr_Ww[MRACSEL]), nonsecure accesses to region r are not allowed. 1b - Secure and nonsecure accesses to region r are based on corresponding MRACSEL field in this register (MRCm_DOMd_RGDr_Ww[MRACSEL]).
3-1 —	Reserved
0 VLD	Valid If set, this region is valid and accesses are checked for this region. **NOTE** This field is locked (read-only) if MRACSEL = r and MRC_GLBACr[LK] = 1.

10.7.1.54 MRC Region Descriptor NonSecure Enable (MRC0_DOM0_RGD_NSE - MRC0_DOM2_RGD_NSE)

Offset

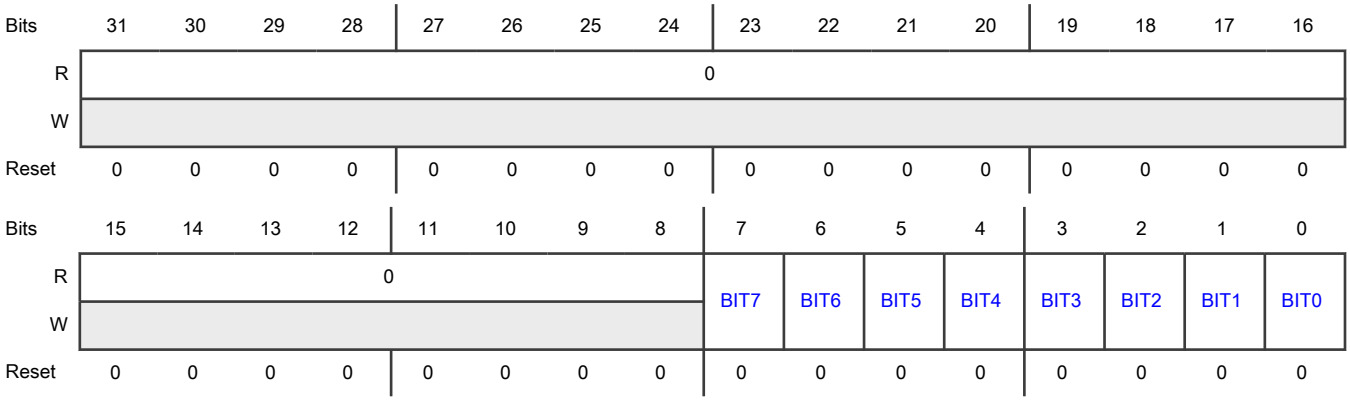
Register	Offset
MRC0_DOM0_RGD_NSE	40C0h
MRC0_DOM1_RGD_NSE	41C0h
MRC0_DOM2_RGD_NSE	42C0h

Function

This register is the bitmap of the individual NSE bits for the region descriptors. Bit n corresponds to region n.

These bits can also be written or "indirectly" through writes to NSE_SET, NSE_CLR, NSE_CLR_ALL, and RGD_W0[NSE] registers.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 BITn	Bit n NonSecure Enable [n = 0 - 15] 0b - Secure accesses to region r are based on corresponding MRACSEL field in this register (MRCm_DOMd_RGDr_Ww[MRACSEL]), nonsecure accesses to region r are not allowed. 1b - Secure and nonsecure accesses to region r are based on corresponding MRACSEL field in register (MRCm_DOMd_RGDr_Ww[MRACSEL]).

Chapter 11
Enhanced Direct Memory Access (eDMA)

11.1 Chip-specific eDMA information

Table 47. Reference links to related information

Topic	Related module	Reference
Full description	eDMA	eDMA
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

11.1.1 Module instances

This device has one instance of the eDMA module.

11.1.2 Direct Memory Access Multiplexer (DMAMUX)

11.1.2.1 DMAMUX0 request sources

The peripheral request line for each channel of the Enhanced Direct Memory Access Controller 0 (eDMA0) is driven from a Direct Memory Access Multiplexer (DMAMUX). This is a flexible configuration that allows the user to select the appropriate peripheral to connect to each channel of the DMA Controller. The DMAMUX for this device allows up to 64 DMA request signals to be mapped to each channel. Because of the mux, there is not a correlation between any of the DMA request sources and a specific DMA channel.

The DMAMUX is an integrated component of the DMA Controller. This allows each DMA channel and DMA Multiplexer to configured as secure or non-secure on initial configuration of the device and not be changed without the correct permissions. For more information, please refer to the DMA Controller (DMA) chapter of the reference manual.

Table 48. DMAMUX0 request assignments

DMAMUX Number	Alias	Source Description
Modules		
0	—	Disabled
SYS Modules		
1	WUU0	Wake up event
SEC Modules		
2	Sentinel	DMA request from sentinel core
TMR Modules		
3	LPTMR0	Counter match event
4	LPTMR1	Counter match event
5	TPM0	Channel 0 request
6	TPM0	Channel 1 request

Table continues on the next page...

Table 48. DMAMUX0 request assignments (continued)

DMAMUX Number	Alias	Source Description
7	TPM0	Channel 2 request
8	TPM0	Channel 3 request
9	TPM0	Channel 4 request
10	TPM0	Channel 5 request
11	TPM0	Counter overflow request
12	TPM1	Channel 0 request
13	TPM1	Channel 1 request
14	TPM1	Channel 2 request
15	TPM1	Channel 3 request
16	TPM1	Channel 4 request
17	TPM1	Channel 5 request
18	TPM1	Counter overflow request
RF Modules		
19	RF[1]	Radio Bric Input data request
20	RF[1]	Radio Bric Output data request
COM Modules		
21	LPI2C0	Master / Slave receive request
22	LPI2C0	Master / Slave transmit request
23	LPI2C1	Master / Slave receive request
24	LPI2C1	Master / Slave transmit request
25	I3C0	Master / Slave receive request
26	I3C0	Master / Slave transmit request
27	LPSPI0	Master/Slave receive request
28	LPSPI0	Master/Slave transmit request
29	LPSPI1	Master/Slave receive request
30	LPSPI1	Master/Slave transmit request
31	LPUART0	Receive request
32	LPUART0	Transmit request
33	LPUART1	Receive request
34	LPUART1	Transmit request
35	FLEXIO0	Shift register 0 request
36	FLEXIO0	Shift register 1 request

Table continues on the next page...

Table 48. DMAMUX0 request assignments (continued)

DMAMUX Number	Alias	Source Description
37	FLEXIO0	Shift register 2 request
38	FLEXIO0	Shift register 3 request
39	FLEXIO0	Shift register 4 request
40	FLEXIO0	Shift register 5 request
41	FLEXIO0	Shift register 6 request
42	FLEXIO0	Shift register 7 request
43	CAN0 [1]	DMA request
HMI Modules		
44	GPIOA	Pin event request 0
45	GPIOA	Pin event request 1
46	GPIOB	Pin event request 0
47	GPIOB	Pin event request 1
48	GPIOC	Pin event request 0
49	GPIOC	Pin event request 1
50	GPIOD	Pin event request 0
51	GPIOD	Pin event request 1
ANA Modules		
52	ADC-GP0	FIFO A request
53	ADC-GP0	FIFO B request
54	CMP-GP0	DMA request
55	CMP-GP1	DMA request
COM Modules		
56	CAN1[1]	DMA request
Modules		
57 - 63	—	-

1. Refer to Ordering information for parts have this module.

11.2 Overview

The enhanced direct memory access (eDMA) controller is capable of performing complex data transfers with minimal intervention from a host processor. The hardware microarchitecture includes:

- A DMA engine that performs:
  - — Source address and destination address calculations
  - — Data-movement operations
- Local memory containing transfer control descriptors for each of the 16 channels

NOTE

The terminology in this chapter has been updated to align with NXP's inclusive language standards, as shown in the table below.

Table 49. Updated terms

Updated term	Deprecated term
Initiator	Master
Target	Slave

11.2.1 Block diagram

Figure 14 illustrates the components of the eDMA system, including the eDMA module (engine).

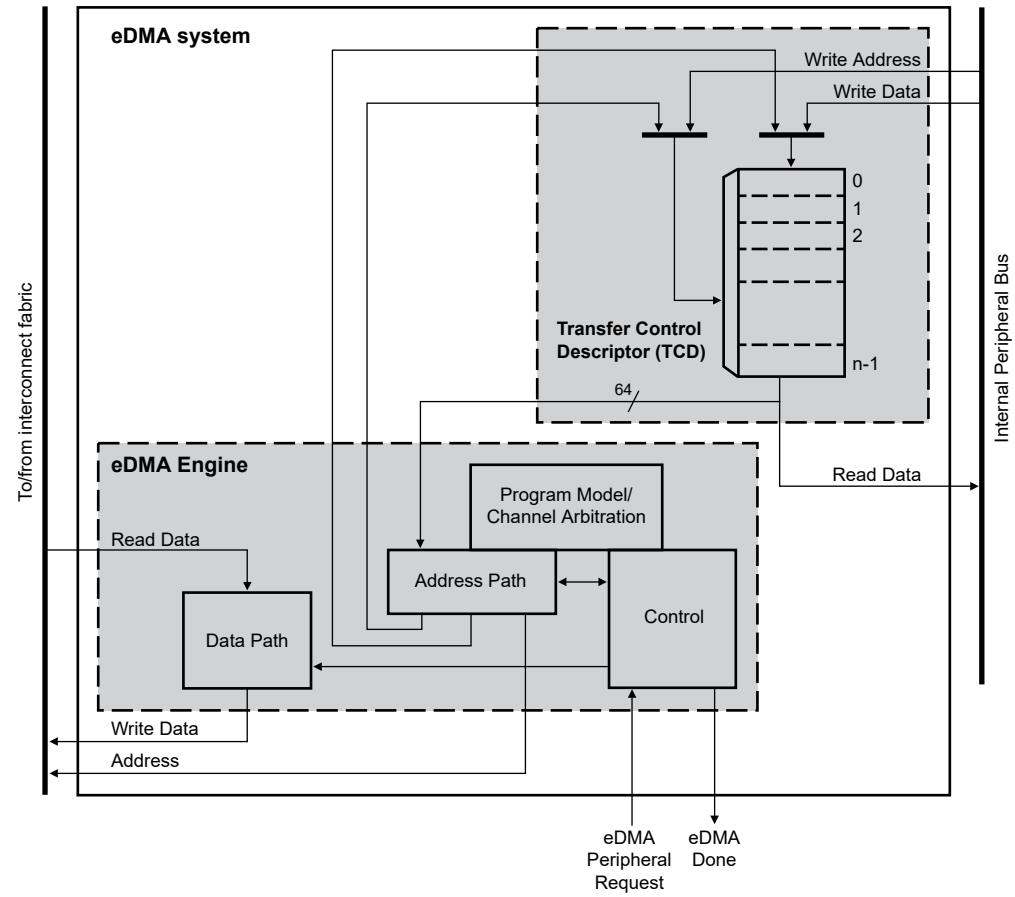


Figure 14. Block diagram

11.2.2 Block parts

The eDMA module is partitioned into two major modules: the eDMA engine and the transfer control descriptor local memory.

The eDMA engine is further partitioned into four submodules:

Table 50. eDMA engine submodules

Submodule	Function
Address path	This block: • Implements a primary channel and secondary (preempt) channel • Manages all initiator bus-address calculations All the channels provide the same functionality. This structure allows data transfers associated with one channel to be preempted after the completion of a read/write sequence if a higher priority channel activation is asserted while the primary channel is active. After a channel is activated, it runs until the minor loop is completed, unless preempted by a higher priority channel. This provides a mechanism (enabled by CH*n*_PRI[ECP]) where a large data transfer can be preempted to minimize the time another channel is blocked from execution. When any channel is selected to execute, the contents of its TCD are read from local memory and loaded into the address path channel x registers for a normal start and into channel y registers for a preemption start. After the minor loop completes execution, the address path hardware writes the new values for the TCD*n*_{SADDR, DADDR, CITER} back to local memory. If the major iteration count is exhausted, additional processing is performed, including the final address pointer updates, reloading the TCD*n*_CITER field, and a possible fetch of a new TCD*n* from memory as part of a scatter/gather operation. See Dynamic scatter/gather for more details.
Data path	This block implements the bus initiator read/write data path. It includes a data buffer and the necessary multiplex logic to support any required data alignment. The internal read data bus is the primary input, and the internal write data bus is the primary output. The address and data path modules directly support the 2-stage pipelined internal bus. The address path module represents the first stage of the bus pipeline (address phase), and the data path module implements the second stage of the pipeline (data phase).
Program model/channel arbitration	This block implements the first section of the eDMA programming model as well as the channel arbitration logic. The programming model registers are connected to the internal peripheral bus. The eDMA peripheral request inputs and interrupt request outputs are also connected to this block (via control logic).
Control	This block provides all the control functions for the eDMA engine. For data transfers where the source and destination sizes are equal, the eDMA engine performs a series of source read/destination write operations until the number of bytes specified in the minor loop byte count has been moved from the source to the destination. For descriptors where the sizes are not equal, multiple accesses of the smaller size data are required for each reference of the larger size. As an example, if the source size references 16-bit data and the destination is 32-bit data, the eDMA performs two reads, then one 32-bit write.

The transfer control descriptor local memory is further partitioned into:

Table 51. Transfer control descriptor memory

Submodule	Description
Memory controller	This logic implements the required dual-ported controller, and manages accesses from the eDMA engine as well as references from the internal peripheral bus. In simultaneous accesses, the eDMA engine is given priority and the peripheral transaction is stalled.
Memory array	TCD storage for each channel's transfer profile.

11.2.3 Features

The eDMA is a highly programmable data-transfer engine optimized to minimize any required intervention from the host processor. It is intended for use in applications where the data size to be transferred is statically known and is not defined within the transferred data itself. The eDMA module features:

- All data movement via dual-address transfers: read from source, write to destination
  - Programmable source and destination addresses and transfer size
  - Support for complex address calculations
- 16-channel implementation that performs complex data transfers with minimal intervention from a host processor
  - Internal data buffer, used as temporary storage for all transfers
  - Connections to the crossbar switch for bus driving the data movement
- TCD organized to support two-deep, nested transfer operations
  - 32-byte TCD stored in local memory for each channel
  - An inner data transfer loop defined by a minor byte transfer count
  - An outer data transfer loop defined by a major iteration count
- Channel activation via one of three methods:
  - Explicit software initiation
  - Initiation via a channel-to-channel linking mechanism for continuous transfers
  - Peripheral-paced hardware requests, one per channel
- Fixed-priority and round-robin channel arbitration
- Channel completion reported via programmable interrupt requests
  - One interrupt per channel, which can be asserted at completion of major iteration count
  - Programmable error terminations per channel that are logically summed together to form one error interrupt to the interrupt controller
- Programmable support for scatter/gather DMA processing
- Support for complex data structures

In the discussion of this module, *n* is used to reference the channel number.

11.3 Functional description

The operation of eDMA is described in the following subsections.

11.3.1 Modes of operation

The eDMA operates in the following modes:

Table 52. Modes of operation

Mode	Description
Normal	In Normal mode, eDMA transfers data between a source and a destination. The source and destination can be a memory block or an I/O block capable of operation with eDMA. A service request initiates a transfer of a specific number of bytes (NBYTES) as specified in the TCD. The minor loop is the sequence of read-write operations that transfers these NBYTES per service

Table continues on the next page...

Table 52. Modes of operation (continued)

Mode	Description
	request. Each service request executes one iteration of the major loop, which transfers NBYTES of data.
Debug	eDMA operation is configurable in Debug mode via the control register: • If CSR[EDBG] is cleared to 0, eDMA continues to operate. • If CSR[EDBG] is set to 1, eDMA stops transferring data. If Debug mode is entered when a channel is active, eDMA continues operation until the channel retires.

11.3.2 eDMA basic data flow

The basic flow of a data transfer can be partitioned into three segments.

As shown in the following diagram, the first segment involves the channel activation:

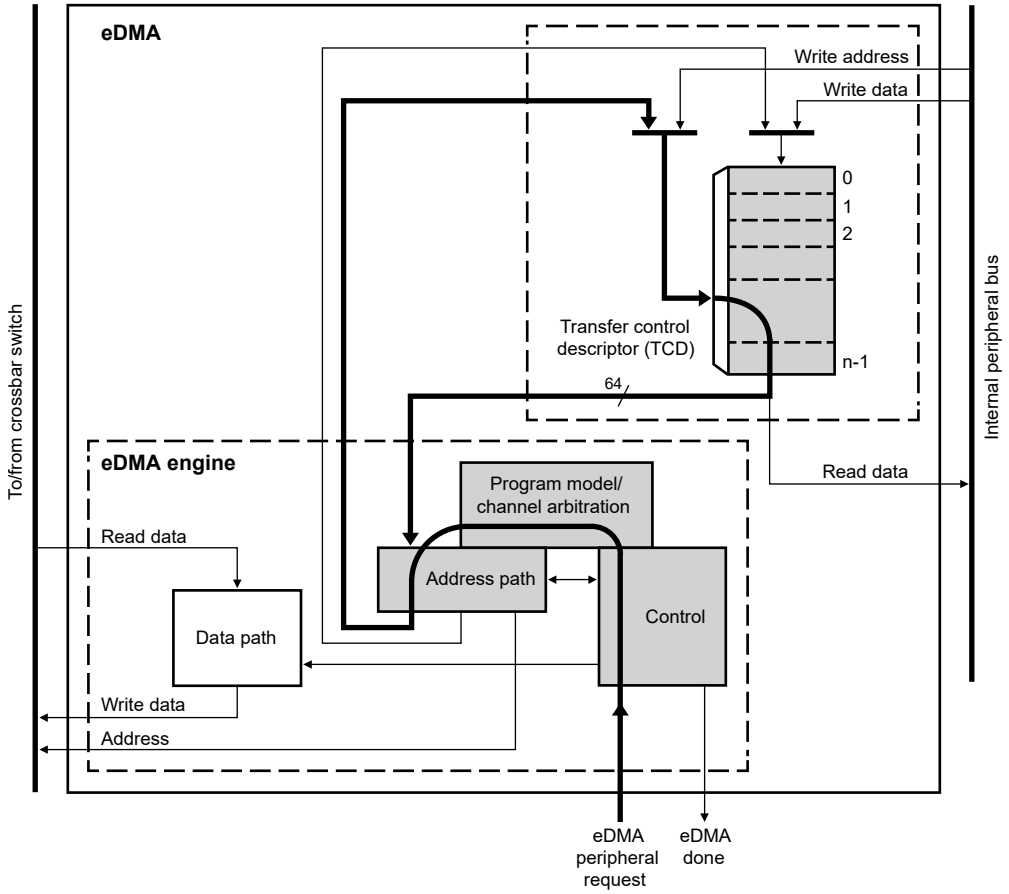


Figure 15. eDMA operation, part 1

This example uses the assertion of the eDMA peripheral request signal to request service for channel *n*. Channel activation via software and the TCD*n*_CSR[START] field follows the same basic flow as peripheral requests. The eDMA request input signal is registered internally and then routed through the eDMA engine: first through the control module, then into the program model and channel arbitration.

In the next cycle, the channel arbitration begins using fixed-priority plus the optional round-robin algorithm. After arbitration is complete, the activated channel number is sent through the address path and converted into the required address to access the

local memory for TCD*n*. Next, the TCD memory is accessed and the required descriptor is read from the local memory and then loaded into the eDMA engine address path's primary or secondary channel execution registers. The TCD memory is 64 bits wide to minimize the time needed to fetch the activated channel descriptor and load it into the address path registers.

The following diagram illustrates the second part of the basic data flow:

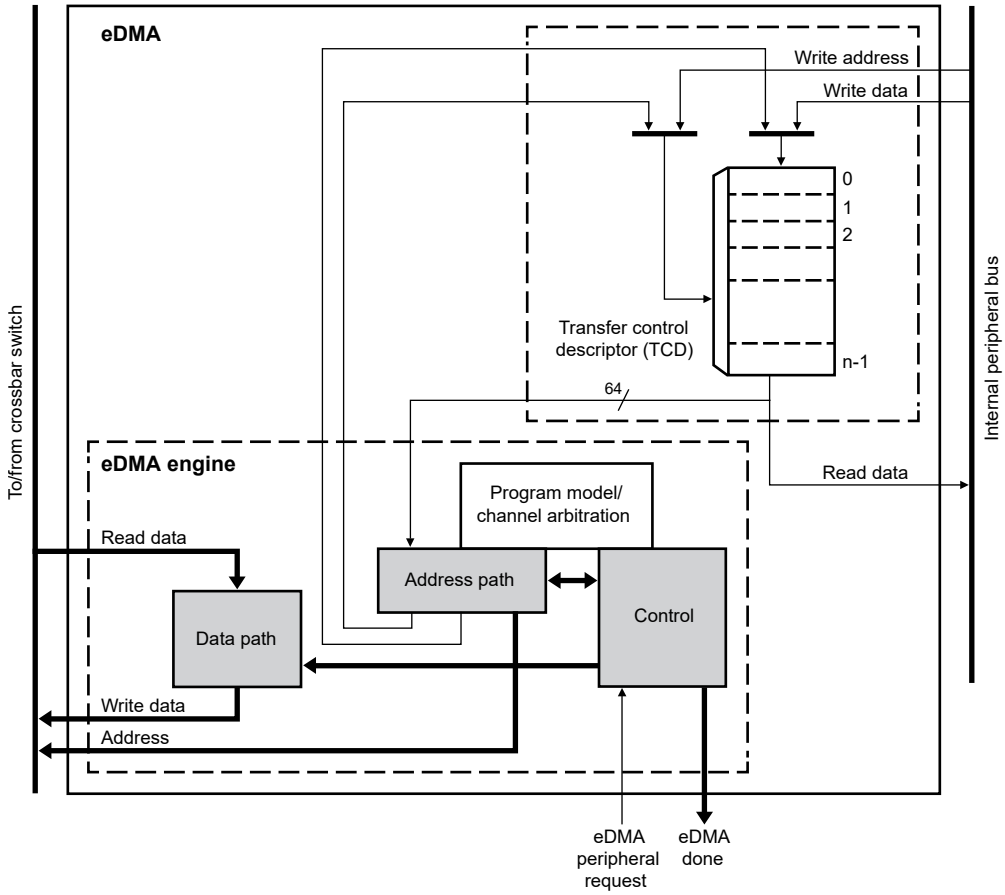


Figure 16. eDMA operation, part 2

The modules associated with the data transfer (address path, data path, and control) go through the required sequence of source reads and destination writes to perform the actual data movement. The source reads are initiated, and the fetched data is temporarily stored in the data path block until it is gated onto the internal bus during the destination write. This source read/destination write processing continues until the byte count, NBYTES, has been transferred.

After NBYTES of data has been moved, the final phase of the basic data flow is performed. In this segment, the address path logic performs the required updates to certain fields in the appropriate TCD (for example, SADDR, DADDR, CITER). If the major iteration count is exhausted, additional operations are performed. These include the final address adjustments and reloading of the BITER field into the CITER field. Assertion of an optional interrupt request also occurs at this time, as does a possible fetch of a new TCD from memory using the scatter/gather address pointer included in the descriptor (if scatter/gather is enabled). The updates to the TCD memory and the assertion of an interrupt request are shown in the following diagram.

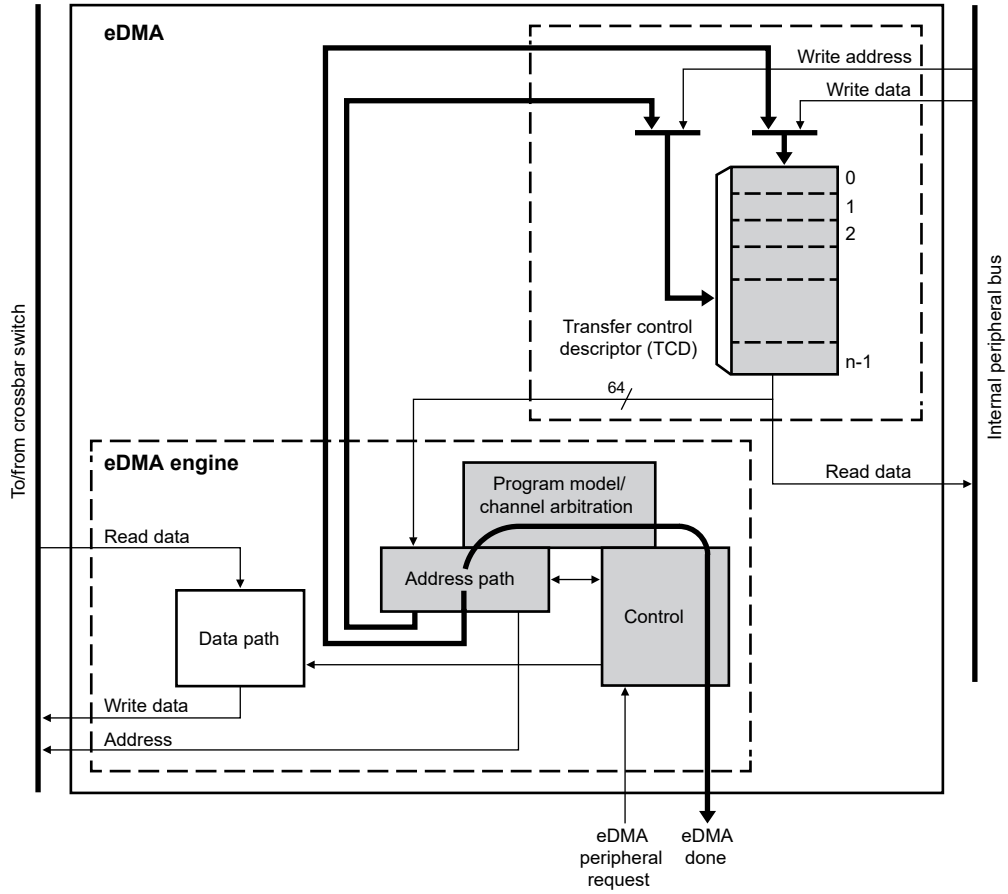


Figure 17. eDMA operation, part 3

11.3.3 Fault reporting and handling

Channel errors are reported in the Error Status register (CHn_ES) and can be caused by any of the following:

- A configuration error, which is an illegal setting in the transfer control descriptor
- An active channel canceled via a "cancel transfer with error" hardware or software request
- An error termination to a bus initiator read or write cycle

A configuration error is reported when an inconsistent state is represented by one of these factors:

- Starting source or destination address
- Source or destination offsets
- Minor loop byte count
- Transfer size

Each of these possible causes is detailed below:

- The addresses and offsets must be aligned on zero-modulo-transfer-sized boundaries.
- The minor loop byte count must be a multiple of the source and destination transfer sizes.
- All source reads and destination writes must be configured to the natural boundary of the programmed transfer size.

NOTE

To aid in debugging, set the Halt After Error field in the DMA's Control Status register, CSR[HAE]. Upon any error condition, the DMA is halted after the error is recorded. The DMA remains halted and does not process any channel service requests. After the error is fixed, the DMA may be enabled again by clearing the Halt field, CSR[HALT].

- If a scatter/gather operation is enabled upon channel completion, a configuration error is reported if the scatter/gather address (TCDn_DLAST_SGA) is not aligned on a 32-byte boundary.
- If minor loop channel linking is enabled upon channel completion, a configuration error is reported when the link is attempted if the TCDn_CITER[ELINK] field does not equal the TCDn_BITER[ELINK] field.

If enabled, all configuration error conditions, except the scatter/gather and minor-loop link errors, are reported as the channel activates and asserts an error interrupt request. A scatter/gather configuration error is reported when the scatter/gather operation begins at major loop completion if properly enabled. A minor loop channel link configuration error is reported when the link operation is serviced at minor loop completion.

If a system bus read or write is terminated with an error, the data transfer is stopped and the appropriate bus error flag set. In this case, the state of the channel's transfer control descriptor is updated by the eDMA engine with the current source address, destination address, and current iteration count at the point of the fault. When a system bus error occurs, the channel terminates after the next transfer. Due to pipeline effect, the next transfer is already in progress when the bus error is received by the eDMA. If a bus error occurs on the last read prior to beginning the write sequence, the write executes using the data captured during the bus error. If a bus error occurs on the last write prior to switching to the next read sequence, the read sequence executes before the channel terminates due to the destination bus error.

The occurrence of any error causes the eDMA engine to stop normal processing of the active channel immediately (it goes to its error processing states and the transaction to the system bus still has pipeline effect), and the appropriate channel field in the eDMA error register is set to 1. At the same time, the details of the error condition are loaded into the Error Status register (CHn_ES). The major loop complete indicators, setting the transfer control descriptor DONE flag, and the possible assertion of an interrupt request are not affected when an error is detected.

After the error status has been updated, the eDMA engine continues operating by servicing the next appropriate channel. A channel that experiences an error condition is not automatically disabled. If a channel is terminated by an error and then issues another service request before the error is fixed, that channel executes and terminates with the same error condition.

The error status fields are read-only. These error indicators are sticky and cannot be cleared. They show the last recorded error until the DMA is reset. CHn_ES[ERR] is used to determine if a new error condition exists. This field is the logical OR of each channel's error interrupt field (ERR).

After the software has resolved all errors and cleared all of the error interrupt fields, the MP_ES[VLD] is cleared to 0 but the cause of the last error is still indicated.

11.3.4 Channel preemption

The eDMA uses a priority vector value to determine the highest priority channel requesting service.

The priority vector is a combination of:

1. the channel's group priority, CHn_GRPRI
2. the channel's priority level, CHn_PRI[APL]

It can be considered a number composed of these concatenated priority levels: CHn_GRPRI : CHn_PRI[APL]

Priority vector = ((CHn_GRPRI << 8) + (CHn_PRI[APL] << 5) + CH_NUM)

A channel requesting service with the highest priority vector value will receive the next execution slot.

An execution slot is available:

1. immediately if the eDMA is idle
2. when an active channel retires
3. when valid preemption conditions exist

NOTE

Preemption is strictly priority based. Preemption is not bound by a specific group number as defined by CHn_GRPRI.

Channel preemption is enabled on a per-channel basis by setting the CHn_PRI[ECP] field. Channel preemption allows the executing channel's data transfers to temporarily suspend in favor of starting a higher-priority channel. After the preempting channel has completed all of its minor loop data transfers, the preempted channel is restored and resumes execution.

After the restored channel completes one read/write sequence, it is again eligible for preemption. If any higher priority channel is requesting service, the restored channel is suspended, and the higher-priority channel is serviced. Nested preemption, that is, attempting to preempt a preempting channel, is not supported. After a preempting channel begins execution, it cannot be preempted.

A channel's ability to preempt another channel can be disabled by setting CHn_PRI[DPA] to 1. When a channel's preempt ability is disabled, that channel cannot suspend a lower-priority channel's data transfer, regardless of the lower-priority channel's ECP setting. This allows for a pool of low-priority, large-data-moving channels to be defined.

You can configure these low-priority channels to not preempt each other, thus preventing a low-priority channel from consuming the preempt slot normally available to a true high-priority channel. When you enable round-robin channel arbitration mode (CSR[ERCA] is set to 1), any channel with a priority level equal to 0 (CHn_PRI[APL] = 0) has preemption disabled and cannot preempt another channel.

11.3.5 Clocking

The following table describes the clock sources:

Table 53. Clocks

Clock	Description
hclk	Clock used for the DMA engine
ipg_clk	Clock used for the DMA programming model
dma_ram_clk	Clock used for the TCD RAMs

11.3.6 Interrupts

Software can enable the interrupt for each channel for the following events:

1. The major loop is half complete (INTHALF)
2. The major loop is complete (INTMAJOR)
3. A configuration error occurs (EEI)

11.4 Memory map and register definition

The eDMA programming model is partitioned into three parts:

1. The first part defines a number of registers providing overall control functions and is known as the management page.
2. The second part corresponds to the channel (CH) control, status, and configuration.
3. The third part corresponds to the local TCD memory.

TCD memory

Each channel requires a 32-byte transfer control descriptor for defining the data movement operation. Each TCDn definition is presented as 11 registers of 16 or 32 bits. See EDMA_TCD register descriptions for details.

TCD initialization

Prior to activating a channel, you must initialize its TCD with the appropriate transfer profile.

TCD structure

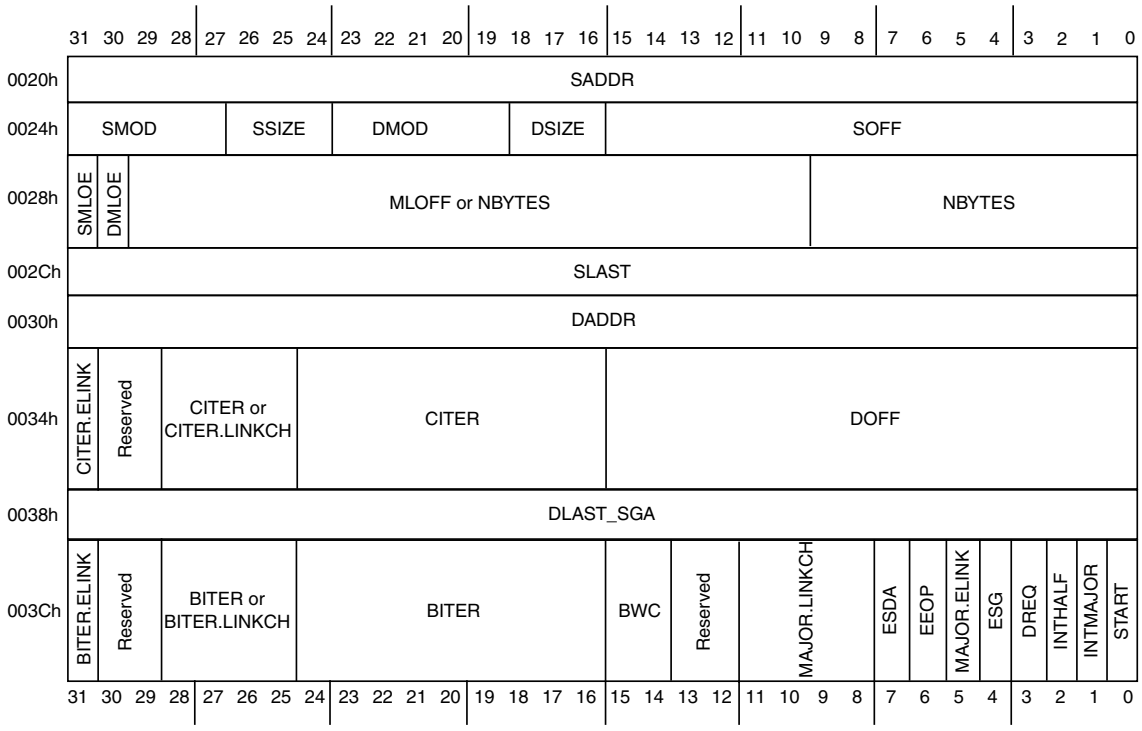


Figure 18. TCD structure

Accesses to reserved memory and fields

- Reading reserved fields in a register returns the value of zero.
- Writes to reserved fields in a register are ignored.
- Reading or writing a reserved memory location generates a bus error.

11.4.1 EDMA_MP register descriptions

11.4.1.1 EDMA_MP memory map

DMA3 base address: 4000_2000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Management Page Control (MP_CSR)	32	RW	0031_0000h
4h	Management Page Error Status (MP_ES)	32	R	0000_0000h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
8h	Management Page Interrupt Request Status (MP_INT)	32	R	0000_0000h
Ch	Management Page Hardware Request Status (MP_HRS)	32	R	0000_0000h
100h - 13Ch	Channel Arbitration Group (CH0_GRPRI - CH15_GRPRI)	32	RW	0000_0000h

11.4.1.2 Management Page Control (MP_CSR)

Offset

Register	Offset
MP_CSR	0h

Function

The Management Page Control register defines the basic operating configuration of the DMA.

Arbitration uses a two-tier priority system; group and channel priority. The eDMA assigns each channel to a priority group. Group arbitration is fixed-priority and cannot be changed. Channel arbitration uses fixed priority and may be configured to use a selective round-robin scheme for specified channels within each priority group. For fixed-priority arbitration, eDMA selects for execution the highest priority channel requesting service in the highest priority arbitration group.

The channel priority registers assign the relative priorities within each arbitration group; see CHn_PRI. All channels with a non-zero CHn_PRI value use fixed-priority arbitration.

When you enable round-robin arbitration, all channels with channel priority set to zero do not have a priority and, of those channels requesting service, are cycled through (from high to low channel number) without regard to priority relative to each other within the same priority group. Any channel with a non-zero CHn_PRI value automatically has a higher priority over the round-robin channels. A channel's priority group is assigned in Channel Arbitration Group (CH0_GRPRI - CH15_GRPRI).

NOTE

For correct operation, changes to the MP_CSR[ERCA, GCLC, GMRC] fields must be performed when the DMA channels are inactive; that is, when the MP_CSR[ACTIVE] field is 0.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	ACTIVE	Reserved			ACTIVE_ID				Reserved							
W																
Reset	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved				CX	ECX	GMRC	GCLC	HALT	HAE	Reserved	ERCA	EDBG	Reserved		
W	0										0			0		
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 ACTIVE	DMA Active Status 0b - eDMA is idle 1b - eDMA is executing a channel
30-28 —	Reserved
27-24 ACTIVE_ID	Active Channel ID This field identifies the channel number that is executing when the ACTIVE bit is 1.
23-16 —	Reserved
15-10 —	Reserved
9 CX	Cancel Transfer When set to 1, this field cancels the remaining data transfer, stops the executing channel, and forces the minor loop to finish. The cancel takes effect after the last write of the current read/write sequence. CX clears itself to 0 after the cancel has been honored. This cancel retires the channel normally as if the minor loop had been completed. 0b - Normal operation 1b - Cancel the remaining data transfer
8 ECX	Cancel Transfer With Error Cancellation of the remaining data transfer is similar to that of the CX field. Execution of the channel is stopped and the minor loop is forced to finish. The cancellation takes effect after the last write of the current read/write sequence. The ECX field clears itself to 0 after the cancel is honored. In addition to cancelling the transfer, ECX treats the cancel as an error condition, thus updating Management Page Error Status (MP_ES) and generating an optional error interrupt. 0b - Normal operation 1b - Cancel the remaining data transfer
7 GMRC	Global Initiator ID Replication Control **NOTE** If initiator ID replication is disabled, the nonsecure, user protection level for DMA transfers is used. 0b - Initiator ID replication disabled for all channels 1b - Initiator ID replication available and controlled by each channel's CHn_SBR[EMI] setting
6	Global Channel Linking Control

Table continues on the next page...

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Field	Function
GCLC	0b - Channel linking disabled for all channels 1b - Channel linking available and controlled by each channel's link settings
5 HALT	Halt DMA Operations This field stalls the start of any new channels. Executing channels are allowed to complete. Channel execution resumes when this field is cleared to 0. 0b - Normal operation 1b - Stall the start of any new channels
4 HAE	Halt After Error When this field is set to 1, any error causes the HALT field to be set to 1. Then all service requests are ignored until the HALT field is cleared to 0. 0b - Normal operation 1b - Any error causes the HALT field to be set to 1
3 —	Reserved
2 ERCA	Enable Round Robin Channel Arbitration 0b - Round-robin channel arbitration disabled. Fixed priority arbitration used for channel selection 1b - Round-robin channel arbitration enabled. Round-robin arbitration used for channel selection
1 EDBG	Enable Debug When in debug mode, the DMA stalls the start of a new channel. Executing channels are allowed to complete. DMA resumes channel execution when the system exits debug mode or clears the EDBG field to 0. 0b - Debug mode disabled. When in debug mode, the DMA continues to operate 1b - Debug mode is enabled. When in debug mode, the DMA stalls the start of a new channel
0 —	Reserved

11.4.1.3 Management Page Error Status (MP_ES)

Offset

Register	Offset
MP_ES	4h

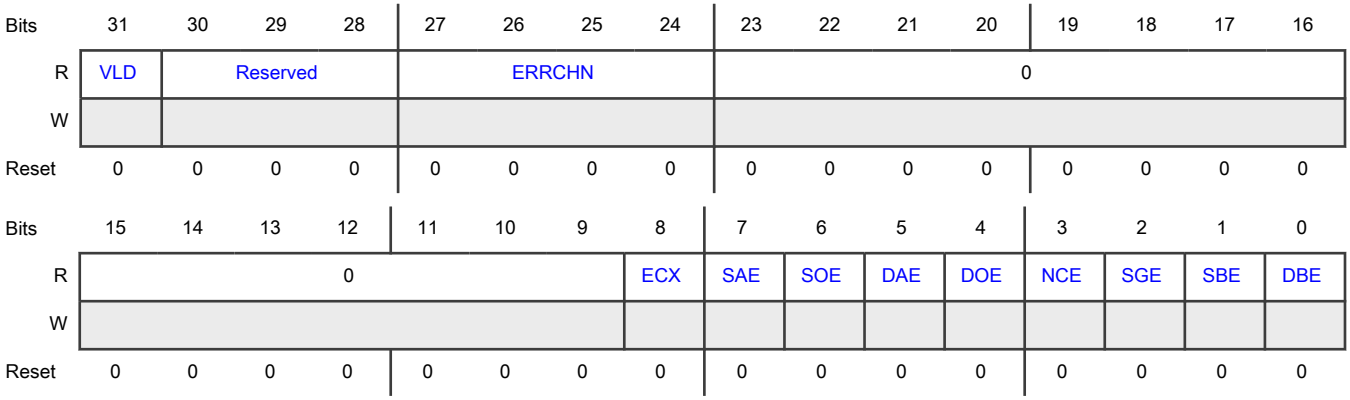
Function

The ES provides information concerning the last recorded channel error. Channel errors can be caused by:

- An illegal setting in the transfer control descriptor
- An error termination to a bus initiator read or write cycle
- An uncorrectable error that occurred when the device was accessing the TCD SRAM
- A "cancel transfer with error" request was made via the corresponding cancel transfer field or input signal

Upon any error condition, the software must initialize the TCD of the channel that contains the error, as it is in an incomplete state after an error. See Fault reporting and handling for more details.

Diagram



Fields

Field	Function
31 VLD	Valid Logical OR of all CHn_ES[ERR] status fields. 0b - No CHn_ES[ERR] fields are set to 1 1b - At least one CHn_ES[ERR] field is set to 1, indicating a valid error exists that software has not cleared
30-28 —	Reserved
27-24 ERRCHN	Error Channel Number or Canceled Channel Number The channel number of the last recorded error or last recorded error-canceled transfer.
23-9 —	Reserved
8 ECX	Transfer Canceled The ECX operation is a management page function. When employed, the targeted channel's CHn_ES register reports an unspecified error; that is, only the CHn_ES[ERR] field is set to 1. The management page has full view of the error condition. 0b - No canceled transfers 1b - Last recorded entry was a canceled transfer by the error cancel transfer input

Table continues on the next page...

Table continued from the previous page...

Field	Function
7 SAE	Source Address Error When this field is 1, it indicates that TCDn_SADDR is inconsistent with TCDn_ATTR[SSIZE]. 0b - No source address configuration error 1b - Last recorded error was a configuration error detected in the TCDn_SADDR field
6 SOE	Source Offset Error When this field is 1, it indicates that TCDn_SOFF is inconsistent with TCDn_ATTR[SSIZE]. 0b - No source offset configuration error 1b - Last recorded error was a configuration error detected in the TCDn_SOFF field
5 DAE	Destination Address Error When this field is 1, it indicates that TCDn_DADDR is inconsistent with TCDn_ATTR[DSIZE]. 0b - No destination address configuration error 1b - Last recorded error was a configuration error detected in the TCDn_DADDR field
4 DOE	Destination Offset Error When this field is 1, it indicates that TCDn_DOFF is inconsistent with TCDn_ATTR[DSIZE]. 0b - No destination offset configuration error 1b - Last recorded error was a configuration error detected in the TCDn_DOFF field
3 NCE	NBYTES/CITER Configuration Error This error indicates that one of the following has occurred: • TCDn_NBYTES is not a multiple of TCDn_ATTR[SSIZE] and TCDn_ATTR[DSIZE] • TCDn_CITER[CITER] is equal to zero • TCDn_CITER[ELINK] is not equal to TCDn_BITER[ELINK] 0b - No NBYTES/CITER configuration error 1b - The last recorded error was NBYTES equal to zero or a CITER not equal to BITER error. Last recorded error was a configuration error detected in the TCDn_NBYTES or TCDn_CITER fields
2 SGE	Scatter/Gather Configuration Error When this field is 1, it indicates that TCDn_DLAST_SGA is not on a 32-byte boundary. This field is checked at the beginning of a scatter/gather operation after major loop completion if TCDn_CSR[ESG] is enabled. 0b - No scatter/gather configuration error 1b - Last recorded error was a configuration error detected in the TCDn_DLAST_SGA field
1 SBE	Source Bus Error

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - No source bus error 1b - Last recorded error was a bus error on a source read
0 DBE	Destination Bus Error 0b - No destination bus error 1b - Last recorded error was a bus error on a destination write

11.4.1.4 Management Page Interrupt Request Status (MP_INT)

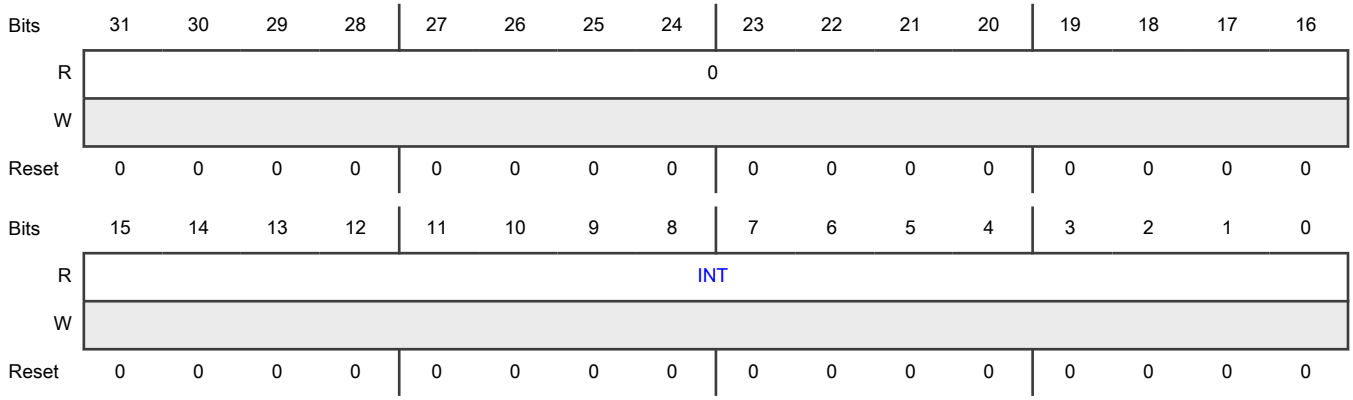
Offset

Register	Offset
MP_INT	8h

Function

This register shows the current state of the interrupt service requests for all eDMA channels.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 INT	Interrupt Request Status The INT register presents the interrupt request status for each eDMA channel. Depending on the appropriate field setting in the transfer control descriptors, the eDMA engine generates an interrupt

Table continues on the next page...

Table continued from the previous page...

Field	Function
	on data transfer completion or an error condition. The eDMA routes channel interrupt requests to the interrupt controller. During the interrupt service routine associated with any given channel, it is the software's responsibility to clear the appropriate field in the channel's interrupt request register, CHn_INT, thus negating the interrupt request. 0b - Interrupt request for corresponding channel not present 1b - Interrupt request for corresponding channel present

11.4.1.5 Management Page Hardware Request Status (MP_HRS)

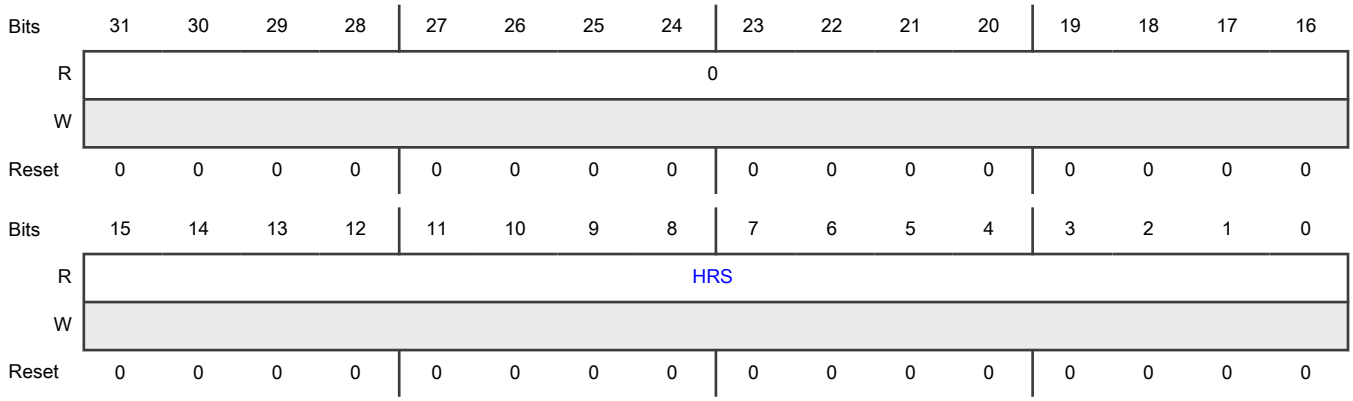
Offset

Register	Offset
MP_HRS	Ch

Function

The hardware request status register (HRS) shows the current state of the hardware service request signaling as seen by eDMA's arbitration logic.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 HRS	Hardware Request Status The HRS bit for its respective channel remains asserted for the period when a hardware request is present on the channel.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Hardware service request for corresponding channel is not present 1b - Hardware service request for corresponding channel is present

11.4.1.6 Channel Arbitration Group (CH0_GRPRI - CH15_GRPRI)

Offset

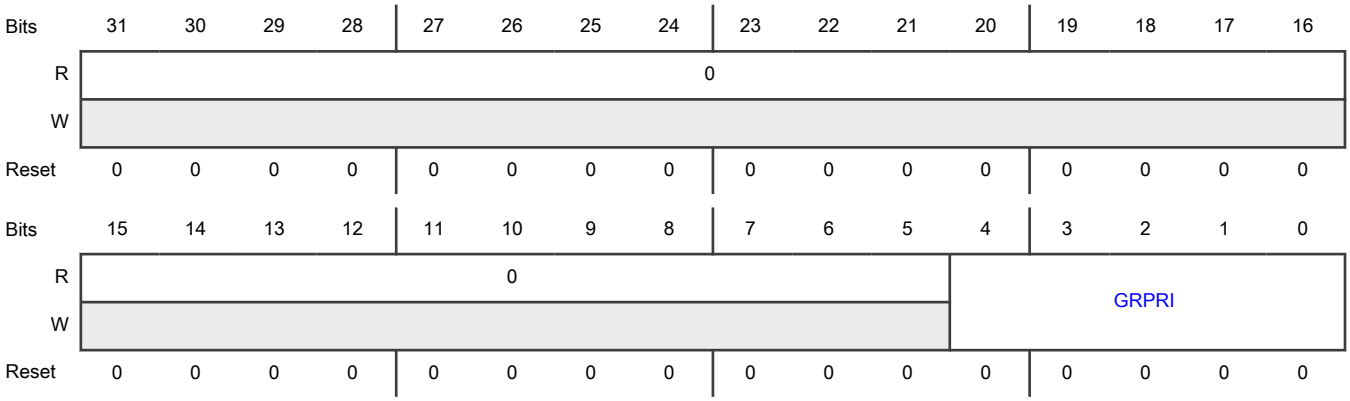
For n = 0 to 15:

Register	Offset
CHn_GRPRI	100h + (n × 4h)

Function

The contents of this register define the arbitration group associated with each channel. Using a fixed-priority group arbitration scheme, eDMA evaluates the arbitration group priorities by numeric value from highest group number to lowest; for example, 0 is the lowest priority, 1 is the next higher priority, then 2, 3, and so on. The range of the group priority values is limited to the values of 0 through 31. Within each arbitration group, the channel priority assignment CH*n*_PRI determines the highest-priority channel.

Diagram



Fields

Field	Function
31-5 —	Reserved
4-0 GRPRI	Arbitration Group For Channel n Fixed-priority arbitration group number.

11.4.2 EDMA_TCD register descriptions

11.4.2.1 EDMA_TCD memory map

DMA3_TCD base address: 4000_3000h

Offset	Register	Width (In bits)	Access	Reset value
0h - F000h	Channel Control and Status (CH0_CSR - CH15_CSR)	32	RW	0000_0000h
4h - F004h	Channel Error Status (CH0_ES - CH15_ES)	32	RW	0000_0000h
8h - F008h	Channel Interrupt Status (CH0_INT - CH15_INT)	32	RW	0000_0000h
Ch - F00Ch	Channel System Bus (CH0_SBR - CH15_SBR)	32	RW	0000_0012h
10h - F010h	Channel Priority (CH0_PRI - CH15_PRI)	32	RW	0000_0000h
14h - F014h	Channel Multiplexor Configuration (CH0_MUX - CH15_MUX)	32	RW	0000_0000h
20h - F020h	TCD Source Address (TCD0_SADDR - TCD15_SADDR)	32	RW	See section
24h - F024h	TCD Signed Source Address Offset (TCD0_SOFF - TCD15_SOFF)	16	RW	See section
26h - F026h	TCD Transfer Attributes (TCD0_ATTR - TCD15_ATTR)	16	RW	See section
28h - F028h	TCD Transfer Size Without Minor Loop Offsets (TCD0_NBYTES_MLOFFNO - TCD15_NBYTES_MLOFFNO)	32	RW	See section
28h - F028h	TCD Transfer Size with Minor Loop Offsets (TCD0_NBYTES_MLOFFYES - TCD15_NBYTES_MLOFFYES)	32	RW	See section
2Ch - F02Ch	TCD Last Source Address Adjustment / Store DADDR Address (TCD0_SLAST_SDA - TCD15_SLAST_SDA)	32	RW	See section
30h - F030h	TCD Destination Address (TCD0_DADDR - TCD15_DADDR)	32	RW	See section
34h - F034h	TCD Signed Destination Address Offset (TCD0_DOFF - TCD15_DOFF)	16	RW	See section
36h - F036h	TCD Current Major Loop Count (Minor Loop Channel Linking Disabled) (TCD0_CITER_ELINKNO - TCD15_CITER_ELINKNO)	16	RW	See section
36h - F036h	TCD Current Major Loop Count (Minor Loop Channel Linking Enabled) (TCD0_CITER_ELINKYES - TCD15_CITER_ELINKYES)	16	RW	See section
38h - F038h	TCD Last Destination Address Adjustment / Scatter Gather Address (TCD0_DLAST_SGA - TCD15_DLAST_SGA)	32	RW	See section
3Ch - F03Ch	TCD Control and Status (TCD0_CSR - TCD15_CSR)	16	RW	See section
3Eh - F03Eh	TCD Beginning Major Loop Count (Minor Loop Channel Linking Disabled) (TCD0_BITER_ELINKNO - TCD15_BITER_ELINKNO)	16	RW	See section
3Eh - F03Eh	TCD Beginning Major Loop Count (Minor Loop Channel Linking Enabled) (TCD0_BITER_ELINKYES - TCD15_BITER_ELINKYES)	16	RW	See section

11.4.2.2 Channel Control and Status (CH0_CSR - CH15_CSR)

Offset

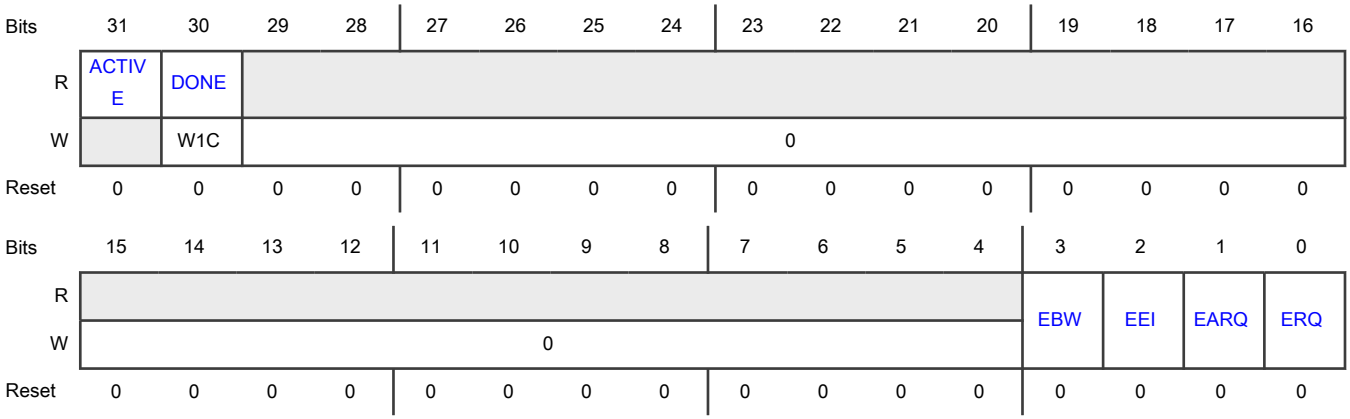
For n = 0 to 15:

Register	Offset
CHn_CSR	0h + (n × 1000h)

Function

This register contains several fields related to hardware and interrupt requests, configuration, and status for the given channel.

Diagram



Fields

Field	Function
31 ACTIVE	Channel Active The ACTIVE field indicates the channel was selected by arbitration and is executing the prescribed transfers. The eDMA sets it to 1 when channel service begins, and clears it to 0 as the minor loop completes or when any error condition is detected. Except for dynamic scatter/gather or dynamic channel linking, you must not modify the transfer control descriptor when a channel is active.
30 DONE	Channel Done The DONE field indicates the eDMA has completed the major loop. The eDMA engine sets this field as the CITER count reaches zero. If enabled, the eDMA generates an interrupt request corresponding to this completed channel. The software clears it, or the hardware clears it when the channel is activated. **NOTE** This field must be cleared to 0 before writing the MAJORELINK or ESG fields.
29-4 —	Reserved
3 EBW	Enable Buffered Writes When buffered writes are enabled, all writes except for the last write sequence of the minor loop are signaled by the eDMA as bufferable. 0b - Buffered writes on system bus disabled. Buffered writes on system bus disabled

Table continues on the next page...

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Field	Function
	1b - Buffered writes on system bus enabled. Bufferable write signal asserted on all system bus writes except during last write sequence
2 EEI	Enable Error Interrupt The EEI field enables the error interrupt signal for the channel. The DMA error indicator and the error interrupt enable flag must be asserted before an error interrupt request for a given channel is asserted to the interrupt controller. 0b - Error signal for corresponding channel does not generate error interrupt 1b - Assertion of error signal for corresponding channel generates error interrupt request
1 EARQ	Enable Asynchronous DMA Request The enable asynchronous DMA request field (EARQ) does not affect DMA operations. When set to 1, this field allows the hardware service request enable field (ERQ) to propagate out of the DMA to the power controller. When cleared to 0, this field masks the hardware service request enable field to the power controller. 0b - Disable asynchronous DMA request for the channel 1b - Enable asynchronous DMA request for the channel
0 ERQ	Enable DMA Request Disable a channel's hardware service request at the source before clearing the channel's ERQ field. The DMA hardware request input signal and the enable request field (ERQ) must be asserted before a channel's hardware service request is accepted. The state of the eDMA enable request field does not affect a channel service request made explicitly through software or channel linking. The state of the ERQ field does not affect the channel's START field. 0b - DMA hardware request signal for corresponding channel disabled 1b - DMA hardware request signal for corresponding channel enabled

11.4.2.3 Channel Error Status (CH0_ES - CH15_ES)

Offset

For n = 0 to 15:

Register	Offset
CHn_ES	4h + (n × 1000h)

Function

The ES provides information concerning the last recorded channel error. Channel errors can be caused by:

- An illegal setting in the transfer control descriptor
- An error termination to a bus initiator read or write cycle

The ERR field signals the presence of an error for the channel. The eDMA engine signals the occurrence of an error condition by setting the appropriate field in this register. The outputs of this register are enabled by the contents of the CHn_CSR[EEI] field,

then logically summed across all channels to form an error interrupt request, which may be routed to the interrupt controller. In addition, this enabled error status is logically OR'd onto the channel done interrupt, CHn_INT[INT], thus forming a done or error interrupt on a per channel basis.

During the execution of the interrupt service routine associated with any DMA errors, it is software's responsibility to clear the appropriate bit, negating the error-interrupt request. The normal DMA channel completion indicators (setting the transfer control descriptor DONE flag and the possible assertion of an interrupt request) are not affected when eDMA detects an error. The contents of this ERR register field can also be polled because a non-zero value indicates the presence of a channel error, regardless of the state of the EEI mask.

The state of any given channel's error indicators is affected by writes to this register. Writing a 1 to the ERR field clears the channel's error status, and writing a 0 has no effect.

An unspecified error, where only the ERR field is set to 1, indicates that either a transfer was cancelled with an error. The Management Page Error Status register has full view of the error condition.

See Fault reporting and handling for more details.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	ERR	Reserved														
W	W1C	0														
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved								SAE	SOE	DAE	DOE	NCE	SGE	SBE	DBE
W	0															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 ERR	Error In Channel 0b - An error in this channel has not occurred 1b - An error in this channel has occurred
30-8 —	Reserved
7 SAE	Source Address Error TCDn_SADDR is inconsistent with TCDn_ATTR[SSIZE]. 0b - No source address configuration error 1b - Last recorded error was a configuration error detected in the TCDn_SADDR field
6 SOE	Source Offset Error TCDn_SOFF is inconsistent with TCDn_ATTR[SSIZE].

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Field	Function
	0b - No source offset configuration error 1b - Last recorded error was a configuration error detected in the TCDn_SOFF field
5 DAE	Destination Address Error TCDn_DADDR is inconsistent with TCDn_ATTR[DSIZE]. 0b - No destination address configuration error 1b - Last recorded error was a configuration error detected in the TCDn_DADDR field
4 DOE	Destination Offset Error TCDn_DOFF is inconsistent with TCDn_ATTR[DSIZE]. 0b - No destination offset configuration error 1b - Last recorded error was a configuration error detected in the TCDn_DOFF field
3 NCE	NBYTES/CITER Configuration Error This error indicates that one of the following has occurred: • TCDn_NBYTES is not a multiple of TCDn_ATTR[SSIZE] and TCDn_ATTR[DSIZE] • TCDn_CITER[CITER] is equal to zero • TCDn_CITER[ELINK] is not equal to TCDn_BITER[ELINK] 0b - No NBYTES/CITER configuration error 1b - Last recorded error was a configuration error detected in the TCDn_NBYTES or TCDn_CITER fields
2 SGE	Scatter/Gather Configuration Error When this field is 1, it indicates that TCDn_DLAST_SGA is not on a 32-byte boundary. This field is checked at the beginning of a scatter/gather operation after major loop completion if TCDn_CSR[ESG]is enabled. 0b - No scatter/gather configuration error 1b - Last recorded error was a configuration error detected in the TCDn_DLAST_SGA field
1 SBE	Source Bus Error 0b - No source bus error 1b - Last recorded error was bus error on source read
0 DBE	Destination Bus Error 0b - No destination bus error 1b - Last recorded error was bus error on destination write

11.4.2.4 Channel Interrupt Status (CH0_INT - CH15_INT)

Offset

For n = 0 to 15:

Register	Offset
CHn_INT	8h + (n × 1000h)

Function

The INT field signals the presence of an interrupt request for the channel. Depending on the appropriate bit setting in the transfer control descriptors, the eDMA engine generates an interrupt on data transfer completion or an error condition.

The outputs of this register are directly routed to the interrupt controller. During the interrupt service routine associated with any given channel, it is the software's responsibility to clear the appropriate bit, negating the interrupt request. On writes to INT, a 1 clears the channel's interrupt request. A zero has no effect on the channel's current interrupt status.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															INT
W																W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-1 —	Reserved
0 INT	Interrupt Request 0b - Interrupt request for corresponding channel cleared 1b - Interrupt request for corresponding channel active

11.4.2.5 Channel System Bus (CH0_SBR - CH15_SBR)

Offset

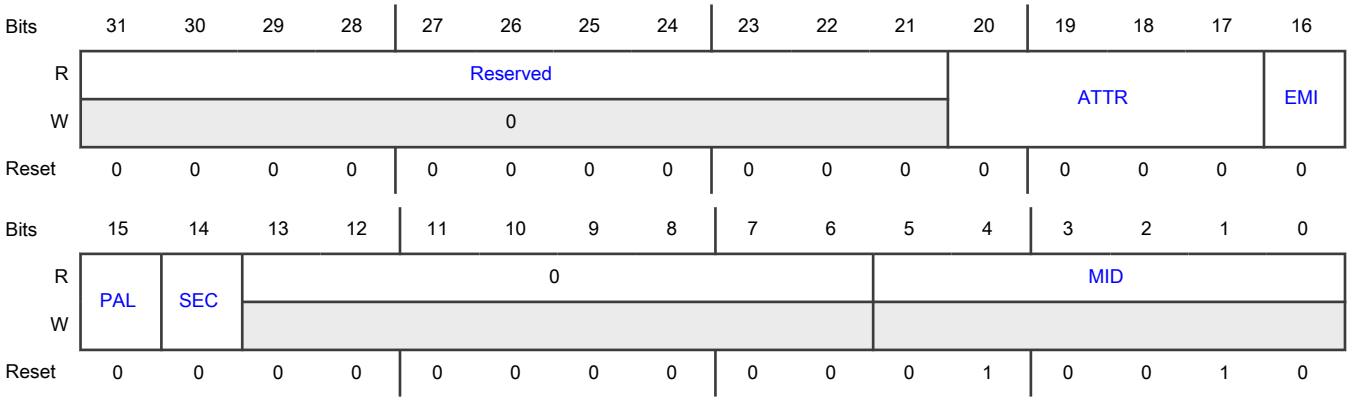
For n = 0 to 15:

Register	Offset
CHn_SBR	Ch + (n × 1000h)

Function

The Channel System Bus register places identification and attribute information on the system bus interface for the eDMA.

Diagram



Fields

Field	Function
31-21 —	Reserved
20-17 ATTR	Attribute Output DMA's system bus attribute output value.
16 EMI	Enable Initiator ID Replication The eDMA initiator ID replication field allows the eDMA to use the same protection level and system bus ID of the initiator programming the eDMA's TCD. When enabled, the eDMA uses the initiator ID and protection level stored in the CHn_SBR registers, instead of the eDMA's default values. When a initiator (for example a core) programs a TCD, its initiator ID is captured when the TCD*n*_CSR control attributes are written. A scatter/gather operation does not affect the CHn_SBR registers. You can write the EMI only if MP_CSR[GMRC] = 1, which means Global Initiator ID Replication Control is enabled; otherwise, the EMI is forced to zero. **NOTE** If initiator ID replication is disabled, the nonsecure, user protection level for DMA transfers is used. 0b - Initiator ID replication is disabled 1b - Initiator ID replication is enabled
15	Privileged Access Level

Table continues on the next page...

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Field	Function
PAL	This field controls DMA's protection level on the system bus when the channel is active. **NOTE** The value written into this register cannot exceed the security and privilege level of the core or other initiator writing the channel's system bus register; CH*n*_SBR. The order of precedence is SecurePriv>SecureUser>NonsecurePriv>NonsecureUser 0b - User protection level for DMA transfers 1b - Privileged protection level for DMA transfers
14 SEC	Security Level DMA's security level on the system bus when the channel is active. **NOTE** The value written into this register cannot exceed the security and privilege level of the core or other initiator writing the channel's system bus register; CH*n*_SBR. The order of precedence is SecurePriv>SecureUser>NonsecurePriv>NonsecureUser 0b - Nonsecure protection level for DMA transfers 1b - Secure protection level for DMA transfers
13-6 —	Reserved
5-0 MID	Initiator ID This field controls the DMA's initiator ID on the system bus when the channel is active. **NOTE** The ID captured in this register reflects the initiator ID of the core or other initiator writing the channel's security attributes, TCD*n*_SBR[SEC].

11.4.2.6 Channel Priority (CH0_PRI - CH15_PRI)

Offset

For n = 0 to 15:

Register	Offset
CHn_PRI	10h + (n × 1000h)

Function

The contents of these registers define unique priorities associated with each channel within the same channel group. Channel grouping is programmed via Channel Arbitration Group (CH0_GRPRI - CH15_GRPRI).

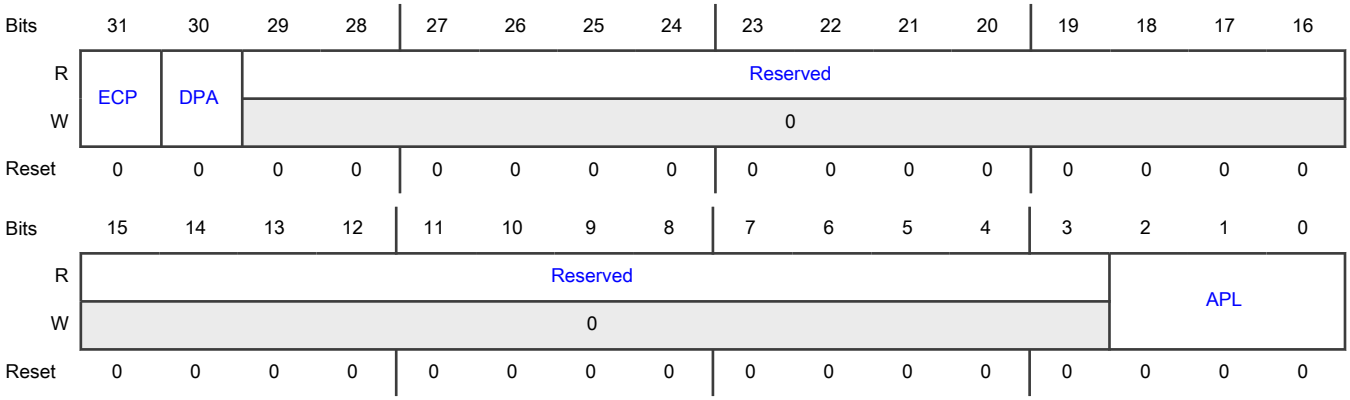
The channel priorities within a group are evaluated by numeric value; for example, 0 is the lowest priority, 1 is the next higher priority, then 2, 3, and so on. Software must program the channel priorities with unique values; otherwise, channel numbers with the same, non-zero value, will be selected based on channel number with the higher channel number having higher priority.

If more than one channel in a group has an arbitration priority level value of zero, then the arbitration mode field MP_CSR[ERCA] is used to determine the arbitration scheme for all channels with APL=0 within a group.

When you enable round-robin channel arbitration (MP_CSR[ERCA] = 1), all channels with APL=0 within a group will use a round-robin arbitration scheme, which rotates among these channels requesting service without regard to priority. Round-robin provides a fairness mechanism within an arbitration group.

When you enable fixed-priority channel arbitration (MP_CSR[ERCA] = 0), eDMA selects channels with APL=0 based on channel number, with the higher channel number having higher priority.

Diagram



Fields

Field	Function
31 ECP	Enable Channel Preemption 0b - Channel cannot be suspended by a higher-priority channel's service request 1b - Channel can be temporarily suspended by a higher-priority channel's service request
30 DPA	Disable Preempt Ability 0b - Channel can suspend a lower-priority channel 1b - Channel cannot suspend any other channel, regardless of channel priority
29-3 —	Reserved
2-0 APL	Arbitration Priority Level Channel priority level for arbitration within the assigned arbitration group.

11.4.2.7 Channel Multiplexor Configuration (CH0_MUX - CH15_MUX)

Offset

For n = 0 to 15:

Register	Offset
CHn_MUX	14h + (n × 1000h)

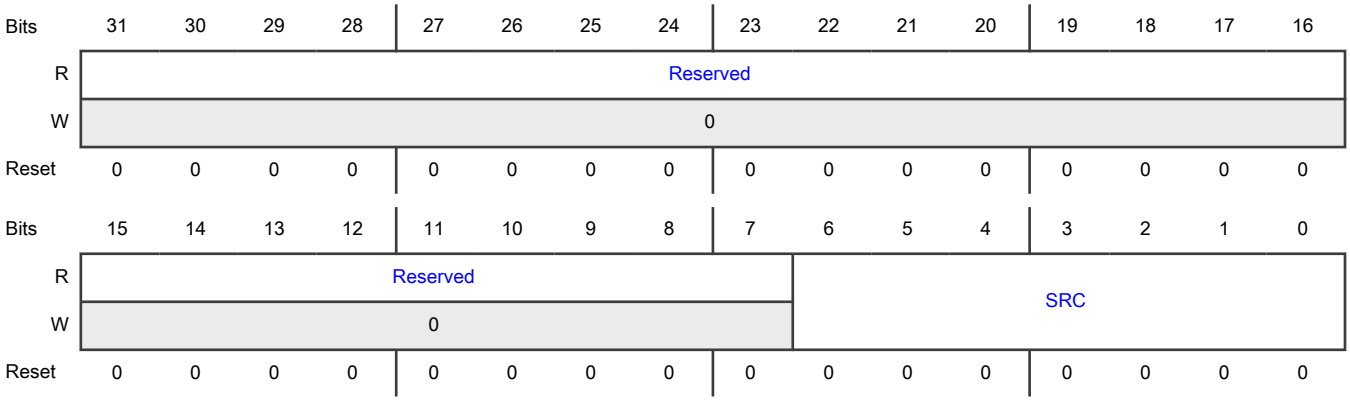
Function

Each of the DMA channels can be independently associated with various peripherals in the system. The Channel Multiplexor Configuration register selects the peripheral assigned to each channel. Service requests from the peripheral should be disabled when configuring a channel to a peripheral source.

Each channel must have a unique value when selecting a peripheral slot in the channel mux configuration. The only value that may overlap is source 0. If there is an attempt to write a mux configuration value that is already consumed by any channel, a mux configuration of 0 (SRC = 0) will be written.

All channels will default to source 0. When a particular peripheral is needed, the channel's mux configuration is set to that source number. When the peripheral is no longer needed, the mux configuration for that channel should be written to 0, thus releasing the resource.

Diagram



Fields

Field	Function
31-7 —	Reserved
6-0 SRC	Service Request Source Hardware service request source for the channel. **NOTE** With the exception of 0, attempts to write a value already in use will be forced to 0.

11.4.2.8 TCD Source Address (TCD0_SADDR - TCD15_SADDR)

Offset

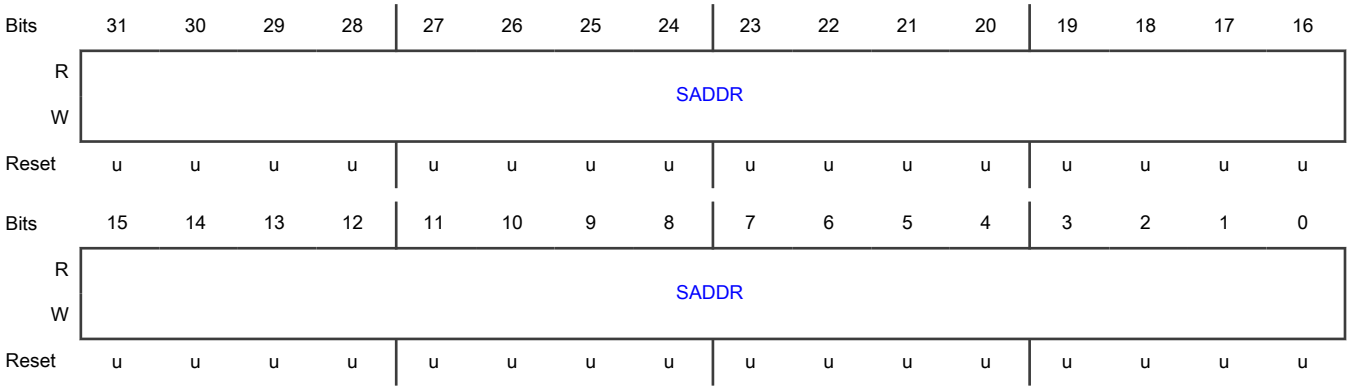
For n = 0 to 15:

Register	Offset
TCDn_SADDR	20h + (n × 1000h)

Function

This register contains the address for the read transactions.

Diagram



Fields

Field	Function
31-0 SADDR	Source Address Memory address pointing to the source data.

11.4.2.9 TCD Signed Source Address Offset (TCD0_SOFF - TCD15_SOFF)

Offset

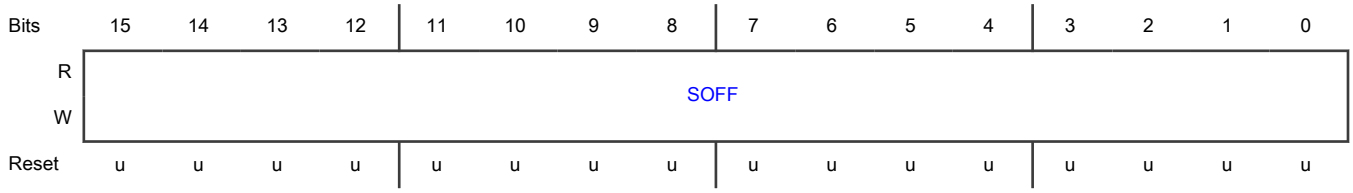
For n = 0 to 15:

Register	Offset
TCDn_SOFF	24h + (n × 1000h)

Function

This register contains the sign-extended value added to Source Address register after each read transaction.

Diagram



Fields

Field	Function
15-0 SOFF	Source Address Signed Offset Sign-extended offset applied to the current source address to form the next-state value as each source read is completed.

11.4.2.10 TCD Transfer Attributes (TCD0_ATTR - TCD15_ATTR)

Offset

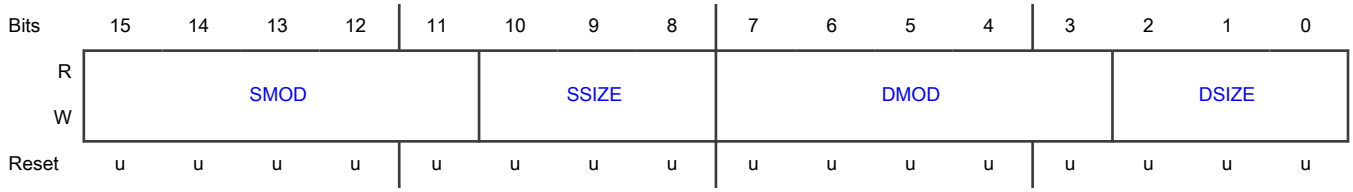
For n = 0 to 15:

Register	Offset
TCDn_ATTR	26h + (n × 1000h)

Function

This register contains size and option modulo addressing information for source and destination addresses.

Diagram



Fields

Field	Function
15-11 SMOD	Source Address Modulo This field defines a specific address range, which is the value after the SADDR + SOFF calculation is performed on the original register value. Setting this field makes it easy to implement a circular data queue. For data queues requiring power-of-2-sized bytes, the queue must start at a 0-modulo-size address and the SMOD field must be set to the appropriate value for the queue, freezing the required number of upper address bits.

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Field	Function
	The value programmed into this field specifies the number of lower address bits that are allowed to change. For a circular queue application, you typically set TCDn_SOFF[SOFF] to the transfer size to implement post-increment addressing, with the SMOD function constraining the addresses to a 0-modulo-size range. 0_0000b - Source address modulo feature disabled
10-8 SSIZE	Source Data Transfer Size 000b - 8-bit 001b - 16-bit 010b - 32-bit 011b - 64-bit 100b - 16-byte 101b - 32-byte 110b - Reserved 111b - Reserved
7-3 DMOD	Destination Address Modulo See the SMOD definition.
2-0 DSIZE	Destination Data Transfer Size See the SSIZE definition.

11.4.2.11 TCD Transfer Size Without Minor Loop Offsets (TCD0_NBYTES_MLOFFNO - TCD15_NBYTES_MLOFFNO)

Offset

For n = 0 to 15:

Register	Offset
TCDn_NBYTES_MLOFFNO	28h + (n × 1000h)

Function

The TCDn_NBYTES field defines the number of bytes to transfer per service request.

Minor loop offsets are address offset values added to the final source address (TCDn_SADDR), or destination address (TCDn_DADDR), upon minor loop completion. Minor loop completion is when the channel has finished the service request and has transferred NBYTES. When minor loop offsets are enabled, the minor loop offset value (TCDn_NBYTES_MLOFFYES[MLOFF]) is added to the final source address (TCDn_SADDR), to the final destination address (TCDn_DADDR), or to both, prior to the addresses being written back to the TCD. If the major loop is complete, the minor loop offset is ignored and the major loop address offsets (TCDn_SLAST_SDA and TCDn_DLAST_SGA) are used to compute the next TCDn_SADDR and TCDn_DADDR values.

When minor loop mapping is enabled (SMLOE or DMLOE is 1), TCDn_NBYTES_MLOFFNO/TCDn_NBYTES_MLOFFYES is redefined. A portion of TCDn_NBYTES_MLOFFNO/TCDn_NBYTES_MLOFFYES is used to specify multiple fields:

- A source enable bit (SMLOE) to specify the minor loop offset must be applied to the source address (TCDn_SADDR) upon minor loop completion
- A destination enable bit (DMLOE) to specify the minor loop offset must be applied to the destination address (TCDn_DADDR) upon minor loop completion
- The sign extended minor loop offset value (MLOFF)

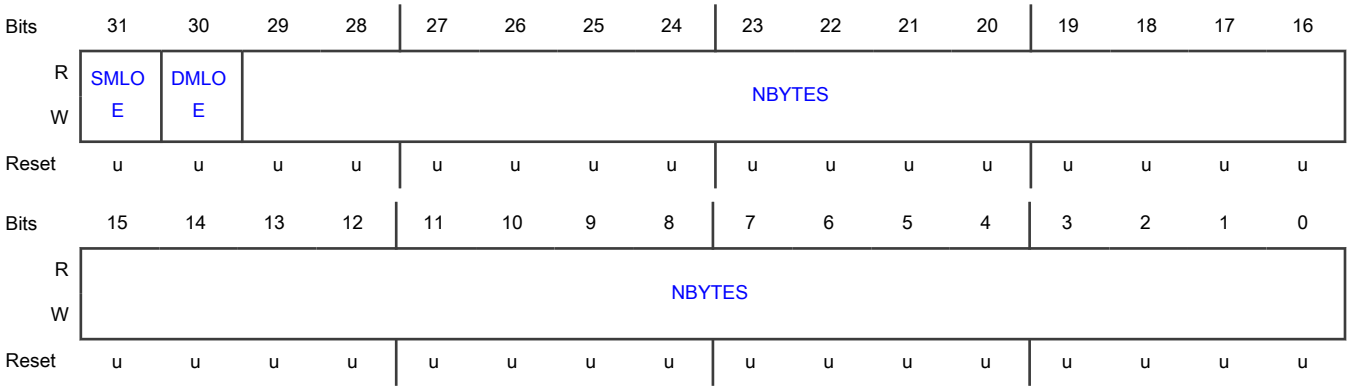
The same offset value (MLOFF) is used for both source and destination minor loop offsets. When either minor loop offset is enabled (SMLOE set or DMLOE set), the NBYTES field is reduced to 10 bits. If both minor loop offsets are disabled (SMLOE cleared and DMLOE cleared), the NBYTES field is a 30-bit vector.

One of two register profiles (this register or TCDn_NBYTES_MLOFFYES), defines the number of bytes to transfer per request. Which register to use depends on whether source or destination minor loop mapping is enabled.

TCDn_NBYTES_MLOFFNO/TCDn_NBYTES_MLOFFYES is defined as follows:

- If SMLOE = 0 and DMLOE = 0, then see the TCDn_NBYTES_MLOFFNO register description.
- If either SMLOE or DMLOE is 1, then see the TCDn_NBYTES_MLOFFYES register description.

Diagram



Fields

Field	Function
31 SMLOE	Source Minor Loop Offset Enable Selects whether the minor loop offset is applied to the source address upon minor loop completion. 0b - Minor loop offset not applied to SADDR 1b - Minor loop offset applied to SADDR
30 DMLOE	Destination Minor Loop Offset Enable Selects whether the minor loop offset is applied to the destination address upon minor loop completion. 0b - Minor loop offset not applied to DADDR 1b - Minor loop offset applied to DADDR
29-0	Number of Bytes To Transfer Per Service Request

Table continues on the next page...

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Field	Function
NBYTES	Number of bytes to be transferred for each service request of the channel. When a channel activates, the module loads the appropriate TCD contents into the eDMA engine and performs the appropriate reads and writes until the byte transfer count has been reached. This process is normally an indivisible operation and cannot be halted. It can, however, be stalled by using the bandwidth control field, or via preemption. After the byte count is exhausted, the SADDR and DADDR values are written back into the TCD memory, and the major loop iteration count (CITER) is decremented by one and written back to the TCD memory. If the major iteration count is complete, additional processing is performed.

11.4.2.12 TCD Transfer Size with Minor Loop Offsets (TCD0_NBYTES_MLOFFYES - TCD15_NBYTES_MLOFFYES)

Offset

For n = 0 to 15:

Register	Offset
TCDn_NBYTES_MLOFFYES	28h + (n × 1000h)

Function

The TCDn_NBYTES field defines the number of bytes to transfer per service request.

Minor loop offset is an address offset value added to the final source address (TCDn_SADDR) or destination address (TCDn_DADDR) upon minor loop completion. Minor loop completion occurs when the channel has finished the service request and has transferred NBYTES. Minor loop offsets are enabled by setting either the source enable bit (SMLOE) or the destination enable bit (DMLOE).

The source enable bit (SMLOE) specifies the minor loop offset value (MLOFF) that is to be applied to the source address (TCDn_SADDR) upon minor loop completion. The destination enable bit (DMLOE) specifies the minor loop offset (MLOFF) that is to be applied to the destination address (TCDn_DADDR) upon minor loop completion.

If the major loop is complete, the minor loop offsets are ignored and the major loop address offsets (TCDn_SLAST_SDA and TCDn_DLAST_SGA) are used to compute the next TCDn_SADDR and TCDn_DADDR values.

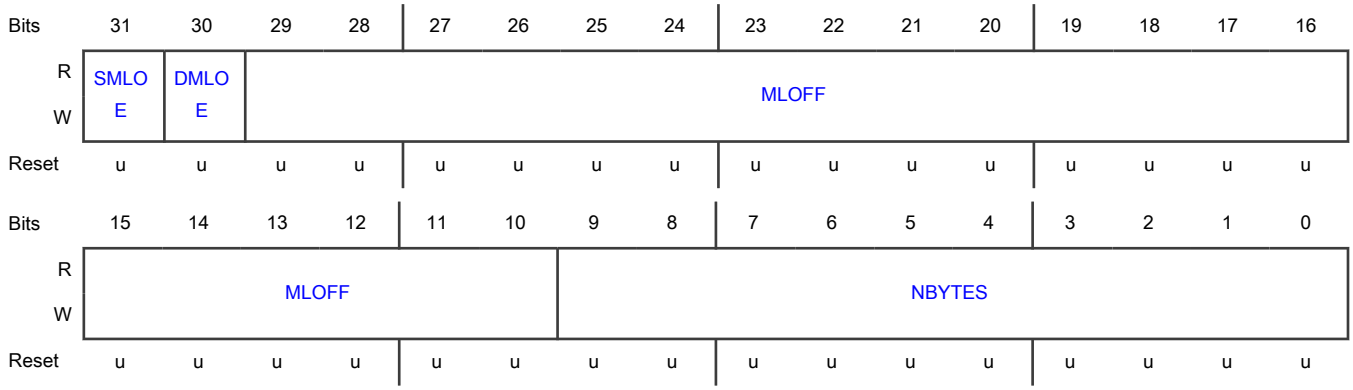
When you enable the minor loop offset overlay (either SMLOE or DMLOE is 1), eDMA redefines TCDn_NBYTES_MLOFFNO/TCDn_NBYTES_MLOFFYES. A portion of TCDn_NBYTES_MLOFFNO/TCDn_NBYTES_MLOFFYES specifies the sign-extended minor loop offset value (MLOFF). The same offset value (MLOFF) applies to both source and destination minor loop offsets. When the minor loop offset is enabled, you must align it to the transfer size of the source or destination it is associated with. When either minor loop offset is enabled (SMLOE set or DMLOE set), the NBYTES field is reduced to 10 bits. If both minor loop offsets are disabled (SMLOE cleared and DMLOE cleared), the NBYTES field is a 30-bit vector.

One of two register profiles (this register or TCDn_NBYTES_MLOFFNO) defines the number of bytes to transfer per request. Which register to use depends on whether source or destination minor loop mapping is enabled.

TCDn_NBYTES_MLOFFYES is defined as follows:

- If either minor loop offset is enabled (SMLOE or DMLOE = 1), then see the TCDn_NBYTES_MLOFFYES register description.
- If SMLOE and DMLOE are both 0, then see the TCDn_NBYTES_MLOFFNO register description.

Diagram



Fields

Field	Function
31 SMLOE	Source Minor Loop Offset Enable Selects whether the minor loop offset is applied to the source address upon minor loop completion. 0b - Minor loop offset not applied to SADDR 1b - Minor loop offset applied to SADDR
30 DMLOE	Destination Minor Loop Offset Enable Selects whether the minor loop offset is applied to the destination address upon minor loop completion. 0b - Minor loop offset not applied to DADDR 1b - Minor loop offset applied to DADDR
29-10 MLOFF	Minor Loop Offset If SMLOE or DMLOE is 1, this field represents a sign-extended offset applied to the source or destination address to form the next-state value after the minor loop completes.
9-0 NBYTES	Number of Bytes To Transfer Per Service Request The number of bytes to be transferred in each service request of the channel. As a channel activates, the module loads the appropriate TCD contents into the eDMA engine and performs the appropriate reads and writes until the minor byte transfer count has been reached. This is an indivisible operation and cannot be halted. It can, however, be stalled by using the bandwidth control field, or via preemption. After the minor count is exhausted, the SADDR and DADDR values are written back into the TCD memory, and the major iteration count is decremented and restored to the TCD memory. If the major iteration count is complete, additional processing is performed.

11.4.2.13 TCD Last Source Address Adjustment / Store DADDR Address (TCD0_SLAST_SDA - TCD15_SLAST_SDA)

Offset

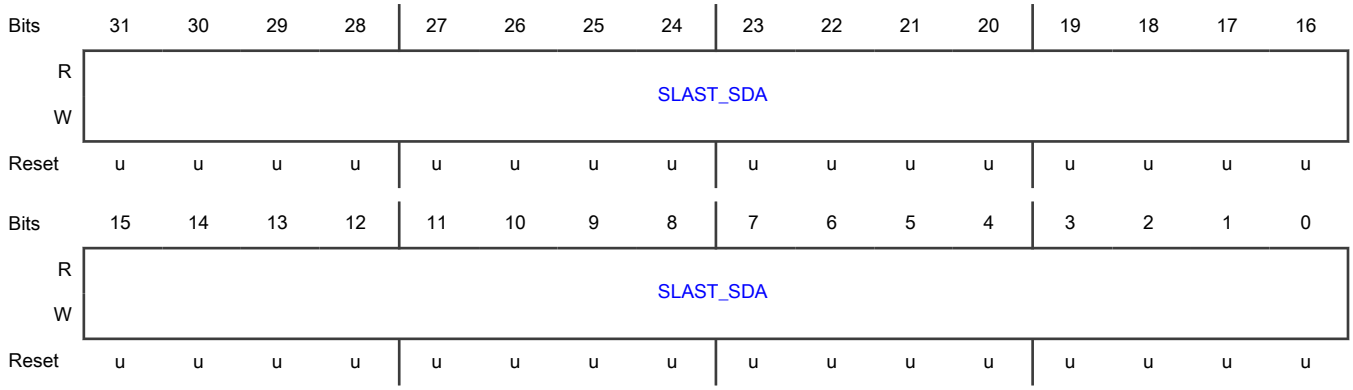
For n = 0 to 15:

Register	Offset
TCDn_SLAST_SDA	2Ch + (n × 1000h)

Function

This register contains the value added to the source address when the major loop is complete. When the store destination address option is enabled, this field provides a pointer to memory for storing the final destination address.

Diagram



Fields

Field	Function
31-0 SLAST_SDA	Last Source Address Adjustment / Store DADDR Address Source last address adjustment or the system memory address for destination address (DADDR) storage. If (TCDn_CSR[ESDA] = 0), then: • Adjustment value is added to the source address at the completion of the major iteration count. This value can be used to restore the source address to the initial value or adjust the address to reference the next data structure. • This field uses two's complement notation for the final source address adjustment. Otherwise: • This address points to the 32-bit-aligned memory location where the destination address (DADDR) is to be stored in system memory. By saving the final destination address in system memory via the ESDA feature, you are able to compute the size of a variable destination data buffer by simply subtracting the beginning DADDR from the final, saved DADDR. This feature is used together with the scatter/gather operation to prevent the loss of the final DADDR, which is overwritten during the scatter/gather operation. The "Store Destination Address" (SDA) value must be a 32-bit-aligned location because the eDMA forces the lower two address bits of the SLAST_SDA field to zero when ESDA is enabled. The module performs this write operation when the major loop is done; that is, when the major iteration count (CITER) decrements to zero.

11.4.2.14 TCD Destination Address (TCD0_DADDR - TCD15_DADDR)

Offset

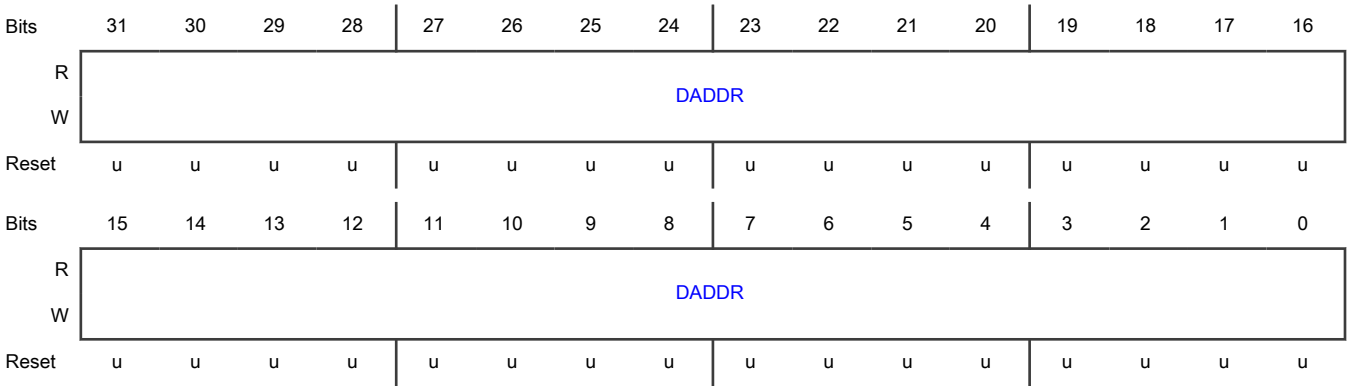
For n = 0 to 15:

Register	Offset
TCDn_DADDR	30h + (n × 1000h)

Function

This register contains the address for the write transactions.

Diagram



Fields

Field	Function
31-0 DADDR	Destination Address Memory address pointing to the destination data.

11.4.2.15 TCD Signed Destination Address Offset (TCD0_DOFF - TCD15_DOFF)

Offset

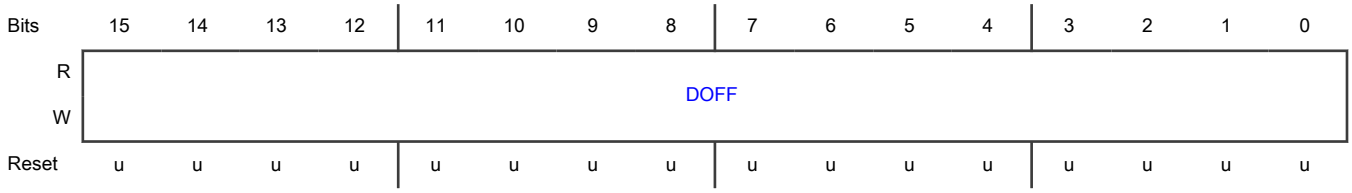
For n = 0 to 15:

Register	Offset
TCDn_DOFF	34h + (n × 1000h)

Function

This register contains the sign-extended value added to Destination Address register after each write transaction.

Diagram



Fields

Field	Function
15-0 DOFF	Destination Address Signed Offset Sign-extended offset that is applied to the current destination address to form the next-state value as each destination write is completed.

11.4.2.16 TCD Current Major Loop Count (Minor Loop Channel Linking Disabled) (TCD0_CITER_ELINKNO - TCD15_CITER_ELINKNO)

Offset

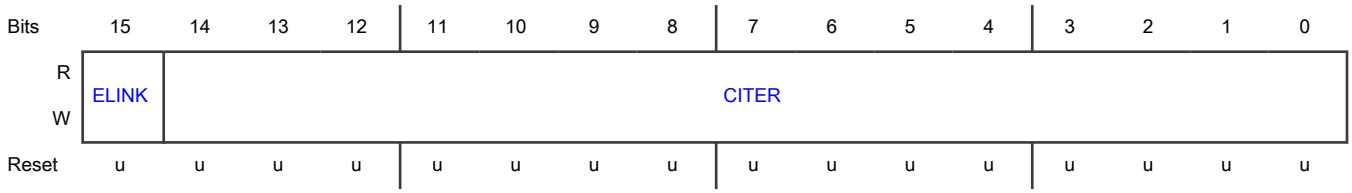
For n = 0 to 15:

Register	Offset
TCDn_CITER_ELINKNO	36h + (n × 1000h)

Function

If TCDn_CITER[ELINK] is 0, the TCDn_CITER register is defined as follows.

Diagram



Fields

Field	Function
15 ELINK	Enable Link As the channel completes the minor loop, this flag enables linking to another channel as defined by the relevant LINKCH field. The link target channel initiates a channel service request via an internal mechanism that sets the TCDn_CSR[START] bit of the specified channel to 1. If channel linking is disabled, the CITER value is extended to 15 bits in place of a link channel number. If the major loop is exhausted, this link mechanism is suppressed in favor of MAJORELINK channel linking.

Table continues on the next page...

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Field	Function
	NOTE This field must be equal to the BITER[ELINK] field; otherwise, a configuration error is reported. 0b - Channel-to-channel linking disabled 1b - Channel-to-channel linking enabled
14-0 CITER	Current Major Iteration Count This 9-bit (ELINK = 1) or 15-bit (ELINK = 0) count represents the current major loop count for the channel. It is decremented each time the channel finishes a service request and is written back to TCD memory. After the major iteration count is exhausted, the channel performs a number of operations — for example, final source and destination address calculations — and optionally generates an interrupt to signal channel completion before reloading the CITER field from the Beginning Iteration Count (BITER) field. **NOTE** When the CITER field is initially loaded by software, it must be set to the same value as that contained in the BITER field. **NOTE** If the channel is configured to execute a single service request, the initial values of BITER and CITER should be 0x0001.

11.4.2.17 TCD Current Major Loop Count (Minor Loop Channel Linking Enabled) (TCD0_CITER_ELINKYES - TCD15_CITER_ELINKYES)

Offset

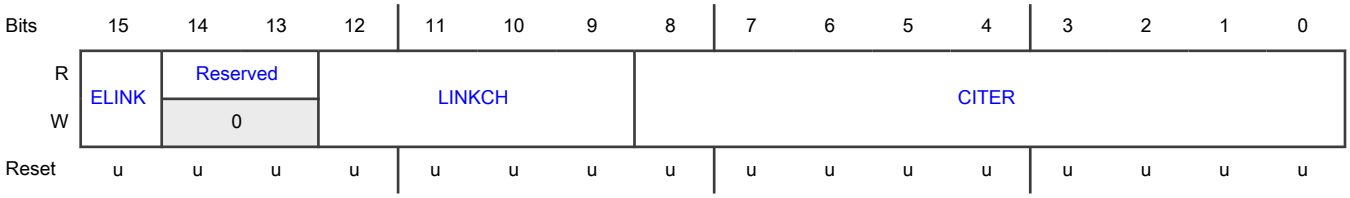
For n = 0 to 15:

Register	Offset
TCDn_CITER_ELINKYES	36h + (n × 1000h)

Function

If TCDn_CITER[ELINK] is 1, the TCDn_CITER register is defined as follows.

Diagram



Fields

Field	Function
15 ELINK	Enable Link As the channel completes the minor loop, this flag enables linking to another channel as defined by the relevant LINKCH field. When enabled, an internal mechanism sets the TCDn_CSR[START] field of the specified channel (LINKCH) upon minor loop completion. If channel linking is disabled, the CITER value is extended to 15 bits in place of a link channel number. If the major loop is exhausted, this link mechanism is suppressed in favor of MAJORELINK channel linking. **NOTE** This field must be equal to the BITER[ELINK] field; otherwise, a configuration error is reported. 0b - Channel-to-channel linking disabled 1b - Channel-to-channel linking enabled
14-13 —	Reserved
12-9 LINKCH	Minor Loop Link Channel Number If channel-to-channel linking is enabled (ELINK = 1), then after the minor loop is exhausted the eDMA engine initiates a channel service request to the channel defined by this field by writing that channel's TCDn_CSR[START] field to 1.
8-0 CITER	Current Major Iteration Count This 9-bit (ELINK = 1) or 15-bit (ELINK = 0) count represents the current major loop count for the channel. It is decremented each time the channel finishes a service request and is written back to the TCD memory. After the major iteration count is exhausted, the channel performs a number of operations — for example, final source and destination address calculations — and optionally generates an interrupt to signal channel completion before reloading the CITER field from the Beginning Iteration Count (BITER) field. **NOTE** When the CITER field is initially loaded by software, it must be set to the same value as that contained in the BITER field. **NOTE** If the channel is configured to execute a single service request, the initial values of BITER and CITER should be 0x0001.

11.4.2.18 TCD Last Destination Address Adjustment / Scatter Gather Address (TCD0_DLAST_SGA - TCD15_DLAST_SGA)

Offset

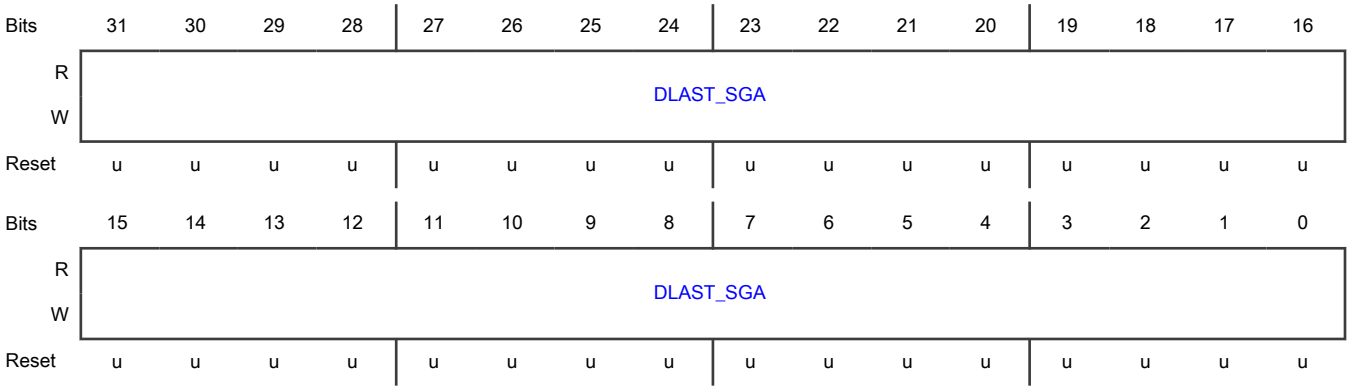
For n = 0 to 15:

Register	Offset
TCDn_DLAST_SGA	38h + (n × 1000h)

Function

This register contains the value added to the destination address when the major loop is complete. When the Scatter/Gather option is enabled, this field provides a pointer to memory for fetching a transfer control descriptor to reprogram the channel.

Diagram



Fields

Field	Function
31-0 DLAST_SGA	Last Destination Address Adjustment / Scatter Gather Address Adjustment of the last destination address or the memory address for the next transfer control descriptor to be loaded into this channel (scatter/gather). If (TCDn_CSR[ESG] = 0) then: • Adjustment value is added to the destination address at the completion of the major iteration count. This value can apply to restore the destination address to the initial value or adjust the address to reference the next data structure. • This field uses two's complement notation for the final destination address adjustment. Otherwise: • This address points to the beginning of a 0-modulo 32-byte region containing the next transfer control descriptor to be loaded into this channel. This channel reload is performed as the major iteration count completes. The scatter/gather address must be 0-modulo 32-byte, or else a configuration error is reported.

11.4.2.19 TCD Control and Status (TCD0_CSR - TCD15_CSR)

Offset

For n = 0 to 15:

Register	Offset
TCDn_CSR	3Ch + (n × 1000h)

Function

This register is used to enable optional features.

Diagram

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	BWC				MAJORLINKCH				ESDA	EEOP	MAJO REL...	ESG	DREQ	INTHA LF	INTMA JOR	STAR T
W			0													
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	0

Fields

Field	Function
15-14 BWC	Bandwidth Control Throttles the amount of bus bandwidth consumed by the eDMA. Generally, as the eDMA processes the minor loop, it continuously generates read/write sequences until the minor count is exhausted. This field forces eDMA to stall after the completion of each read/write access, to control the bus request bandwidth seen by the system bus interconnect. **NOTE** If the source and destination sizes are equal, this field is ignored between the first and second transfers and after the last write of each minor loop. This behavior is a side effect of reducing start-up latency. 00b - No eDMA engine stalls 01b - Reserved 10b - eDMA engine stalls for 4 cycles after each R/W 11b - eDMA engine stalls for 8 cycles after each R/W
13-12 —	Reserved
11-8 MAJORLINKCH	Major Loop Link Channel Number If (MAJORELINK = 0) then: • No channel-to-channel linking, or chaining, is performed after the major loop counter is exhausted. Otherwise:

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Field	Function
	• After the major loop counter is exhausted, the eDMA engine initiates a channel service request at the channel defined by this field by setting that channel's TCDn_CSR[START] field to 1.
7 ESDA	Enable Store Destination Address As the channel completes the major loop by either the current iteration counter (CITER) decrementing to 0, or by receiving an enabled end-of-packet signal, this field enables writing the destination address (DADDR) to the address stored in the SLAST_SDA field. The value written to system memory is the next DADDR value prior to the DLAST_SGA offset being applied, or overwritten by an enabled scatter/gather operation. When the ESDA bit is 1, SLAST_SDA contains the write pointer instead of the final source address offset. Because this is a pointer and not a final offset, a last source address offset of zero is applied to SADDR instead of the SLAST_SGA value. 0b - Ability to store destination address to system memory disabled 1b - Ability to store destination address to system memory enabled
6 EEOP	Enable End-Of-Packet Processing When enabled by the EEOP field, an end-of-packet hardware input signal directs eDMA to discontinue executing the active channel, and to treat the shutdown as the major-loop-completed event. If the EEOP field is 1, the end-of-packet signal from supported peripherals is accepted. If the EEOP field is 0, the end-of-packet input is ignored. With an end-of-packet retirement, the current TCD destination address (or ESDA-saved destination address), minus the software-saved initial address (DADDR), reflects the total amount of data transferred. 0b - End-of-packet operation disabled 1b - End-of-packet hardware input signal enabled
5 MAJORELINK	Enable Link When Major Loop Complete As the channel completes the major loop, this flag enables linking to another channel defined by MAJORLINKCH. The link target channel initiates a channel service request via an internal mechanism that sets the TCDn_CSR[START] field of the specified channel. **NOTE** To support the dynamic linking coherency model, this field is forced to 0 if written when TCDn_CSR[DONE] is 1. 0b - Channel-to-channel linking disabled 1b - Channel-to-channel linking enabled
4 ESG	Enable Scatter/Gather Processing As the channel completes the major loop, this flag enables scatter/gather processing in the current channel. If enabled, the eDMA engine uses TCDn_DLAST_SGA as a memory pointer to a 0-modulo 32-bit address containing a 32-byte data structure, which is loaded as the transfer control descriptor into local memory. **NOTE** To support the dynamic scatter/gather coherency model, this field is forced to 0 if written when TCDn_CSR[DONE] is 1.

Table continues on the next page...

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Field	Function
	0b - Current channel's TCD is normal format 1b - Current channel's TCD specifies scatter/gather format.
3 DREQ	Disable Request If this flag is 1, the eDMA hardware automatically clears the corresponding ERQ bit when the current major iteration count reaches 0. 0b - No operation. Channel's ERQ field not affected 1b - Clear the ERQ field to 0 upon major loop completion, thus disabling hardware service requests. Channel's ERQ field cleared to 0 when major loop complete
2 INTHALF	Enable Interrupt If Major Counter Half-complete If this flag is 1, the channel generates an interrupt request by setting the appropriate field in the INT register to 1 when the current major iteration count reaches the halfway point. Specifically, the comparison performed by the eDMA engine is (CITER = (BITER/2)). This halfway point interrupt request is provided to support double-buffered, also known as ping-pong, schemes, or other types of data movement where the processor needs an early indication of the transfer's progress. **NOTE** If BITER = 1, do not use INTHALF; use INTMAJOR instead. 0b - Halfway point interrupt disabled 1b - Halfway point interrupt enabled
1 INTMAJOR	Enable Interrupt If Major count complete If this flag is 1, the channel generates an interrupt request by setting the appropriate field in the INT register to 1 when the current major iteration count (CITER) reaches 0. 0b - End-of-major loop interrupt disabled 1b - End-of-major loop interrupt enabled
0 START	Channel Start If this flag is 1, the channel is requesting service. The eDMA hardware automatically clears this flag to 0 after the channel begins execution. 0b - Channel not explicitly started 1b - Channel explicitly started via a software-initiated service request

11.4.2.20 TCD Beginning Major Loop Count (Minor Loop Channel Linking Disabled) (TCD0_BITER_ELINKNO - TCD15_BITER_ELINKNO)

Offset

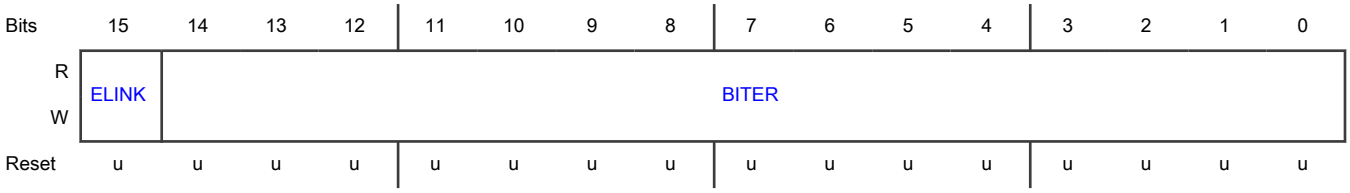
For n = 0 to 15:

Register	Offset
TCDn_BITER_ELINKNO	3Eh + (n × 1000h)

Function

If the TCDn_BITER[ELINK] field is 0, the TCDn_BITER register is defined as follows.

Diagram



Fields

Field	Function
15 ELINK	Enables Link As the channel completes the minor loop, this flag enables linking to another channel as defined by BITER[LINKCH]. The link target channel initiates a channel service request via an internal mechanism that sets the TCDn_CSR[START] field of the specified channel. If channel linking is disabled, the BITER value extends to 15 bits in place of a link channel number. If the major loop is exhausted, this link mechanism is suppressed in favor of the MAJORELINK channel linking. **NOTE** When the software loads the TCD, this field must be set equal to the corresponding CITER field; otherwise, a configuration error is reported. As the major iteration count is exhausted, eDMA reloads the contents of this field into the CITER field. 0b - Channel-to-channel linking disabled 1b - Channel-to-channel linking enabled
14-0 BITER	Starting Major Iteration Count As the transfer control descriptor is first loaded by software, this 9-bit (ELINK = 1) or 15-bit (ELINK = 0) field must be set equal to the value in the CITER field. As the major iteration count is exhausted, eDMA reloads the contents of this field into the CITER field. If the channel is configured to execute a single service request, the initial values of BITER and CITER must be 0x0001.

11.4.2.21 TCD Beginning Major Loop Count (Minor Loop Channel Linking Enabled) (TCD0_BITER_ELINKYES - TCD15_BITER_ELINKYES)

Offset

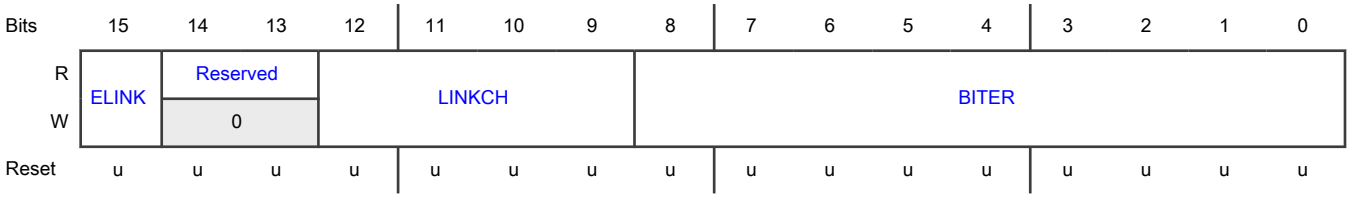
For n = 0 to 15:

Register	Offset
TCDn_BITER_ELINKYES	3Eh + (n × 1000h)

Function

If the TCDn_BITER[ELINK] field is set, the TCDn_BITER register is defined as follows.

Diagram



Fields

Field	Function
15 ELINK	Enable Link As the channel completes the minor loop, this flag enables linking to another channel as defined by BITER[LINKCH]. The link target channel initiates a channel service request via an internal mechanism that sets the TCDn_CSR[START] field of the specified channel. If channel linking disables, the BITER value extends to 15 bits in place of a link channel number. If the major loop is exhausted, this link mechanism is suppressed in favor of the MAJORELINK channel linking. **NOTE** When the software loads the TCD, this field must be set equal to the corresponding CITER field; otherwise, a configuration error is reported. As the major iteration count is exhausted, eDMA reloads the contents of this field into the CITER field. 0b - Channel-to-channel linking disabled 1b - Channel-to-channel linking enabled
14-13 —	Reserved
12-9 LINKCH	Link Channel Number If channel-to-channel linking is enabled (ELINK = 1), then after the minor loop is exhausted, the eDMA engine initiates a channel service request at the channel defined by this field by setting that channel's TCDn_CSR[START] field. **NOTE** When the software loads the TCD, this field must be set equal to the corresponding CITER field; otherwise, a configuration error is reported. As the major iteration count is exhausted, eDMA reloads the contents of this field into the CITER field.
8-0	Starting Major Iteration Count

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Field	Function
BITER	As the transfer control descriptor is first loaded by software, this 9-bit (ELINK = 1) or 15-bit (ELINK = 0) field must be set equal to the value in the CITER field. As the major iteration count is exhausted, eDMA reloads the contents of this field into the CITER field. If the channel is configured to execute a single service request, the initial values of BITER and CITER must be 0x0001.

11.5 External signals

This module has no external signals.

11.6 Initialization

The following sections discuss initialization of the eDMA and programming considerations.

11.6.1 eDMA initialization

To initialize the eDMA:

1. Write to the MP_CSR if a configuration other than the default is wanted.
2. Write the channel priority levels to the CHn_PRI registers and group priority levels to the CHn_GRPRI registers if a configuration other than the default is wanted.
3. Enable error interrupts in the CHn_CSR[EEI] registers if they are wanted.
4. Write the 32-byte TCD for each channel that may request service.
5. Enable any hardware service requests via the CHn_CSR[ERQ] registers.
6. Request channel service via either:
   - Software: setting TCDn_CSR[START]
   - Hardware: target device asserting its eDMA peripheral request signal

After any channel requests service, a channel is selected for execution based on the arbitration and priority levels written into the programmer's model. The eDMA engine reads the entire TCD, including the TCD control and status fields, as shown in Table 54, for the selected channel into its internal address path module.

As the TCD is read, the first transfer is initiated on the internal bus, unless a configuration error is detected. Transfers from the source, defined by TCDn_SADDR, to the destination, defined by TCD_DADDR, continue until the number of bytes specified by TCDn_NBYTES are transferred.

When the transfer is complete, the eDMA engine's local TCDn_SADDR, TCDn_DADDR, and TCDn_CITER are written back to the main TCD memory and any minor loop channel linking is performed, if enabled. If the major loop is exhausted, then eDMA executes further post-processing, such as interrupts, major loop channel linking, and scatter/gather operations, if enabled.

Table 54. TCD control and status (TCDn_CSR) fields

TCDn_CSR field name	Description
START	Control field to start the channel explicitly when using a software-initiated DMA service (automatically cleared by hardware)
EEOP	Control field to enable end-of-packet processing

Table continues on the next page...

Table 54. TCD control and status (TCDn_CSR) fields (continued)

TCDn_CSR field name	Description
ESDA	Control field to enable storing of the destination address to system memory after the major loop completes
DREQ	Control field to disable hardware-initiated DMA service requests after major loop completion
BWC	Control field for throttling the bandwidth control of a channel
ESG	Control field to enable the scatter-gather feature
INTHALF	Control field to enable interrupt when major loop is half-complete
INTMAJOR	Control field to enable interrupt when major loop completes

Table 55. Channel control and status (CHn_CSR) fields

CHn_CSR field name	Description
ACTIVE	Status field indicating the channel is currently in execution
DONE	Status field indicating major loop completion (cleared by software when a channel begins execution)
EEI	Control field to enable error interrupts
EARQ	Control field to enable external, asynchronous wakeup event in conjunction with the ERQ field
ERQ	Control field to enable hardware service requests

The following figure shows how each DMA request initiates one minor-loop transfer, or iteration, without CPU intervention. DMA arbitration can occur after each minor loop, and one level of minor loop DMA preemption is allowed. The number of minor loops in a major loop is specified by the beginning iteration count (BITER).

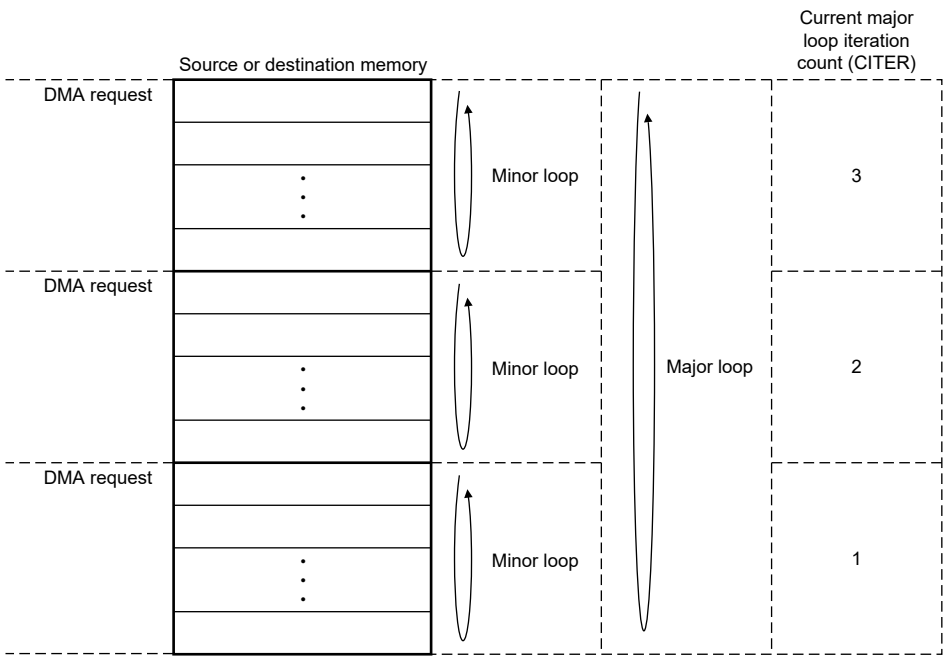


Figure 19. Example of multiple loop iterations

The following figure lists the memory array terms and how the TCD settings are related.

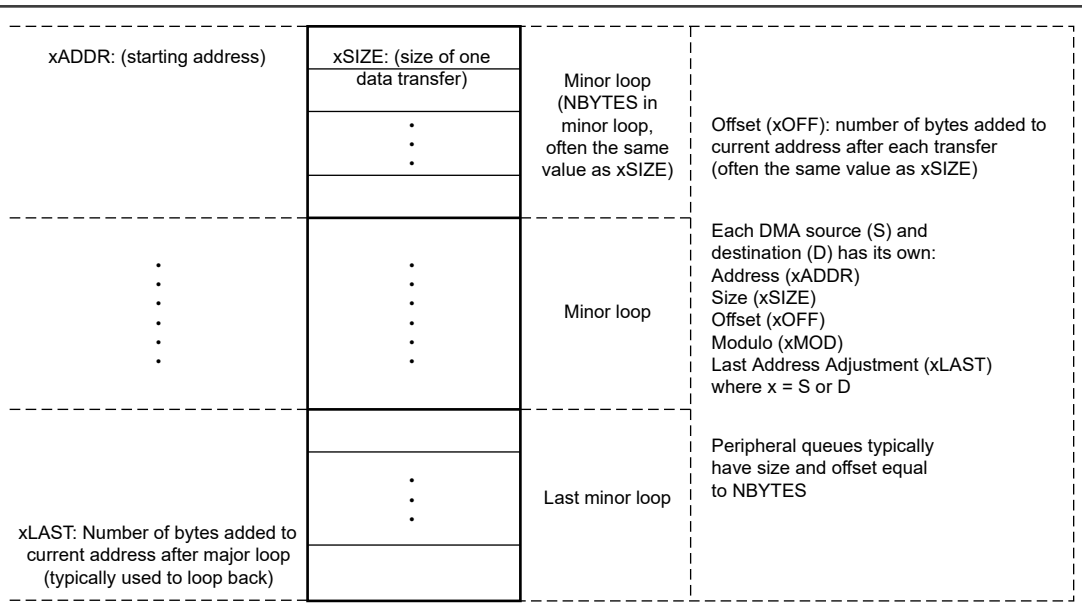


Figure 20. Memory array terms

11.6.2 eDMA arbitration

The eDMA uses a layered arbitration scheme composed of multiple priority levels. The eDMA uses a fixed-priority arbitration scheme with optional round-robin arbitration under specific conditions. The priorities are evaluated in the following order:

Table 56. eDMA arbitration priorities

Priority	Scheme	Description
1 (Highest)	Arbitration group priority	Each channel is assigned an arbitration group via the CHn_GRPRI registers. Priority is given to the highest value (31 being the highest possible value) down to the lowest value (zero, the default).
2	Channel priority	Each channel is assigned a channel priority level via the CHn_PRI registers. The channel priority is a relative priority level within an arbitration group. Priority is given to the highest value (seven being the highest possible value) down to the lowest value (zero, the default). Channel priorities within each arbitration group need not be unique. If multiple channels have the same channel priority level, the channel number will be used to determine priority as defined in row three.
3	Channel number	When two or more channels have the same arbitration group priority and channel priority, the channel number (CHn_NUM) is used to determine the highest priority. Priority is given to the highest channel number. Lowest priority is channel 0. The channel numbers are static and cannot be changed in the programmer's model.
4 (Lowest)	Round-robin	When round-robin is enabled, any channel configured for round-robin operation has lowest priority within an arbitration group. Round-robin is enabled by setting the MP_CSR[ERCA] field to 1. After being enabled, channels with a channel priority of zero (CHn_PRI=0) will use round-robin arbitration. Round-robin arbitration will rotate the channel selection among the channels requesting service with CHn_PRI=0 within the arbitration group. Any non-zero channel within the arbitration group will continue to use fixed-priority arbitration, and if requesting service will be selected over any round-robin channels.

For fixed arbitration, the overall priority can be considered a number composed of three concatenated priority levels: CHn_GRPRI:CHn_PRI:CH_NUM. The largest number has the highest priority and the lowest number has the lowest priority.

For round-robin arbitration, the priority number is CHn_GRPRI:0:X. The module rotates through the CHn_PRI=0 channels requesting service without regard to priority among these channels. Any channel within the arbitration group for which CHn_PRI is greater than 0 will be serviced before the round-robin channels.

11.6.3 Programming errors

The eDMA performs various tests on the transfer control descriptor to verify consistency in the descriptor data.

The channel number causing the error is recorded in the Error Status register (CHn_ES). If the error source is not removed before the next activation of the problematic channel, the error is detected and recorded again. Setting the halt after error field, CSR[HAE], will halt the DMA and prevent recurrence of the error.

11.6.4 Arbitration mode considerations

This section discusses arbitration considerations for eDMA.

11.6.4.1 Fixed group arbitration, fixed channel arbitration

In this mode, eDMA selects for execution the channel service request from the highest-priority channel in the highest-priority group. If eDMA is programmed so that the channels within a high-priority group have a high number of requests or large data transfers, that group may consume all the bandwidth of the eDMA controller. That is, no lower-priority groups are serviced if there is always at least one DMA request pending on a channel in the highest-priority group when the controller arbitrates the next DMA request. The advantage of this scenario is that latency can be small for channels that need to be serviced quickly.

11.6.4.2 Fixed group arbitration, round-robin channel arbitration

The highest-priority group with a request is serviced. Lower-priority groups are serviced if no pending requests exist in the higher-priority groups.

Within each group, channels are serviced starting with the highest non-zero channel priority. For all channels with a channel priority programmed to 0, selection begins with the highest channel number requesting service and then rotates through to the lowest channel number requesting service. The round-robin channel arbitration can provide a fairness mechanism to lower-priority channels.

This scenario could cause the same bandwidth consumption problem as indicated in Fixed group arbitration, fixed channel arbitration, but all the channels in the highest-priority group will be serviced. Service latency is short on the highest-priority group, but could potentially be very much longer as the group priority decreases.

11.6.5 Performing DMA transfers

This section presents examples on how to perform DMA transfers with the eDMA.

11.6.5.1 Single request

To perform a simple transfer of n bytes of data with one activation, set the major loop to one (TCD*n*_CITER = TCD*n*_BITER = 1). The data transfer begins after the channel service request is acknowledged and the channel is selected to execute. After the transfer is complete, the CH*n*_CSR[DONE] field is set to 1 and an interrupt is generated if properly enabled.

For example, the following TCD entry is configured to transfer 16 bytes of data. The eDMA is programmed for one iteration of the major loop transferring 16 bytes per iteration. The source memory has a byte-wide memory port located at 0x1000. The destination memory has a 32-bit port located at 0x2000. The address offsets are programmed in increments to match the transfer size: one byte for the source, and four bytes for the destination. The final source and destination addresses are adjusted to return to their beginning values.

```
TCDn_CITER = TCDn_BITER = 1
TCDn_NBYTES = 16
TCDn_SADDR = 0x1000
TCDn_SOFF = 1
TCDn_ATTR[SSIZE] = 0
TCDn_SLAST = -16
TCDn_DADDR = 0x2000
TCDn_DOFF = 4
TCDn_ATTR[DSIZE] = 2
```

```
TCDn_DLAST_SGA= -16
TCDn_CSR[INTMAJ] = 1
TCDn_CSR[START] = 1 (should be written last after all other fields have been initialized)
All other TCDn fields = 0
```

This generates the following event sequence:

1. User write to the TCD*n*_CSR[START] field requests channel service.
2. The channel is selected by arbitration for servicing.
3. eDMA engine writes:
   - CH*n*_CSR[DONE] = 0
   - TCD*n*_CSR[START] = 0
   - CH*n*_CSR[ACTIVE] = 1
4. eDMA engine reads: channel TCD data from local memory to internal register file.
5. The source-to-destination transfers are executed as follows:
   a. Read byte from location 0x1000, read byte from location 0x1001, read byte from 0x1002, read byte from 0x1003.
   b. Write 32 bits to location 0x2000 → first iteration of the minor loop.
   c. Read byte from location 0x1004, read byte from location 0x1005, read byte from 0x1006, read byte from 0x1007.
   d. Write 32 bits to location 0x2004 → second iteration of the minor loop.
   e. Read byte from location 0x1008, read byte from location 0x1009, read byte from 0x100A, read byte from 0x100B.
   f. Write 32 bits to location 0x2008 → third iteration of the minor loop.
   g. Read byte from location 0x100C, read byte from location 0x100D, read byte from 0x100E, read byte from 0x100F.
   h. Write 32 bits to location 0x200C → last iteration of the minor loop → major loop complete.
6. The eDMA engine writes: TCD*n*_SADDR = 0x1000, TCD*n*_DADDR = 0x2000, TCD*n*_CITER = 1 (TCD*n*_BITER).
7. The eDMA engine writes: CH*n*_CSR[ACTIVE] = 0, CH*n*_CSR[DONE] = 1, CH*n*_INT[INT] = 1.
8. The channel retires and the eDMA goes idle or services the next channel.

11.6.5.2 Multiple requests

The following example transfers 32 bytes via two hardware requests, but is otherwise the same as the previous example. The only fields that change are the major loop iteration count and the final address offsets. The eDMA is programmed for two iterations of the major loop, transferring 16 bytes per iteration. After the channel's hardware requests are enabled via the CHn_CSR[ERQ] register field, the target device initiates channel service requests.

```
TCDn_CITER = TCDn_BITER = 2
TCDn_SLAST = -32
TCDn_DLAST_SGA = -32
```

This would generate the following sequence of events:

1. First hardware (eDMA peripheral) requests channel service.
2. The channel is selected by arbitration for servicing.
3. eDMA engine writes: CH*n*_CSR[DONE] = 0, TCD*n*_CSR[START] = 0, CH*n*_CSR[ACTIVE] = 1.
4. eDMA engine reads: channel TCD*n* data from local memory to internal register file.
5. The source-to-destination transfers are executed as follows:

a. Read byte from location 0x1000, read byte from location 0x1001, read byte from 0x1002, read byte from 0x1003.
b. Write 32 bits to location 0x2000 → first iteration of the minor loop.
c. Read byte from location 0x1004, read byte from location 0x1005, read byte from 0x1006, read byte from 0x1007.
d. Write 32 bits to location 0x2004 → second iteration of the minor loop.
e. Read byte from location 0x1008, read byte from location 0x1009, read byte from 0x100A, read byte from 0x100B.
f. Write 32 bits to location 0x2008 → third iteration of the minor loop.
g. Read byte from location 0x100C, read byte from location 0x100D, read byte from 0x100E, read byte from 0x100F.
h. Write 32 bits to location 0x200C → last iteration of the minor loop.

6. eDMA engine writes: TCD*n*_SADDR = 0x1010, TCD*n*_DADDR = 0x2010, TCD*n*_CITER = 1.
7. eDMA engine writes: CH*n*_CSR[ACTIVE] = 0.
8. The channel retires, which concludes one iteration of the major loop. The eDMA goes idle or services the next channel.
9. Second hardware (eDMA peripheral) requests channel service.
10. The channel is selected by arbitration for servicing.
11. eDMA engine writes: CH*n*_CSR[DONE] = 0, TCD*n*_CSR[START] = 0, CH*n*_CSR[ACTIVE] = 1.
12. eDMA engine reads: Channel TCD data from local memory to internal register file.
13. The source-to-destination transfers are executed as follows:
    a. Read byte from location 0x1010, read byte from location 0x1011, read byte from 0x1012, read byte from 0x1013.
    b. Write 32 bits to location 0x2010 → first iteration of the minor loop.
    c. Read byte from location 0x1014, read byte from location 0x1015, read byte from 0x1016, read byte from 0x1017.
    d. Write 32 bits to location 0x2014 → second iteration of the minor loop.
    e. Read byte from location 0x1018, read byte from location 0x1019, read byte from 0x101A, read byte from 0x101B.
    f. Write 32 bits to location 0x2018 → third iteration of the minor loop.
    g. Read byte from location 0x101C, read byte from location 0x101D, read byte from 0x101E, read byte from 0x101F.
    h. Write 32 bits to location 0x201C → last iteration of the minor loop → major loop complete.
14. eDMA engine writes: TCD*n*_SADDR = 0x1000, TCD*n*_DADDR = 0x2000, TCD*n*_CITER = 2 (TCD*n*_BITER).
15. eDMA engine writes: CH*n*_CSR[ACTIVE] = 0, CH*n*_CSR[DONE] = 1, CH*n*_INT[INT] = 1.
16. The channel retires, which concludes with the major loop complete. The eDMA goes idle or services the next channel.

11.6.5.3 Using the modulo feature

The modulo feature of the eDMA allows implementation of a circular data queue in which the size of the queue is a power of 2. xMOD is a 5-bit field for the source and destination in the TCD, and it specifies which lower address bits increment from their original value after the address+offset calculation. All upper address bits remain the same as in the original value. A setting of 0 for this field disables the modulo feature. Modulo addressing applies to cases where the minor loop offset is enabled; that is, the upper address bits remain the same after the minor loop offset is added to the source or destination address.

The following table shows how the transfer addresses are specified based on the setting of the MOD field. Here a circular buffer is created where the address wraps to the original value but the 28 upper address bits (0x1234567*x*) retain their original value. In this example, the source address is set to 0x12345670, the offset is set to four bytes, and the MOD field is set to four, which allows for a 2^4 byte (16 byte) queue size.

Table 57. Modulo example

Transfer number	Address
1	0x12345670
2	0x12345674
3	0x12345678
4	0x1234567C
5	0x12345670
6	0x12345674

11.6.6 Monitoring transfer descriptor status

This section discusses how to monitor eDMA status.

11.6.6.1 Testing for minor loop completion

There are two methods to test for minor loop completion when using software-initiated service requests.

1. The first method is to read the TCDn_CITER field and test for a change.
2. The second method, extracted from the sequence shown below, is to test the TCDn_CSR[START] field and the CHn_CSR[ACTIVE] field. The minor-loop-complete condition is indicated by both fields reading 0 after TCDn_CSR[START] is set to 1. Polling the CHn_CSR[ACTIVE] field only may be inconclusive because the active status may be missed if the channel execution is short in duration.

The CHn_CSR and TCDn_CSR status fields execute the following sequence for a software-activated channel:

Stage	TCDn_CSR field	CHn_CSR fields		State
	START	ACTIVE	DONE	
1	1	0	0	Initiate channel service request via software.
2	0	1	0	Channel is executing.
3a	0	0	0	Channel has completed the minor loop and is idle.
3b	0	0	1	Channel has completed the major loop and is idle.

The best method to test for minor-loop completion when using hardware-initiated (that is, peripheral-initiated) service requests is to read the TCDn_CITER field and test for a change. The hardware request and acknowledge handshake signals are not visible in the programmer's model.

The TCD status fields execute the following sequence for a hardware-activated channel:

Stage	TCDn_CSR field	CHn_CSR fields		State
	START	ACTIVE	DONE	
1	0	0	0	Initiate channel service request via hardware (peripheral request asserted).
2	0	1	0	Channel is executing.
3a	0	0	0	Channel has completed the minor loop and is idle.
3b	0	0	1	Channel has completed the major loop and is idle.

For both activation types, the major-loop-complete status is explicitly indicated via the CHn_CSR[DONE] field.

The TCDn_CSR[START] field is cleared to 0 automatically when the channel begins execution, regardless of how the channel activates.

11.6.6.2 Reading the transfer descriptors of active channels

The eDMA reads back the true TCDn_SADDR, TCDn_DADDR, and TCDn_NBYTES values if they are read when a channel executes. The true values of SADDR, DADDR, and NBYTES are the values the eDMA engine currently uses in its internal register file, and not the values in the TCD local memory for that channel. The addresses, SADDR and DADDR, and NBYTES (which decrements to zero as the transfer progresses), can give an indication of the progress of the transfer. All other values are read back from the TCD local memory.

11.6.6.3 Checking channel preemption status

A preemptive situation is one in which a preempt-enabled channel is executing and a higher-priority request becomes active. When round-robin channel arbitration mode is enabled, all channels with their channel priority set to 0 lose their preempt ability. Channel priorities of 0 are treated as equal, that is, they are constantly rotating, when round-robin arbitration mode is enabled.

The CHn_CSR[ACTIVE] field for the preempted channel remains asserted throughout the preemption. The preempted channel is temporarily suspended when the preempting channel executes one major loop iteration. If two CHn_CSR[ACTIVE] fields are set simultaneously in the global TCD map, a higher-priority channel is actively preempting a lower-priority channel.

11.6.7 Channel linking

Channel linking (or chaining) is a mechanism in which one channel sets the TCDn_CSR[START] field of another channel (or itself), thus initiating a service request for that channel. When properly enabled, the eDMA engine automatically performs this operation at the major or minor loop completion.

The minor loop channel linking occurs at the completion of the minor loop (or one iteration of the major loop). The TCDn_CITER[ELINK] field determines whether a minor loop link is requested. When enabled, the channel link is made after each iteration of the major loop except for the last. When the major loop is exhausted, only the major loop channel link fields are used to determine if a channel link should be made. For example, using an initial field setting of:

```
MP_CSR[GCLC] = 1
TCDn_CITER[ELINK] = 1
TCDn_CITER[LINKCH] = 0xC
TCDn_CITER[CITER] value = 0x4
TCDn_CSR[MAJORELINK] = 1
TCDn_CSR[MAJORLINKCH] = 0x7
```

executes as:

1. Minor loop done → set TCD12_CSR[START] field
2. Minor loop done → set TCD12_CSR[START] field
3. Minor loop done → set TCD12_CSR[START] field
4. Minor loop done, major loop done→ set TCD7_CSR[START] field

When minor loop linking is enabled (TCDn_CITER[ELINK] = 1), the TCDn_CITER[CITER] field uses a nine-bit vector to form the current iteration count. When minor loop linking is disabled (TCDn_CITER[ELINK] = 0), the TCDn_CITER[CITER] field uses a 15-bit vector to form the current iteration count. The bits associated with the TCDn_CITER[LINKCH] field are concatenated onto the CITER value to increase the range of the CITER.

NOTE

The TCDn_CITER[ELINK] field and the TCDn_BITER[ELINK] field must be equal — if they are not, a configuration error is reported. The CITER and BITER vector widths must be equal to calculate the major loop halfway done interrupt point.

The following table summarizes how a DMA channel can link to another DMA channel, that is, use another channel's TCD, at the end of a loop.

Table 58. Channel linking parameters

Wanted link behavior	TCD control field name	Description
Link at end of minor loop	TCDn_CITER[ELINK]	Enable channel-to-channel linking on minor loop completion (current iteration)
	TCDn_CITER[LINKCH]	Link channel number when linking at end of minor loop (current iteration)
Link at end of major loop	TCDn_CSR[MAJORELINK]	Enable channel-to-channel linking on major loop completion
	TCDn_CSR[MAJORLINKCH]	Link channel number when linking at end of major loop

11.6.8 Dynamic programming

This section provides recommended methods to change the programming model during channel execution.

Steps for channel linking:

1. Set GCLC = 1
2. For linking after major loop complete:
   a. Set MAJORLINKCH = target channel number
   b. Set MAJORELINK = 1, enable the major loop link
   c. Upon major loop completion (CITER decrements to 0), the link will be made.
3. For linking on minor loop completion:
   a. Set LINKCH = target channel number
   b. Set ELINK = 1, enable the minor loop link
   c. Set the beginning iteration count to the same values; LINKCH = target channel and ELINK = 1,
   d. Upon minor loop completion (that is, after each service request except when the major loop is complete) the link will be made.

11.6.8.1 Dynamically changing the channel priority

To change group or channel priority levels:

1. Halt the DMA by writing 1 to the CSR[HALT] field.
2. Change the group or channel priorities as wanted.
3. Enable normal DMA operations by writing 0 to the CSR[HALT] field.

11.6.8.2 Dynamic channel linking

Dynamic channel linking is the process of setting the TCDn_CSR[MAJORELINK] field during channel execution (see the diagram in TCD structure). This field is read from the TCD local memory at the end of channel execution, thus allowing you to enable the feature during channel execution.

Because you are allowed to change the configuration during execution, you need a coherency model. Consider the scenario where you attempt to execute a dynamic channel link by enabling the TCDn_CSR[MAJORELINK] field at the same time the eDMA engine is retiring the channel. TCDn_CSR[MAJORELINK] would be set in the programmer's model, but it would be unclear whether the actual link was made before the channel retired.

We recommend that you use the following coherency model when executing a dynamic channel link request.

1. Write 1 to the TCDn_CSR[MAJORELINK] field.
2. Read back the TCDn_CSR[MAJORELINK] field.
3. Test the TCDn_CSR[MAJORELINK] request status:
   - If TCDn_CSR[MAJORELINK] = 1, the dynamic link attempt was successful.
   - If TCDn_CSR[MAJORELINK] = 0, the attempted dynamic link did not succeed (the channel was already retiring).

For this request, the TCD local memory controller forces the TCDn_CSR[MAJORELINK] field to 0 on any writes to a channel's TCDn_CSR[7:0] after that channel's CHn_CSR[DONE] field is set to 1, indicating the major loop is complete.

NOTE

You must clear the CHn_CSR[DONE] field to 0 before writing to the TCDn_CSR[MAJORELINK] field. The CHn_CSR[DONE] field is cleared to 0 automatically by the eDMA engine after a channel begins execution.

11.6.8.3 Dynamic scatter/gather

Scatter/gather is the process of automatically loading a new TCD into a channel. It allows a DMA channel to use multiple TCDs; this enables a DMA channel to scatter the DMA data to multiple destinations or gather it from multiple sources. When scatter/gather is enabled and the channel has finished its major loop, a new TCD is fetched from system memory and loaded into that channel's descriptor location in the eDMA programmer's model, thus replacing the current descriptor.

Because you are allowed to change the configuration during execution, you need a coherency model. Consider the scenario where you attempt to execute a dynamic scatter/gather operation by enabling the TCDn_CSR[ESG] field at the same time the eDMA engine is retiring the channel. The TCDn_CSR[ESG] field would be set in the programmer's model, but it would be unclear whether the actual scatter/gather request was honored before the channel retired.

Two methods are recommended for executing a dynamic scatter/gather request. Whenever the TCDn_CSR is written, the TCD local memory controller forces the TCDn_CSR[ESG] field to 0 on any writes to a channel's TCDn_CSR[7:0] after that channel's CHn_CSR[DONE] field has been set to 1, indicating the major loop is complete. If attempting to set the ESG, ensure the DONE field is cleared to 0.

NOTE

You must clear the CHn_CSR[DONE] field to 0 before writing the TCDn_CSR[MAJORELINK] or TCDn_CSR[ESG] fields. The CHn_CSR[DONE] field is cleared to 0 automatically by the eDMA engine after a channel begins execution and is set to 1 upon major loop completion.

11.6.8.3.1 Method 1 (channel not using major loop channel linking)

For a channel not using major loop channel linking, the coherency model described here may be used for a dynamic scatter/gather request.

When the TCDn_CSR[MAJORELINK] field is 0, the TCDn_CSR[MAJORLINKCH] field is not used by the eDMA. In this case, the TCDn_CSR[MAJORLINKCH] bits may be used for other purposes. This method uses the TCDn_CSR[MAJORLINKCH] field as a TCDn_CSR identification (ID).

When the descriptors are built, write a unique TCDn_CSR ID in the TCDn_CSR[MAJORLINKCH] field for each TCDn_CSR associated with a channel using dynamic scatter/gather.

1. Write a 1 to the TCDn_CSR[DREQ] field. Should a dynamic scatter/gather attempt fail, setting the TCDn_CSR[DREQ] field to 1 will prevent future hardware activation of this channel. This stops the channel from executing with a destination address (daddr) that was calculated using a scatter/gather address (written in the next step) instead of a DLAST final offset value.
2. Write the TCDn_DLAST_SGA field with the scatter/gather address.
3. Write a 1 to the TCDn_CSR[ESG] field.
4. Read back the 16-bit TCDn_CSR control/status field.
5. Test the TCDn_CSR[ESG] request status and TCDn_CSR[MAJORLINKCH] value:
   - If ESG = 1, the dynamic scatter/gather attempt was successful.
   - If ESG = 0 and the MAJORLINKCH (ID) did not change, the dynamic scatter/gather attempt was not successful (the channel was already retiring).
   - If ESG = 0 and the MAJORLINKCH (ID) changed, the dynamic scatter/gather attempt was successful (the new TCDn_CSR's ESG value cleared the ESG field to 0).

11.6.8.3.2 Method 2 (channel using major loop channel linking)

For a channel using major loop channel linking, the coherency model described here may be used for a dynamic scatter/gather request. This method uses the TCDn_DLAST_SGA field as a TCD identification (ID).

1. Write a 1 to the TCDn_CSR[DREQ] field. Should a dynamic scatter/gather attempt fail, setting the DREQ field to 1 will prevent a future hardware activation of this channel. This stops the channel from executing with a destination address (DADDR) that was calculated using a scatter/gather address (written in the next step) instead of a DLAST final offset value.
2. Write the TCDn_DLAST_SGA field with the scatter/gather address.
3. Write a 1 to the TCDn_CSR[ESG] field.
4. Read back the TCDn_CSR[ESG] field.
5. Test the TCDn_CSR[ESG] request status:
   - If ESG = 1, the dynamic scatter/gather attempt was successful.
   - If ESG = 0, read the 32-bit TCDn_DLAST_SGA field.
   - If ESG = 0 and the TCDn_DLAST_SGA did not change, the dynamic scatter/gather attempt was not successful (the channel was already retiring).
   - If ESG = 0 and the TCDn_DLAST_SGA changed, the dynamic scatter/gather attempt was successful (the new TCDn_CSR's ESG value cleared the ESG field to 0).

11.6.9 Suspend/resume a DMA channel with active hardware service requests

The DMA allows you to move data from memory or peripheral registers to another location in memory or to peripheral registers without CPU interaction. After the DMA and peripherals are configured and active, it is rare but supported to suspend a peripheral's

service request dynamically. In this scenario, there are certain restrictions to disabling a DMA hardware service request. For coherency, you must follow a specific procedure.

11.6.9.1 Suspend an active DMA channel

To suspend an active DMA channel:

1. Stop the DMA service request at the peripheral first. Confirm it has been disabled by reading back the appropriate register in the peripheral.
2. Check the DMA's Hardware Request Status (MP_HRS) to ensure there is no service request to the DMA channel being suspended. Then disable the hardware service request by clearing the ERQ field to 0 on the appropriate DMA channel.

For example, assume the DSPI is set as a initiator for transmitting data via a DMA service request when the TXFIFO has an empty slot. The DMA will transfer the next command and data to the TXFIFO upon the request. If you need to suspend the DMA/DSPI transfer loop, perform the following steps:

1. Disable the DMA service request at the SPI.
2. Ensure there is no DMA service request from the DSPI by verifying that MP_HRS[HRS] is 0 for the appropriate channel. If no service request is present, disable the DMA channel by clearing the channel's ERQ field to 0. If a service request is present, wait until the request has been processed and the HRS field reads 0.

11.6.9.2 Resume a DMA channel

To resume a DMA channel:

1. Enable the DMA service request on the appropriate channel by setting its ERQ field to 1.
2. Enable the DMA service request at the peripheral.

Chapter 12
Miscellaneous System Control Module (MSCM)

12.1 Chip-specific MSCM information

Table 59. Reference links to related information

Topic	Related module	Reference
Full description	MSCM	MSCM
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

12.1.1 Module instances

This device has one instance of the MSCM module.

12.1.2 OCMDR1[OCMSZ]

This devices supports the following encoded values.

OCMEM Size. This read-only field provides an encoded value of the on-chip memory size.

0000b - no OCMEMn

0001b - 1KB OCMEMn

0010b - 2KB OCMEMn

0011b - 4KB OCMEMn

0100b - 8KB OCMEMn

0101b - 16KB OCMEMn

0110b - 32KB OCMEMn

0111b - 64KB OCMEMn

1000b - 96KB OCMEMn

1001b - 256KB OCMEMn

1010b - 512KB OCMEMn

1011b - 1MB OCMEMn

1100b - 2MB OCMEMn

1101b - 4MB OCMEMn

1110b - 8MB OCMEMn

1111b - 16MB OCMEMn

12.1.3 SID[FAMID]

This devices supports the following encoded values.

0001b- MCX W72

Others - Reserved

12.2 Overview

The Miscellaneous System Control Module (MSCM) contains CPU configuration registers and on-chip memory controller registers.

12.2.1 Block Diagram

The MSCM block diagram is shown below in Figure 21:

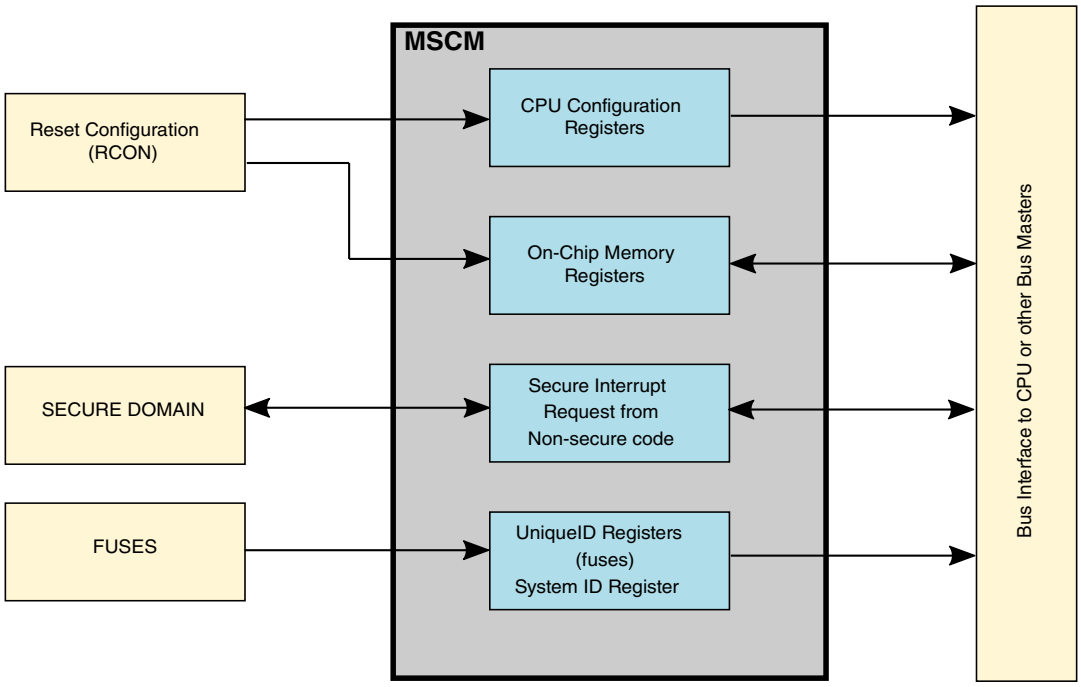


Figure 21. MSCM Block Diagram

12.2.2 Features

The MSCM has the following registers:

- Generic processor "x" configuration registers - These registers are only accessible by the main processor core
- Configuration registers containing information for processor 0 (main processor core) - These registers are accessible to any bus master
- On-Chip Memory Descriptor Registers - Provides static information about the attached memories. These registers are only accessible to the processor core or debugger
- Secure interrupt register - Provides a mechanism for non-secure code to generate a low latency pulsed exception into the secure privileged domain and can only be written in nonsecure mode
- Unique ID registers - Loaded directly from ECID fuse words
- System ID register - Loaded from IFR

12.3 Functional Description

12.3.1 Chip Configuration and Boot

The device's logical definition is controlled via chip-specific configuration bits, supported memory sizes and packing options. Collectively, these configuration bits define a reset configuration value (RCON).

Once the core has fetched the reset vector(s), core and system configuration information is read from a globally-accessible slave peripheral that properly converts the information into more appropriate values. More specifically, the core accesses configuration information from a common set of peripheral addresses and the chip configuration logic properly evaluates based on the requesting processor and returns the appropriate value for the given processor, including core identification.

As an example, there is a single 32-bit read-only location for the core identification. A 32-bit read from this location returns a 4-character ASCII string: 0x4D333301 .

The programming model associated with the core configuration information is included as part of the Miscellaneous System Control Module (MSCM). It specifically includes multiple views of the processor configuration; one view that is available generically to the core, and other views that are available to any bus masters in the system.

12.4 MSCM Memory Map/Register Definition

12.4.1 CPU Configuration Memory Map and Registers

The CPU configuration portion of the MSCM module provides a set of memory-mapped read-only addresses defining the processor set-up. This portion of the MSCM programming model can only be accessed with 32-bit read references; any other size is terminated with an error. If the processor is logically not included in the chip configuration, then reads of its configuration registers return zeroes.

The CPU Configuration registers are organized based on the logical processor number (not any type of physical port number) and partitioned into the following equal sections:

Table 60. CPU Configuration Register Sections

Offset addresses	Function
0x000 - 0x01F	Defines the generic processor "x" configuration. This region is only accessible to the processor core; reads by non-core bus masters are treated as read-as-zero (RAZ) accesses.
0x020 - 0x03F	Defines the configuration information for processor 0 (CP0). This region is accessible to any bus master.

12.4.2 MSCM register descriptions

12.4.2.1 MSCM memory map

MSCM base address: 4001_4000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Processor X Type Register (CPxTYPE)	32	R	See section
4h	Processor X Number Register (CPxNUM)	32	R	See section
8h	Processor X Master Register (CPxMASTER)	32	R	See section
Ch	Processor X Count Register (CPxCOUNT)	32	R	0000_0000h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
10h	Processor X Configuration Register 0 (CPxCFG0)	32	R	See section
14h	Processor X Configuration Register 1 (CPxCFG1)	32	R	See section
18h	Processor X Configuration Register 2 (CPxCFG2)	32	R	See section
1Ch	Processor X Configuration Register 3 (CPxCFG3)	32	R	See section
20h	Processor 0 Type Register (CP0TYPE)	32	R	4D33_3301h
24h	Processor 0 Number Register (CP0NUM)	32	R	0000_0000h
28h	Processor 0 Master Register (CP0MASTER)	32	R	0000_0000h
2Ch	Processor 0 Count Register (CP0COUNT)	32	R	0000_0000h
30h	Processor 0 Configuration Register 0 (CP0CFG0)	32	R	0508_0000h
34h	Processor 0 Configuration Register 1 (CP0CFG1)	32	R	0000_0000h
38h	Processor 0 Configuration Register 2 (CP0CFG2)	32	R	0001_0001h
3Ch	Processor 0 Configuration Register 3 (CP0CFG3)	32	R	0000_0231h
400h	On-Chip Memory Descriptor Register (OCMDR0)	32	R	EC08_9000h
404h	On-Chip Memory Descriptor Register (OCMDR1)	32	R	D804_7000h
408h	On-Chip Memory Descriptor Register (OCMDR2)	32	R	E504_1000h
40Ch	On-Chip Memory Descriptor Register (OCMDR3)	32	R	E704_1000h
410h	On-Chip Memory Descriptor Register (OCMDR4)	32	R	C504_1000h
414h	On-Chip Memory Descriptor Register (OCMDR5)	32	R	E404_1000h
418h	On-Chip Memory Descriptor Register (OCMDR6)	32	R	C704_1000h
800h	Secure Interrupt Request (SECURE_IRQ)	32	RW	0000_0000h
810h	Unique ID 0 (UID0)	32	R	See section
814h	Unique ID 1 (UID1)	32	R	See section
818h	Unique ID 2 (UID2)	32	R	See section
81Ch	Unique ID 3 (UID3)	32	R	See section
820h	System ID (SID)	32	R	See section

12.4.2.2 Processor X Type Register (CPxTYPE)

Offset

Register	Offset
CPxTYPE	0h

Function

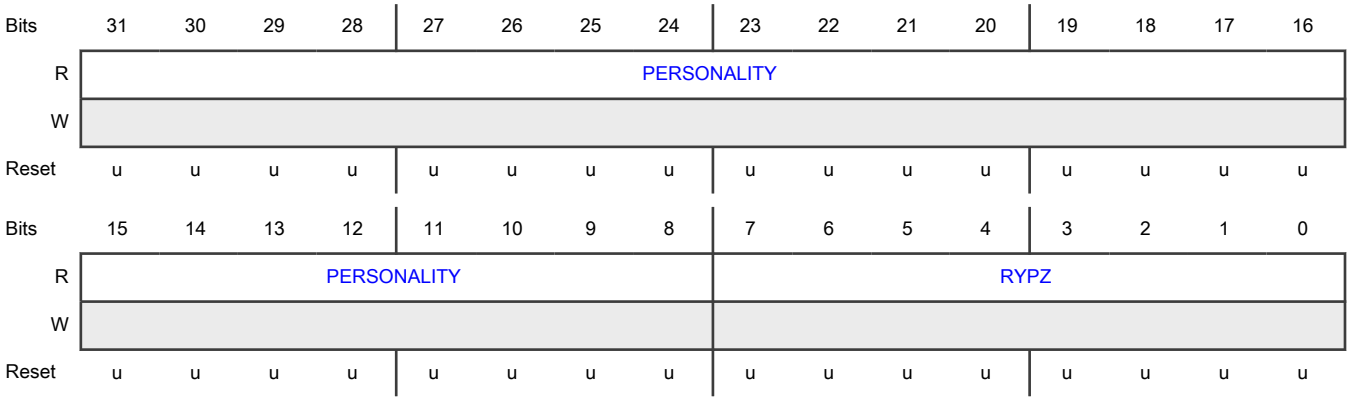
The register provides a CPU-specific response indicating the personality of the core making the access. The 32-bit response includes 3 ASCII characters that define the CPU type, along with a byte that defines the logical revision number. The logical revision number follows Arm's rYpZ nomenclature.

NOTE

CPxTYPE value(s) for this device:

- If CPU0 is making the access, then the value read is 0x4D333301
- If the read access is not from a CPU, then the value read is 0x00000000

Diagram



Fields

Field	Function
31-8 PERSONALITY	Processor x Personality This read-only field defines the processor personality for CPUx
7-0 RYPZ	Processor x Revision This read-only field defines the processor revision for CPUx: 0x00 corresponds to the r0p0 core release. 0x01 corresponds to the r0p1 core release. ...

12.4.2.3 Processor X Number Register (CPxNUM)

Offset

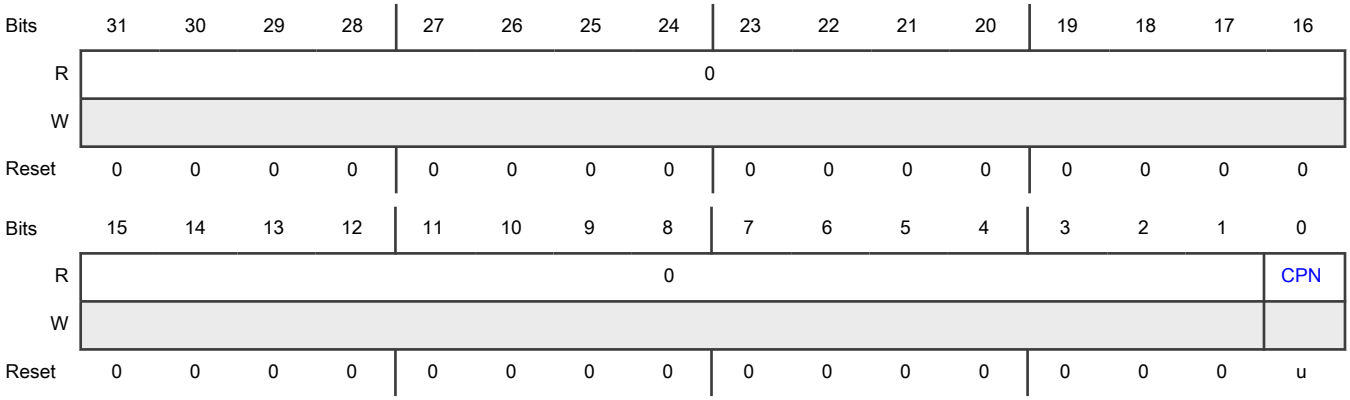
Register	Offset
CPxNUM	4h

Function

The register provides a CPU-specific response indicating the logical processor number of the core making the access. The logical processor number is always 0.

If the read access is not from a CPU, then the value read is 0x00000000.

Diagram



Fields

Field	Function
31-1 —	Reserved
0 CPN	Processor x Number This zero-filled word defines the logical processor number for CPUx If single core configuration, then CPN = 0

12.4.2.4 Processor X Master Register (CPxMASTER)

Offset

Register	Offset
CPxMASTER	8h

Function

The register provides a CPU-specific response indicating the physical bus master number of the core that is making the access. The 32-bit response defines the physical master number for processor x.

- CPxMASTER = 0x00000000

NOTE

A read from a CPU returns the appropriate processor information. Reads from a non-CPU bus master returns all zeroes. Write accesses are terminated with an error.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0										PPMN					
W																
Reset	0	0	0	0	0	0	0	0	0	0	u	u	u	u	u	u

Fields

Field	Function
31-6 —	Reserved
5-0 PPMN	Processor x Physical Master Number This read-only field defines the physical bus master number for CPUx. PPMN = 0x00

12.4.2.5 Processor X Count Register (CPxCOUNT)

Offset

Register	Offset
CPxCOUNT	Ch

Function

The register indicates the total number of processor cores in the chip configuration.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0														PCNT	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-2 —	Reserved
1-0 PCNT	Processor Count This read-only field defines the processor count for the chip configuration: PCNT = 00 (Single Core)

12.4.2.6 Processor X Configuration Register 0 (CPxCFG0)

Offset

Register	Offset
CPxCFG0	10h

Function

The CPxCFG0 register provides a CPU-specific response detailing configuration information, in this case, information on the Level 1 caches (if present).

NOTE

Reset values for the Processor X Configuration Register 0:

- For CPU0, the CPxCFG0 value read is 0x05080000
- If the read access is not from a CPU, then the value read is 0x00000000

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	ICSZ								ICWY							
W																
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	DCSZ								DCWY							
W																
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Fields

Field	Function
31-24 ICSZ	Level 1 Instruction Cache Size This read-only field provides an encoded value of the Instruction Cache size. The capacity of the memory is expressed as Size [bytes] = $2^{(9+ICSZ)}$, where ICSZ is non-zero; a ICSZ = 0 indicates the memory is not present. • if no Instruction Cache, then ICSZ = 0x00 • if a 1 Kbyte Instruction Cache, then ICSZ = 0x01 • if a 2 Kbyte Instruction Cache, then ICSZ = 0x02 • if a 4 Kbyte Instruction Cache, then ICSZ = 0x03 • if an 8 Kbyte Instruction Cache, then ICSZ = 0x04 • if a 16 Kbyte Instruction Cache, then ICSZ = 0x05 • if a 32 Kbyte Instruction Cache, then ICSZ = 0x06 • if a 64 Kbyte Instruction Cache, then ICSZ = 0x07 • if a 128 Kbyte Instruction Cache, then ICSZ = 0x08
23-16 ICWY	Level 1 Instruction Cache Ways This read-only field provides the number of cache ways for the Instruction Cache. ICWY=0x00 indicates not present.
15-8 DCSZ	Level 1 Data Cache Size This read-only field provides an encoded value of the Data Cache size. The capacity of the memory is expressed as Size [bytes] = $2^{(9+DCSZ)}$, where DCSZ is non-zero; a DCSZ = 0 indicates the memory is not present. • if no Data Cache, then DCSZ = 0x00 • if a 1 Kbyte Data Cache, then DCSZ = 0x01 • if a 2 Kbyte Data Cache, then DCSZ = 0x02 • if a 4 Kbyte Data Cache, then DCSZ = 0x03 • if an 8 Kbyte Data Cache, then DCSZ = 0x04 • if a 16 Kbyte Data Cache, then DCSZ = 0x05 • if a 32 Kbyte Data Cache, then DCSZ = 0x06 • if a 64 Kbyte Data Cache, then DCSZ = 0x07 • if a 128 Kbyte Data Cache, then DCSZ = 0x08
7-0 DCWY	Level 1 Data Cache Ways This read-only field provides the number of cache ways for the Data Cache. DCWY=0x00 indicates not present.

12.4.2.7 Processor X Configuration Register 1 (CPxCFG1)

Offset

Register	Offset
CPxCFG1	14h

Function

The CPxCFG1 register provides a CPU-specific response detailing configuration information, in this case, information on a Level 2 cache (if present).

NOTE

Reset values for the Processor X Configuration Register 1:

- For CPU0, the CPxCFG1 value read is 0x00000000
- If the read access is not from a CPU, then the value read is 0x00000000

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	L2SZ								L2WY							
W																
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 L2SZ	Level 2 Instruction Cache Size This read-only field provides an encoded value of the Instruction Cache size. The capacity of the memory is expressed as Size [bytes] = $2^{(9+L2SZ)}$, where L2SZ is non-zero; a L2SZ = 0 indicates the memory is not present. • if no Level 2 Cache, then L2SZ = 0x00 • if a 1 Kbyte Level 2 Cache, then L2SZ = 0x01 • if a 2 Kbyte Level 2 Cache, then L2SZ = 0x02 • if a 4 Kbyte Level 2 Cache, then L2SZ = 0x03 • if an 8 Kbyte Level 2 Cache, then L2SZ = 0x04 • if a 16 Kbyte Level 2 Cache, then L2SZ = 0x05

Table continues on the next page...

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Field	Function
	• if a 32 Kbyte Level 2 Cache, then L2SZ = 0x06 • if a 64 Kbyte Level 2 Cache, then L2SZ = 0x07 • if a 128 Kbyte Level 2 Cache, then L2SZ = 0x08
23-16 L2WY	Level 2 Instruction Cache Ways This read-only field provides the number of cache ways for the Instruction Cache. L2WY=0x00 indicates not present.
15-0 —	Reserved

12.4.2.8 Processor X Configuration Register 2 (CPxCFG2)

Offset

Register	Offset
CPxCFG2	18h

Function

The CPxCFG2 register provides a CPU-specific response detailing configuration information, in this case, information on tightly-coupled local memories (if present).

NOTE

Reset values for the Processor X Configuration Register 2:

- For CPU0, the CPxCFG2 value read is 0x00010001
- If the read access is not from a CPU, then the value read is 0x00000000

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	TMLSZ								Reserved							
W																
Reset	u	u	u	u	u	u	u	u	0	0	0	0	0	0	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	TMUSZ								Reserved							
W																
Reset	u	u	u	u	u	u	u	u	0	0	0	0	0	0	0	1

Fields

Field	Function
31-24 TMLSZ	Tightly-coupled Memory Lower Size This field provides an encoded value of the tightly-coupled local memory lower size. The capacity of the memory is expressed as Size [bytes] = $2^{(9+TMLSZ)}$, where TMLSZ is non-zero; a TMLSZ = 0 indicates the memory is not present. • if no TCML, then TMLSZ = 0x00 • if a 1 Kbyte TCML, then TMLSZ = 0x01 • if a 2 Kbyte TCML, then TMLSZ = 0x02 • if a 4 Kbyte TCML, then TMLSZ = 0x03 • if an 8 Kbyte TCML, then TMLSZ = 0x04 • if a 16 Kbyte TCML, then TMLSZ = 0x05 • if a 32 Kbyte TCML, then TMLSZ = 0x06 • if a 64 Kbyte TCML, then TMLSZ = 0x07 • if a 128 Kbyte TCML, then TMLSZ = 0x08 • if a 256 Kbyte TCML, then TMLSZ = 0x09
23-16 —	Reserved
15-8 TMUSZ	Tightly-coupled Memory Upper Size This field provides an encoded value of the tightly-coupled local memory upper size. The capacity of the memory is expressed as Size [bytes] = $2^{(9+TMUSZ)}$, where TMUSZ is non-zero; a TMUSZ = 0 indicates the memory is not present. • if no TCMU, then TMUSZ = 0x00 • if a 1 Kbyte TCMU, then TMUSZ = 0x01 • if a 2 Kbyte TCMU, then TMUSZ = 0x02 • if a 4 Kbyte TCMU, then TMUSZ = 0x03 • if an 8 Kbyte TCMU, then TMUSZ = 0x04 • if a 16 Kbyte TCMU, then TMUSZ = 0x05 • if a 32 Kbyte TCMU, then TMUSZ = 0x06 • if a 64 Kbyte TCMU, then TMUSZ = 0x07 • if a 128 Kbyte TCMU, then TMUSZ = 0x08 • if a 256 Kbyte TCMU, then TMUSZ = 0x09
7-0 —	Reserved

12.4.2.9 Processor X Configuration Register 3 (CPxCFG3)

Offset

Register	Offset
CPxCFG3	1Ch

Function

The CPxCFG3 register provides a CPU-specific response detailing configuration information, in this case, information on processor options.

Details regarding Arm core features, such as Trust Zone, Jazelle, SIMD/NEON, can be found in Arm documentation.

NOTE

Reset values for the Processor X Configuration Register 3:

- For CPU0, the CPxCFG3 value read is 0x00000231
- If the read access is not from a CPU, then the value read is 0x00000000

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0						SBP		0	BB	CMP	TZ	MMU	JAZ	SIMD	FPU
W																
Reset	0	0	0	0	0	0	u	u	0	u	u	u	u	u	u	u

Fields

Field	Function
31-10 —	Reserved
9-8 SBP	System Bus Ports This field defines the number of physical connections to the system bus fabric for this processor.
7 —	Reserved
6 BB	Bit Banding This field defines if the processor supports "bit banding".

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Bit Banding is not supported. 1b - Bit Banding is supported.
5 CMP	Core Memory Protection unit This field indicates if the core memory protection hardware is included in the processor. 0b - Core Memory Protection is not included. 1b - Core Memory Protection is included.
4 TZ	Trust Zone This field indicates if the Trust Zone capabilities are supported in the processor. 0b - Trust Zone support is not included. 1b - Trust Zone support is included.
3 MMU	Memory Management Unit Memory Management Unit. This field indicates if the virtual memory management capabilities are supported in the processor. 0b - MMU support is not included. 1b - MMU support is included.
2 JAZ	Jazelle support This field indicates if Jazelle hardware is supported in the processor. 0b - Jazelle support is not included. 1b - Jazelle support is included.
1 SIMD	SIMD/NEON instruction support This field indicates if the instruction set extensions supporting SIMD and/or NEON capabilities are supported in the processor. 0b - SIMD/NEON support is not included. 1b - SIMD/NEON support is included.
0 FPU	Floating Point Unit This field indicates if hardware support for floating point capabilities are supported in the processor. 0b - FPU support is not included. 1b - FPU support is included.

12.4.2.10 Processor 0 Type Register (CP0TYPE)

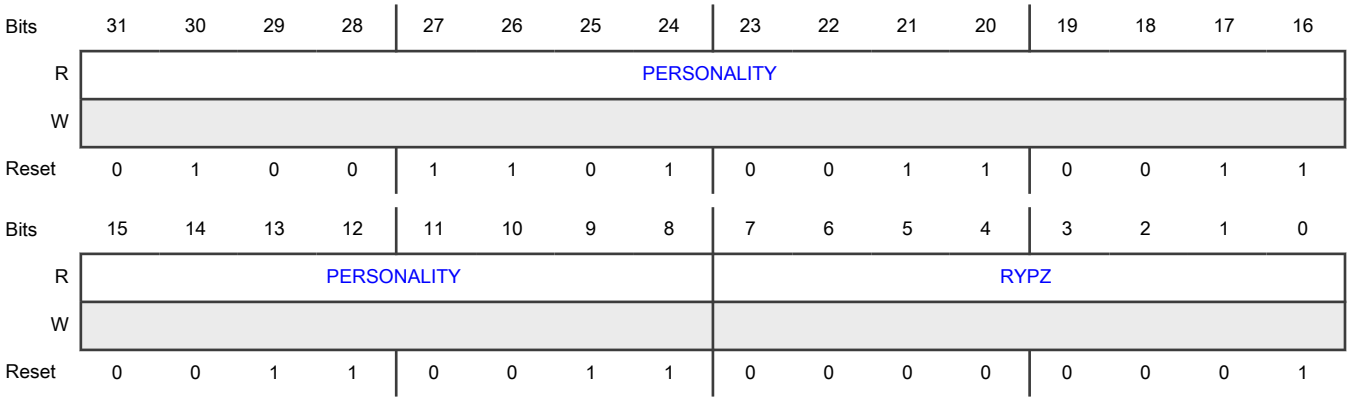
Offset

Register	Offset
CP0TYPE	20h

Function

The register provides the personality of Processor 0. The 32-bit response includes 3 ASCII characters defining the CPU type, along with a byte defining the logical revision number. The logical revision number follows Arm's rYpZ nomenclature.

Diagram



Fields

Field	Function
31-8 PERSONALITY	Processor 0 Personality This read-only field defines the processor personality for CP0
7-0 RYPZ	Processor 0 Revision This read-only field defines the processor revision for CPU0: 0x00 corresponds to the r0p0 core release. 0x01 corresponds to the r0p1 core release. ...

12.4.2.11 Processor 0 Number Register (CP0NUM)

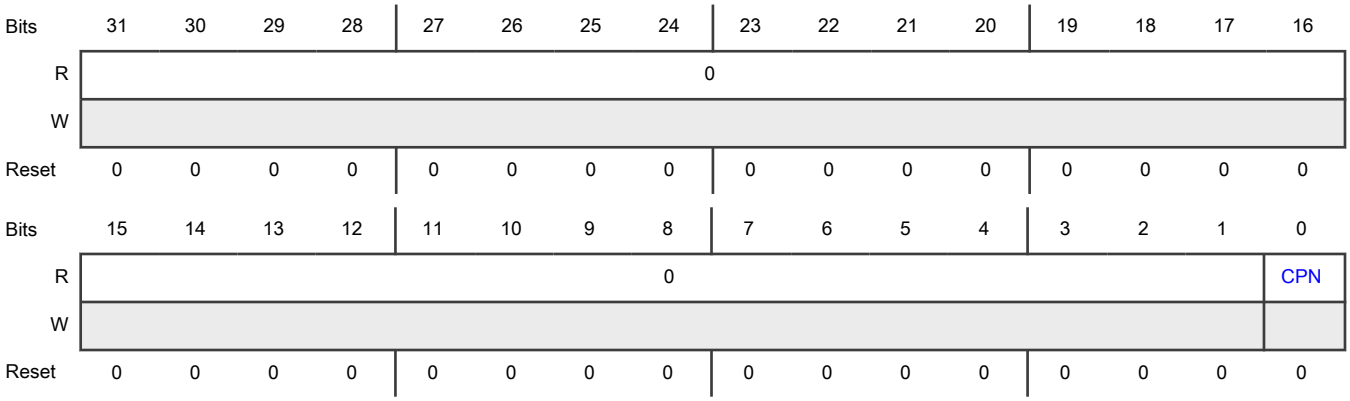
Offset

Register	Offset
CP0NUM	24h

Function

The register provides the logical processor number of Processor 0. The logical processor number is always 0.

Diagram



Fields

Field	Function
31-1 —	Reserved
0 CPN	Processor 0 Number This zero-filled word defines the logical processor number for CPU0 If single core configuration, then CPN = 0

12.4.2.12 Processor 0 Master Register (CP0MASTER)

Offset

Register	Offset
CP0MASTER	28h

Function

The register provides the physical bus master number of Processor 0.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0										PPMN					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-6 —	Reserved
5-0 PPMN	Processor 0 Physical Master Number This read-only field defines the physical bus master number for CPU0

12.4.2.13 Processor 0 Count Register (CP0COUNT)

Offset

Register	Offset
CP0COUNT	2Ch

Function

The register indicates the total number of processor cores in the chip configuration.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0														PCNT	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-2 —	Reserved
1-0 PCNT	Processor Count This read-only field defines the processor count for the chip configuration: PCNT = 00 (Single Core)

12.4.2.14 Processor 0 Configuration Register 0 (CP0CFG0)

Offset

Register	Offset
CP0CFG0	30h

Function

The CP0CFG0 register provides information on the CPU0 Level 1 caches (if present).

NOTE

Reset values for the Processor 0 Configuration Register 0:

- CP0CFG0 = 0x05080000

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	ICSZ								ICWY							
W																
Reset	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	DCSZ								DCWY							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 ICSZ	Level 1 Instruction Cache Size

Table continues on the next page...

Table continued from the previous page...

Field	Function
	This read-only field provides an encoded value of the Instruction Cache size. The capacity of the memory is expressed as Size [bytes] = $2^{(9+ICSZ)}$, where ICSZ is non-zero; a ICSZ = 0 indicates the memory is not present. • if no Instruction Cache, then ICSZ = 0x00 • if a 1 Kbyte Instruction Cache, then ICSZ = 0x01 • if a 2 Kbyte Instruction Cache, then ICSZ = 0x02 • if a 4 Kbyte Instruction Cache, then ICSZ = 0x03 • if an 8 Kbyte Instruction Cache, then ICSZ = 0x04 • if a 16 Kbyte Instruction Cache, then ICSZ = 0x05 • if a 32 Kbyte Instruction Cache, then ICSZ = 0x06 • if a 64 Kbyte Instruction Cache, then ICSZ = 0x07 • if a 128 Kbyte Instruction Cache, then ICSZ = 0x08
23-16 ICWY	Level 1 Instruction Cache Ways This read-only field provides the number of cache ways for the Instruction Cache. ICWY=0x00 indicates not present.
15-8 DCSZ	Level 1 Data Cache Size This read-only field provides an encoded value of the Data Cache size. The capacity of the memory is expressed as Size [bytes] = $2^{(9+DCSZ)}$, where DCSZ is non-zero; a DCSZ = 0 indicates the memory is not present. • if no Data Cache, then DCSZ = 0x00 • if a 1 Kbyte Data Cache, then DCSZ = 0x01 • if a 2 Kbyte Data Cache, then DCSZ = 0x02 • if a 4 Kbyte Data Cache, then DCSZ = 0x03 • if an 8 Kbyte Data Cache, then DCSZ = 0x04 • if a 16 Kbyte Data Cache, then DCSZ = 0x05 • if a 32 Kbyte Data Cache, then DCSZ = 0x06 • if a 64 Kbyte Data Cache, then DCSZ = 0x07 • if a 128 Kbyte Data Cache, then DCSZ = 0x08
7-0 DCWY	Level 1 Data Cache Ways This read-only field provides the number of cache ways for the Data Cache. DCWY=0x00 indicates not present.

12.4.2.15 Processor 0 Configuration Register 1 (CP0CFG1)

Offset

Register	Offset
CP0CFG1	34h

Function

The CP0CFG1 register provides information on CPU0 Level 2 cache (if present).

NOTE

Reset values for the Processor 0 Configuration Register 1:

- CP0CFG1 = 0x00000000

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	L2SZ								L2WY							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 L2SZ	Level 2 Instruction Cache Size This read-only field provides an encoded value of the Instruction Cache size. The capacity of the memory is expressed as Size [bytes] = $2^{(9+L2SZ)}$, where L2SZ is non-zero; a L2SZ = 0 indicates the memory is not present. • if no Level 2 Cache, then L2SZ = 0x00 • if a 1 Kbyte Level 2 Cache, then L2SZ = 0x01 • if a 2 Kbyte Level 2 Cache, then L2SZ = 0x02 • if a 4 Kbyte Level 2 Cache, then L2SZ = 0x03 • if an 8 Kbyte Level 2 Cache, then L2SZ = 0x04 • if a 16 Kbyte Level 2 Cache, then L2SZ = 0x05 • if a 32 Kbyte Level 2 Cache, then L2SZ = 0x06

Table continues on the next page...

Table continued from the previous page...

Field	Function
	• if a 64 Kbyte Level 2 Cache, then L2SZ = 0x07 • if a 128 Kbyte Level 2 Cache, then L2SZ = 0x08
23-16 L2WY	Level 2 Instruction Cache Ways This read-only field provides the number of cache ways for the Instruction Cache. L2WY=0x00 indicates not present.
15-0 —	Reserved

12.4.2.16 Processor 0 Configuration Register 2 (CP0CFG2)

Offset

Register	Offset
CP0CFG2	38h

Function

The CP0CFG2 register provides information on CPU0 tightly-coupled local memories (if present).

NOTE

Reset values for the Processor 0 Configuration Register 2:

- CP0CFG2 = 0x00010001

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	TMLSZ								Reserved							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	TMUSZ								Reserved							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Fields

Field	Function
31-24 TMLSZ	Tightly-coupled Memory Lower Size This field provides an encoded value of the tightly-coupled local memory lower size. The capacity of the memory is expressed as Size [bytes] = $2^{(9+TMLSZ)}$, where TMLSZ is non-zero; a TMLSZ = 0 indicates the memory is not present. • if no TCML, then TMLSZ = 0x00 • if a 1 Kbyte TCML, then TMLSZ = 0x01 • if a 2 Kbyte TCML, then TMLSZ = 0x02 • if a 4 Kbyte TCML, then TMLSZ = 0x03 • if an 8 Kbyte TCML, then TMLSZ = 0x04 • if a 16 Kbyte TCML, then TMLSZ = 0x05 • if a 32 Kbyte TCML, then TMLSZ = 0x06 • if a 64 Kbyte TCML, then TMLSZ = 0x07 • if a 128 Kbyte TCML, then TMLSZ = 0x08 • if a 256 Kbyte TCML, then TMLSZ = 0x09
23-16 —	Reserved
15-8 TMUSZ	Tightly-coupled Memory Upper Size This field provides an encoded value of the tightly-coupled local memory upper size. The capacity of the memory is expressed as Size [bytes] = $2^{(9+TMUSZ)}$, where TMUSZ is non-zero; a TMUSZ = 0 indicates the memory is not present. • if no TCMU, then TMUSZ = 0x00 • if a 1 Kbyte TCMU, then TMUSZ = 0x01 • if a 2 Kbyte TCMU, then TMUSZ = 0x02 • if a 4 Kbyte TCMU, then TMUSZ = 0x03 • if an 8 Kbyte TCMU, then TMUSZ = 0x04 • if a 16 Kbyte TCMU, then TMUSZ = 0x05 • if a 32 Kbyte TCMU, then TMUSZ = 0x06 • if a 64 Kbyte TCMU, then TMUSZ = 0x07 • if a 128 Kbyte TCMU, then TMUSZ = 0x08 • if a 256 Kbyte TCMU, then TMUSZ = 0x09
7-0 —	Reserved

12.4.2.17 Processor 0 Configuration Register 3 (CP0CFG3)

Offset

Register	Offset
CP0CFG3	3Ch

Function

The CP0CFG3 register provides information on Processor 0 options.

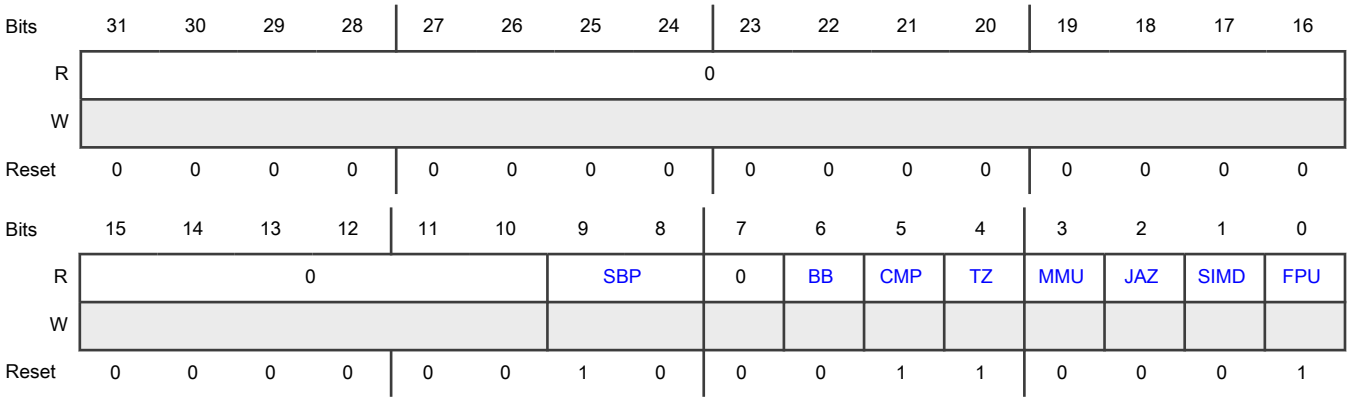
Details regarding Arm core features, such as Trust Zone, Jazelle, SIMD/NEON, can be found in Arm documentation.

NOTE

Reset values for the Processor 0 Configuration Register 3:

- CP0CFG3 = 0x00000231

Diagram



Fields

Field	Function
31-10 —	Reserved
9-8 SBP	System Bus Ports This field defines the number of physical connections to the system bus fabric for this processor.
7 —	Reserved
6 BB	Bit Banding This field defines if the processor supports "bit banding". 0b - Bit Banding is not supported.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Bit Banding is supported.
5 CMP	Core Memory Protection unit This field indicates if the core memory protection hardware is included in the processor. 0b - Core Memory Protection is not included. 1b - Core Memory Protection is included.
4 TZ	Trust Zone This field indicates if the Trust Zone capabilities are supported in the processor. 0b - Trust Zone support is not included. 1b - Trust Zone support is included.
3 MMU	Memory Management Unit Memory Management Unit. This field indicates if the virtual memory management capabilities are supported in the processor. 0b - MMU support is not included. 1b - MMU support is included.
2 JAZ	Jazelle support This field indicates if Jazelle hardware is supported in the processor. 0b - Jazelle support is not included. 1b - Jazelle support is included.
1 SIMD	SIMD/NEON instruction support This field indicates if the instruction set extensions supporting SIMD and/or NEON capabilities are supported in the processor. 0b - SIMD/NEON support is not included. 1b - SIMD/NEON support is included.
0 FPU	Floating Point Unit This field indicates if hardware support for floating point capabilities are supported in the processor. 0b - FPU support is not included. 1b - FPU support is included.

12.4.2.18 On-Chip Memory Descriptor Register (OCMDR0)

Offset

Register	Offset
OCMDR0	400h

Function

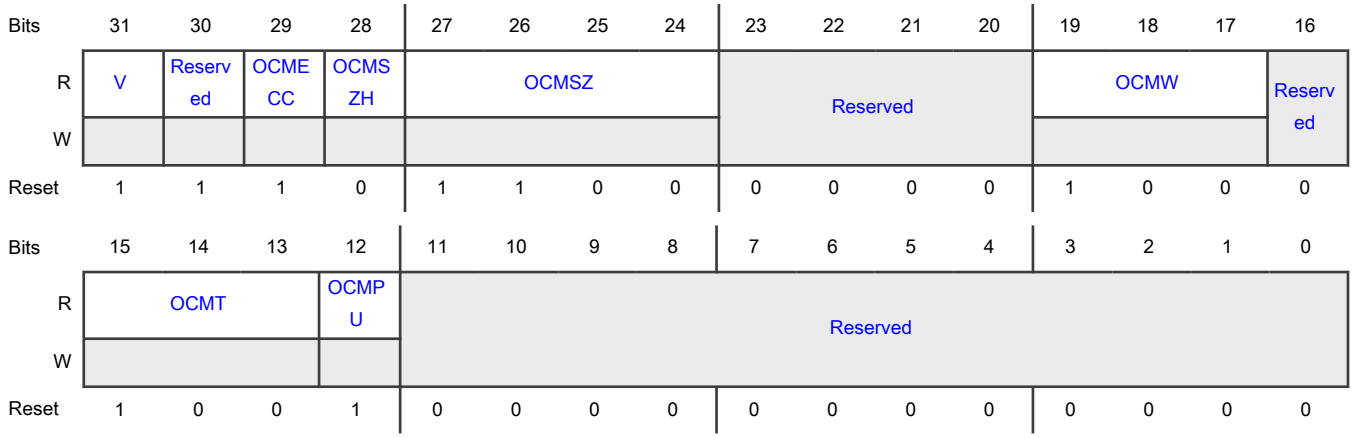
This section of the programming model is an array of 32-bit generic on-chip memory descriptor registers that provide static information about the attached memories, as well as configurable controls (where appropriate).

- The access permissions for this module are set in the TRDC.
- 32-bit reads from a processor core or the debugger return the appropriate processor information.
- Reads from any other bus master return all zeroes.
- Writes from a processor core or the debugger to writeable registers update the appropriate fields.
- Writes from other bus masters are ignored.
- Any access with a size other than 32 bits are terminated with an error.

The following table describes the OCMDRn reset values and the associated memory type:

OCMDRn	Reset Value	On-Chip Memory Type
OCMDR0	0xEC089000	Program Flash
OCMDR1	0xD8047000	ROM
OCMDR2	0xE5041000	System RAM
OCMDR3	0xE7041000	System RAM
OCMDR4	0xC5041000	System RAM
OCMDR5	0xE4041000	System RAM
OCMDR6	0xC7041000	System RAM

Diagram



Fields

Field	Function
31	V

Table continues on the next page...

Table continued from the previous page...

Field	Function
V	OCMEM Valid bit. This read-only field defines the validity (presence) of the on-chip memory 0b - OCMEMn is not present. 1b - OCMEMn is present.
30 —	FMT This Reserved field always has the value of 1.
29 OCMECC	OCMECC OCMEM has support for ECC. 0b - OCMEMn does not have ECC support. 1b - OCMEMn has ECC support.
28 OCMSZH	OCMSZH OCMEM Size “Hole”. For on-chip memories that are not fully populated, that is, include a memory “hole” in the upper 25% of the address range, this bit is used. 0b - OCMEMn is a power-of-2 capacity. 1b - OCMEMn is not a power-of-2, with a capacity is 0.75 * OCMSZ.
27-24 OCMSZ	OCMSZ OCMEM Size. This read-only field provides an encoded value of the on-chip memory size. 0000b - no OCMEMn 0001b - 1KB OCMEMn 0010b - 2KB OCMEMn 0011b - 4KB OCMEMn 0100b - 8KB OCMEMn 0101b - 16KB OCMEMn 0110b - 32KB OCMEMn 0111b - 64KB OCMEMn 1000b - 128KB OCMEMn 1001b - 256KB OCMEMn 1010b - 512KB OCMEMn 1011b - 1MB OCMEMn 1100b - 2MB OCMEMn 1101b - 4MB OCMEMn 1110b - 8MB OCMEMn 1111b - 16MB OCMEMn

Table continues on the next page...

Table continued from the previous page...

Field	Function
23-20 —	Reserved
19-17 OCMW	OCMW OCMEM datapath Width. This read-only field defines the width of the on-chip memory: 000b-001b - Reserved 010b - OCMEMn 32-bits wide 011b - OCMEMn 64-bits wide 100b - OCMEMn 128-bits wide 101b - OCMEMn 256-bits wide 110b-111b - Reserved
16 —	Reserved
15-13 OCMT	OCMT OCMEM Type. This field defines the type of the on-chip memory: 000b - OCMEMn is a System RAM. 001b - Reserved 010b - Reserved 011b - OCMEMn is a ROM. 100b - OCMEMn is a Program Flash. 101b - Reserved 110b - Reserved 111b - Reserved
12 OCMPU	OCMPU OCMEM Memory Protection Unit. This field is reserved for this device.
11-0 —	Reserved

12.4.2.19 On-Chip Memory Descriptor Register (OCMDR1)

Offset

Register	Offset
OCMDR1	404h

Function

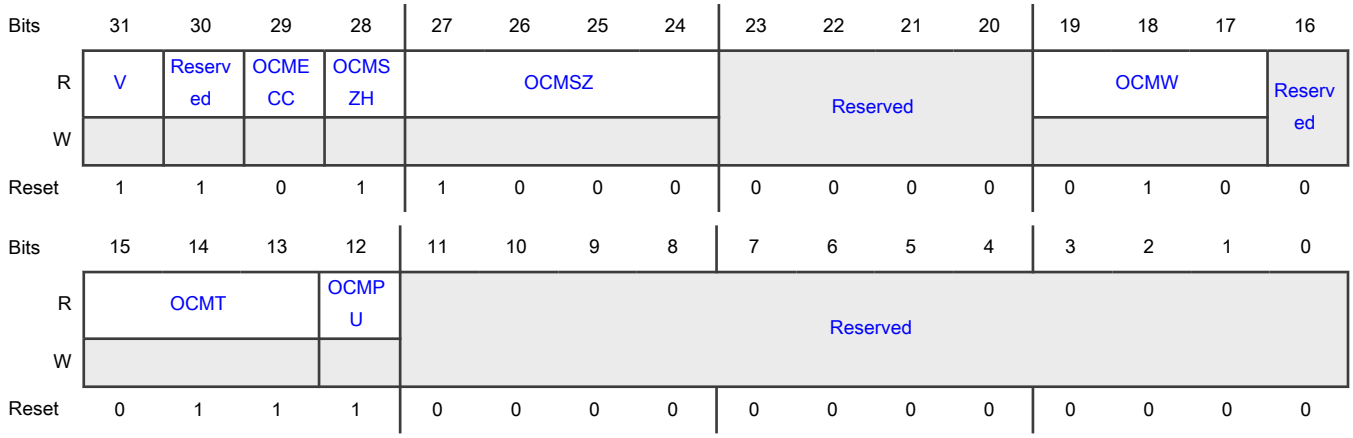
This section of the programming model is an array of 32-bit generic on-chip memory descriptor registers that provide static information about the attached memories, as well as configurable controls (where appropriate).

- The access permissions for this module are set in the TRDC.
- 32-bit reads from a processor core or the debugger return the appropriate processor information.
- Reads from any other bus master return all zeroes.
- Writes from a processor core or the debugger to writeable registers update the appropriate fields.
- Writes from other bus masters are ignored.
- Any access with a size other than 32 bits are terminated with an error.

The following table describes the OCMDRn reset values and the associated memory type:

OCMDRn	Reset Value	On-Chip Memory Type
OCMDR0	0xEC089000	Program Flash
OCMDR1	0xD8047000	ROM
OCMDR2	0xE5041000	System RAM
OCMDR3	0xE7041000	System RAM
OCMDR4	0xC5041000	System RAM
OCMDR5	0xE4041000	System RAM
OCMDR6	0xC7041000	System RAM

Diagram



Fields

Field	Function
31	V

Table continues on the next page...

Table continued from the previous page...

Field	Function
V	OCMEM Valid bit. This read-only field defines the validity (presence) of the on-chip memory 0b - OCMEMn is not present. 1b - OCMEMn is present.
30 —	FMT This Reserved field always has the value of 1.
29 OCMECC	OCMECC OCMEM has support for ECC. 0b - OCMEMn does not have ECC support. 1b - OCMEMn has ECC support.
28 OCMSZH	OCMSZH OCMEM Size “Hole”. For on-chip memories that are not fully populated, that is, include a memory “hole” in the upper 25% of the address range, this bit is used. 0b - OCMEMn is a power-of-2 capacity. 1b - OCMEMn is not a power-of-2, with a capacity is 0.75 * OCMSZ.
27-24 OCMSZ	OCMSZ OCMEM Size. This read-only field provides an encoded value of the on-chip memory size. 0000b - no OCMEMn 0001b - 1KB OCMEMn 0010b - 2KB OCMEMn 0011b - 4KB OCMEMn 0100b - 8KB OCMEMn 0101b - 16KB OCMEMn 0110b - 32KB OCMEMn 0111b - 64KB OCMEMn 1000b - 128KB OCMEMn 1001b - 256KB OCMEMn 1010b - 512KB OCMEMn 1011b - 1MB OCMEMn 1100b - 2MB OCMEMn 1101b - 4MB OCMEMn 1110b - 8MB OCMEMn 1111b - 16MB OCMEMn

Table continues on the next page...

Table continued from the previous page...

Field	Function
23-20 —	Reserved
19-17 OCMW	OCMW OCMEM datapath Width. This read-only field defines the width of the on-chip memory: 000b-001b - Reserved 010b - OCMEMn 32-bits wide 011b - OCMEMn 64-bits wide 100b - OCMEMn 128-bits wide 101b - OCMEMn 256-bits wide 110b-111b - Reserved
16 —	Reserved
15-13 OCMT	OCMT OCMEM Type. This field defines the type of the on-chip memory: 000b - OCMEMn is a System RAM. 001b - Reserved 010b - Reserved 011b - OCMEMn is a ROM. 100b - OCMEMn is a Program Flash. 101b - Reserved 110b - Reserved 111b - Reserved
12 OCMPU	OCMPU OCMEM Memory Protection Unit. This field is reserved for this device.
11-0 —	Reserved

12.4.2.20 On-Chip Memory Descriptor Register (OCMDR2)

Offset

Register	Offset
OCMDR2	408h

Function

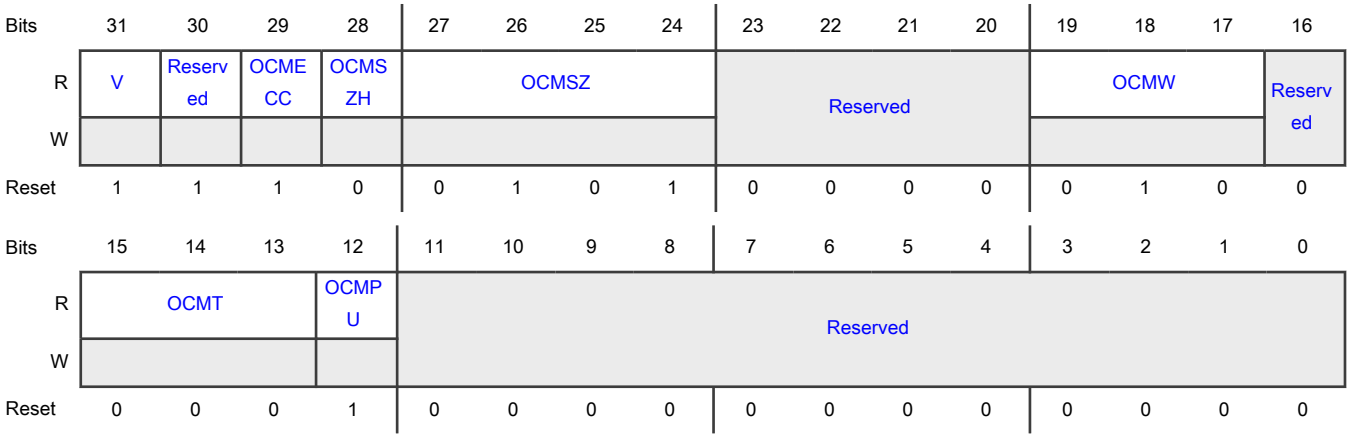
This section of the programming model is an array of 32-bit generic on-chip memory descriptor registers that provide static information about the attached memories, as well as configurable controls (where appropriate).

- The access permissions for this module are set in the TRDC.
- 32-bit reads from a processor core or the debugger return the appropriate processor information.
- Reads from any other bus master return all zeroes.
- Writes from a processor core or the debugger to writeable registers update the appropriate fields.
- Writes from other bus masters are ignored.
- Any access with a size other than 32 bits are terminated with an error.

The following table describes the OCMDRn reset values and the associated memory type:

OCMDRn	Reset Value	On-Chip Memory Type
OCMDR0	0xEC089000	Program Flash
OCMDR1	0xD8047000	ROM
OCMDR2	0xE5041000	System RAM
OCMDR3	0xE7041000	System RAM
OCMDR4	0xC5041000	System RAM
OCMDR5	0xE4041000	System RAM
OCMDR6	0xC7041000	System RAM

Diagram



Fields

Field	Function
31	V

Table continues on the next page...

Table continued from the previous page...

Field	Function
V	OCMEM Valid bit. This read-only field defines the validity (presence) of the on-chip memory 0b - OCMEMn is not present. 1b - OCMEMn is present.
30 —	FMT This Reserved field always has the value of 1.
29 OCMECC	OCMECC OCMEM has support for ECC. 0b - OCMEMn does not have ECC support. 1b - OCMEMn has ECC support.
28 OCMSZH	OCMSZH OCMEM Size “Hole”. For on-chip memories that are not fully populated, that is, include a memory “hole” in the upper 25% of the address range, this bit is used. 0b - OCMEMn is a power-of-2 capacity. 1b - OCMEMn is not a power-of-2, with a capacity is 0.75 * OCMSZ.
27-24 OCMSZ	OCMSZ OCMEM Size. This read-only field provides an encoded value of the on-chip memory size. 0000b - no OCMEMn 0001b - 1KB OCMEMn 0010b - 2KB OCMEMn 0011b - 4KB OCMEMn 0100b - 8KB OCMEMn 0101b - 16KB OCMEMn 0110b - 32KB OCMEMn 0111b - 64KB OCMEMn 1000b - 128KB OCMEMn 1001b - 256KB OCMEMn 1010b - 512KB OCMEMn 1011b - 1MB OCMEMn 1100b - 2MB OCMEMn 1101b - 4MB OCMEMn 1110b - 8MB OCMEMn 1111b - 16MB OCMEMn

Table continues on the next page...

Table continued from the previous page...

Field	Function
23-20 —	Reserved
19-17 OCMW	OCMW OCMEM datapath Width. This read-only field defines the width of the on-chip memory: 000b-001b - Reserved 010b - OCMEMn 32-bits wide 011b - OCMEMn 64-bits wide 100b - OCMEMn 128-bits wide 101b - OCMEMn 256-bits wide 110b-111b - Reserved
16 —	Reserved
15-13 OCMT	OCMT OCMEM Type. This field defines the type of the on-chip memory: 000b - OCMEMn is a System RAM. 001b - Reserved 010b - Reserved 011b - OCMEMn is a ROM. 100b - OCMEMn is a Program Flash. 101b - Reserved 110b - Reserved 111b - Reserved
12 OCMPU	OCMPU OCMEM Memory Protection Unit. This field is reserved for this device.
11-0 —	Reserved

12.4.2.21 On-Chip Memory Descriptor Register (OCMDR3)

Offset

Register	Offset
OCMDR3	40Ch

Function

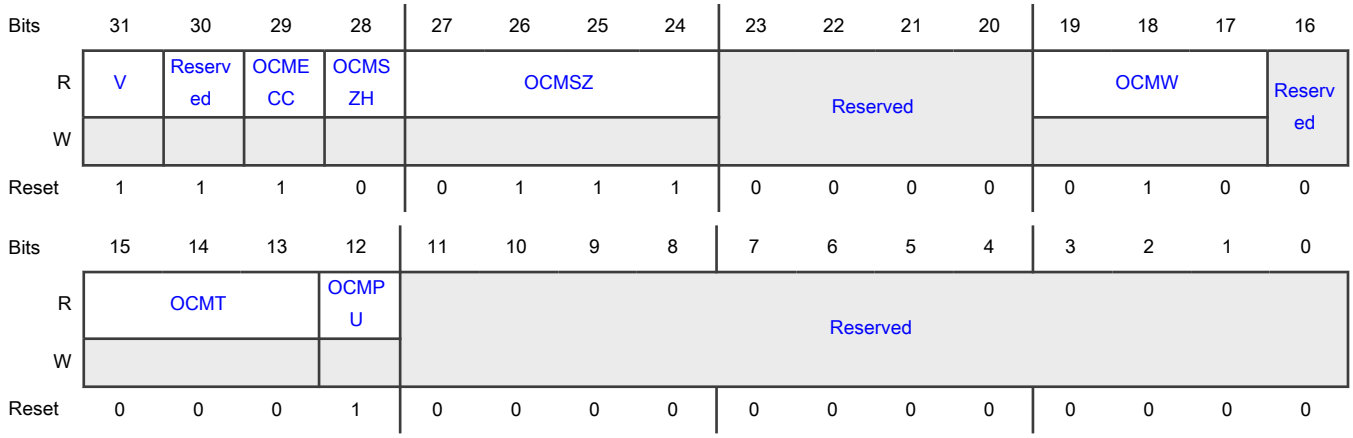
This section of the programming model is an array of 32-bit generic on-chip memory descriptor registers that provide static information about the attached memories, as well as configurable controls (where appropriate).

- The access permissions for this module are set in the TRDC.
- 32-bit reads from a processor core or the debugger return the appropriate processor information.
- Reads from any other bus master return all zeroes.
- Writes from a processor core or the debugger to writeable registers update the appropriate fields.
- Writes from other bus masters are ignored.
- Any access with a size other than 32 bits are terminated with an error.

The following table describes the OCMDRn reset values and the associated memory type:

OCMDRn	Reset Value	On-Chip Memory Type
OCMDR0	0xEC089000	Program Flash
OCMDR1	0xD8047000	ROM
OCMDR2	0xE5041000	System RAM
OCMDR3	0xE7041000	System RAM
OCMDR4	0xC5041000	System RAM
OCMDR5	0xE4041000	System RAM
OCMDR6	0xC7041000	System RAM

Diagram



Fields

Field	Function
31	V

Table continues on the next page...

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Field	Function
V	OCMEM Valid bit. This read-only field defines the validity (presence) of the on-chip memory 0b - OCMEMn is not present. 1b - OCMEMn is present.
30 —	FMT This Reserved field always has the value of 1.
29 OCMECC	OCMECC OCMEM has support for ECC. 0b - OCMEMn does not have ECC support. 1b - OCMEMn has ECC support.
28 OCMSZH	OCMSZH OCMEM Size “Hole”. For on-chip memories that are not fully populated, that is, include a memory “hole” in the upper 25% of the address range, this bit is used. 0b - OCMEMn is a power-of-2 capacity. 1b - OCMEMn is not a power-of-2, with a capacity is 0.75 * OCMSZ.
27-24 OCMSZ	OCMSZ OCMEM Size. This read-only field provides an encoded value of the on-chip memory size. 0000b - no OCMEMn 0001b - 1KB OCMEMn 0010b - 2KB OCMEMn 0011b - 4KB OCMEMn 0100b - 8KB OCMEMn 0101b - 16KB OCMEMn 0110b - 32KB OCMEMn 0111b - 64KB OCMEMn 1000b - 128KB OCMEMn 1001b - 256KB OCMEMn 1010b - 512KB OCMEMn 1011b - 1MB OCMEMn 1100b - 2MB OCMEMn 1101b - 4MB OCMEMn 1110b - 8MB OCMEMn 1111b - 16MB OCMEMn

Table continues on the next page...

Table continued from the previous page...

Field	Function
23-20 —	Reserved
19-17 OCMW	OCMW OCMEM datapath Width. This read-only field defines the width of the on-chip memory: 000b-001b - Reserved 010b - OCMEMn 32-bits wide 011b - OCMEMn 64-bits wide 100b - OCMEMn 128-bits wide 101b - OCMEMn 256-bits wide 110b-111b - Reserved
16 —	Reserved
15-13 OCMT	OCMT OCMEM Type. This field defines the type of the on-chip memory: 000b - OCMEMn is a System RAM. 001b - Reserved 010b - Reserved 011b - OCMEMn is a ROM. 100b - OCMEMn is a Program Flash. 101b - Reserved 110b - Reserved 111b - Reserved
12 OCMPU	OCMPU OCMEM Memory Protection Unit. This field is reserved for this device.
11-0 —	Reserved

12.4.2.22 On-Chip Memory Descriptor Register (OCMDR4)

Offset

Register	Offset
OCMDR4	410h

Function

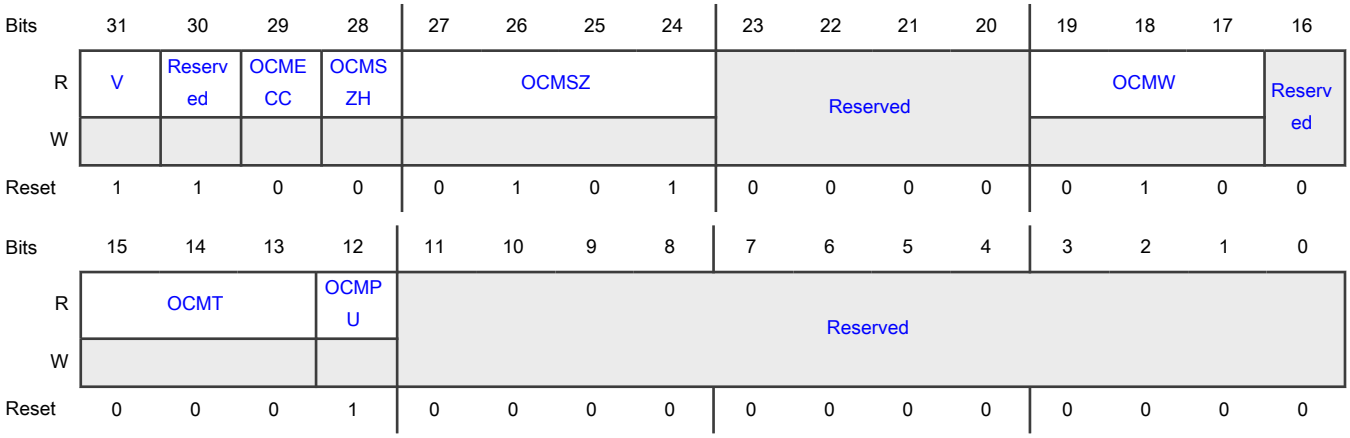
This section of the programming model is an array of 32-bit generic on-chip memory descriptor registers that provide static information about the attached memories, as well as configurable controls (where appropriate).

- The access permissions for this module are set in the TRDC.
- 32-bit reads from a processor core or the debugger return the appropriate processor information.
- Reads from any other bus master return all zeroes.
- Writes from a processor core or the debugger to writeable registers update the appropriate fields.
- Writes from other bus masters are ignored.
- Any access with a size other than 32 bits are terminated with an error.

The following table describes the OCMDRn reset values and the associated memory type:

OCMDRn	Reset Value	On-Chip Memory Type
OCMDR0	0xEC089000	Program Flash
OCMDR1	0xD8047000	ROM
OCMDR2	0xE5041000	System RAM
OCMDR3	0xE7041000	System RAM
OCMDR4	0xC5041000	System RAM
OCMDR5	0xE4041000	System RAM
OCMDR6	0xC7041000	System RAM

Diagram



Fields

Field	Function
31	V

Table continues on the next page...

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Field	Function
V	OCMEM Valid bit. This read-only field defines the validity (presence) of the on-chip memory 0b - OCMEMn is not present. 1b - OCMEMn is present.
30 —	FMT This Reserved field always has the value of 1.
29 OCMECC	OCMECC OCMEM has support for ECC. 0b - OCMEMn does not have ECC support. 1b - OCMEMn has ECC support.
28 OCMSZH	OCMSZH OCMEM Size “Hole”. For on-chip memories that are not fully populated, that is, include a memory “hole” in the upper 25% of the address range, this bit is used. 0b - OCMEMn is a power-of-2 capacity. 1b - OCMEMn is not a power-of-2, with a capacity is 0.75 * OCMSZ.
27-24 OCMSZ	OCMSZ OCMEM Size. This read-only field provides an encoded value of the on-chip memory size. 0000b - no OCMEMn 0001b - 1KB OCMEMn 0010b - 2KB OCMEMn 0011b - 4KB OCMEMn 0100b - 8KB OCMEMn 0101b - 16KB OCMEMn 0110b - 32KB OCMEMn 0111b - 64KB OCMEMn 1000b - 128KB OCMEMn 1001b - 256KB OCMEMn 1010b - 512KB OCMEMn 1011b - 1MB OCMEMn 1100b - 2MB OCMEMn 1101b - 4MB OCMEMn 1110b - 8MB OCMEMn 1111b - 16MB OCMEMn

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Field	Function
23-20 —	Reserved
19-17 OCMW	OCMW OCMEM datapath Width. This read-only field defines the width of the on-chip memory: 000b-001b - Reserved 010b - OCMEMn 32-bits wide 011b - OCMEMn 64-bits wide 100b - OCMEMn 128-bits wide 101b - OCMEMn 256-bits wide 110b-111b - Reserved
16 —	Reserved
15-13 OCMT	OCMT OCMEM Type. This field defines the type of the on-chip memory: 000b - OCMEMn is a System RAM. 001b - Reserved 010b - Reserved 011b - OCMEMn is a ROM. 100b - OCMEMn is a Program Flash. 101b - Reserved 110b - Reserved 111b - Reserved
12 OCMPU	OCMPU OCMEM Memory Protection Unit. This field is reserved for this device.
11-0 —	Reserved

12.4.2.23 On-Chip Memory Descriptor Register (OCMDR5)

Offset

Register	Offset
OCMDR5	414h

Function

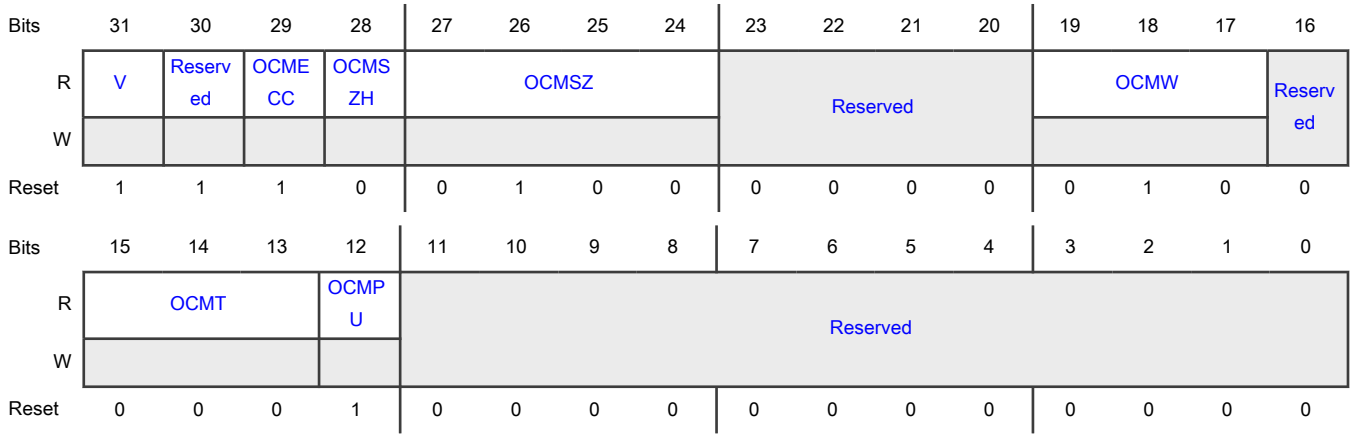
This section of the programming model is an array of 32-bit generic on-chip memory descriptor registers that provide static information about the attached memories, as well as configurable controls (where appropriate).

- The access permissions for this module are set in the TRDC.
- 32-bit reads from a processor core or the debugger return the appropriate processor information.
- Reads from any other bus master return all zeroes.
- Writes from a processor core or the debugger to writeable registers update the appropriate fields.
- Writes from other bus masters are ignored.
- Any access with a size other than 32 bits are terminated with an error.

The following table describes the OCMDRn reset values and the associated memory type:

OCMDRn	Reset Value	On-Chip Memory Type
OCMDR0	0xEC089000	Program Flash
OCMDR1	0xD8047000	ROM
OCMDR2	0xE5041000	System RAM
OCMDR3	0xE7041000	System RAM
OCMDR4	0xC5041000	System RAM
OCMDR5	0xE4041000	System RAM
OCMDR6	0xC7041000	System RAM

Diagram



Fields

Field	Function
31	V

Table continues on the next page...

Table continued from the previous page...

Field	Function
V	OCMEM Valid bit. This read-only field defines the validity (presence) of the on-chip memory 0b - OCMEMn is not present. 1b - OCMEMn is present.
30 —	FMT This Reserved field always has the value of 1.
29 OCMECC	OCMECC OCMEM has support for ECC. 0b - OCMEMn does not have ECC support. 1b - OCMEMn has ECC support.
28 OCMSZH	OCMSZH OCMEM Size “Hole”. For on-chip memories that are not fully populated, that is, include a memory “hole” in the upper 25% of the address range, this bit is used. 0b - OCMEMn is a power-of-2 capacity. 1b - OCMEMn is not a power-of-2, with a capacity is 0.75 * OCMSZ.
27-24 OCMSZ	OCMSZ OCMEM Size. This read-only field provides an encoded value of the on-chip memory size. 0000b - no OCMEMn 0001b - 1KB OCMEMn 0010b - 2KB OCMEMn 0011b - 4KB OCMEMn 0100b - 8KB OCMEMn 0101b - 16KB OCMEMn 0110b - 32KB OCMEMn 0111b - 64KB OCMEMn 1000b - 128KB OCMEMn 1001b - 256KB OCMEMn 1010b - 512KB OCMEMn 1011b - 1MB OCMEMn 1100b - 2MB OCMEMn 1101b - 4MB OCMEMn 1110b - 8MB OCMEMn 1111b - 16MB OCMEMn

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Field	Function
23-20 —	Reserved
19-17 OCMW	OCMW OCMEM datapath Width. This read-only field defines the width of the on-chip memory: 000b-001b - Reserved 010b - OCMEMn 32-bits wide 011b - OCMEMn 64-bits wide 100b - OCMEMn 128-bits wide 101b - OCMEMn 256-bits wide 110b-111b - Reserved
16 —	Reserved
15-13 OCMT	OCMT OCMEM Type. This field defines the type of the on-chip memory: 000b - OCMEMn is a System RAM. 001b - Reserved 010b - Reserved 011b - OCMEMn is a ROM. 100b - OCMEMn is a Program Flash. 101b - Reserved 110b - Reserved 111b - Reserved
12 OCMPU	OCMPU OCMEM Memory Protection Unit. This field is reserved for this device.
11-0 —	Reserved

12.4.2.24 On-Chip Memory Descriptor Register (OCMDR6)

Offset

Register	Offset
OCMDR6	418h

Function

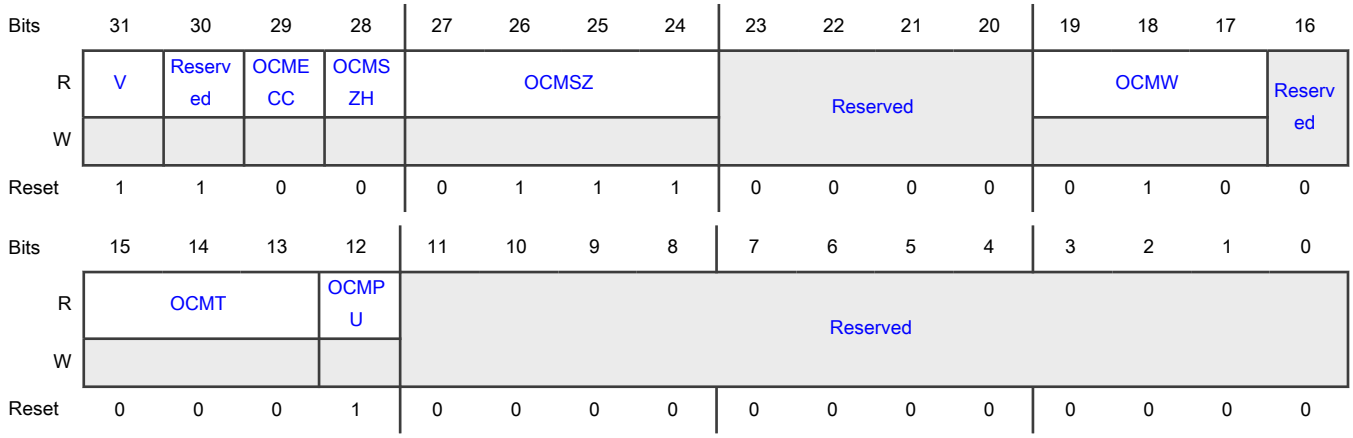
This section of the programming model is an array of 32-bit generic on-chip memory descriptor registers that provide static information about the attached memories, as well as configurable controls (where appropriate).

- The access permissions for this module are set in the TRDC.
- 32-bit reads from a processor core or the debugger return the appropriate processor information.
- Reads from any other bus master return all zeroes.
- Writes from a processor core or the debugger to writeable registers update the appropriate fields.
- Writes from other bus masters are ignored.
- Any access with a size other than 32 bits are terminated with an error.

The following table describes the OCMDRn reset values and the associated memory type:

OCMDRn	Reset Value	On-Chip Memory Type
OCMDR0	0xEC089000	Program Flash
OCMDR1	0xD8047000	ROM
OCMDR2	0xE5041000	System RAM
OCMDR3	0xE7041000	System RAM
OCMDR4	0xC5041000	System RAM
OCMDR5	0xE4041000	System RAM
OCMDR6	0xC7041000	System RAM

Diagram



Fields

Field	Function
31	V

Table continues on the next page...

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Field	Function
V	OCMEM Valid bit. This read-only field defines the validity (presence) of the on-chip memory 0b - OCMEMn is not present. 1b - OCMEMn is present.
30 —	FMT This Reserved field always has the value of 1.
29 OCMECC	OCMECC OCMEM has support for ECC. 0b - OCMEMn does not have ECC support. 1b - OCMEMn has ECC support.
28 OCMSZH	OCMSZH OCMEM Size “Hole”. For on-chip memories that are not fully populated, that is, include a memory “hole” in the upper 25% of the address range, this bit is used. 0b - OCMEMn is a power-of-2 capacity. 1b - OCMEMn is not a power-of-2, with a capacity is 0.75 * OCMSZ.
27-24 OCMSZ	OCMSZ OCMEM Size. This read-only field provides an encoded value of the on-chip memory size. 0000b - no OCMEMn 0001b - 1KB OCMEMn 0010b - 2KB OCMEMn 0011b - 4KB OCMEMn 0100b - 8KB OCMEMn 0101b - 16KB OCMEMn 0110b - 32KB OCMEMn 0111b - 64KB OCMEMn 1000b - 128KB OCMEMn 1001b - 256KB OCMEMn 1010b - 512KB OCMEMn 1011b - 1MB OCMEMn 1100b - 2MB OCMEMn 1101b - 4MB OCMEMn 1110b - 8MB OCMEMn 1111b - 16MB OCMEMn

Table continues on the next page...

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Field	Function
23-20 —	Reserved
19-17 OCMW	OCMW OCMEM datapath Width. This read-only field defines the width of the on-chip memory: 000b-001b - Reserved 010b - OCMEMn 32-bits wide 011b - OCMEMn 64-bits wide 100b - OCMEMn 128-bits wide 101b - OCMEMn 256-bits wide 110b-111b - Reserved
16 —	Reserved
15-13 OCMT	OCMT OCMEM Type. This field defines the type of the on-chip memory: 000b - OCMEMn is a System RAM. 001b - Reserved 010b - Reserved 011b - OCMEMn is a ROM. 100b - OCMEMn is a Program Flash. 101b - Reserved 110b - Reserved 111b - Reserved
12 OCMPU	OCMPU OCMEM Memory Protection Unit. This field is reserved for this device.
11-0 —	Reserved

12.4.2.25 Secure Interrupt Request (SECURE_IRQ)

Offset

Register	Offset
SECURE_IRQ	800h

Function

The SECURE_IRQ register provides a mechanism for non-secure code to generate a low latency pulsed exception into the secure privileged domain. This register is accessible in a non-secure peripheral address slot that non-secure code can write a specific value that forces an interrrupt that executes as a secure exception and enters the secure domain.

This register can only be written in both, secure mode or non-secure mode.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEC_IRQ_ARG															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEC_IRQ_ARG															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 SEC_IRQ_ARG	Secure Interrupt Argument 32-bit secure interrupt argument. Any 32-bit write triggers a pulsed secure interrupt request.

12.4.2.26 Unique ID 0 (UID0)

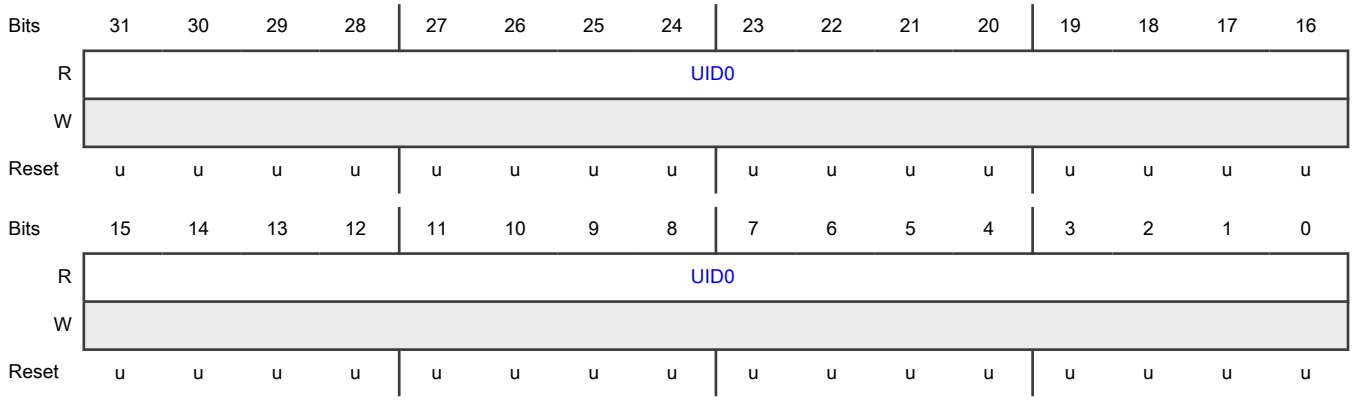
Offset

Register	Offset
UID0	810h

Function

UID[31:0] of the 128-bit UID. The UID is loaded directly from ECID fuse words.

Diagram



Fields

Field	Function
31-0 UID0	Unique ID 0 UID[31:0] of the 128-bit UID.

12.4.2.27 Unique ID 1 (UID1)

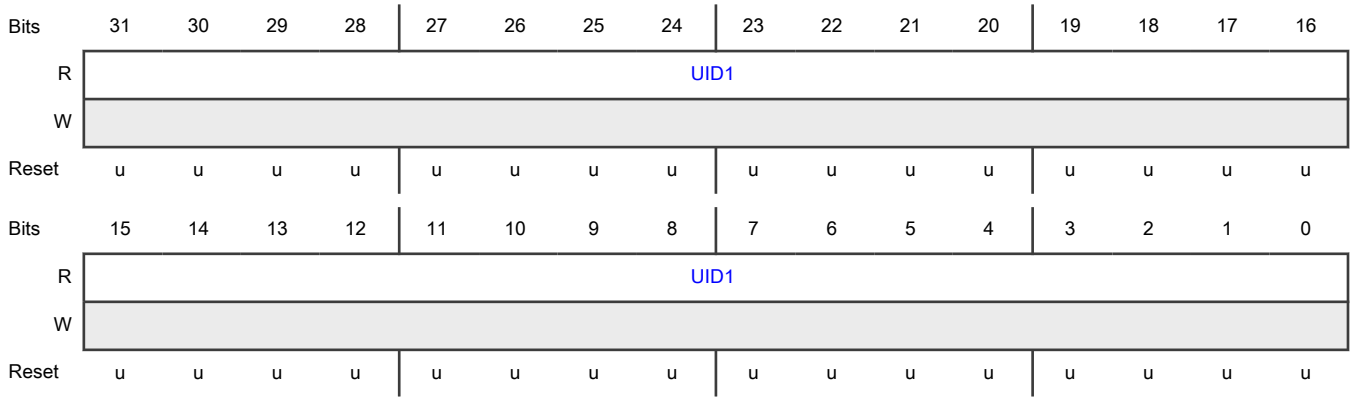
Offset

Register	Offset
UID1	814h

Function

UID[63:32] of the 128-bit UID. The UID is loaded directly from ECID fuse words.

Diagram



Fields

Field	Function
31-0 UID1	Unique ID 1 UID[63:32] of the 128-bit UID.

12.4.2.28 Unique ID 2 (UID2)

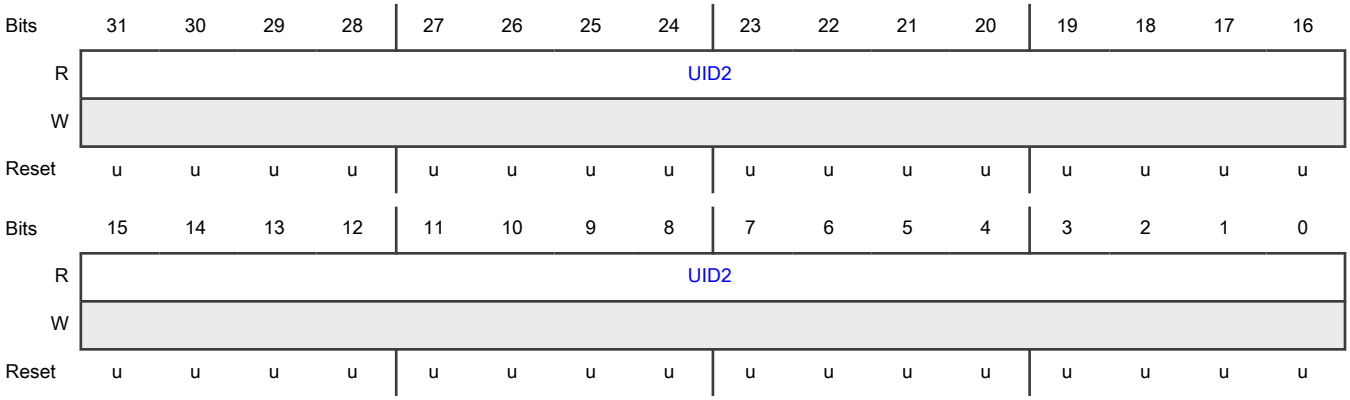
Offset

Register	Offset
UID2	818h

Function

UID[95:64] of the 128-bit UID. The UID is loaded directly from ECID fuse words.

Diagram



Fields

Field	Function
31-0 UID2	Unique ID 2 UID[95:64] of the 128-bit UID.

12.4.2.29 Unique ID 3 (UID3)

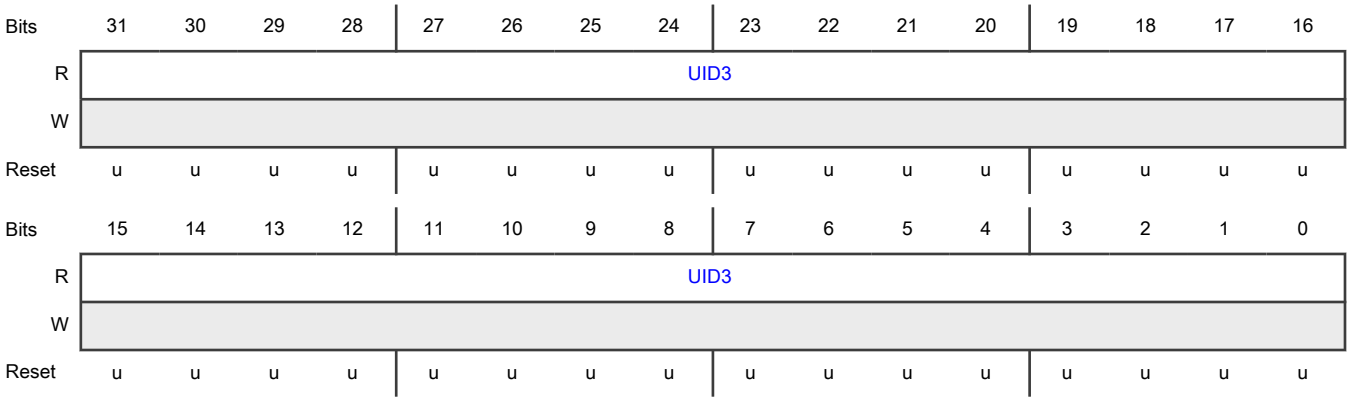
Offset

Register	Offset
UID3	81Ch

Function

UID[127:96] of the 128-bit UID. The UID is loaded directly from ECID fuse words.

Diagram



Fields

Field	Function
31-0 UID3	Unique ID 3 UID[127:96] of the 128-bit UID.

12.4.2.30 System ID (SID)

Offset

Register	Offset
SID	820h

Function

Loaded from IFR

NOTE

This register is not valid for non-radio devices.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	FAMID				RADIOF				BLEF				FLSZ			
W																
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	RAMSZ			SEC	CAN	I3C	VREF	FLXIO	LCE	PINID			SIREV		QI	
W																
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Fields

Field	Function
31-28 FAMID	Family ID See the chip-specific information for details.
27-24 RADIOF	Radio Feature 0000b - Reserved 0001b - Reserved 0010b - Bluetooth LE + 802.15.4
23-20 BLEF	Bluetooth LE Feature 0000b - No Bluetooth LE present 0001b - Reserved 0010b - Reserved 0011b - Reserved 0100b - Reserved 1000b - Reserved 1111b - Bluetooth LE Upgrade
19-16 FLSZ	Flash Size 1011b - Reserved 1101b - 1 MB + 512 KB 1110b - Reserved 1111b - 2 MB + 512 KB
15-13 RAMSZ	RAM Size 101b - 136 KB + 171 KB 110b - Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
	111b - 264 KB + 171 KB
12 SEC	Secure Enclave Presence 0b - No Secure Enclave 1b - Secure Enclave present
11 CAN	CAN Presence 0b - No CAN 1b - CAN present
10 I3C	I3C Presence 0b - No I3C 1b - I3C present
9 VREF	VREF Presence 0b - No VREF 1b - VREF present
8 FLXIO	FlexIO Presence 0b - No FlexIO 1b - FlexIO present
7 LCE	LCE Presence 0b - No LCE 1b - LCE present
6-4 PINID	Pin Identification 010b - Reserved 011b - 48HVQFN 100b - Reserved 101b - Reserved 110b - Reserved
3-2 SIREV	Silicon Revision 00b - Reserved 01b - 2nd Major Spin 10b - 1st Major Spin 11b - Initial mask set
1-0 QI	Qual Info

Table continues on the next page...

Table continued from the previous page...

Field	Function
	00b - Reserved 01b - Industrial 10b - Reserved 11b - Auto

Chapter 13
Miscellaneous Control Module (MCM)

13.1 Chip-specific MCM information

Table 61. Reference links to related information

Topic	Related module	Reference
Full description	MCM	MCM
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing
Cache	LPCAC	Low Power Cache Controller (LPCAC)

13.1.1 Module instances

This device has one instance of the MCM module.

13.1.2 LMFATR[PEFSYN]

LMFATR[PEFSYN] field indicates the master that accesses the cache when the LMEM fault is detected.

- 0x0 - Core
- 0x1 - Debug tool
- Others - Reserved

13.1.3 ISCR[CWBEE]

In this device, the ISCR[CWBEE] must be configured as 0.

13.1.4 CPCR2

In this device, When configure the CPCR2[DCBC] to disable cache, also need clear cache with CPCR2[CCBC].

NOTE

After the cache is enabled, you must first disable it before clearing it to avoid subsequent accesses to miss the cache.

13.2 Overview

MCM provides many miscellaneous control functions.

NOTE

The terminology in this chapter has been updated to align with NXP's inclusive language standards, as shown in the table below.

Table 62. Updated terms

Updated term	Deprecated term
Initiator	Master
Target	Slave

13.2.1 Features

- Error status and interrupts for the cache write buffer
- Error status and interrupts for the core's floating-point unit (FPU)

13.3 Functional description

13.3.1 Clocking

This module has no clocking considerations.

13.3.2 Interrupts

MCM generates an interrupt if any of the following is true:

- FPU input denormal interrupt is enabled (ISCR[FIDCE] = 1) and an input is denormalized (ISCR[FIDC] = 1).
- FPU inexact interrupt is enabled (ISCR[FIXCE] = 1) and a number is inexact (ISCR[FIXC] = 1).
- FPU underflow interrupt is enabled (ISCR[FUFCE] = 1) and an underflow occurs (ISCR[FUFC] = 1).
- FPU overflow interrupt is enabled (ISCR[FOFCE] = 1) and an overflow occurs (ISCR[FOFC] = 1).
- FPU divide-by-zero interrupt is enabled (ISCR[FDZCE] = 1) and a divide-by-zero occurs (ISCR[FDZC] = 1).
- FPU invalid operation interrupt is enabled (ISCR[FIOCE] = 1) and an invalid operation occurs (ISCR[FIOC] = 1).
- A PC data parity error occurs.
- A PC tag parity error occurs.
- A cache write buffer error occurs.

See Determining the source of the interrupt for more details.

13.4 External signals

This module has no external signals.

13.5 Application information

13.5.1 Determining the source of the interrupt

To determine the exact source of the interrupt, check the interrupt status flags with the corresponding interrupt enable fields.

1. Read the fields located in ISCR[31:16] and in ISCR[15:0].
2. Search the result for asserted flags, which indicate the exact interrupt sources.

NOTE

Parity interrupts are determined by LMEPECR (interrupt enable) and LMPEIR (interrupt source).

13.6 Memory map and register descriptions

The memory map and register descriptions below describe the registers using byte addresses.

NOTE

All MCM registers support only 32-bit writes. Any attempted 8-bit or 16-bit writes will result in undefined behavior.

13.6.1 MCM register descriptions

13.6.1.1 MCM memory map

MCM base address: E008_0000h

Offset	Register	Width (In bits)	Access	Reset value
Ch	Core Platform Control (CPCR)	32	RW	See section
10h	Interrupt Status and Control (ISCR)	32	RW	0000_0000h
20h	Write Buffer Fault Address (FADR)	32	R	See section
24h	Store Buffer Fault Attributes (FATR)	32	R	See section
28h	Store Buffer Fault Data (FDR)	32	R	See section
34h	Core Platform Control 2 (CPCR2)	32	RW	0001_0050h
408h	Local Memory Descriptor 2 (LMDR2)	32	RW	8584_4000h
480h	LMEM Parity Control (LMPECR)	32	RW	0000_0000h
488h	LMEM Parity Interrupt (LMPEIR)	32	RW	0000_0000h
490h	LMEM Fault Address (LMFAR)	32	R	0000_0000h
494h	LMEM Fault Attribute (LMFATR)	32	R	0000_0000h
4A0h	LMEM Fault Data High (LMFDHR)	32	R	0000_0000h
4A4h	LMEM Fault Data Low (LMFDLR)	32	R	0000_0000h

13.6.1.2 Core Platform Control (CPCR)

Offset

Register	Offset
CPCR	Ch

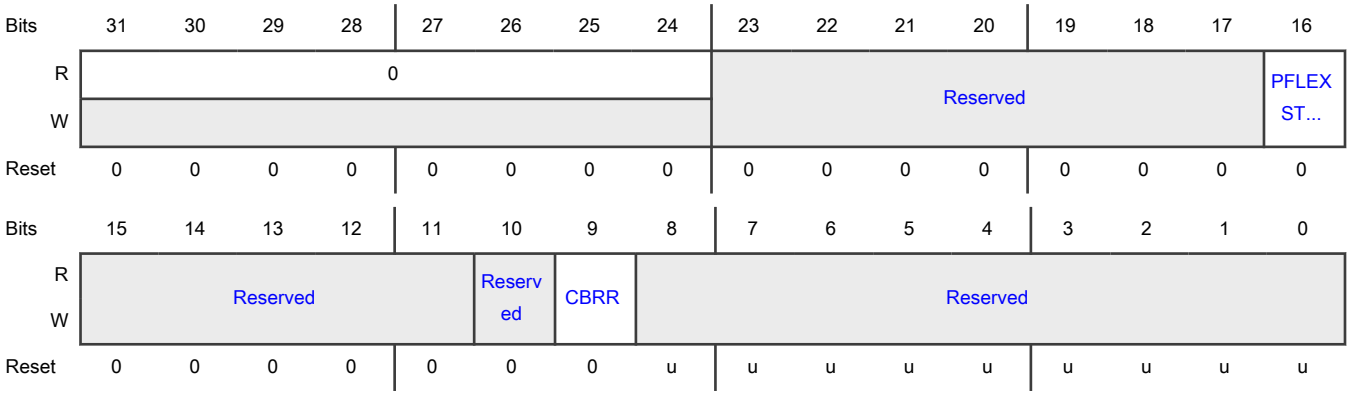
Function

The Core Platform Control Register (CPCR) configures the arbitration.

NOTE

Bits 8-0 are undefined after reset.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-17 —	Reserved
16 PFLEXSTALL	Flash Stall Enable This field configures whether to enable flash stall when the flash is busy. 0b - Flash stall is disabled when flash is busy. 1b - Flash stall is enabled when flash is busy.
15-11 —	Reserved
10 —	Reserved
9 CBRR	Crossbar Round-robin Arbitration Enable This field configures the crossbar target ports to fixed-priority or round-robin arbitration. 0b - Fixed-priority arbitration 1b - Round-robin arbitration
8-0 —	Reserved

13.6.1.3 Interrupt Status and Control (ISCR)

Offset

Register	Offset
ISCR	10h

Function

Configures and reports the status of core-related interrupt exception conditions. The individual event indicators are first checked with their exception enables and then logically summed to form an interrupt request sent to the core's NVIC.

The fields in bits 15–8 are indicator flags based on the processor's FPSCR register. Attempted writes to these fields are ignored. After the flags are set, they remain set until you write 0 to the corresponding FPSCR field.

The fields in bits 31–24 control the interrupt enablement. If you write 1 to an interrupt enablement control field, MCM generates an interrupt when the corresponding status field is 1.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	FIDCE	0		FIXCE	FUFCE	FOFCE	FDZCE	FIOCE	0		CPEE	CWBEE	0			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	FIDC	0		FIXC	FUFC	FOFC	FDZC	FIOC	0		CPES	CWBER	0			0
W												W1C				
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 FIDCE	FPU Input Denormal Interrupt Enable 0b - Disable 1b - Enable
30-29 —	Reserved
28 FIXCE	FPU Inexact Interrupt Enable 0b - Disable 1b - Enable
27	FPU Underflow Interrupt Enable

Table continues on the next page...

Table continued from the previous page...

Field	Function
FUFCE	0b - Disable 1b - Enable
26 FOFCE	FPU Overflow Interrupt Enable 0b - Disable 1b - Enable
25 FDZCE	FPU Divide-by-Zero Interrupt Enable 0b - Disable 1b - Enable
24 FIOCE	FPU Invalid Operation Interrupt Enable 0b - Disable 1b - Enable
23-22 —	Reserved
21 CPEE	Cache Parity Error Enable This field enables the generation of an interrupt in response to the cache parity error. 0b - Disable 1b - Enable
20 CWBEE	Cache Write Buffer Error Enable Enables the generation of an interrupt in response to a bus error termination reported on a system bus transfer that has been initiated from the cache's write buffer. 0b - Disable 1b - Enable
19-16 —	Reserved
15 FIDC	FPU Input Denormal Interrupt Status Contains a copy of the core's FPSCR[IDC] and indicates that an input denormalized number has been detected in the processor's FPU. After this field becomes 1, it remains 1 until you write 0 to FPSCR[IDC]. 0b - No interrupt 1b - Interrupt occurred
14-13 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
12 FIXC	FPU Inexact Interrupt Status Contains a copy of the core's FPSCR[IXC] and indicates that an inexact number has been detected in the processor's FPU. After this field becomes 1, it remains 1 until you write 0 to FPSCR[IXC]. 0b - No interrupt 1b - Interrupt occurred
11 FUFC	FPU Underflow Interrupt status Contains a copy of the core's FPSCR[UFC] and indicates that an underflow has been detected in the processor's FPU. After this field becomes 1, it remains 1 until you write 0 to FPSCR[UFC]. 0b - No interrupt 1b - Interrupt occurred
10 FOFC	FPU Overflow Interrupt Status Contains a copy of the core's FPSCR[OFC] and indicates that an overflow has been detected in the processor's FPU. After this field becomes 1, it remains 1 until you write 0 to FPSCR[OFC]. 0b - No interrupt 1b - Interrupt occurred
9 FDZC	FPU Divide-by-Zero Interrupt Status Contains a copy of the core's FPSCR[DZC] and indicates that a divide-by-zero has been detected in the processor's FPU. After this field becomes 1, it remains 1 until you write 0 to FPSCR[DZC]. 0b - No interrupt 1b - Interrupt occurred
8 FIOC	FPU Invalid Operation Interrupt Status Contains a copy of the core's FPSCR[IOC] and indicates that an illegal operation has been detected in the processor's FPU. After this field becomes 1, it remains 1 until you write 0 to FPSCR[IOC]. 0b - No interrupt 1b - Interrupt occurred
7-6 —	Reserved
5 CPES	Cache Parity Error Status Indicates whether a cache parity error is detected. You can write 1 to this field only when the corresponding enable field (CPEE) is 1. 0b - Not detected 1b - Detected
4	Cache Write Buffer Error Status

Table continues on the next page...

Table continued from the previous page...

Field	Function
CWBER	Indicates whether a data transfer from the core's cache write buffer was terminated because of a bus error. This field can become 1 only when the corresponding enable field (ISCR[CWBEE]) = 1. The corresponding core fault address, attributes, and write data are typically retrieved from Write Buffer Fault Address (FADR), Store Buffer Fault Attributes (FATR), and Store Buffer Fault Data (FDR) registers during the interrupt handler before clearing the CWBER flag. 0b - No error 1b - Error occurred
3-1 —	Reserved
0 —	Reserved

13.6.1.4 Write Buffer Fault Address (FADR)

Offset

Register	Offset
FADR	20h

Function

Captures the faulty address if a properly enabled cache write buffer error interrupt event is detected.

MCM captures a single cache write buffer bus error event. If a subsequent error is detected before the captured error information has been read from the corresponding registers and ISCR[CWBER] is 0, then FATR[BEOVR] becomes 1. However, no additional information is captured.

MCM writes 1 to the field in this register when ISCR[CWBER] is 1. Attempted writes have no effect.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	ADDRESS															
W	-															
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	ADDRESS															
W	-															
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Fields

Field	Function
31-0 ADDRESS	Fault Address Contains the faulty address if a properly enabled cache write buffer error interrupt event is detected.

13.6.1.5 Store Buffer Fault Attributes (FATR)

Offset

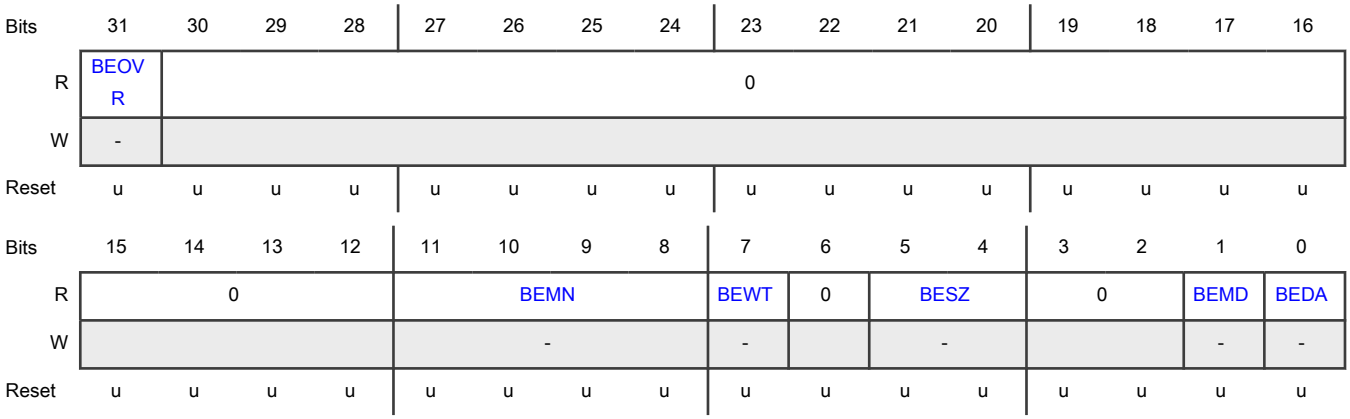
Register	Offset
FATR	24h

Function

Indicates the faulty attributes if a properly enabled cache write buffer error interrupt event is detected.

MCM writes values to the fields in this register when ISCR[CWBER] is 1b. Your attempted writes have no effect.

Diagram



Fields

Field	Function
31 BEOVR	Bus Error Overrun Indicates if another cache write buffer bus error is detected before system software has retrieved all the error information from the original event. The time window is from the detection of the original cache write buffer error termination to the time when you write 1 to ISCR[CWBER] to clear it and rearm the capture logic. MCM writes 1 to this field and it becomes 0 whenever you write 1 to ISCR[CWBER]. Write Buffer Fault Address (FADR), Store Buffer Fault Data (FDR), and the other FATR fields do not update to reflect this new bus error.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - No overrun 1b - Overrun
30-12 —	Reserved
11-8 BEMN	Bus Error Initiator Number Indicates the crossbar switch bus initiator number of the captured cache write buffer bus error.
7 BEWT	Bus Error Write Indicates the type of system bus access when the cache write buffer error was detected. 0b - Read 1b - Write
6 —	Reserved
5-4 BESZ	Bus Error Size Indicates the size of the cache write buffer access when the error was detected. 00b - 8-bit 01b - 16-bit 10b - 32-bit 11b - Reserved
3-2 —	Reserved
1 BEMD	Bus Error Privilege Level Indicates the privilege level of the cache write buffer access when the error was detected. 0b - User mode 1b - Supervisor or privileged mode
0 BEDA	Bus Error Data Access Type Indicates the type of cache write buffer access when the error was detected. 0b - Instruction 1b - Data

13.6.1.6 Store Buffer Fault Data (FDR)

Offset

Register	Offset
FDR	28h

Function

Indicates the captured faulty data, when a properly enabled cache write buffer error interrupt event is detected.

MCM writes 1 to DATA when ISCR[CWBER] is 1. Only the accessed byte lanes contain valid data for byte and halfword writes. Contents of the other bytes are undefined. Attempted writes have no effect.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	DATA															
W	-															
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	DATA															
W	-															
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Fields

Field	Function
31-0 DATA	Fault Data Contains the captured faulty data, when a properly enabled cache write buffer error interrupt event is detected.

13.6.1.7 Core Platform Control 2 (CPCR2)

Offset

Register	Offset
CPCR2	34h

Function

Configures the cache-related properties.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0										0		0		LCCPWB	1
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				0				CBCS				DCBC	FCCNA	DCCWB	0
W																CCBC
Reset	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0

Fields

Field	Function
31-22 —	Reserved
21-20 —	Reserved
19-18 —	Reserved
17 LCCPWB	Limit Code Cache Peripheral Write Buffering If write buffering is not limited and the write buffer is enabled, then bufferable write is buffered. If write buffering is limited, then only bufferable and cacheable write is buffered. 0b - Do not limit 1b - Limit
16 PCCMCTRL	Bypass Fixed Code Cache Map 0b - Do not bypass 1b - Bypass
15-12 —	Reserved
11-8 —	Reserved
7-4 CBCS	Code Bus Cache Size 0000b - 0 KB 0001b - 1 KB

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0010b - 2 KB 0011b - 4 KB 0100b - 8 KB 0101b - 16 KB 0110b - 32 KB
3 DCBC	Disable Code Bus Cache 0b - Enable 1b - Disable
2 FCCNA	Force Code Cache to No Allocation 0b - Allocation 1b - No allocation
1 DCCWB	Disable Code Cache Write Buffer 0b - Enable 1b - Disable
0 CCBC	Clear Code Bus Cache 0b - No effect 1b - Clear code bus cache

13.6.1.8 Local Memory Descriptor 2 (LMDR2)

Offset

Register	Offset
LMDR2	408h

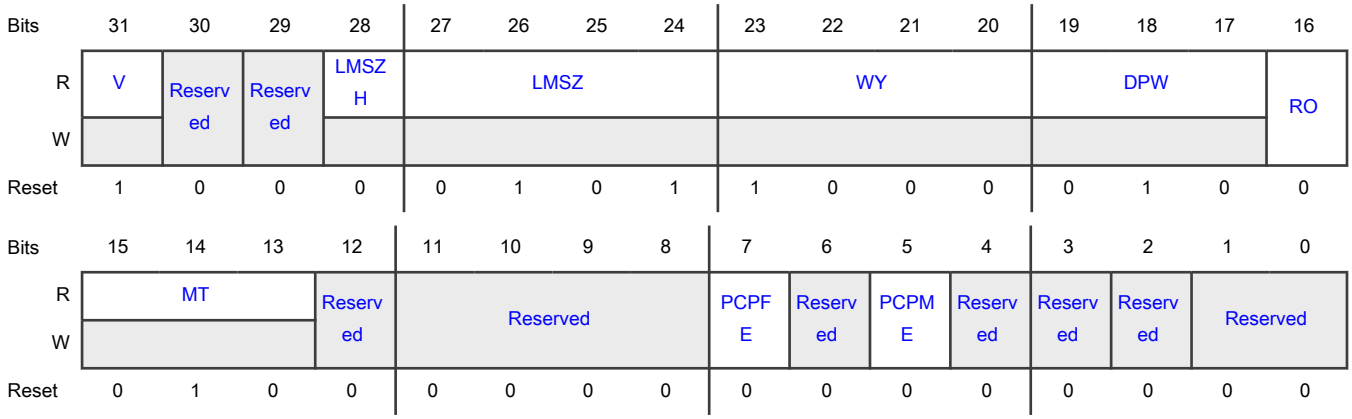
Function

Indicates static information about the attached memories, as well as configurable controls (where appropriate).

NOTE

See chip-specific MCM information for this register's mapping to the LMEMs.

Diagram



Fields

Field	Function
31 V	Valid Indicates the validity (presence) of the local memory. 0b - Not present 1b - Present
30 —	Reserved
29 —	Reserved
28 LMSZH	LMEM Size Hole Specifies the capacity of local memories. This field is used for local memories that are not fully populated, including a memory hole in the upper 25% of the address range. 0b - LMEM has a power-of-2 capacity 1b - LMEM has a capacity of 0.75 × LMSZ
27-24 LMSZ	LMEM Size Indicates an encoded value of the local memory size. The capacity of the memory is: Size (bytes) = $2^{(9+LMSZ)}$ when LMSZ is nonzero. LMSZ = 0 indicates that the memory is not present. 0000b - No memory 0001b - 1 KB 0010b - 2 KB

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0011b - 4 KB 0100b - 8 KB 0101b - 16 KB 0110b - 32 KB 0111b - 64 KB 1000b - 128 KB 1001b - 256 KB 1010b - 512 KB 1011b - 1024 KB 1100b - 2048 KB 1101b - 4096 KB 1110b - 8192 KB 1111b - 16384 KB
23-20 WY	Level 1 Cache Ways 0000b - No cache 0010b - 2-way set associative 0100b - 4-way set associative 1000b - 8-way set associative
19-17 DPW	LMEM Data Path Width Indicates the width of the local memory. 000b-001b - Reserved 010b - 32 bits 011b - 64 bits 100b-111b - Reserved
16 RO	Read-Only Controls the writes to the LMDR*n*[7:0] bits. After you write 1 to this field, MCM ignores attempted writes to the corresponding LMDR*n*[7:0] until the next reset clears the flag. 0b - Writes allowed 1b - Writes ignored
15-13 MT	Memory Type Indicates the type of the local memory. 000b - SRAM_L

Table continues on the next page...

Table continued from the previous page...

Field	Function
	001b - SRAM_U 010b - PC Cache 011b - PS Cache
12 —	Reserved
11-8 —	Reserved
7 PCPFE	Enable PC Parity Fault Report **NOTE** When RO = 1b, this field is read-only. 0b - Disable 1b - Enable
6 —	Reserved
5 PCPME	Enable PC Parity **NOTE** When RO = 1b, this field is read-only. 0b - Disable 1b - Enable
4 —	Reserved
3 —	Reserved
2 —	Reserved
1-0 —	Reserved

13.6.1.9 LMEM Parity Control (LMPECR)

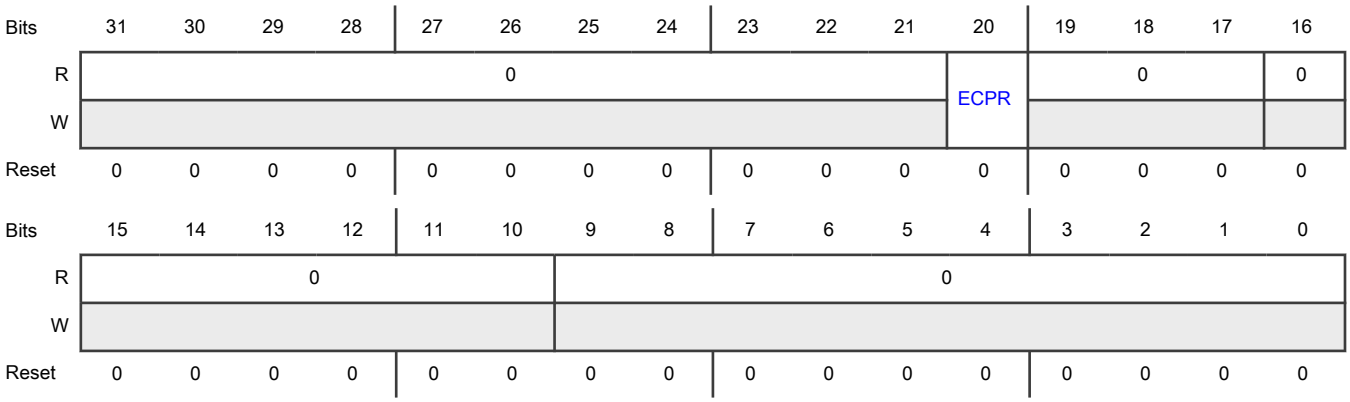
Offset

Register	Offset
LMPECR	480h

Function

Specifies the LMEM parity reporting.

Diagram



Fields

Field	Function
31-21 —	Reserved
20 ECPR	Enable Cache Parity Reporting LMPEIR[PE] is functional only when this field is 1. 0b - Disable 1b - Enable
19-17 —	Reserved
16 —	Reserved
15-10 —	Reserved
9-0 —	Reserved

13.6.1.10 LMEM Parity Interrupt (LMPEIR)

Offset

Register	Offset
LMPEIR	488h

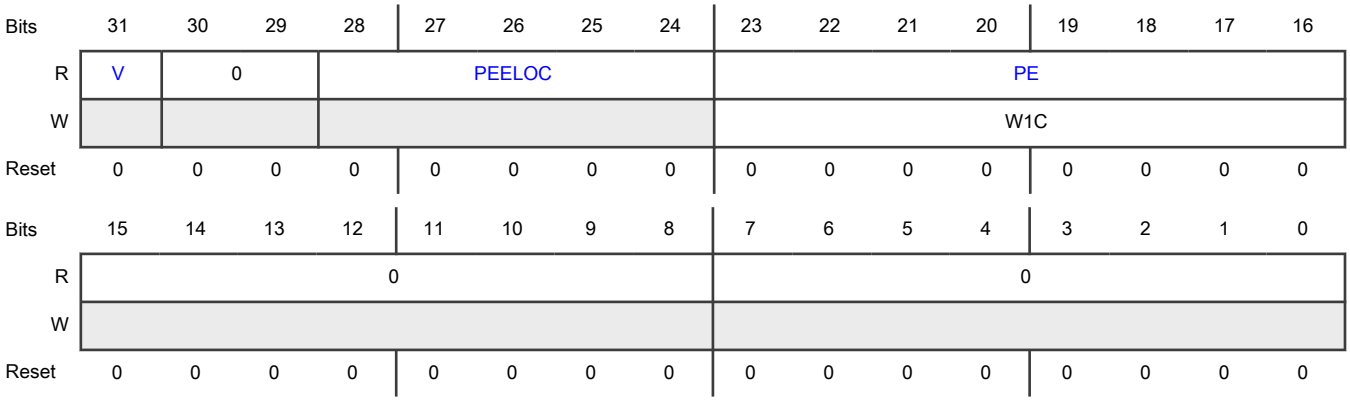
Function

The LMEM Parity Interrupt Register (LMPEIR) indicates the Parity error information.

NOTE

Write 1 to the error bit in this register can clear the related interrupt flag.

Diagram



Fields

Field	Function
31 V	Valid bit This field indicates whether the other fields in this register are valid.
30-29 —	Reserved
28-24 PEELOC	Error Location This field indicates the parity error location. See the following for errors, all the others are reserved. 10100b - a PC Tag Parity Error 10101b - a PC Data Parity Error
23-16 PE	Parity Error This field indicates the parity error type. This field is functional only when the LMPECR[ECPR] is set. • LMPEIR[21] - PC Data Parity Error

Table continues on the next page...

Table continued from the previous page...

Field	Function
	• LMPEIR[20] - PC Tag Parity Error • LMPEIR[19-16] - Reserved
15-8 —	Reserved
7-0 —	Reserved

13.6.1.11 LMEM Fault Address (LMFAR)

Offset

Register	Offset
LMFAR	490h

Function

The LMEM Fault Address Register (LMFAR) captures the faulting address where the LMEM fault is detected.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	EFADD															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	EFADD															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 EFADD	Fault Address

13.6.1.12 LMEM Fault Attribute (LMFATR)

Offset

Register	Offset
LMFATR	494h

Function

The LMEM Fault Attribute Register (LMFATR) indicates the attributes of the LMEM fault detected.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	OVR	0	0		0				PEFSYN							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	BKD	0							PEFW	PEFSIZE			PEFPRT			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 OVR	Overrun 0b - There is single fault or no fault. 1b - There are multiple faults
30 —	Reserved
29-28 —	Reserved
27-24 —	Reserved
23-16 PEFSYN	Parity Fault Syndrome See chip-specific section for details.
15 BKD	Backdoor Access This field indicates that the LMEM access fault is initiated by core access or backdoor access.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Core access 1b - Backdoor access
14-8 —	Reserved
7 PEFW	Parity Fault Write This field indicates that the parity fault is caused by read or write. 0b - Read fault 1b - Write fault
6-4 PEFSIZE	PEFSIZE Parity Fault Initiator Size 000b - 8-bit access 001b - 16-bit access 010b - 32-bit access 011b - 64-bit access others - Reserved
3-0 PEFPRT	Parity Fault Protection Signal Features of parity fault protection signal FATR[3] is Cacheable: 0=Noncacheable, 1=Cacheable FATR[2] is Bufferable: 0=Nonbufferable, 1=Bufferable FATR[1] is Mode: 0=User mode, 1=Supervisor mode FATR[0] is Type: 0=I-Fetch, 1=Data

13.6.1.13 LMEM Fault Data High (LMFDHR)

Offset

Register	Offset
LMFDHR	4A0h

Function
The LMEM Fault Data High Register (LMFDHR), together with LMFDLR, indicates the read data which has failed in parity check.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PEFDH															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	PEFDH															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 PEFDH	PEFDH Parity Fault Data High

13.6.1.14 LMEM Fault Data Low (LMFDLR)

Offset

Register	Offset
LMFDLR	4A4h

Function

The LMEM Fault Data Low Register (LMFDLR), together with LMFDHR, indicates the read data which has failed in parity check.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PEFDL															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	PEFDL															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 PEFDL	PEFDL Parity Fault Data Low

Chapter 14
Memories

14.1 Introduction

This chapter presents the hierarchical memory architecture and descriptions of memory modules available in this device. This chapter also details bus master access latency to the memory modules in the system where it is applicable.

14.2 Memory architecture

The memory architecture supports a wide range of applications and maximizes performance while maintaining low power consumption.

14.3 Memory hierarchy

The memory hierarchy is an arrangement of different types of memories with different capacities and operating speeds, to approximate the ideal memory behavior in a cost-efficient way. The following figure shows the memory hierarchical architecture implemented on this device.

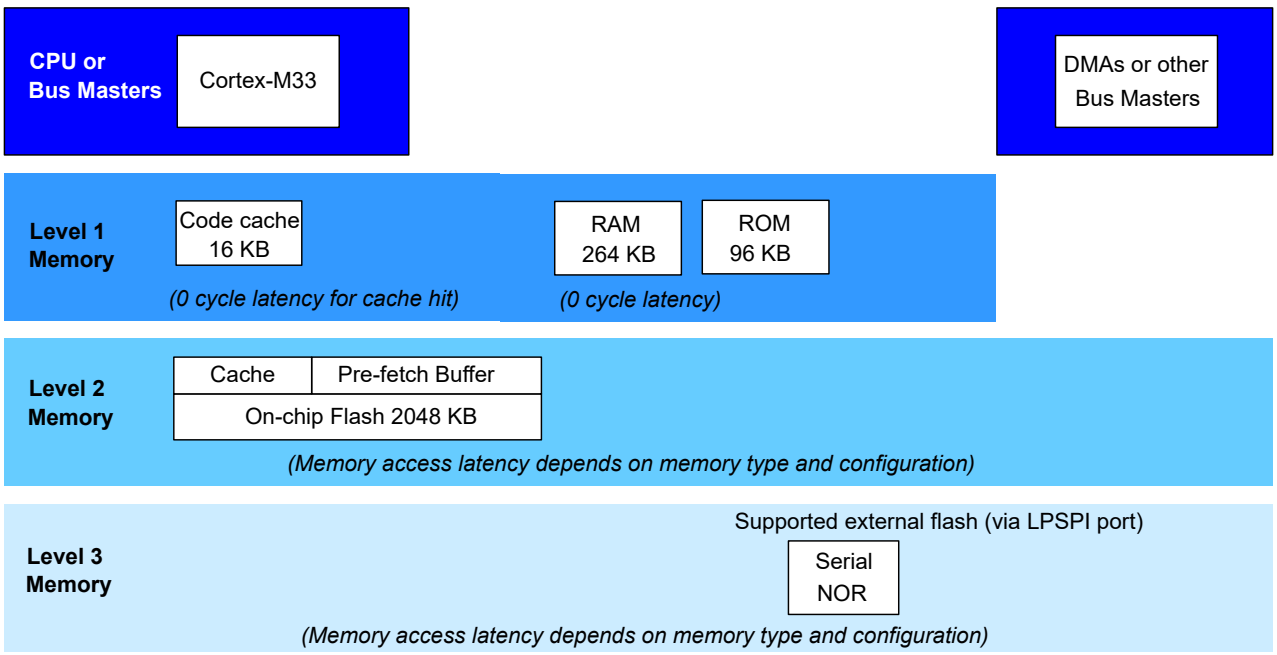


Figure 22. Memory hierarchy

14.4 TCM SRAMs

The core's local Tightly Coupled Memory (TCM) consists of two logical arrays, Code TCM (CTCM) and System TCM (STCM).

14.4.1 TCM SRAM configurations

- The CTCM is 32 KB
  - CTCM array 0: 16 KB
  - CTCM array 1: 16 KB

- The STCM is 232 KB
  - STCM array 0: 16 KB
  - STCM array 1: 16 KB
  - STCM array 2: 32 KB
  - STCM array 3: 32 KB
  - STCM array 4: 32 KB
  - STCM array 5: 32 KB
  - STCM array 6: 32 KB
  - STCM array 7: 32 KB
  - STCM array 8: 8 KB

The address ranges of the TCMs are provided in the TCM arrays section

14.4.2 TCM SRAM retention

The TCM SRAMs can be retained in Sleep, Deep Sleep, and Power Down modes. Each instantiated block of TCM SRAM can be individually power gated. This allows the user to achieve the proper balance of power savings versus data retention.

Entering Deep Power Down mode will automatically power gate all of the SRAM instantiations, and all data is lost.

The last 8 KB RAM (0x2003_8000) is from independent power switch domain which can keep data retention in all power modes.

The first 16 KB of STCM (STCM0) is reserved for ROM use, and it will be initialized when waking up from Power Down mode

14.5 L1 Cache

A cache is a block of high-speed memory locations containing address information, which is commonly known as a tag, and the associated data. The purpose is to decrease the average time of a memory access to lower-level memory. The primary cache, or Level 1 (L1) cache, resides close to the CPU and is used for temporary storage of instructions and data organized in blocks of cache-line size.

This device implements one instance of L1 - the Code cache. The Code cache is accessible through the Code bus of Cortex-M33 core.

14.5.1 L1 cache principles

L1 caches operate on two principles of locality:

- Spatial locality - An access to one location is likely to be followed by accesses to adjacent locations, such as when executing sequential instructions or accessing a data structure. The spatial locality property is used to group several locations together using the same tag. This logical block is commonly known as a cache line.
- Temporal locality - An access to an area of memory is likely to be repeated within a short time period, such as when executing a code loop.

14.5.2 L1 cache features

Each L1 cache instance has following features:

- 16 KB cache array
- 32-bit wide SRAM for data storage
- Register based tags
- 8-way set associative
- 4-word (or 16-byte) lines

- Performs 4-beat, 32-bit wrapped burst to fetch 16 bytes of the cache line when a read misses
- Entire cache can be flushed at once

14.5.3 Cache policies

The following cache interaction policies with lower-level memories are applied to the Code cache:

- Write Through (WT) - accesses to address spaces with this cache mode are cacheable.
  - A read miss in the cache causes a line read of a 16-byte aligned memory address containing the desired address in the lower-level memory. This miss data is loaded into the cache and is marked as valid and not modified.
  - A read hit to a valid cache location returns data from the cache with no bus access to lower-level memory.
  - A write miss bypasses the cache and writes to the lower-level memory; that means no allocate on write miss policy for write-through mode spaces.
  - A write hit updates the cache hit line with the write data and writes to the desired address in the lower-level memory.
- Non-Cacheable (NC) - accesses to address spaces with this cache mode are not cacheable. These accesses bypass the cache and access the lower-level memory directly.

14.5.4 Cache control

In normal operation, caches are self-managing, with the updates occurring automatically on demand. Whenever the processor wants to access a cacheable location, the cache is checked. If the access is a cache hit, the access occurs immediately. Otherwise, a location is allocated and the cache line is loaded from lower-level memory.

The Code Cache doesn't have a programming model; all control comes from the Miscellaneous Control Module (MCM). The MCM has cache enable, cache clear, and cache force-no-allocate mode control per cache instance.

14.5.5 Low Power

The caches can be put in state retention or powered down in any of low power modes. The caches need to be flushed before being powered down. This affects the time it takes for the system to transition into the new power mode.

14.6 Read Only Memory (ROM)

The internal ROM memory is used to store the boot code and time-critical software library routines. After a reset, the Cortex-M33 processor starts its code execution from this memory.

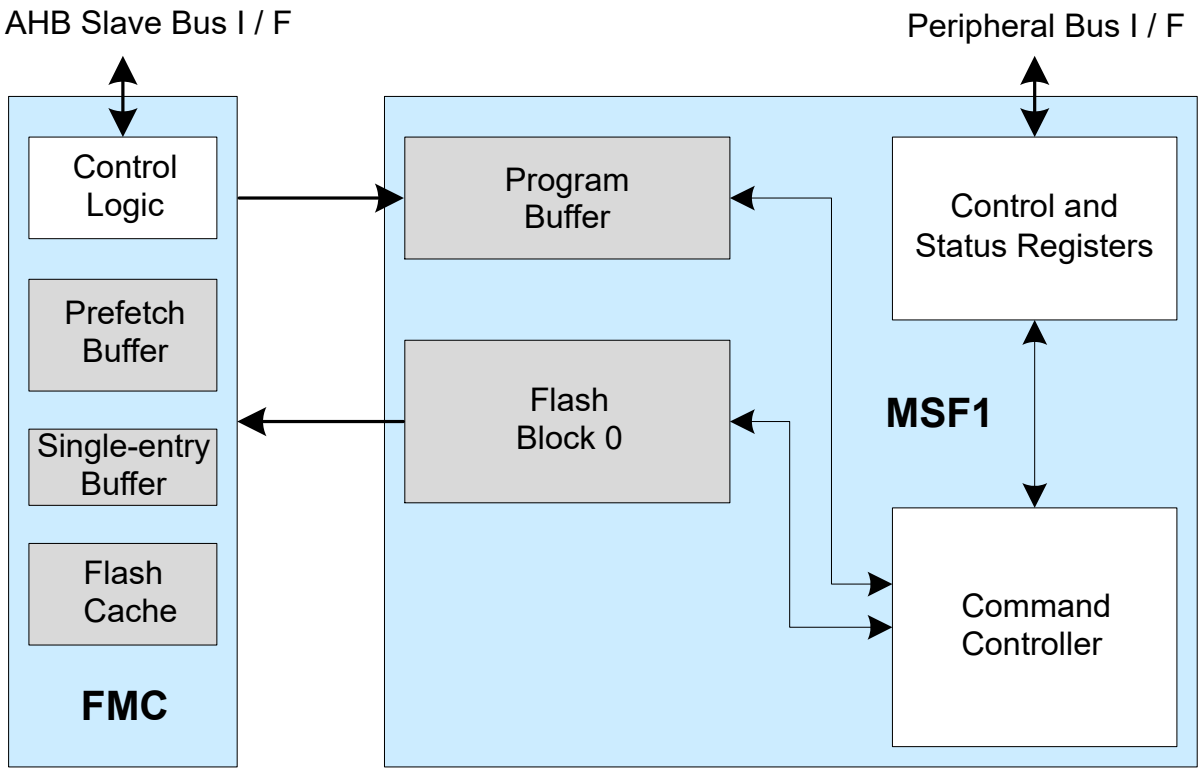
14.6.1 ROM size

The Boot ROM of this device is 96 KB.

14.7 Internal flash

This device embeds 2.00 MB of flash.

The following figure shows the high-level block diagram of the on-chip flash.



14.7.1 Flash memory controller

The Flash Memory Controller (FMC) manages accesses performed by the bus masters of the system to the flash memory. The FMC accelerates flash memory transfers to allow program code execution at higher clock frequency than flash memory.

The FMC provides three separate mechanisms for accelerating read operations to the flash memory:

- A single-entry 128-bit buffer, which can store previously accessed flash memory
- A 128-bit prefetch buffer, which can prefetch the next 128-bit flash memory location
- A 64-Byte cache organized as a one set, four way associative cache with 128-bit (or 16-Byte) size entries.

Note the FMC has no visibility into flash memory erase and program cycles because the Flash Memory module manages them directly.

14.7.1.1 Single entry buffer

The width of the bus between the FMC and the flash blocks is 128-bit. A single read of the flash will return an entire bus width worth of data. Because the flash bus is wider than the master's bus, the Single-Entry Buffer is used to store data from the last flash read for quick access times on subsequent reads if the buffer is hit.

The FMC provides invalidation control for the Single-Entry Buffer.

14.7.1.2 Prefetch buffer

When speculative reads are enabled, the FMC immediately requests the next sequential address after a read completes. The next 128-bit memory location is read and placed in the Prefetch Buffer. The speculative prefetch mechanism improves performance by reducing or even eliminating wait states when accessing sequential code and/or data.

Speculative prefetching is programmable for each bank of memory. The FMC provides invalidation control for the Prefetch Buffer.

14.7.1.3 Flash cache

Cache memory stores already executed code. This code is immediately available for repeated execution without any wait states, if needed.

The FMC provides controls for flash replacement algorithm, lock per way, and invalidation per way. The ways are numbered 0-3 and the sets are numbered 0-3. The cache supports Least Recently Used (LRU) replacement algorithm per set across all 4 ways.

The cache entries, both data and tag/valid, can be read at any time.

Software is required to maintain memory coherence when any segment of the flash cache is programmed. For example, all buffer data associated with the reprogrammed flash should be invalidated. Accordingly, cache program visible writes must occur after a programming or erase event is completed and before the new memory image is accessed.

Chapter 15
ROM Bootloader

15.1 Introduction

ROM bootloader is the boot code resident in the internal read-only memory (ROM). The ROM bootloader begins its execution when the Cortex-M33 processor is released from reset. This chapter highlights the features supported by the bootloader and describes its execution flow logic.

15.2 Boot ROM

In this device, the ROM bootloader supports automated booting from internal flash and downloading image from serial interface (LPUART, LPI2C, LPSPI).

The ROM bootloader is in the memory region starting from the address 0x1480 0000. The following diagram shows the memory map in-use during ROM execution. The first 32 KB of STCM (0x30000000 – 0x30008000) needs to be reserved for ROM bootloader execution and some ROM API execution. Please note that STCM has ECC enabled. To avoid STCM ECC error, users must always program word-aligned data to word-aligned address before reading.

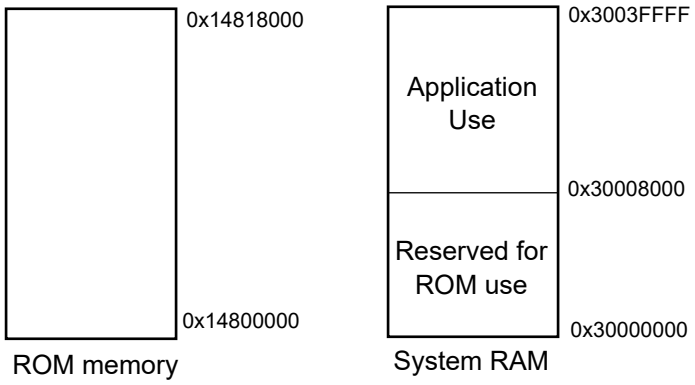


Figure 23. ROM bootloader memory usage

There are several alternate paths through the ROM bootloader:

- Normal boot path with security and TrustZone Mode (TZ-M) option.
- In-system programming (ISP) path.
- Debugger mailbox path which supports debug authentication.

The decision about which path to take depends on fuses, boot configuration in user IFR, boot pin, debug request and low power wakeup configuration. Figure below shows the top-level boot flow.

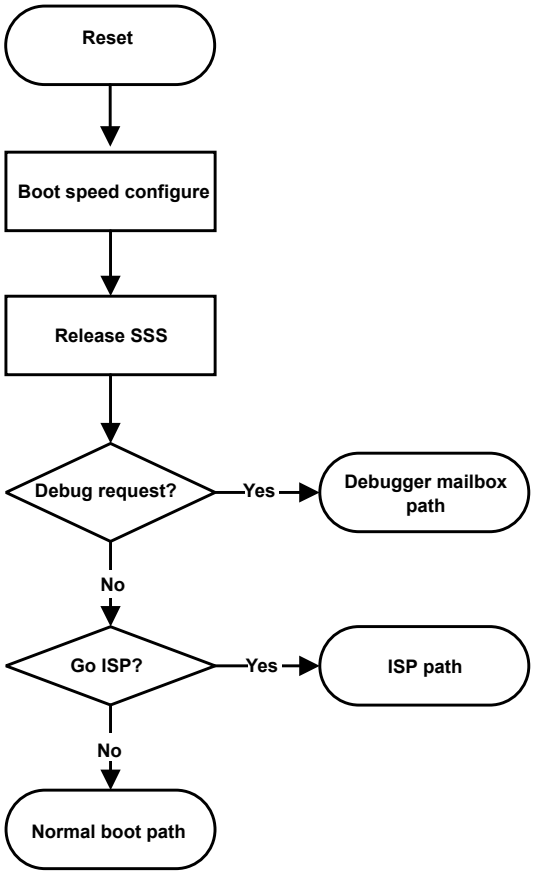


Figure 24. Top-level boot flow

15.2.1 Lifecycle and fuses

The table and diagram below describe the lifecycle states and transitions. ROM behavior is different at different lifecycle state. The lifecycle fuse needs to be programmed correctly, otherwise ROM bootloader will not boot. The NA in the table means the feature is not available.

Table 63. Lifecycle states

LIFECYCLE	Lifecycle state [0:7]	Debug authentication required to debug CM33?	Debug authentication required to debug radio core?
0000_0111	OEM Open	No	No
0000_1111	OEM Secure World Closed	Yes[1]	Yes
0001_1111	OEM Closed	Yes	Yes
1001_1111	OEM Locked	NA	NA
0011_1111	OEM Return	No	NA
11xx_xxxx	Brick	NA	NA

1. For secure world only.

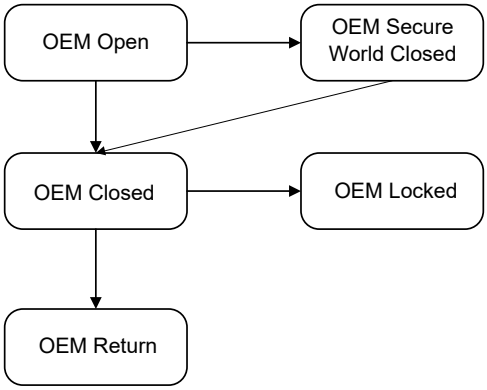


Figure 25. Lifecycle transitions

In addition to the lifecycle fuses, there are a handful of other fuse fields that will be used by the ROM bootloader during its operation. These fuse fields are shown in the table below.

Table 64. Additional fuse fields of interest

Name	Fuse index	Description
LIFECYCLE	0x0A	Lifecycle state. Corresponding product state can be determined from Table 1. Lifecycle States
DBG_EN_LOCK	0x0B	Debug Enable Lock 0b - The debug access control registers remain open when jumping to customer code. 1b - The debug access control registers are write-locked before jumping to customer code.
DBG_AUTH_DIS	0x0C	Debug Authentication Disabled 0b - Debug Authentication enabled. 1b - Debug Authentication disabled.
TZM_EN	0x0D	Trust Zone Mode Enable 0b - TZ-M is disabled by default. 1b - TZ-M is enabled.
SERIAL_DIS	0x11	Serial Download Disabled 0b - ISP path is enabled. 1b - ISP path is disabled.
WAKEUP_DIS	0x12	Wakeup Disabled 0b - Boot-ROM LP wakeup is enabled. 1b - Boot-ROM LP wakeup is disabled.

Table continues on the next page...

Table 64. Additional fuse fields of interest (continued)

Name	Fuse index	Description
CUST_PROD_OEMFW_AUTH_PUK_REVOKE[3:0]	0x13	Key revocation indicators of CUST_PROD_OEMFW_AUTH_PUK.
DBG_AUTH_VU[15:0]	0x15	These Debug Authentication Vendor Usage fuses are used by customers to restrict debug certificates.
IMG_KEY_REVOKE[15:0]	0x16	These fuses are used to revoke image signing keys separately from root keys.
SECURE_PHANTOM_CONFIG	0x18	Token configuration.
CUST_PROD_OEMFW_AUTH_PUK	0x1f	256-bit RoTKTH (customer trusted root key) typically used for CM33 main flash image authentication.
CUST_PROD_OEMFW_ENC_SK	0x20	256-bit encryption key used to protect confidentiality of OEM firmware. Typically required for firmware updates using sb3 (SB3KDK).
OEM_Enablement_Token	0x21	256-bit RoTKTH (root key hash) typically used for radio firmware authentication. (if valid token is intended to be used by programming SECURE_PHANTOM_CONFIG fuse)
DCFG_CC_SOCU_L1[8:0]	0x22	Debug authentication configuration for level 1 customer.
DCFG_CC_SOCU_L2[8:0]	0x23	Debug authentication configuration for level 2 customer.
SOC_VER_CNT	0x24	512-bits of version counter for various software components in SoC. Each software component version counter has dedicated fuse index 0x25 to 0x29.
CM33_S_VER_CNT	0x25	64-bit secure OEM CM33 firmware version counter (number of set fuse bits).
CM33_NS_VER_CNT	0x26	256-bit non-secure OEM CM33 firmware version counter (number of set fuse bits).
RADIO_VER_CNT	0x27	128-bit radio firmware version counter (number of set fuse bits).
SNT_VER_CNT	0x28	32-bit s200 loadable firmware version counter (number of set fuse bits).
CM33_BOOTLOADER_VER_CNT	0x29	Reserved for future usage of additional NXP software deliverable.
CM33_S_VER_CNT_VIRTUAL	0x2A	64-bit secure OEM CM33 firmware version counter (Integer value equivalent to number of set fuse bits).
CM33_NS_VER_CNT_VIRTUAL	0x2B	256-bit non-secure OEM CM33 firmware version counter (Integer value equivalent to number of set fuse bits).
RADIO_VER_CNT_VIRTUAL	0x2C	128-bit radio firmware version counter (Integer value equivalent to number of set fuse bits).
SNT_VER_CNT_VIRTUAL	0x2D	32-bit s200 loadable firmware version counter (Integer value equivalent to number of set fuse bits).
CM33_BOOTLOADER_VER_CNT_VIRTUAL	0x2E	Reserved for future usage of additional NXP software deliverable.
NBU_SEC_BOOT_EN	0x33	NBU secure boot enable fuse, NBU image must be authenticated successfully to boot if this fuse is set. See the Security Reference

Table continues on the next page...

Table 64. Additional fuse fields of interest (continued)

Name	Fuse index	Description
		Manual for the value of this fuse reflected in bit 12 of SMSCM [LIFECYCLE] register. 0b - NBU image doesn't need to be authenticated (default) 1b - NBU image must be authenticated to boot
OEM_SEC_BOOT_EN	0x35	Main core secure boot enable boot enable fuse, boot image must be authenticated successfully to boot if this fuse field is set to 0xA. See the Security Reference Manual for the value of this fuse reflected in bit 24-27 of SMSCM [LIFECYCLE] register. 0000b - Boot image doesn't need to be authenticated to boot (default) 1010b - Boot image must be authenticated to boot Other value - Reserved

ROM bootloader provides following ways to do the fuse reading and programming:

- nboot API (See nboot API for more details about fuse programming using nboot API),
- ISP fuse-program and fuse-read command,
- sbloader “programFuses” command in sb3.1 file

15.2.2 User IFR (IFR0) configuration

User IFR, known as IFR0 is reserved for software usage. First sector of User IFR is not able to be erased and is write-once. Other three sectors are erasable and programmable.

The allocation of User IFR pages is as follows:

Table 65. User IFR allocation

Sector	Name	Description
0	ROMCFG	ROM Bootloader configurations
1	User	Reserved for customer usage
2	CMAC table	Used to save hashes of multiple boot components.
3	OTACFG	Used for Over-the-Air update

15.2.2.1 ROM bootloader configuration

Sector 0 of User IFR is ROM and ISP configuration, which provide configuration for ROM bootloader.

Table 66. ROM Configuration fields

Offset	Size (bytes)	Configuration Field	Description
0x0000	1	Restore FLW Flag	Bit 0 – FLW state, whether enable dual image boot • 0 = Normal, use specified mapping • 1 = Uninitialized (default) Bit 7:1 – Reserved

Table continues on the next page...

Table 66. ROM Configuration fields (continued)

Offset	Size (bytes)	Configuration Field	Description
	7	Reserved	Reserved
	8	FLW region definition	Fields to be used for FLW configuration
0x0010	1	Configure NPX for Normal Boot	Bit 0 – Configure NPX to use PRINCE • 0 = Configure NPX • 1 = Not configure NPX (default) Bit 1: • 0=Global lock enable • 1=Global lock disable (default) Bit 2: • 0=System lock enable • 1=System lock disable (default) Bit 3: • 0=Global decryption enable • 1=Global decryption disable (default) Bit 4: • 0=Global encryption enable • 1=Global encryption disable (default) Bit 7:5 – Reserved
	1	Sticky NPX Configuration for Waking up from Deep Power Down	Bit 0 – Configure NPX required: • 0 = NPX config. required; ROM follows normal boot path • 1 = Not required; ROM follows Low-power wakeup path (default) Bit 7:1 – Reserved
	6	Reserved	Reserved
	56	NPX Region Definitions	Setting for NVM PRINCE XEX, the inline flash encryption IP module
0x0050	1	Boot Configuration	Bit 0 - Enable ISP or not • 0 = BOOT_CFG pin disabled • 1 = BOOT_CFG pin enabled (default) Bit 2:1 – Boot speed • 00 = Normal boot (32 MHz) • 10 = Fast Boot (96 MHz) • 01, 11 = Normal boot (default) Bit 3 – DCDC boot power mode

Table continues on the next page...

Table 66. ROM Configuration fields (continued)

Offset	Size (bytes)	Configuration Field	Description
			• 0 = Lower power boot mode • 1 = Normal power mode See Table 67 for more details. bit 7:4 – Reserved
	15	Reserved	Reserved
0x0070	16	Reserved	Reserved
0x0080	64	Boot Image Base Address	Start address of Boot image, should align with 32 KB. ROM Bootloader does search from 0x80 and the first not 0xFFFFFFFF 32-bit will be the boot address. So, it's better to program from 0xB0 to 0x80, users will have 4 chances to update boot address.
0x00C0	64	Reserved	Reserved
0x0100	1	Peripherals Enable	Bit 0 – LPUART1 peripheral for ISP • 0 = LPUART1 disabled • 1 = LUPART1 enabled (default) Bit 1 – LPI2C1 peripheral for ISP • 0 = LPI2C1 disabled • 1 = LPI2C1 enabled (default) Bit 2 – LPSPI1 peripheral for ISP • 0 = LPSPI1 disabled • 1 = LPSPI1 enabled (default) Bit 3 – Reserved Bit 7:4 – Reserved
	3	Reserved	Reserved
	2	Peripheral Detection Timeout	If 0xFFFF, defaults to no timeout. If not 0xFFFF, use this value as timeout in milliseconds for active peripheral detection.
	2	Reserved	Reserved
	1	I2C Slave Address	If 0xFF, defaults to 0x10 for LPI2C slave address. If not 0xFF, use this value as the 7-bit LPI2C slave address.
	7	Reserved	Reserved
0x110	4	SSS Loadable FW Entry Address	Secure Sub-System (SSS) loadable firmware resides address
	12	Reserved	Reserved

Table continues on the next page...

Table 66. ROM Configuration fields (continued)

Offset	Size (bytes)	Configuration Field	Description
0x120	4	Secure Hash based image verification feature (for faster subsequent boot)	0xFFFFFFFF – Disabled (ECDSA based verification will be used). If 0x48534148 (“HASH”) – Enabled.
	12	Reserved	Reserved
0x130	16	Reserved	Reserved
0x140	1	Go Isp Mode Options	If enter ISP mode, the log will be recorded on the corresponding pin when this bit and go Isp mode fail alert pin are enable. Bit 0 – Reserved Bit 1– Secure boot option • 0 = Enable • 1 = 1 disable (default) Bit 7:2 – Reserved
	1	Go Isp Mode Fail Alert Pin	Set the ISP log pin Bit [4:0] – Pin Selection • 0x0~0x1F = Pin0~Pin31 Bit [7:5] – Port Selection • 0x0~0x4 = PortA ~PortE • 0x5~7 Reserved
	14	Reserved	Reserved

Restore FLW Flag and FLW Region Definitions fields are Flash Logic Window configurations used for dual image boot. When dual image boot is enabled, there are two boot images on the internal flash. ROM bootloader first tries to boot the boot image with latest version, if fails, ROM bootloader tries to boot the other boot image. To enable the dual image boot, Restore FLW Flag needs to be enabled, Boot Image Base Address field and FLW Region Definition fields need to be configured correctly. Boot Image Base Address indicates the start address of one boot image. FLW Region Definitions indicate the start address and the size of the alternative boot image. Here is the FLW Region Definition structure:

```
struct flw_region {
   uint32_t abase;
   uint32_t bcnt; };
```

The FLW region descriptors simply consist of FLW ABASE, the starting address of the alternative boot image, and, FLW BCNT, the size of the alternative boot image in 32 KB blocks.

If dual image boot is not enabled, ROM bootloader boots from Boot Image Base Address. If Boot Image Base Address is not configured, ROM bootloader will boot from the beginning of flash.

Configure NPX for Normal Boot, NPX Region Definitions fields are used for NPX feature.

Bit 0 of Boot Configuration field is used to enable ISP path for ROM bootloader. BOOT_CFG pin will be enabled if this bit is set. The pull-down on the BOOT_CFG pin is to ensure the device does not enter ISP by default. When BOOT_CFG pin is enabled and the BOOT_CFG pin is not pulled down, ROM bootloader will enter ISP path.

Boot Speed bits will be loaded by ROM bootloader to decide how to configure the power and clock. Bit 1:2 of Boot Configuration indicates the boot speed:

Table 67. Boot speed

Boot speed value in IFR0	Clock source	CPU_CLK/BUS_CLK/SLOW_CLK	DCDC & CORE_LDO voltage
11/00/01: Normal Boot (default)	FRO_192M	48/48/24 MHz	CORE_LDO : 1.0 V DCDC : 1.8 V or 1.25 V
10: Fast Boot	FRO_192M	96/96/24 MHz	CORE_LDO : 1.1 V DCDC : 1.8 V or 1.35 V

15.2.2.2 Over-the-air (OTA) update configuration

Table 68. OTA update configuration

Offset	Size (bytes)	Configuration Field	Description
0x00	4	Update available	0x746f4278u = Indicates update is available
	12	Reserved	Reserved
0x10	4	Update(sb3) dumped location	0x74784578 = sb3 is dumped in external flash
			Other values = sb3 is dumped in internal flash
0x14	4	Baud rate (in bps)	Value used to configure LPSPI NOR flash if update(sb3) is dumped in external flash.
0x18	4	Update(sb3) dump address	Start address (internal/external flash) where update(sb3) is dumped.
0x1c	4	Update(sb3) file bytes	Size of update(sb3) file in number of bytes.
0x20	4	FW update status	0x5ac3c35a = Indicates update was success 0x4412d283/0x2d61e1ac = Indicates failure to process sb3 file OR failure to erase/write update status to OTACFG page
	12	Reserved	Reserved
0x30	16	Feature unlock key	To use FW update feature offered by ROM (instead of extended bootloader) 16-byte key must be programmed. updKey[16] = {0x61, 0x63, 0x74, 0x69, 0x76, 0x61, 0x74, 0x65, 0x53, 0x65, 0x63, 0x72, 0x65, 0x74, 0x78, 0x4d};

15.2.3 Normal boot path

ROM bootloader follows this path when device goes through a WARM reset or POR if not getting a request to go to another path. The ROM bootloader validates the application code residing in the internal flash and boot when validation is successful. By default, when there is no fuse/IFR0 boot configuration programmed, the ROM bootloader does validation for boot image based on image type. It does basic SP and PC value check for raw binary application; CRC check for CRC image and ECDSA authentication for signed image. Secure boot can be enabled and enforced by setting OEM_SEC_BOOT_EN fuse. Radio image sits on radio flash is not validated by the ROM bootloader by default. NBU_SEC_BOOT_EN can be used to enable the authentication for radio image during boot time. If authentication for radio image is enabled but failed during boot time, then radio core will be locked, and it can't be released from reset.

Please note that WDOG0 is disabled during normal boot path and enabled before jumping to the boot image. Meanwhile, the WDOG0 timeout value (TOVAL) has been set to longest (0xFFFF).

Figure below shows the flow of normal boot.

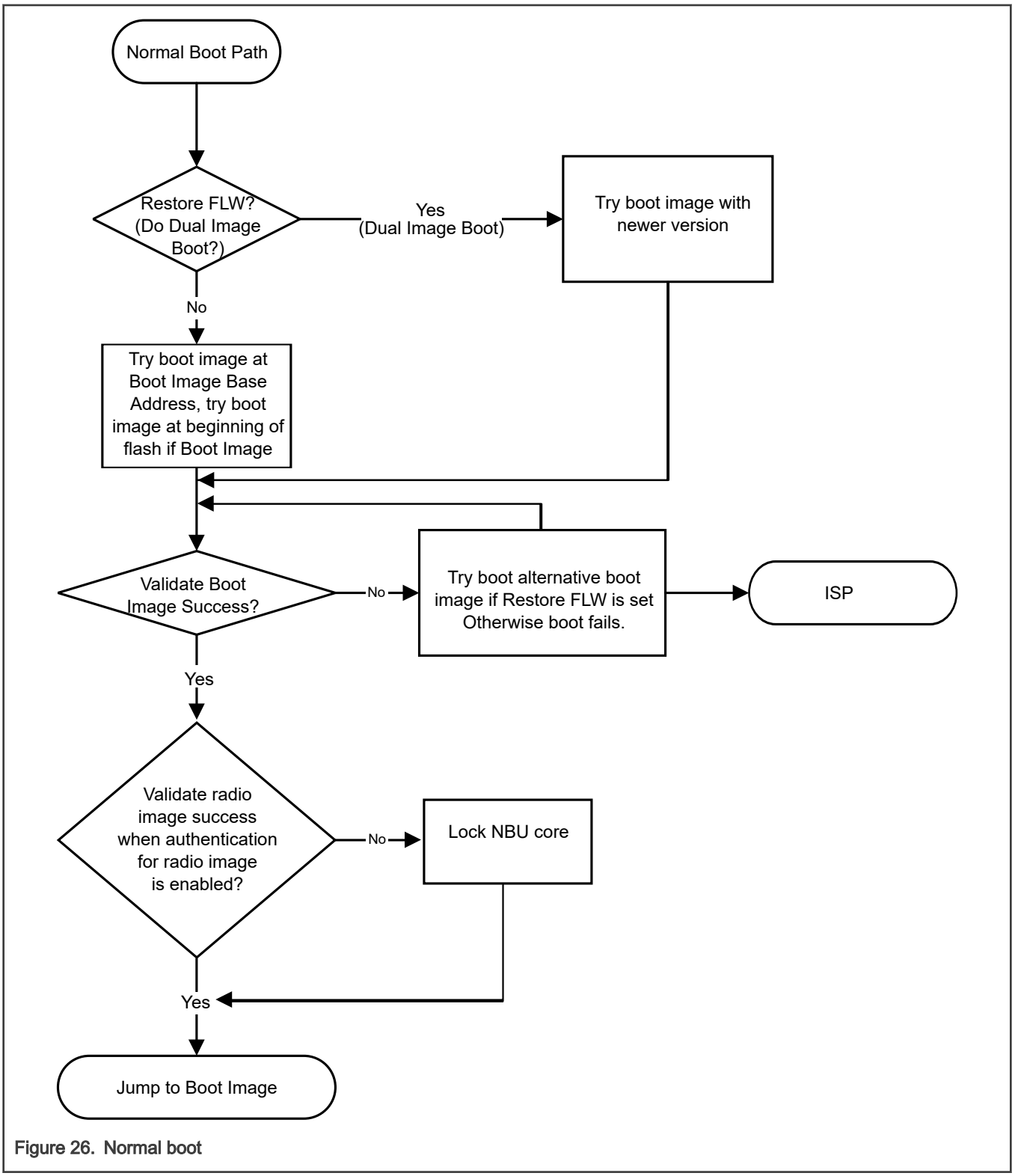


Figure 26. Normal boot

15.2.3.1 Dual image boot

Boot ROM supports dual image boot, useful in scenario where primary image fails to boot for any reason so secondary image (as a backup) can boot. This is achieved in conjunction with Flash Logical Window feature. It will allow developing for position independent code. That means same linker file can be used for creating multiple application images to be treated as primary (experimental or latest firmware image) and secondary (as a backup fallback image).

Use case example of dual boot:

1. “Restore FLW Flag” bit 0 is set to indicate ROM to use FLW feature.
2. Primary image is placed at address 0x10000 and “Boot Image Base Address” field of ROMCFG in user IFR0 is programmed accordingly.
3. Secondary image (fallback/backup) is placed at address 0x20000 and “ABASE” field in FLW region definitions of ROMCFG in user IFR0 is programmed accordingly.
4. Make sure BCNT field of FLW region definitions is set correctly to indicate image size as multiple of 32 KB block size.
5. Boot ROM will compare versions of primary and secondary image.
6. Boot ROM will try to boot latest versioned image. At the same time older versioned image base address is stored in ROM runtime context.
7. If both images have same version, then image located at address specified by “Boot Image Base Address” field of ROMCFG in user IFR0 is considered for boot.
8. For any reason (mainly authentication failure or rollback protection) latest versioned image fails to boot then boot ROM falls back to the older versioned image.

15.2.4 Faster subsequent boot

Boot ROM supports secure boot primarily using an ECDSA verification. And it can also support secure boot using hash (cmac) based image verification for faster subsequent boot.

- The user need to:
  - Program IFR0 page0 at offset 0x120 to request hash based image verification.
  - Include a sbloader command to erase IFR0 page2 for every FW update.
- The ROM handles this request with the following steps:
  - First time after resetting to boot or trying to boot using jump/execute sbloader command after successful FW update, requires ROM to compute hash of image data.
  - Boot ROM computes hash (cmac) for multiple boot components, viz., main flash image (application), radio FW. And stores it in a IFR0 page2 in structured format as described. So it can be used to achieve faster boot time from next boot attempt.
  - But for very first time post FW update, after calculating hash of image data, boot ROM will still use ECDSA based image verification mechanism to perform secure boot.
  - For all subsequent FW updates, it is user’s responsibility to erase IFR0 page2. So that boot ROM understands it needs to calculate hash for multiple bootable components and store it in a structured format.
  - If no FW update is required/performed then triggering multiple resets could utilize faster secure boot sequence.
- If hash based image authentication fails
  - Images are still expected to have signature. So boot ROM would fall back to ECDSA based verification as a primary secure boot mechanism.

IFR0 page2 (hash structure/cmac table maintenance):

This IFR0 dedicated page is used to store hash for boot images in a structured format as shown below. Note that, Buffer size of hash table to be reprogrammed must be at max. 48*4 bytes (to save flash programming time) but phrase-by-phrase programming can also be done as boot ROM progresses through various stages.

```
enum _cmac_table_index
{
kCmacIndexPrim = 0x0U,
kCmacIndexOEM = 0x1U,
kCmacIndexNBU = 0x2U,
kCmacIndexELEfirmware = 0x3U,
kCmacIndexLast = 0x4U,
};

typedef struct{
uint32_t update_needed;
uint32_t reserved0[3];
uint8_t imgHash[NBOOT_CMAC_SIZE_IN_BYTES];
}cmac_info_t;

typedef struct {
cmac_info_t components[kCmacIndexLast]; /*!< Upto 4 components: 2 images (dual), 1 radio, 1 extended
bootloader (TBD) */
}cmac_table_t;
```

Offset	Size (bytes)	Field description	Description
0x0000	4	Hash update needed	0xFFFFFFFF - Yes 0x00000000 – No
	12	Reserved	Reserved
0x0010	16	16 byte CMAC for application image	Hash of main flash primary boot image data at 0x0 OR Hash of Image data at ABASE (if FLW is enabled)
0x0020	4	Hash update needed	0xFFFFFFFF - Yes 0x00000000 – No
	12	Reserved	Reserved
0x0030	16	16 byte CMAC for fallback image	Hash of fallback image data (if “Image 1 Base Address” field in IFR0 page0 is not 0xFFFFFFFF)
0x0040	4	Hash update needed	0xFFFFFFFF - Yes 0x00000000 – No
	12	Reserved	Reserved
0x0050	16	16 byte CMAC for radio image	Hash of radio (NBU) flash image data

Table continues on the next page...

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Offset	Size (bytes)	Field description	Description
0x0060	4	Hash update needed	0xFFFFFFFF - Yes 0x00000000 – No
	12	Reserved	Reserved
0x0070	16	16 byte CMAC for ELE's image	Hash of ELE's image data

15.2.5 Low power wakeup path

The ROM bootloader provides a fast low power wakeup mechanism that supports all low power modes, including:

- Power Down (PD) mode
- Deep Power Down (DPD) mode
- Smart Power Switch (SPS) mode

When the WAKEUP_DIS flag is cleared (WAKEUP_DIS = 0) and the sticky NPX configuration for DPD wakeup is not enabled, the ROM bootloader can execute low power wakeup path after waking up from low power mode. ROM bootloader does normal boot if low power wakeup path fails.

Figure 27 Illustrates the low power wakeup path.

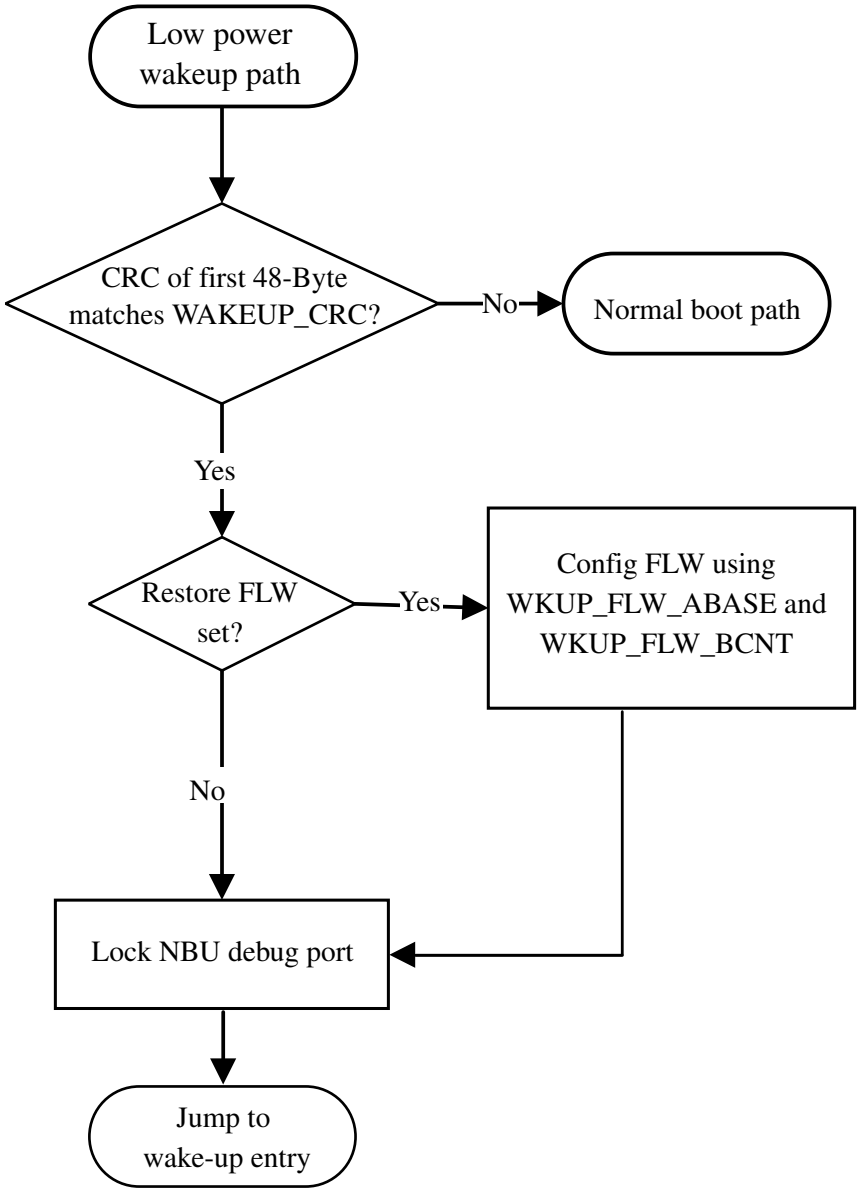

Figure 27. Low power wakeup flow

15.2.5.1 Wakeup from PD mode and DPD mode

When the wakeup path is enabled (i.e., WAKEUP_DIS = 0) and the system wakes up from Power Down (PD) or Deep Power Down (DPD) mode, the ROM bootloader enters the low power wakeup path if the WAKEUP register in SPC0 is set to a non-zero value.

If the CRC value preloaded into REG[0] of REGFILE1 matches the CRC computed over the first 48 bytes of the wakeup image, the ROM bootloader transfers control to the wakeup image at the entry point specified in the WAKEUP register in SPC0. Otherwise, the ROM bootloader exits the low power wakeup path and proceeds with the normal boot sequence.

If the Flash Logic Window (FLW) must be configured for the low power wakeup path, the following values must be correctly set. The ROM bootloader uses WAKEUP_FLW_ABASE and WAKEUP_FLW_BCNT to configure the FLW for low power wakeup path.

- FLW restore flag in IFR0
- WAKEUP_FLW_ABASE in REG[1] of REGFILE1
- WAKEUP_FLW_BCNT in REG[2] of REGFILE1 (Bit 31: Valid bit, Bit 30: Lock bit, Bits 0–14: Block count)

NOTE

If the system boots successfully via the low power wakeup path, the ROM bootloader does not modify WDOG0. In this path, the ELE remains unreleased, and the CM3 debug port remains locked.

15.2.5.2 Wakeup from Smart Power Switch (SPS) mode

Compared to PD and DPD modes, SPS mode offers significantly lower leakage power. In SPS mode, all RAM instances are automatically power-gated, resulting in complete data loss across RAM - except for the last 8 KB of RAM (TCM8), which can remain powered and retain data.

This retained memory region enables the ROM bootloader to execute a fast low power wakeup path. The last two words of TCM8 are reserved by the ROM bootloader for:

- WAKEUP Entry Point at offset 0x1FFC
- WAKEUP_CRC at offset 0x1FF8

During wakeup, if the CRC value stored in WAKEUP_CRC matches the CRC computed over the first 48 bytes of the wakeup image, the ROM bootloader transfers control to the wakeup image at the entry point specified in WAKEUP Entry. If the CRC check fails, the ROM bootloader exits the low power wakeup path and proceeds with the normal boot path.

When using the low power wakeup path from SPS mode, the FLW restore flag in IFR0 must not be configured. FLW restoration is not supported in this wakeup scenario.

15.2.6 Firmware update feature

ROM Bootloader has firmware update feature. It can be used for updating main flash (CM33) as well as radio flash firmware.

Use case example of remote radio firmware update:

1. Main flash (CM33) contains a customer's application image along with NXP delivered OTA client.
2. NXP OTA client helps in fetching image over-the-air via wireless protocol.
3. Image blocks fetched over-the-air are dumped in either internal or external flash.
4. Once the entire image is received, OTA client must indicate and provide meta data information for update to be performed in User IFR0 OTACFG page. (Refer to OTA update configuration).
5. Application is responsible of triggering a software reset upon which boot ROM uses data provided in OTACFG page to start firmware update.
6. Upon successful update, IFR0 OTACFG page is erased and “FW update status” is updated by boot ROM and reset is triggered to follow "Normal boot path".

If the external flash is used, LPSPI1 is configured to master mode and pin assignment is showed in table below.

Table 69. LPSPI1 pin assignment when external flash used and LPSPI1 configured to master mode

Pin name	Pin assignment	Alt
LPSPI1_SCK	PTB2	2
LPSPI1_SIN	PTB1	2
LPSPI1_SOUT	PTB3	2
LPSPI1_DATA2	PTB5	2
LPSPI1_DATA3	PTB4	2
LPSPI1_SS0	PTB0	2

15.2.7 ISP path

ROM bootloader provides in-system programming utility that operates over a serial connection on the MCUs. It enables quick and easy programming of MCUs through the entire product lifecycle, including application development, final product manufacturing, and beyond. Host-side command line tool is available to communicate with the bootloader. Users can utilize host tools to upload/download application code and do manufacturing via the bootloader.

When ROM bootloader enters ISP mode and it will auto-detect activity on the LPI2C/LPSPI/LPUART interface. The auto-detect looks for activity on the LPUART, LPI2C, LPSPI interface and selects the appropriate interface once a properly formed frame is received. If an invalid frame is received, the data is discarded and scanning resumes.

Users can make ROM bootloader go to ISP path by pressing the BOOT_CONFIG pin (PTA4) since BOOT_CONFIG pin is enabled by default in User IFR (IFR0). See ROM bootloader configuration for details of config BOOT_CONFIG pin. In addition, ROM bootloader will go to ISP path when no boot image is found, PC and SP are not valid and some other boot failure conditions.

15.2.7.1 Available peripherals

Table below shows the peripheral instances and pin assignments used by ISP.

Table 70. Peripheral instances and pin assignments used by ISP

Peripheral instances	Pin name	Pin assignment	Alt
LPUART1	LPUART1_TX	PTC3	3
	LPUART1_RX	PTC2	3
LPSPI1	LPSPI1_PCS0	PTB0	2
	LPSPI1_SIN	PTB1	2
	LPSPI1_SCK	PTB2	2
	LPSPI1_SOUT	PTB3	2
LPI2C1	LPI2C1_SCL	PTB5	4
	LPI2C1_SDA	PTB4	4
Boot pin	BOOT_CONFIG	PTA4	Default

15.2.7.2 Available ISP commands

ISP commands availability is controlled by lifecycle. Table below shows the ISP commands available for each lifecycle. Details of several commands can be found in sections below.

Table 71. Available ISP commands for different lifecycle

Command	Description	Before OEM Open	At OEM Open	After OEM Open
Reset	Reset the device	Available	Available	Available
get-property <tag>	Query about various properties and settings	Available	Available	Available
set-property <tag> <value>	Change properties or options in ROM Bootloader	Available	Available	Available
receive-sb-file <file>	Receive a file in Secure Binary (SB) format	Available	Available	Available
flash-erase-region	Erase one or more sectors of the flash memory	Available	With limitation for radio flash	NA

Table continues on the next page...

Table 71. Available ISP commands for different lifecycle (continued)

Command	Description	Before OEM Open	At OEM Open	After OEM Open
flash-erase-all [<memoryID>]	Erase the entire flash memory specified by memoryID	Available	With limitation for radio flash	NA
read-memory <addr> <byte_count> [<file>]	Read memory at specified address	Available	With limitation for radio flash	NA
write-memory <addr> [<file> | {{<hex-data>}}]	Write memory at specified address from a file or string of hex values Note: When write to SRAM, make sure the length of file or hex-data is 4 byte aligned	Available	With limitation for radio flash	NA
fill-memory <addr> <byte_count> <pattern> [word | short | byte]	Fill memory with pattern; pattern size can be word(default), short or byte	Available	With limitation for radio flash	NA
fuse-program <index> [<file> | {{<hex-data>}}]	Program fuse at the specified index from file or string of hex values	Available	Available	NA
fuse-read <index> <byte_count> [<file>]	Read fuse from the specified index	Available	Available	NA
Execute <address> <arg> <stackpointer>	Jumps to code at the provided address and does not return to the ROM bootloader	Available	Available	NA
trust_provisioning	Only support Operation_Prove_Genuinity, generate a string of numbers, and then spsdk to verify to determine whether it is an NXP product	Available	Available	NA

15.2.7.2.1 Available properties

Table below shows the available properties (tag) for this device.

Table 72. Supported properties in GetProperty and SetProperty

Name	Writable	Tag value	Size in Bytes	Description
CurrentVersion	no	1	4	The current bootloader version.
AvailablePeripherals	no	2	4	The set of peripherals supported on this chip.
FlashStartAddress	no	3	4	Start address of program flash.
FlashSizeInBytes	no	4	4	Program flash size in bytes.
FlashSectorSize	no	5	4	The size of one sector of program flash in bytes.
FlashBlockCount	no	6	4	The number of blocks of the on-chip flash.
AvailableCommands	no	7	4	The set of commands supported by the bootloader.
CRCCheckStatus	no	8	4	The status of the application CRC check.

Table continues on the next page...

Table 72. Supported properties in GetProperty and SetProperty (continued)

Name	Writable	Tag value	Size in Bytes	Description
VerifyErase	yes	10	4	Controls whether the bootloader verifies erase to flash. The VerifyErase feature is enabled by default: 1 = Enable 0 = Disable
MaxPacketSize	no	11	4	Maximum supported packet size for the currently active peripheral interface.
ReservedRegions	no	12	4	List of memory regions reserved by the bootloader. Returned as value pairs (<startaddress-ofregion>, <end-addressof-region>).
RAMStartAddress	no	14	4	Start address of RAM
RAMSizeInBytes	no	15	4	RAM size in bytes.
SystemDeviceId	no	16	4	System Device ID
SecurityState	no	17	4	Security status
UniqueDeviceId	no	18	16	Unique device identification
BootStatus	no	32	4	Value of Boot Status Register
LoadableFWVersion	no	33	4	SSS loadable firmware version
FuseProgramVoltage	yes	34	4	Control the System LDO VDD Regulator Voltage Level. To program fuse, System LDO VDD regulator level needs to be regulated to Over Drive Voltage (2.5 V). The default System LDD VDO Regulator Voltage Level is regulated to Normal Voltage (1.8 V). 0 = System LDO VDO Regulator Voltage Level is related to Normal Voltage (1.8 V) 1 = System LDO VDD regulator level is regulated to Over Drive Voltage (2.5 V)
TargetVersion	no	24	4	Target version

15.2.7.2.2 Fuse reading and programming

A set of fuses can be read / programmed using fuse-program and fuse-read commands. The index of fuses can be found in Lifecycle and fuses.

Please note that -- set-property 0x22 needs to be used before -- fuse-program command to ensure fuse can be programmed successfully. And -- set-property 0x22 needs to be done after all the fuse programming completes.

15.2.7.2.3 Commands with limitation

Command flash-erase-all can have memoryID as a parameter, if no ID is specified or 0 is specified, the entire Program Flash will be erased. If 2 is specified as memoryID, the entire radio Program Flash will be erased. If 3 is specified as memoryID, the entire radio User IFR (IFR0) will be erased.

15.2.7.2.4 receive-sb-file

receive-sb-file command is used to do image update on CM33 flash or radio (CM33) flash when security is enforced. It receives a secure binary (SB) file, decrypt, authenticate and program the image to the target memory. CUST_PROD_OEMFW_ENC_SK fuse needs to be programmed correctly to ensure this command can be used successfully. Please note that -- set-property 34 1 needs to be used before receive-sb-file command if the sb file contains "programFuses" command. And -- set-property 34 0 needs to be done after receive-sb-file is done.

15.2.7.3 In-System Programming protocol

This section explains the general protocol for the packet transfers between the host and the ROM Bootloader. The description includes the transfer of packets for different transactions, such as commands with no data phase and commands with incoming or outgoing data phase. The next section describes various packet types used in a transaction.

Each command sent from the host is replied to with a response command.

Commands may include an optional data phase.

- If the data phase is incoming (from the host to the bootloader), it is part of the original command.
- If the data phase is outgoing (from the bootloader to host), it is part of the response command.

15.2.7.3.1 Command with no data phase

The protocol for a command with no data phase contains:

- Command packet (from the host)
- Generic response command packet (to host)

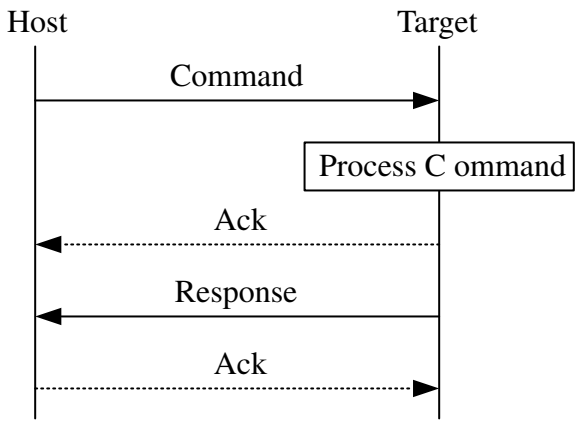

Figure 28. Command with no data phase

NOTE

In these diagrams, the ACK sent in response to a command or a data packet can arrive at any time before, during, or after the command or data packet has processed.

15.2.7.3.2 Command with incoming data phase

The protocol for a command with incoming data phase contains:

- Command packet (from host) (kCommandFlag_HasDataPhase set).
- Generic response command packet (to host).
- Incoming data packets (from the host).
- Generic response command packet.

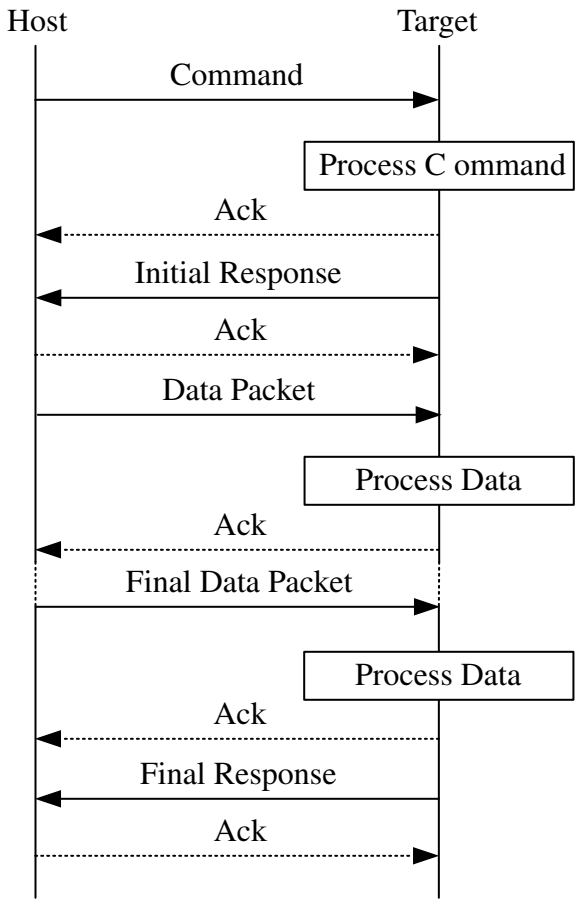

Figure 29. Command with incoming data phase

NOTE

- The host may not send any further packets while it is waiting for the response to a command.
- The data phase is aborted if the Generic Response packet prior to the start of the Data phase does not have a status of kStatus_Success.
- Data phases may be aborted by the receiving side by sending the final GenericResponse early with a status of kStatus_AbortDataPhase. The host may abort the data phase early by sending a zero-length data packet.
- The final Generic Response packet sent after the data phase includes the status of the entire operation.

15.2.7.3.3 Command with outgoing data phase

The protocol for a command with an outgoing data phase contains:

- Command packet (from the host).
- ReadMemory Response command packet (to host) (kCommandFlag_HasDataPhase set).
- Outgoing data packets (to host).
- Generic response command packet (to host).

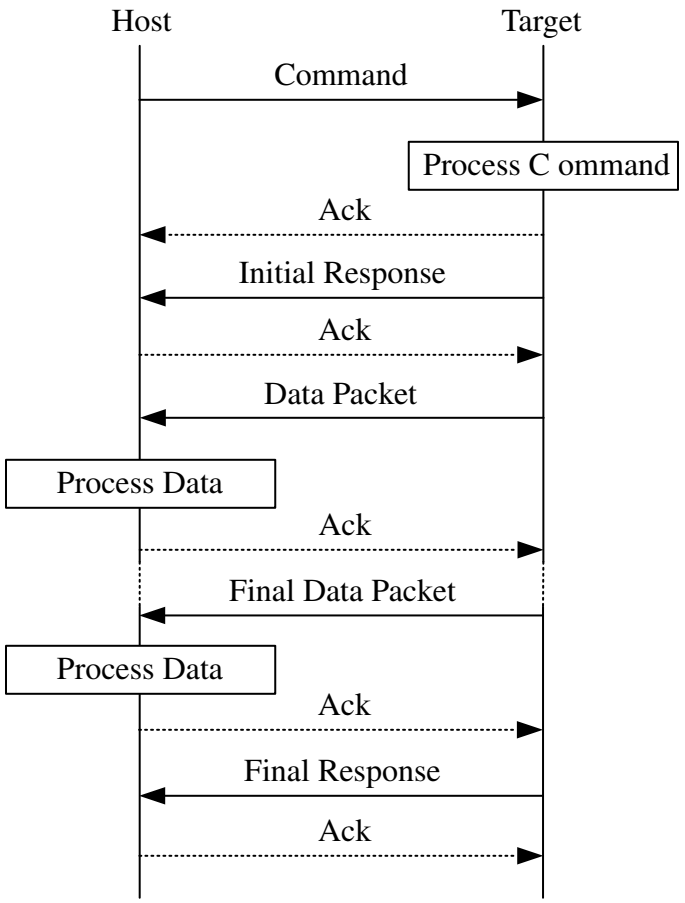

Figure 30. Command with outgoing data phase

NOTE

- The data phase is considered part of the response command for the outgoing data phase sequence. The host may not send any further packets while the host is waiting for the response to a command.
- The data phase is aborted if the ReadMemory Response command packet, prior to the start of the data phase, does not contain the kCommandFlag_HasDataPhase flag. Data phases may be aborted by the host sending the final Generic Response early with a status of kStatus_AbortDataPhase. The sending side may abort the data phase early by sending a zero-length data packet.
- The final Generic Response packet sent after the data phase includes the status of the entire operation.

15.2.7.4 ISP packet type

The bootloader device works in slave mode. All data communications are initiated by a host, which is either a PC or an embedded host. The bootloader device is the target, which receives a command or data packet. All data communications between host and target are packetized.

There are six types of packets used:

- Ping packet.
- Ping Response packet.
- Framing packet.
- Command packet.

- Data packet.
- Response packet.

All fields in the packets are in little-endian byte order.

15.2.7.4.1 Ping packet

The Ping packet is the first packet sent from a host to the target to establish a connection on the selected peripheral in order to run autobaud detection. The Ping packet can be sent from host to target at any time that the target is expecting a command packet. If the selected peripheral is LPUART, a ping packet must be sent before any other communications. For other serial peripherals, it is optional.

In response to a Ping packet, the target sends a Ping Response packet, discussed in later sections.

Table 73. Ping packet format

Byte #	Value	Name
0	0x5A	start byte
1	0xA6	ping

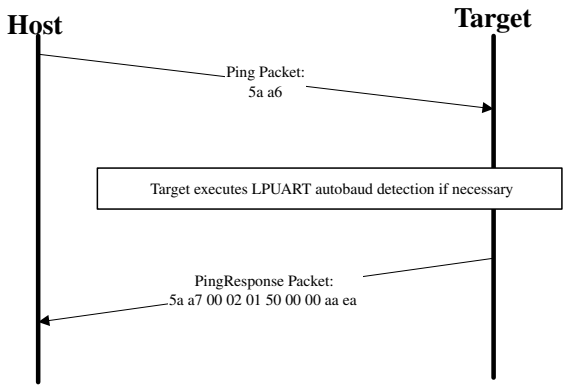

Figure 31. Ping packet protocol sequence

15.2.7.4.2 Ping response packet

The target sends a Ping Response packet back to the host after receiving a Ping packet. If communication is over an LPUART peripheral, the target uses the incoming Ping packet to determine the baud rate before replying with the Ping Response packet. Once the Ping Response packet is received by the host, the connection is established, and the host starts sending commands to the target.

Table 74. ping response packet format

Byte #	Value	Parameter
0	0x5A	Start byte
1	0xA7	Ping response code
2	0x00	Protocol bugfix
3	0x03	Protocol minor
4	0x01	Protocol major

Table continues on the next page...

Table 74. ping response packet format (continued)

Byte #	Value	Parameter
5	0x50	Protocol name = 'P' (0x50)
6	0x00	Options low
7	0x00	Options high
8	0xaa	CRC16 low
9	0xea	CRC16 high

The Ping Response packet can be sent from host to target any time the target expects a command packet. For the LPUART peripheral, it must be sent by the host when a connection is first established, in order to run outbound. For other serial peripherals, it is optional but recommended to determine the serial protocol version. The version number is in the same format as the bootloader version number returned by the GetProperty command.

15.2.7.4.3 Framing packet

The framing packet is used for flow control and error detection for the communications links that do not have such features built-in. The framing packet structure sits between the link layer and the command layer. It wraps command and data packets as well.

Every framing packet containing data sent in one direction results in a synchronizing response framing packet in the opposite direction.

The framing packet described in this section is used for serial peripherals including the LPUART, LPI2C, and LPSPI.

Table 75. Framing packet format

Byte #	Value	Parameter	Remark
0	0x5A	Start byte	
1		packetType	
2		length_low	Length is a 16-bit field that specifies the entire command or data packet size in bytes.
3		length_high	
4		crc16_low	This is a 16-bit field. The CRC16 value covers entire framing packet, including the start byte and command or data packets, but does not include the CRC bytes. See the CRC16 algorithm after this table.
5		crc16_high	
6 . . . n		Command or Data packet payload	

A special framing packet that contains only a start byte and a packet type is used for synchronization between the host and target.

Table 76. Special framing packet format

Byte #	Value	Parameter
0	0x5A	Start byte
1	0xA*n*	packetType

The Packet Type field specifies the type of the packet from one of the defined types (below):

Table 77. packetType field

packetType	Name	Description
0xA1	kFramingPacketType_Ack	The previous packet was received successfully; the sending of more packets is allowed.
0xA2	kFramingPacketType_Nak	The previous packet was corrupted and must be re-sent.
0xA3	kFramingPacketType_AckAbort	Data phase is being aborted.
0xA4	kFramingPacketType_Command	The framing packet contains a command packet payload.
0xA5	kFramingPacketType_Data	The framing packet contains a data packet payload.
0xA6	kFramingPacketType_Ping	Sent to verify the other side is alive. Also used for LPUART autobaud.
0xA7	kFramingPacketType_PingResponse	A response to Ping; contains the framing protocol version number and options.

15.2.7.4.4 CRC16 algorithm

This section provides the CRC16 algorithm.

The CRC is computed over each byte in the framing packet header, excluding the crc16 field itself, plus all of the payload bytes. The CRC algorithm is the XMODEM variant of CRC-16.

Table 78. Characteristics of the XMODEM variant

Variant	Values
Width	16
Polynomial	0x1021
Init value	0x0000
Reflect in	False
Reflect out	False
xor out	0x0000
Check result	0x31c3

The check result is computed by running the ASCII character sequence "123456789" through the algorithm.

```
uint16_t crc16_update(const uint8_t * src, uint32_t lengthInBytes)
{
   uint32_t crc = 0;
   uint32_t j;
   for (j=0; j < lengthInBytes; ++j)
   {
        uint32_t i;
    uint32_t byte = src[j];
     crc ^= byte << 8;
```

```
      for (i = 0; i < 8; ++i)
       {
          uint32_t temp = crc << 1;
          if (crc & 0x8000)
           {
               temp ^= 0x1021;
           }
           crc = temp;
       }
    }
    return crc;
}
```

15.2.7.4.5 Command packet

The command packet carries a 32-bit command header and a list of 32-bit parameters.

Table 79. Command packet format (32 bytes)

Command Header (4 bytes)				28 bytes for Parameters (Max 7 parameters)						
Tag	Flags	Rsvd	Param Count	Param1 (32-bit)	Param2 (32-bit)	Param3 (32-bit)	Param4 (32-bit)	Param5 (32-bit)	Param6 (32-bit)	Param7 (32-bit)
Byte 0	Byte 1	Byte 2	Byte 3	-	-	-	-	-	-	-

Table 80. Command header format

Byte #	Command Header Field	Remark
0	Command or Response tag	The command header is 4 bytes long, with these fields.
1	Flags	
2	Reserved. Should be 0x00.	
3	ParameterCount	

The header is followed by 32-bit parameters up to the value of the ParameterCount field specified in the header. Because a command packet is 32 bytes long, only 7 parameters can fit into the command packet.

Command packets are also used by the target to send responses back to the host. As mentioned earlier, command packets and data packets are embedded into framing packets for all the transfers.

Table 81. Command tags

Command Tag	Name	Remark
0x01	FlashEraseAll	The command tag specifies one of the commands supported by the bootloader. The valid command tags for the bootloader are listed here.
0x02	FlashEraseRegion	
0x03	ReadMemory	
0x04	WriteMemory	
0x05	FillMemory	
0x06	Reserved	
0x07	GetProperty	

Table continues on the next page...

Table 81. Command tags (continued)

Command Tag	Name	Remark
0x08	ReceiveSbFile	
0x09	Execute	
0x0A	Reserved	
0x0B	Reset	
0x0C	SetProperty	
0x0D	Reserved	
0x0E	Reserved	
0x0F	Reserved	
0x10	Reserved	
0x11	Reserved	
0x12	Reserved	
0x13	Reserved	
0x14	FuseProgram	
0x15	Reserved	
0x16	TrustProvisioning	
0x17	FuseRead	

Table 82. Response tags

Response Tag	Name	Remark
0xA0	GenericResponse	The response tag specifies one of the responses the bootloader (target) returns to the host. The valid response tags are listed here.
0xA7	GetPropertyResponse (used for sending responses to GetProperty command only)	
0xA3	ReadMemoryResponse (used for sending responses to ReadMemory command only)	
0xAF	FlashReadOnceResponse (used for sending responses to FlashReadOnce command only)	
0xB5	TrustProvisioningResponse	

Flags: Each command packet contains a Flag byte. Only bit 0 of the flag byte is used. If bit 0 of the flag byte is set to 1, then data packets follow the command sequence. The number of bytes that are transferred in the data phase is determined by a command specific parameter in the parameters array.

ParameterCount: The number of parameters included in the command packet.

Parameters: The parameters are word-length (32 bits). With the default maximum packet size of 32 bytes, a command packet can contain up to 7 parameters.

15.2.7.4.6 Response packet

The responses are carried using the same command packet format wrapped with framing packet data. Types of responses include:

- GenericResponse
- GetPropertyResponse
- ReadMemoryResponse
- FlashReadOnceResponse
- TrustProvisioningResponse

GenericResponse: After the bootloader has processed a command, the bootloader sends a generic response with status and command tag information to the host. The generic response is the last packet in the command protocol sequence. The generic response packet contains the framing packet data and the command packet data (with generic response tag = 0xA0) and a list of parameters (defined in the next section). The parameter count field in the header is always set to 2, for status code and command tag parameters.

Table 83. GenericResponse parameters

Byte #	Parameter	Description
0 - 3	Status code	The Status codes are errors encountered during the execution of a command by the target. If a command succeeds, then a kStatus_Success code is returned.
4 - 7	Command tag	The Command tag parameter identifies the response to the command sent by the host.

GetPropertyResponse: The GetPropertyResponse packet is sent by the target in response to the host query that uses the GetProperty command. The GetPropertyResponse packet contains the framing packet data and the command packet data, with the command/response tag set to a GetPropertyResponse tag value (0xA7).

The parameter count field in the header is set to greater than 1, to always include the status code and one or many property values.

Table 84. GetPropertyResponse parameters

Byte #	Parameter
0 - 3	Status code
4 - 7	Property value
. . .	. . .
	Can be up to maximum 6 property values, limited to the size of the 32-bit command packet and property type.

ReadMemoryResponse: The ReadMemoryResponse packet is sent by the target in response to the host sending a ReadMemory command. The ReadMemoryResponse packet contains the framing packet data and the command packet data, with the command/response tag set to a ReadMemoryResponse tag value (0xA3), the flags field set to kCommandFlag_HasDataPhase (1).

The parameter count set to 2 for the status code and the data byte count parameters shown below.

Table 85. ReadMemoryResponse parameters

Byte #	Parameter	Description
0 - 3	Status code	The status of the associated Read Memory command.
4 - 7	Data byte count	The number of bytes sent in the data phase.

FlashReadOnceResponse: The FlashReadOnceResponse packet is sent by the target in response to the host sending a FlashReadOnce command. The FlashReadOnceResponse packet contains the framing packet data and the command packet data, with the command/response tag set to a FlashReadOnceResponse tag value (0xAF), and the flags field set to 0. The parameter count is set to 2 plus the number of words requested to be read in the FlashReadOnceCommand.

Table 86. FlashReadOnceResponse parameters

Byte #	Parameter
0 – 3	Status code
4 – 7	Byte count to read
…	…
	Can be up to 20 bytes of requested read data.

TrustProvisioningResponse packet is sent by the target in response to the host sending a TrustProvisioning command. The TrustProvisioningResponse packet contains the framing packet data and the command packet data, with the command /response tag set to a TrustProvisioning tag value(0xB5), and the flag is set to 0.

15.2.7.5 Bootloader command set

All bootloader commands follow the command packet format wrapped by the framing packet as explained in previous sections.

See Available ISP commands for different lifecycle for a list of commands supported by the bootloader.

15.2.7.5.1 GetProperty command

The GetProperty command is used to query the bootloader about various properties and settings. Each supported property has a unique 32-bit tag associated with it. The tag occupies the first parameter of the command packet. The target returns a GetPropertyResponse packet with the property values for the property identified with the tag in the GetProperty command.

Properties are the defined units of data that can be accessed with the GetProperty or SetProperty commands. Properties may be read-only or read-write. All read-write properties are 32-bit integers, so they can easily be carried in a command parameter.

The 32-bit property tag is the only parameter required for GetProperty command.

Table 87. Parameters for GetProperty Command

Byte #	Command
0 - 3	Property tag See Available properties for more details.
4 - 7	External Memory Identifier (only applies to get property for external memory)

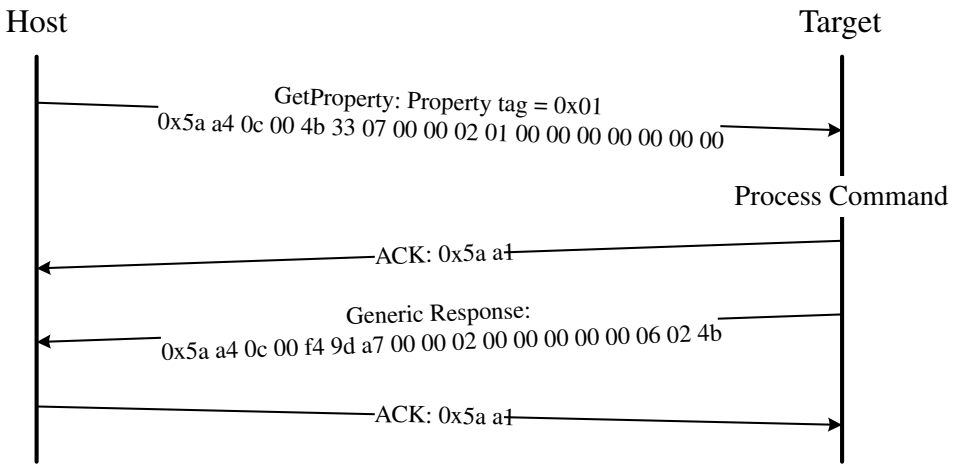

Figure 32. Protocol Sequence for GetProperty Command

Table 88. GetProperty Command Packet Format (Example)

GetProperty	Parameter	Value
Framing packet	start byte	0x5A
	packetType	0xA4, kFramingPacketType_Command
	length	0x0C 0x00
	crc16	0x4B 0x33
Command packet	commandTag	0x07 – GetProperty
	flags	0x00
	reserved	0x00
	parameterCount	0x02
	propertyTag	0x00000001 - CurrentVersion
	Memory ID	0x00000000 - Internal Flash

The GetProperty command has no data phase.

Response: In response to a GetProperty command, the target sends a

GetPropertyResponse packet with the response tag set to 0xA7. The parameter count indicates the number of parameters sent for the property values, with the first parameter showing status code 0, followed by the property value(s). The next table shows an example of a GetPropertyResponse packet.

Table 89. GetProperty Response Packet Format (Example)

GetPropertyResponse	Parameter	Value
Framing packet	start byte	0x5A
	packetType	0xA4, kFramingPacketType_Command
	length	0x0c 0x00 (12 bytes)
	crc16	0x07 0x7a
Command packet	responseTag	0xA7
	flags	0x00
	reserved	0x00
	parameterCount	0x02
	status	0x00000000
	propertyValue	0x0000014b - CurrentVersion

15.2.7.5.2 SetProperty command

The SetProperty command is used to change or alter the values of the properties or options of the bootloader. The command accepts the same property tags used with the GetProperty command. However, only some properties are writable--see Available properties. If an attempt to write a read-only property is made, an error is returned indicating the property is read-only and cannot be changed.

The property tag and the new value to set are the two parameters required for the SetProperty command.

Table 90. Parameters for SetProperty Command

Byte #	Command
0 - 3	Property tag See Available properties for more details.
4 - 7	Property value

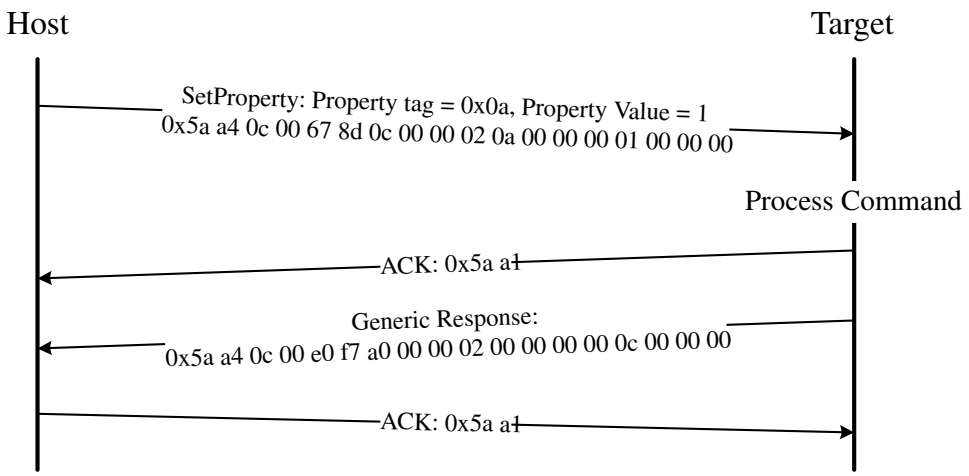

Figure 33. Parameters for SetProperty Command

Table 91. SetProperty Command Packet Format (Example)

SetProperty	Parameter	Value
Framing packet	start byte	0x5A
	packetType	0xA4, kFramingPacketType_Command
	length	0x0C 0x00
	crc16	0x67 0x8D
Command packet	commandTag	0x0C – SetProperty with property tag 10
	flags	0x00
	reserved	0x00
	parameterCount	0x02
	propertyTag	0x0000000A - VerifyWrites
	propertyValue	0x00000001

The SetProperty command has no data phase.

Response: The target returns a GenericResponse packet with one of following status codes:

Table 92. SetProperty Response Status Codes

Status Code
kStatus_Success
kStatus_ReadOnly
kStatus_UnknownProperty
kStatus_InvalidArgument

15.2.7.5.3 FlashEraseAll command

The FlashEraseAll command performs an erase of the entire flash memory. If any flash regions are protected, then the FlashEraseAll command fails and returns an error status code. The Command tag for FlashEraseAll command is 0x01 set in the commandTag field of the command packet.

The FlashEraseAll command requires memory ID. If memory ID is not specified, the internal flash (memory ID =0) will be selected as default.

Table 93. Parameter for FlashEraseAll Command

Byte #	Parameter	
	Memory ID	Descriptions
0-3	0x000	Internal Flash
	0x002	Radio PFlash
	0x003	Radio User IFR

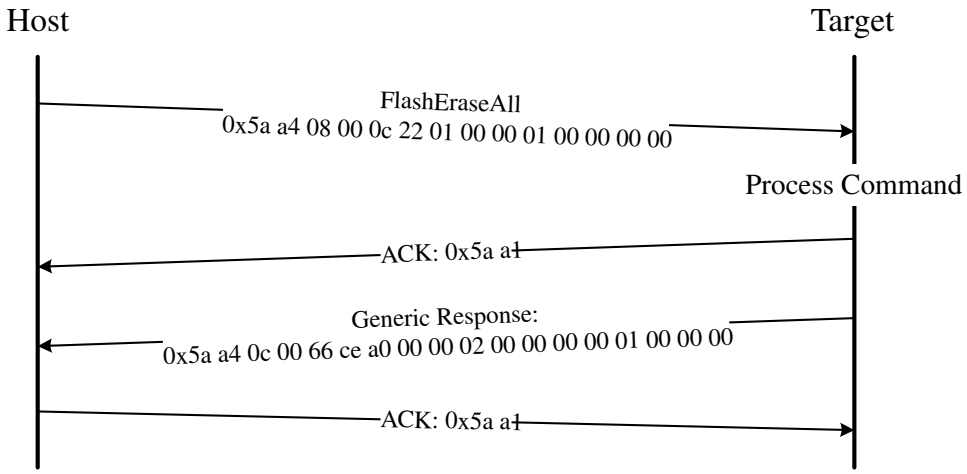

Figure 34. Protocol Sequence for FlashEraseAll Command

Table 94. FlashEraseAll Command Packet Format (Example)

FlashEraseAll	Parameter	Value
Framing packet	start byte	0x5A
	packetType	0xA4, kFramingPacketType_Command
	length	0x08 0x00
	crc16	0x0C 0x22
Command packet	commandTag	0x01 - FlashEraseAll
	flags	0x00
	reserved	0x00
	parameterCount	0x01
	Memory ID	refer to the above table

The FlashEraseAll command has no data phase.

Response: The target returns a GenericResponse packet with status code either set to kStatus_Success for successful execution of the command or set to an appropriate error status code.

15.2.7.5.4 FlashEraseRegion command

The FlashEraseRegion command performs an erase of one or more sectors of the flash memory.

The start address, and number of bytes are the 2 parameters required for the FlashEraseRegion command. The start and byte count parameters must be 32-byte aligned ([3:0] = 0000), or the FlashEraseRegion command fails and returns kStatus_FlashAlignmentError (101). If the region specified does not fit in the flash memory space, the FlashEraseRegion command fails and returns kStatus_FlashAddressError (102). If any part of the region specified is protected, the FlashEraseRegion command fails and returns kStatus_MemoryRangeInvalid (10200).

Table 95. Parameters for FlashEraseRegion Command

Byte #	Parameter
0 - 3	Start address
4 - 7	Byte count
8 - 11	Memory ID

The FlashEraseRegion command has no data phase.

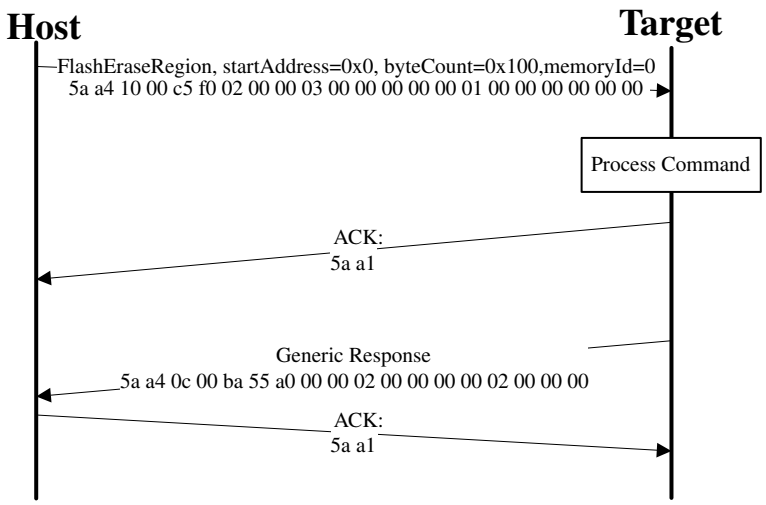

Figure 35. Protocol Sequence for FlashEraseRegion Command

Response: The target returns a GenericResponse packet with one of following error status codes.

Table 96. FlashEraseRegion Response Status Codes

Status Code
kStatus_Success (0)
kStatus_MemoryRangeInvalid (10200)
kStatus_FlashAlignmentError (101)
kStatus_FlashAddressError (102)
kStatus_FlashAccessError (103)
kStatus_FlashCommandFailure (105)

15.2.7.5.5 ReadMemory command

The ReadMemory command returns the contents of memory at the given address, for a specified number of bytes. This command can read any region of memory accessible by the CPU and not protected by security.

The start address, and number of bytes are the two parameters required for ReadMemory command. The memory ID is optional. Internal memory will be selected as default if memory ID is not specified.

Table 97. Parameters for read memory command

Byte	Parameter	Description
0-3	Start address	Start address of memory to read from
4-7	Byte count	Number of bytes to read and return to caller
8-11	Memory ID	Internal or external memory Identifier

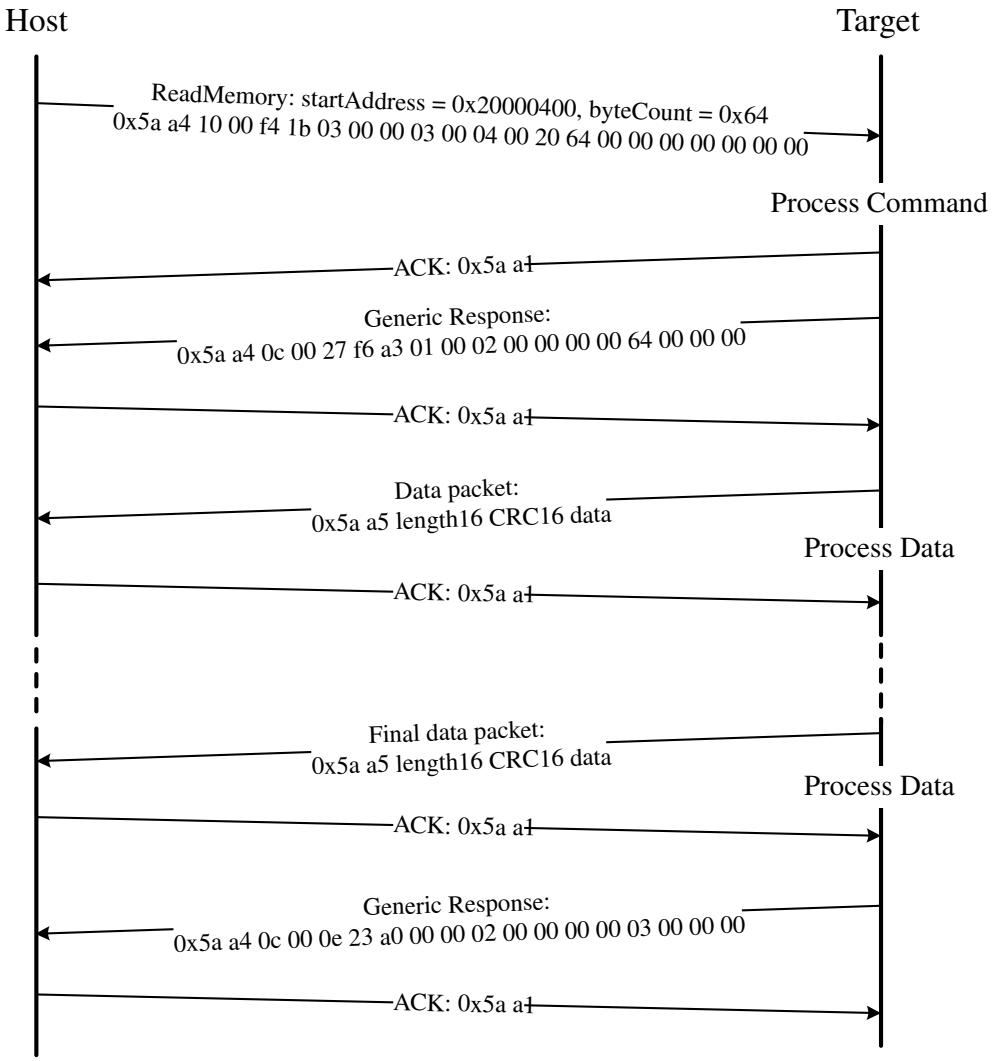

Figure 36. Command sequence for ReadMemory

Table 98. ReadMemory Command Packet Format (Example)

ReadMemory	Parameter	Value
Framing packet	Start byte	0x5A0xA4,
	packetType	kFramingPacketType_Command
	length	0x10 0x00
	crc16	0xF4 0x1B

Table continues on the next page...

Table 98. ReadMemory Command Packet Format (Example) (continued)

Command packet	commandTag	0x03 - readMemory
	flags	0x00
	reserved	0x00
	parameterCount	0x03
	startAddress	0x20000400
	byteCount	0x00000064
	memoryID	0x0

Data Phase: The ReadMemory command has a data phase. Because the target works in slave mode, the host needs to pull data packets until the number of bytes of data specified in the byteCount parameter of ReadMemory command are received by host.

Response: The target returns a GenericResponse packet with a status code either set to kStatus_Success upon successful execution of the command or set to an appropriate error status code.

15.2.7.5.6 WriteMemory command

The WriteMemory command writes data provided in the data phase to a specified range of bytes in memory (flash or RAM). However, if flash protection is enabled, then writes to protected sectors fail.

Special care must be taken when writing to flash.

- First, any flash sector written to must have been previously erased with a FlashEraseAll or FlashEraseRegion command.
- Writing to flash requires the start address to be 16-byte aligned ([3:0] = 0000).
- The byte count is rounded up to a multiple of 4, and trailing bytes are filled with the flash erase pattern (0xff).
- If the VerifyWrites property is set to true, then writes to flash also performs a flash verify program operation.

When writing to RAM, the start address does not need to be aligned, and the data is not padded.

The start address and number of bytes are the 2 parameters required for WriteMemory command. The memory ID is optional. Internal memory will be selected as default if memory ID is not specified.

Table 99. Parameters for WriteMemory Command

Byte #	Command
0 - 3	Start address
4 - 7	Byte count
8 - 11	Memory ID

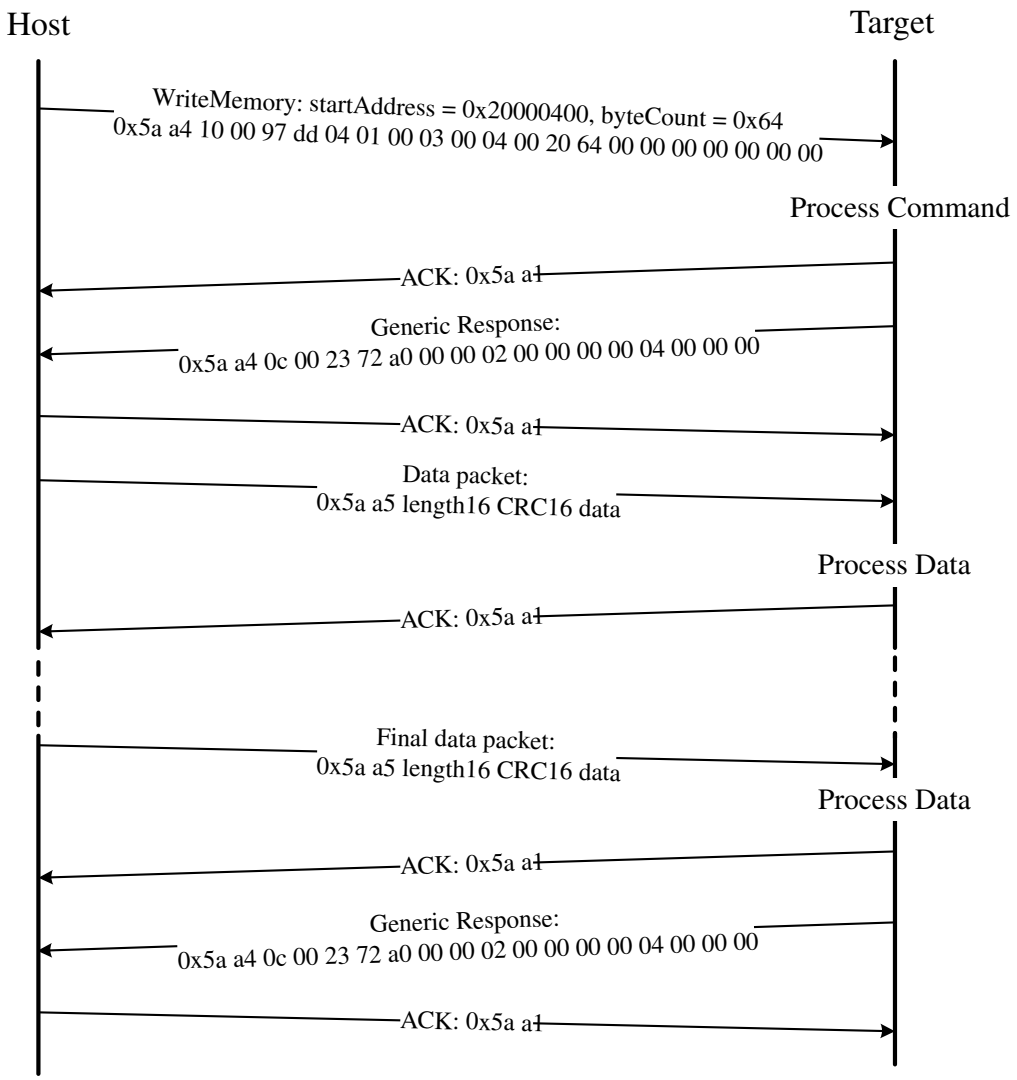

Figure 37. Protocol Sequence for WriteMemory Command

Table 100. WriteMemory Command Packet Format (Example)

WriteMemory	Parameter	Value
Framing packet	start byte	0x5A
	packetType	0xA4, kFramingPacketType_Command
	length	0x10 0x00

Table continues on the next page...

Table 100. WriteMemory Command Packet Format (Example) (continued)

	crc16	0x97 0xDD
Command packet	commandTag	0x04 - writeMemory
	flags	0x01
	reserved	0x00
	parameterCount	0x03
	startAddress	0x20000400
	byteCount	0x00000064
	memoryID	0x0

Data Phase: The WriteMemory command has a data phase; the host sends data packets until the number of bytes of data specified in the byteCount parameter of the WriteMemory command are received by the target.

Response: The target returns a GenericResponse packet with a status code set to kStatus_Success upon successful execution of the command, or to an appropriate error status code.

15.2.7.5.7 FillMemory command

The FillMemory command fills a range of bytes in memory with a data pattern. It follows the same rules as the WriteMemory command. The difference between FillMemory and WriteMemory is that a data pattern is included in FillMemory command parameter, and there is no data phase for the FillMemory command, while WriteMemory does have a data phase.

Table 101. Parameters for FillMemory Command

Byte #	Command
0 - 3	Start address of memory to fill
4 - 7	Number of bytes to write with the pattern • The start address should be 32-bit aligned. • The number of bytes must be evenly divisible by 4.
8 - 11	32-bit pattern

- To fill with a byte pattern (8-bit), the byte must be replicated 4 times in the 32-bit pattern.
- To fill with a short pattern (16-bit), the short value must be replicated 2 times in the 32-bit pattern.

For example, to fill a byte value with 0xFE, the word pattern is 0xFEFEFEFE; to fill a short value 0x5AFE, the word pattern is 0x5AFE5AFE.

Special care must be taken when writing to flash.

- First, any flash sector written to must have been previously erased with a FlashEraseAll or FlashEraseRegion command.
- Writing to flash requires the start address to be 16-byte aligned ([3:0] = 0000).
- If the VerifyWrites property is set to true, then writes to flash also performs a flash verify program operation.

When writing to RAM, the start address does not need to be aligned, and the data is not padded.

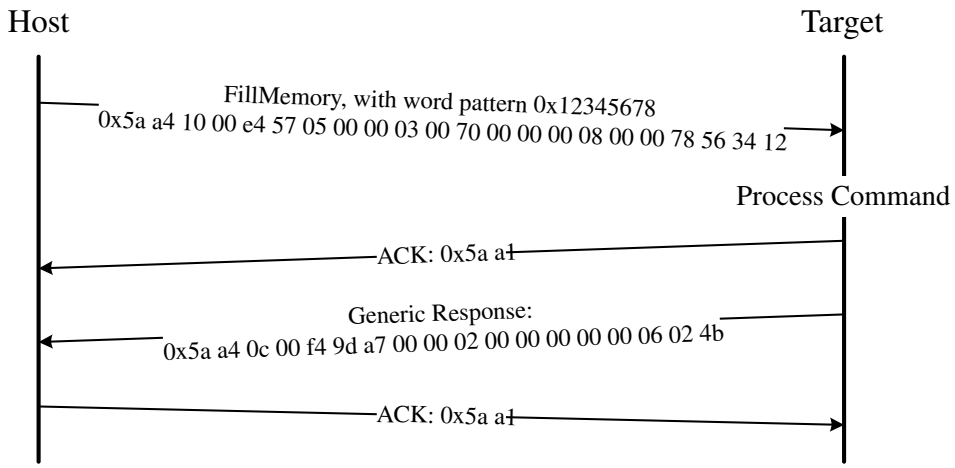

Figure 38. Protocol Sequence for FillMemory Command

Table 102. FillMemory Command Packet Format (Example)

FillMemory	Parameter	Value
Framing packet	start byte	0x5A
	packetType	0xA4, kFramingPacketType_Command
	length	0x10 0x00
	crc16	0xE4 0x57
Command packet	commandTag	0x05 – FillMemory
	flags	0x00
	Reserved	0x00
	parameterCount	0x03
	startAddress	0x00007000
	byteCount	0x00000800
	patternWord	0x12345678

The FillMemory command has no data phase.

Response: upon successful execution of the command, the target (Kinetis bootloader) returns a GenericResponse packet with a status code set to kStatus_Success, or to an appropriate error status code.

15.2.7.5.8 Execute command

The execute command results in the bootloader setting the program counter to the code at the provided jump address, R0 to the provided argument, and a Stack pointer to the provided stack pointer address. Prior to the jump, the system is returned to the reset state.

The Jump address, function argument pointer, and stack pointer are the parameters required for the Execute command. If the stack pointer is set to zero, the called code is responsible for setting the processor stack pointer before using the stack.

Table 103. . Parameters for Execute Command

Byte #	Command
0 - 3	Jump address
4 - 7	Argument word
8 - 11	Stack pointer address

The Execute command has no data phase.

Response: Before executing the Execute command, the target validates the parameters and return a GenericResponse packet with a status code either set to kStatus_Success or an appropriate error status code.

15.2.7.5.9 Reset command

The Reset command results in the bootloader resetting the chip.

The Reset command requires no parameters.

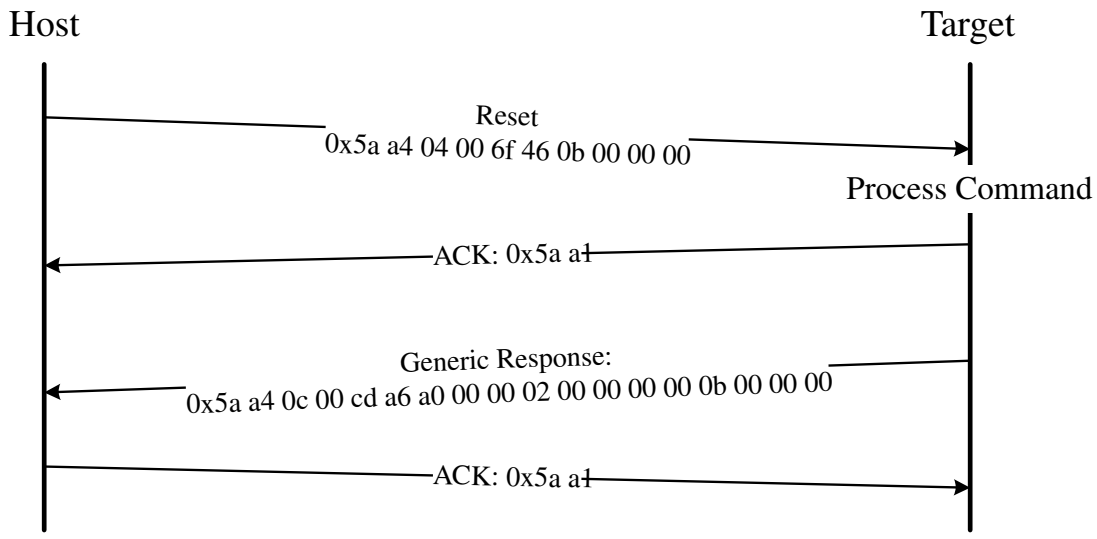

Figure 39. Protocol Sequence for Reset Command

Table 104. Reset Command Packet Format (Example)

Reset	Parameter	Value
Framing packet	start byte	0x5A
	packetType	0xA4, kFramingPacketType_Command
	length	0x04 0x00
	crc16	0x6F 0x46
Command packet	commandTag	0x0B - reset
	flags	0x00
	reserved	0x00
	parameterCount	0x00

The Reset command has no data phase.

Response: The target returns a GenericResponse packet with status code set to kStatus_Success, before resetting the chip.

The reset command can also be used to switch boot from flash after successful flash image provisioning via ROM bootloader. After issuing the reset command, allow 5 seconds for the user application to start running from Flash.

15.2.7.5.10 Receive SBFile command

The Receive SB File command (ReceiveSbFile) starts the transfer of an SB file to the target. The command only specifies the size in bytes of the SB file that is sent in the data phase. The SB file is processed as it is received by the bootloader. See the Secure boot related sections for more details about the SB file.

Table 105. . Parameters for Receive SB File Command

Byte #	Command
0 – 3	Byte count

Data Phase: The Receive SB file command has a data phase; the host sends data packets until the number of bytes of data specified in the byteCount parameter of the Receive SB File command are received by the target.

Response: The target returns a GenericResponse packet with a status code set to the kStatus_Success upon successful execution of the command or set to an appropriate error code.

15.2.7.6 LPUART ISP

The bootloader integrates an autobaud detection algorithm for the LPUART peripheral, thereby providing flexible baud rate choices.

Autobaud feature: If LPUART*n* is used to connect to the bootloader, then the LPUART*n*_RX pin must be kept high and not left floating during the detection phase in order to comply with the autobaud detection algorithm. After the bootloader detects the ping packet (0x5A 0xA6) on LPUART*n*_RX, the bootloader firmware executes the autobaud sequence.

If the baudrate is successfully detected, then the bootloader sends a ping packet response [(0x5A 0xA7), protocol version (4 bytes), protocol version options (2 bytes) and crc16 (2 bytes)] at the detected baudrate. The Kinetis bootloader then enters a loop, waiting for bootloader commands via the LPUART peripheral.

NOTE

The data bytes of the ping packet must be sent continuously (with no more than 80 ms between bytes) in a fixed LPUART transmission mode (8-bit data, no parity bit and 1 stop bit). If the bytes of the ping packet are sent one-by-one with more than 80 ms delay between them, then the autobaud detection algorithm may calculate an incorrect baud rate. In this instance, the autobaud detection state machine should be reset.

Supported baud rates: The baud rate is closely related to the MCU core and system clock frequencies. Typical baud rates supported are 9600, 19200, 38400, 57600, 115200 and 230400.

NOTE

The peripheral baud rate mentioned here is just at ISP packet level, the actual download speed in ISP is lower than the baud rate because of overhead in the ISP protocol and packet handling.

Packet transfer: After autobaud detection succeeds, bootloader communications can take place over the LPUART peripheral. The following flow charts show:

- How the host detects an ACK from the target
- How the host detects a ping response from the target
- How the host detects a command response from the target

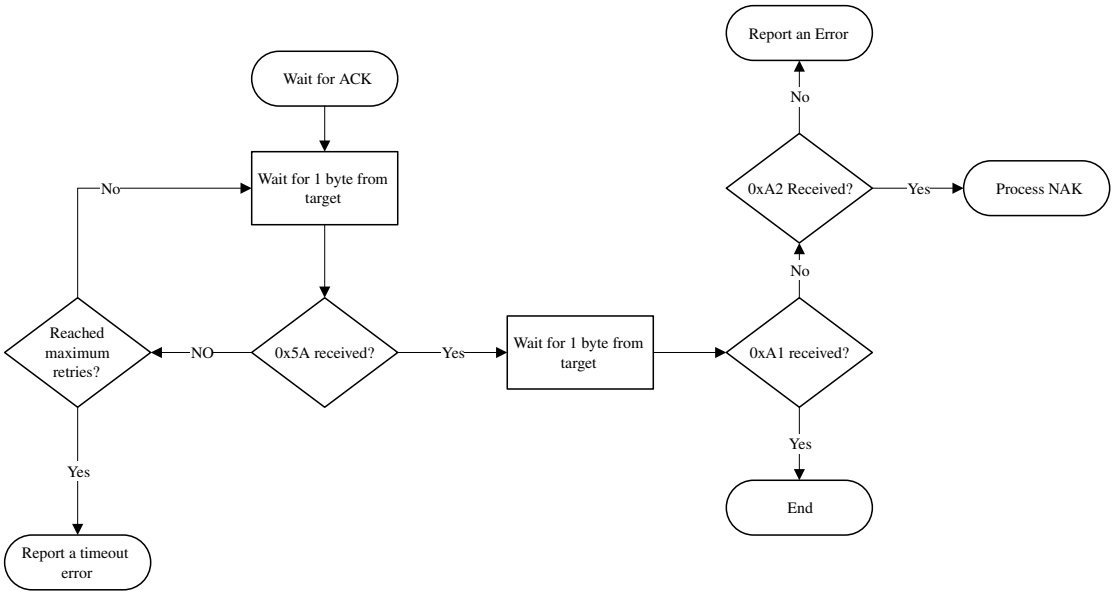

Figure 40. Host reads an ACK from target via LPUART

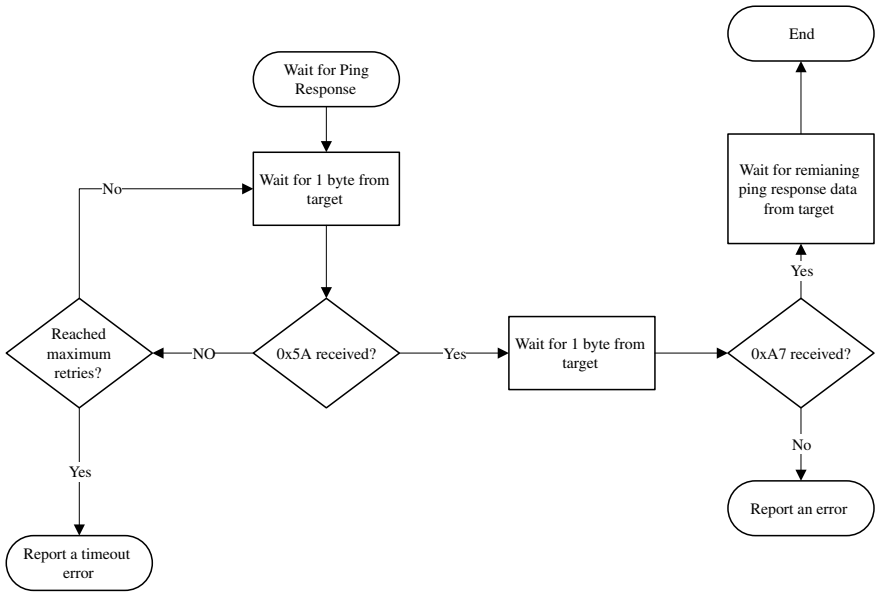

Figure 41. Host reads a ping response from target via LPUART

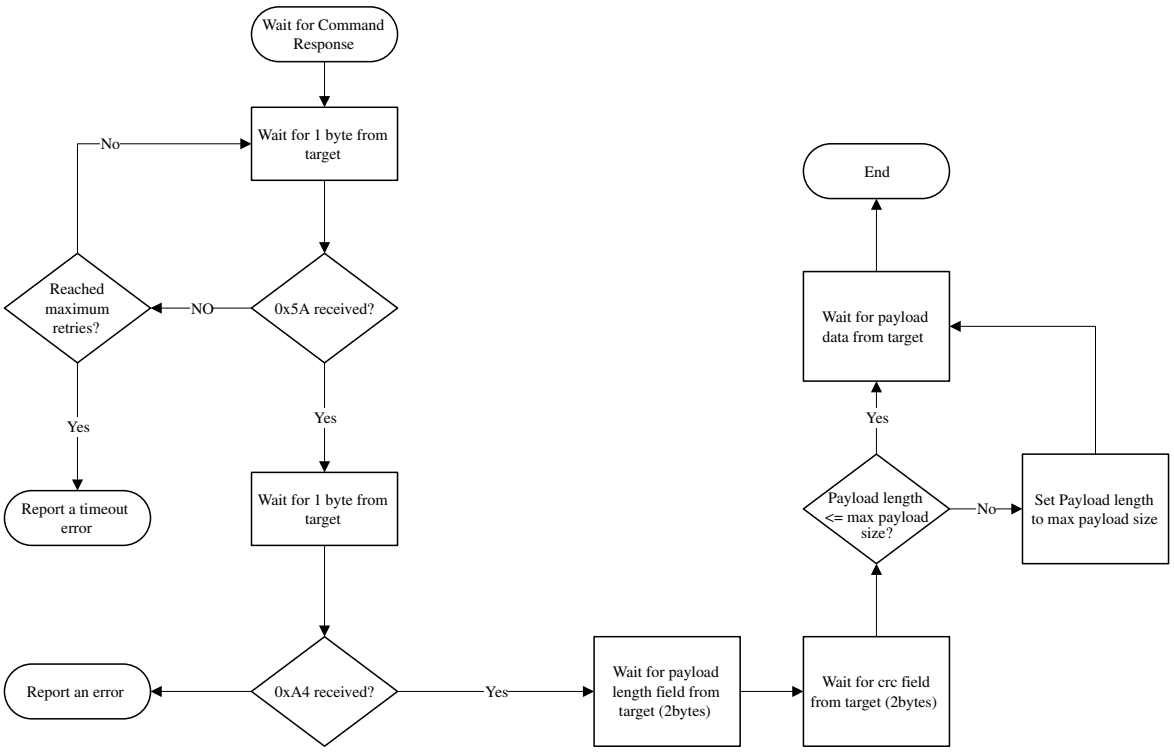

Figure 42. Host reads a command response from target via LPUART

For information on commands and formats, see ISP packet type

15.2.7.7 LPI2C ISP

The bootloader supports In-System Programming or serial boot via the LPI2C peripheral, where the LPI2C peripheral serves as the LPI2C slave. The bootloader uses 0x10 as the 7-bit LPI2C slave address and supports up to 400 kbit/s speed during transfer.

The maximum supported LPI2C baud rate depends on the core clock frequency when the bootloader is running. The typical baud rate is 400 kbit/s with factory settings.

NOTE

The peripheral baud rate mentioned here is just at ISP packet level, the actual download speed in ISP is lower than the baud rate because of overhead in the ISP protocol and packet handling.

The LPI2C peripheral serves as an LPI2C slave device, hence each transfer should be started by the host, and each outgoing packet should be fetched by the host as well.

- An incoming packet is sent by the host with a selected LPI2C slave address and the direction bit is set to write.
- An outgoing packet is read by the host with a selected LPI2C slave address and the direction bit is set as read.
- 0x00 is sent as the response to host if the target is busy with processing or preparing data.

The following charts show the communication flow of the host reading the ACK packet and the corresponding responses from the target.

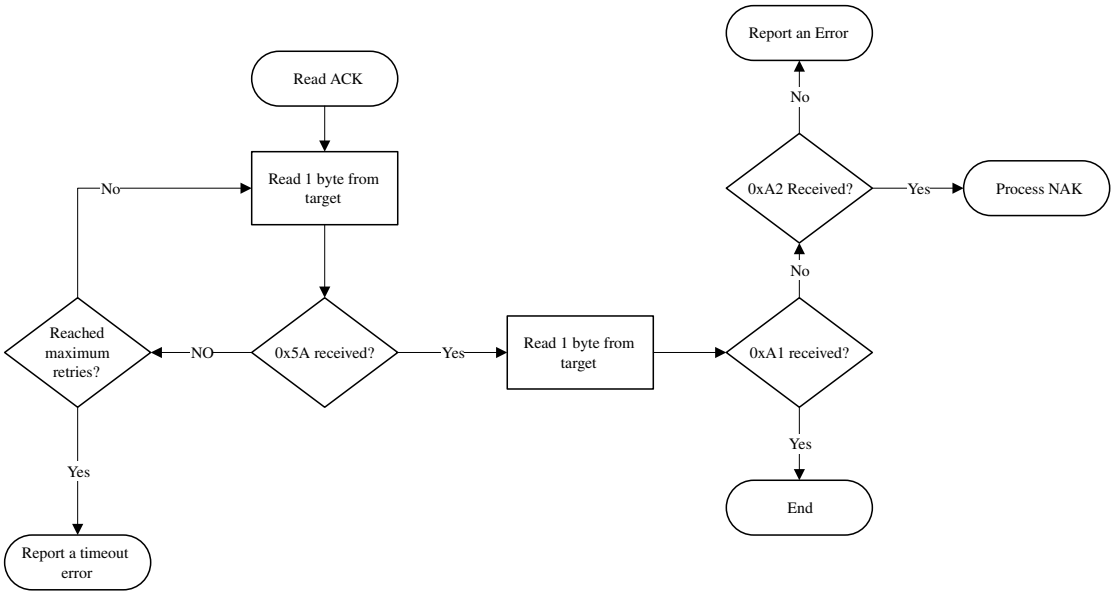

Figure 43. Host reads ACK packet from target via LPI2C

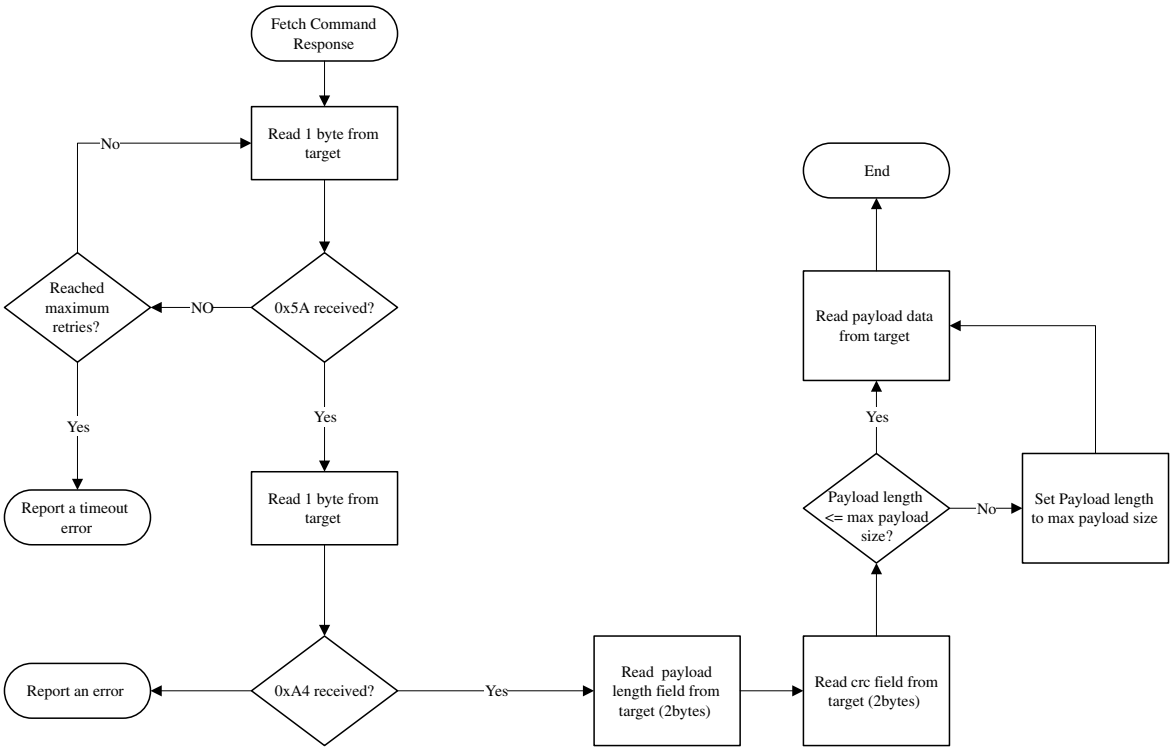

Figure 44. Host reads response from target via LPI2C

For information on commands and formats, see ISP packet type

15.2.7.8 LPSPI ISP

The bootloader supports In-System Programming or serial boot via the LPSPI peripheral.

The maximum supported baud rate of the LPSPI depends on the core clock frequency when the bootloader is running. The typical baud rate is 1 MHz with the factory settings. The actual baud rate is up to 4 MHz when the core is running at high-speed boot mode. The LPSPI peripheral in the bootloader serves as an LPSPI slave device. Each transfer, therefore, must be started by the host, and each outgoing packet should be fetched by the host as well.

NOTE

The peripheral baud rate mentioned here is just at ISP packet level, the actual download speed in ISP is lower than the baud rate because of overhead in the ISP protocol and packet handling.

Compared to LPUART and LPI2C peripherals, the transfer on LPSPI is slightly different:

- The host receives 1 byte after it sends out any byte.
- Received bytes should be ignored when the host is sending out bytes to the target
- The host starts reading bytes by sending 0x00s to target
- The byte 0x00 is sent as a response to host if the target is under the following conditions:
  - Processing incoming packet
  - Preparing outgoing data
  - Received invalid data

The following flowcharts show how the host reads a ping response, an ACK and a command response from target via LPSPI without the nIRQ pin enabled.

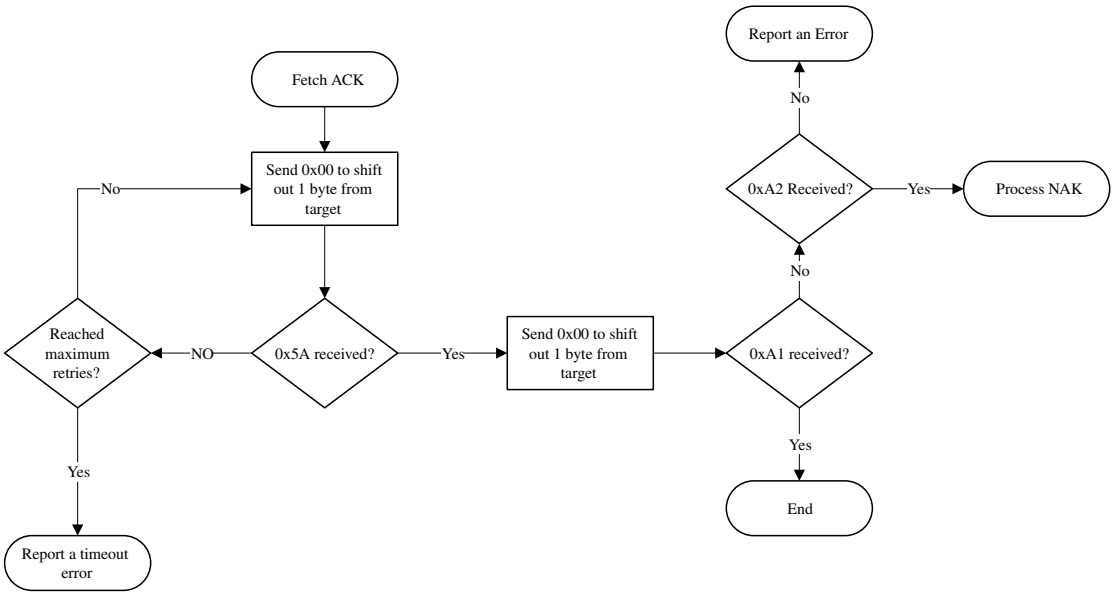

Figure 45. Host reads ACK from target via LPSPI

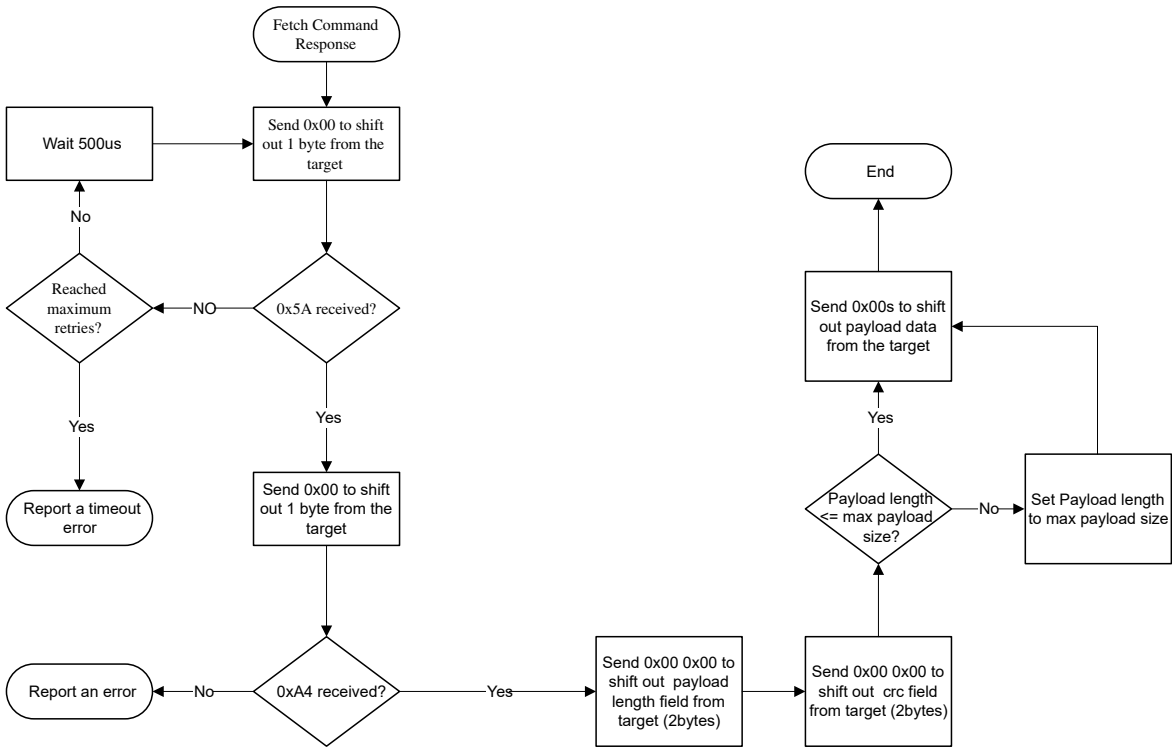

Figure 46. Host reads response from target via LPSPI

For information on commands and formats, see ISP packet type

15.2.8 Debugger mailbox path

Debugger Mailbox (DM) is a register-based mailbox operating over Serial Wire Debug Port (SWD). It can be accessed via a Debug Access port (DM-AP) which is always enabled. The external world can send and receive data to/from the ROM bootloader via Debugger Mailbox. One important feature of Debugger Mailbox is that it supports NXP Debug Authentication Protocol, which

allows users to enable debug access for CM33 and radio (CM33) when security is required. Meanwhile, users can utilize Debugger Mailbox to initiate a debugging session when there is no valid boot image.

The communication to the Debugger Mailbox is initiated by the debugger. It does so by setting a re-synchronization request and then resets the chip. ROM bootloader can observe the request and go to Debugger Mailbox Path.

15.2.8.1 Quick guide of using debugger mailbox

To make ROM bootloader enter the Debugger Mailbox, the debugger needs to select DM-AP and set the RESYNCH_REQ bit and the CHIP_RESET_REQ bit to 1 in the CSW register. Following a successful initial re-synchronization and reset, communication by the debugger to the device is achieved using 32-bit DM-AP command writes to the REQUEST register in the Debug Mailbox (DM-AP Commands are shown in table below) The debugger can read results of communications via the RETURN register. Response codes are shown in DM-AP return codes.

The example below shows how to enter debug mailbox and do the communication:

```
// Pseudo Code Syntax
// ------------------------------------------------------------------------
// WriteDP <register> <value>
// value = ReadDP <register>
// AP transactions presume the DM AP is selected
// WriteAP <register> <value>
// value = ReadAP <register> <value>
// ------------------------------------------------------------------------
// Read AP ID register to identify DM AP at index 2
WriteDP 2 0x020000F0
// The returned AP ID should be 0x002A0000
value = ReadAP 3
print "AP ID: ", value
// Select DM AP index 2
WriteDP 2 0x02000000
// Write DM RESYNC_REQ + CHIP_RESET_REQ
WriteAP 0 0x21
// Write DM-AP Command START DM-AP (1) to REQUEST register (1)
WriteAP 1 1
// Read the return code of START DM-AP command from RETURN register (2), 0x0 means success
ReadAP 2
// Write Get Lifecycle (2) to REQUEST register (1)
WriteAP 1 2
// Read the value of current lifecycle from RETURN register (2)
ReadAP 2
```

When doing debug authentication, Debug Auth Start command needs to be sent first and DAC needs to be read back. Then sending Debug Auth Response command with DAR. Pseudo code below shows how to use debug authentication commands. See Debug authentication for more details.

```
// Assume already in Debugger Mailbox
// Write Debug Auth Start (0x10) to REQUEST register (1)
WriteAP 1 0x10
// Read the data count of DAC
ReadAP 2
// Assume reading back 0x82000000, then the length of DAC is 0x200 word (4-byte)
// Send the ACK_TOKEN with the length of remaining data (word) to receive
WriteAP 1 0x0200A5A5
// Read DAC data
ReadAP 2
WriteAP 1 0x01FFA5A5
ReadAP 2
…
```

```
WriteAP 1 0x0001A5A5
ReadAP 2
// Get the whole DAC, generate DAR using DAC, assume length of DAR is 0x400 word (4-byte)
// Write Debug Auth Response (0x11) with DAR length to REQUEST register (1)
WriteAP 1 0x04000011
// Read the ACK_TOKEN from RETURN register (2), should be 0x0400A5A5
ReadAP 2
// Send DAR data, use 0x00000000 as an example of data
WriteAP 1 0x00000000
// Read the ACK_TOKEN, should be 0x03FFA5A5
ReadAP 2
// Send next DAR data
WriteAP 1 0x00000000
ReadAP 2
…
WriteAP 1 0x00000000
// Complete sending DAR when ACK_TOKEN is 0x0000A5A5
ReadAP 2
```

15.2.8.1.1 DM-AP commands

Commands for the DM-AP are listed below. These would be written to the REQUEST register. Please note that Bulk Erase/ Enter ISP Mode/ Set FA Mode can only be issued after authentication at lifecycle after OEM Open.

Table 106. DM-AP commands

Command	ID	Parameter/Response	Description
Start DM-AP	0x01	*Parameters*: None *Response*: 32-bit status	Cause the device to enter DM-AP command mode. This must be done prior to Get Lifecycle command. This command is provided for backwards compatibility and does not need to be used for most commands.
Bulk Erase	0x03	*Parameters*: None *Response*: 32-bit status	Erase the entire CM33 Program Flash (IFR0 not included).
Exit DM-AP	0x04	*Parameters*: None *Response*: 32-bit status	Cause the device to exit DM-AP command mode. The device returns to normal boot path.
Enter ISP Mode	0x05	*Parameters*: dataWordCount: 0x1 data[0]: ISP mode enum. 0xffffffff – Auto detection 0x1 - LPUART 0x2 - LPI2C 0x4 - LPSPI Others - Reserved	Enter specified ISP path.

Table continues on the next page...

Table 106. DM-AP commands (continued)

Command	ID	Parameter/Response	Description
		Response: 32-bit status	
Set FA Mode	0x06	*Parameters*: data[]: FA Request *Response*: 32-bit status	Set the part permanently in "Fault Analysis" mode to return to NXP factory. ROM erases customer sensitive assets (key codes) stored in PFR. Sets Fault Analysis (FA or RMA) mode bit in PFR field. So, that customers could ship these parts to NXP for FA/RMA testing.
Start Debug Session	0x07	*Parameters*: None *Response*: 32-bit status	This command is used to indicate ROM the intention of connecting debugger. ROM bootloader enables debug access (if no debug authentication required) and enters while(1) loop.
Debug Auth Start	0x10	*Parameters*: dataWordCount: 0x0 *Response*: data[] : DAC	Start Debug Authentication Protocol. ROM responds to debugger with *DAC (Debug Authentication Challenge)* message.
Debug Auth Response	0x11	*Parameters*: data[] : DAR *Response*: 32-bit status	Debug Authentication Response.

15.2.8.1.2 DM-AP return codes

Return codes for DM-AP commands are listed below. These commands can be read from the RETURN register. See table below.

Table 107. DM-AP return codes

Return code	Descriptions
0x0000 0000	Command succeeded.
0x0010 0001	Debug mode not entered. This is returned if other commands are sent prior to the “Enter DM-AP” command.
0x0010 0002	Command not recognized. A command was received other than the ones defined above.
0x0010 0003	Command failed.

15.2.8.2 Debugger Mailbox protocol

ROM Bootloader implements debug mailbox protocol to interact with host debug systems over the SWD interface. The protocol has following features:

- Request/response based.
- Support for relatively large command and response data.
- All commands and responses are 32-bit word aligned.
- Supports data above 32 bits by using an ACK_TOKEN that moderates the transfer in 32-bit value chunks.
- Requests and responses use the same basic structure.

15.2.8.2.1 Mailbox registers

The registers in the debug mailbox are shown in Table below. These registers are readable by the CPU and are intended primarily to allow on-chip ROM routines to implement requests from an external debugger.

Table 108. Register overview: DBGMailbox (base address = 0x58000000)

Name	Access	Offset	Description	Reset value
CSW	R/W	0x000	Command and status word	0x0
REQ	R/W	0x004	Request from the debugger to the device	0x0
RETURN	R/W	0x008	Return value from the device to the debugger	0x0
ID	RO	0x0FC	Identification register	0x002A0000

15.2.8.2.1.1 Command and Status Word Register (CSW)

The CSW register contains command and status bits to facilitate communication between the debugger and the device.

Table 109. Command and Status Word register (CSW, offset = 0x000)

Bit	Symbol	Description	Reset Value
0	RESYNCH_REQ	The debugger sets this bit to request a re-synchronization.	0x0
1	REQ_PENDING	A request is pending for the debugger: a value is waiting to be read from the REQUEST register.	0x0
2	DBG_OR_ERR	When 1, a debug overrun has occurred: a REQUEST value has been overwritten by the debugger before it was read by the device.	0x0
3	AHB_OR_ERR	When 1, an AHB overrun has occurred: a RETURN value has been overwritten by the device before it was read by the debugger.	0x0
4	SOFT_RESET	Setting this write-only bit in the CSW register of the DM-AP by an external debugger resets the DM-AP state machine and its registers. While setting RESYNCH_REQ only resets the DP and CPU handshake state machine.	0x0
5	CHIP_RESET_REQ	This write-only bit causes the device (but not the DM-AP) to be reset by generating SYSRESET_REQ.	0x0
31:6	Reserved		-

15.2.8.2.1.2 Request value register

The REQUEST register is used by a debugger to send action requests to the device.

Table 110. Request value register (REQUEST, offset = 0x004)

Bit	Symbol	Description	Reset Value
31:0	REQUEST	Request value. Reads as 0 when no new request is present. Cleared by the device. Can be read back by the debugger in order to confirm communication.	0x0

15.2.8.2.1.3 Return value register

The RETURN register provides any response from the device to the debugger.

Table 111. Return value register (RETURN, offset = 0x008)

Bit	Symbol	Description	Reset Value
31:0	RET	Return value. This is any response from the device to the debugger. If no new data is present, a debugger read will be stalled until new data is available.	0x0

15.2.8.2.1.4 Identification register

The ID register provides an identification of the DM-AP interface.

Table 112. Identification register (ID, offset = 0x0FC)

Bit	Symbol	Description	Reset Value
31:0	ID	Identification value.	0x002A0000

15.2.8.2.2 Mailbox commands

15.2.8.2.2.1 Request

The first word transmitted in a request is a header word containing the command ID and number of following data words. Following the header are the number of 32-bit words specified in the header.

Table 113. Request register byte description

Word	Byte 0	Byte 1	Byte 2	Byte 3
0	commandID[7:0]	commandID[15:8]	dataWordCount[7:0]	dataWordCount[15:8]
1	*data...*			

The C structure definition for a request is as follows:

```
struct dm_request {
  uint16_t commandID;
  uint16_t dataWordCount;
  uint32_t data[]; };
```

15.2.8.2.2.2 Response

The first word transmitted in a response is a header word containing the command status and number of following data words.

- To support legacy command and response value, Bit_31 in header will be used to indicate that the response follows new protocol structure.

Table 114. Response register byte description

Word	Byte 0	Byte 1	Byte 2	Byte 3
0	commandStatus[7:0]	commandStatus[15:8]	dataWordCount[7:0]	dataWordCount[14:8] new_protocol[15]
1	*data...*			

The C structure definition for a response is as follows:

```
struct dm_response {
    uint16_t commandStatus;
    uint16_t dataWordCount;
    uint32_t data[];
};
```

15.2.8.2.2.3 ACK_TOKEN

- When command has parameters the debugger should wait for ACK_TOKEN (sent through DBG_MB_RETURN register) before sending next 32-bit value.
- Similarly when response packet has data to send back to debugger, ROM will wait for debugger to send ACK_TOKEN (sent through DBG_MB_REQUEST register) before sending next 32-bit value.
- Upper 16 bits are set by receiving end with number of remaining words expected.
- Lower 16 bits are always set to 0xA5A5.

Table 115. ACK_TOKEN register byte description

Word	Byte 0	Byte 1	Byte 2	Byte 3
0	0xA5	0xA5	remainCount[7:0]	remainCount[15:8]

The C structure definition for a ACK_TOKEN is as follows:

```
struct dm_ack_token {
    uint16_t token; /* always set to 0xA5A5 */
    uint16_t remainCount; /* count of remaining word */};
```

15.2.8.2.2.4 Error handling

If an overrun occurs from either side of the communication, the appropriate error flag is set in the CSW. The state machine hardware will prevent further communication in any direction once an overrun has occurred in that direction, so if such an error occurs, the debugger will need to start with a new re-synchronization request in order to clear the error flag.

15.2.8.3 Debug authentication

The fundamental principles of debugging, which require access to the system state and system information, conflict with the principles of security, which require the restriction of access to assets. Thus, many products disable debug access completely

before deploying the product. This causes challenges for product design teams to do proper Return Material Analysis (RMA). To address these challenges, the ROM bootloader offers a debug authentication protocol as a mechanism to authenticate the debugger (an external entity) has the credentials approved by the product manufacturer before granting debug access to the device.

The debug authentication scheme is a challenge-response scheme and assures that debugger in possession of required debug credentials only can successfully authenticate over debug interface and access restricted parts of the device. This protocol is divided into steps as shown in description and figure below.

1. The debugger initiates the Debug Mailbox message exchange by setting the RESYNCH_REQ bit and CHIP_RESET_REQ bit in the CSW register of DM-AP.
2. The debugger waits (minimum 30ms) for the devices to restart and enter debug mailbox request handling loop.
3. The debugger sends Debug Authentication Start command (command code 0x10) to the device.
4. The device responds back with Debug Authentication Challenge (DAC) packet based on the debug access rights pre-configured in CMPA fields, which are collectively referred as Device Credential Constraints Configuration (DCFG_CC). The response packet also contains a 32 bytes random challenge vector.
5. The debugger responds to the challenge with a Debug Authentication Response (DAR) message by using an appropriate debug certificate, matching the device identifier in the DAC. The DAR packet contains the debug access permission certificate, also referred as Debug Credential (DC), and a cryptographic signature binding the DC and the challenge vector provided in the DAC.
6. The device on receiving the DAR, validates the contents by verifying the cryptographic signature of the message using the debugger's public key present in the embedded the Debug Credential (DC). On successful validation of DAR, the device enables access to the debug domains permitted in the DC.

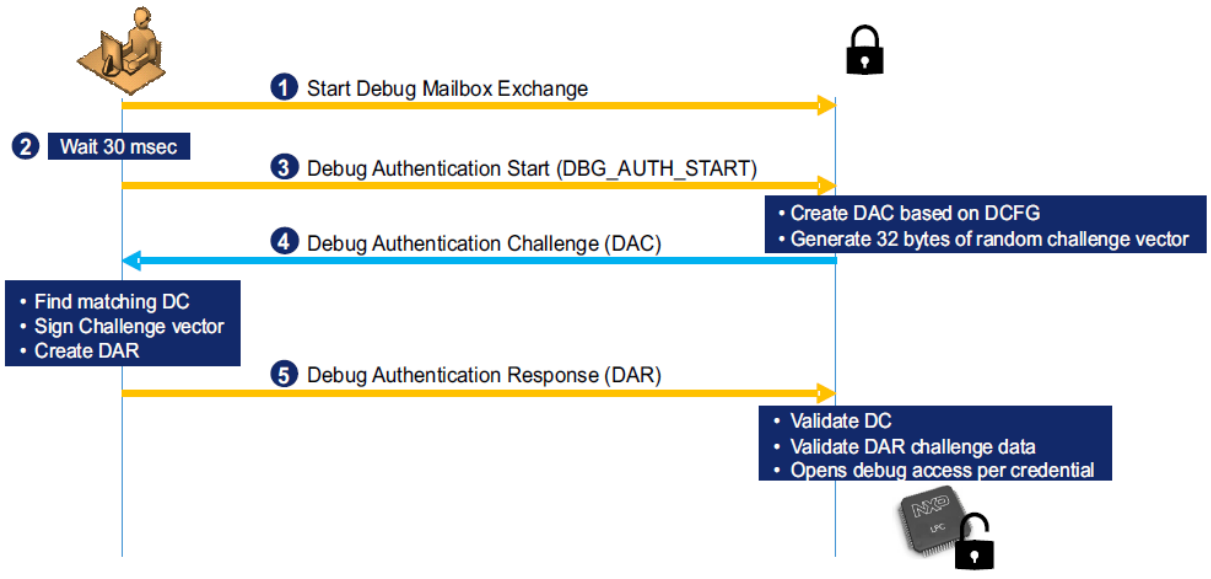

Figure 47. Debug authentication flow

15.2.8.3.1 Debug access control configuration

The ROM bootloader handles the device side of Debug authentication process. However, the debug access control rights and security policies can be configured by programming the following configuration fields which are collectively referred to as Device Configuration for Credential Constraints (DCFG_CC).

- DCFG_VER: This field controls the cryptographic primitives used during authentication.

- DCFG_ROTID: This field defines the Root of trust identifier (ROTID). The ROTID field is used to bind the devices to specific Certificate Authority (CA) keys issuing the debug credentials. These CA keys are also referred as Root of Trust (RoTK) keys.
- DCFG_UUID: Controls whether to enforce UUID check during Debug Credential (DC) validation. If this field is set only DC with matching device UUID can unlock the debug access.
- DCFG_CC_SOCU: This configuration field specifies access rights to various debug domains.
- DCFG_VENDOR_USAGE: This field can be used to define vendor specific debug policy use case such as DC revocations or department identifier. It is recommended to use field for revocation of already issued debug certificates.

15.2.8.3.1.1 Protocol Version (DCFG_VER)

This device supports Debug authentication protocol version 2.1, which are defined based on the secp384r1 curve.

NOTE

Both debug authentication certificates and image signing certificates use same Root of Trust keys (RoTK).

15.2.8.3.1.2 Root of Trust Identifier (DCFG_ROTID)

The Root of Trust Identifier used in debug authentication protocol is composed of two elements.

- A 256-bit cryptographic hash (SHA256 or leading 32 bytes of SHA384, according root certificates EC types, secp256r1->SHA256 or secp384r1->SHA384) over the Root of Trust Keys hash table.
- A 32-bit field containing revocation bits for the four Root of Trust keys in the table.

15.2.8.3.1.3 Enforce UUID checking (DCFG_UUID)

Controls whether to enforce UUID check during Debug Credential (DC) validation. If this field is set, then only DC containing a UUID attribute that is an exact match to the device can unlock the debug access.

This field can be set by programming UUID_CHECK (bit 16) in CC_SOCU.

This device-specific constraint, if enabled, is in addition to all the other constraints defined and enforced by the authentication protocol

15.2.8.3.1.4 Credential Constraints (DCFG_CC_SOCU)

The DCFG_CC_SOCU is a configuration that specifies debug access restrictions per debug domain. These access restrictions are also referred as constraint attributes in this section. The debug subsystem is sub-divided into multiple debug domains to allow finer access control. Table 117 shows debug domains and their corresponding control bit position in DCFG_CC_SOCU. Which is logically composed of two components:

- SOCU_PIN (bit 7-0 in CC_SOCU): A bitmask that specifies which debug domains are predetermined by device configuration.
- SOCU_DFLT (bit 15-8 in CC_SOCU): Provides the final access level for those bits that the SOCU_PIN field indicated are predetermined by device configuration.

The following table shows the restriction levels:

Table 116. Access restriction levels

Restriction Level	SOCU_PIN [n]	SOCU_DFLT [n]	Description
0	1	1	Access to the sub-domain is always enabled.

Table continues on the next page...

Table 116. Access restriction levels (continued)

Restriction Level	SOCU_PIN [n]	SOCU_DFLT [n]	Description
			This setting is provided for module use case scenario where DCFG_CC_SOCU_NS would be used to define further access restrictions before final deployment of the product.
1	0	0	Access to the sub-domain is disabled at start up. But the access can be enabled through debug authentication process by providing appropriate Debug Credential (DC) certificate.
2	0	1	Illegal setting. Part may lock-up if this setting is selected.
3	1	0	Access to the sub-domain is permanently disabled and cannot be reversed. This setting offers the highest level of restriction.

Debug domains supported by this device are shown in table below.

Table 117. CC_LIST_Table

Bit	Symbol	Description
0	NIDEN	Controls non-Invasive debugging of TrustZone for Arm8-M defined non-secure domain of CM33.
1	DBGEN	Controls invasive debugging of TrustZone for Arm8-M defined non-secure domain of CM33.
2	SPNIDEN	Controls non-Invasive debugging of TrustZone for Arm8-M defined secure domain of CM33.
3	SPIDEN	Controls invasive debugging of TrustZone for Arm8-M defined secure domain of CM33.
4	NBU_DBGEN	Controls debugging of NBU (radio, CM33)
5	FA_CMD_EN	Controls whether DM-AP command, Set FA Mode (command code: 0x06), can be issued through after authentication.
6	ISP_CMD_EN	Controls whether ISP boot flow DM-AP command (command code: 0x05) can be issued after authentication.
7	ME_CMD_EN	Controls whether DM-AP command, Bulk Erase (command code: 0x02), can be issued through after authentication.
31:8	RSRVD	Reserved

15.2.8.3.1.5 DCFG_VENDOR_USAGE

This field can be used to define vendor specific debug policy use case such as Debug Credential (DC) certificate revocations or department identifier or model identifier. During Debug Authentication Response (DAR) processing the device checks that

the value specified in Vendor Usage field of DC matches exactly the value programmed in DCFG_VENDOR_USAGE fields of device configurations.

15.2.8.3.2 Debug Authentication Challenge (DAC)

The debug authentication protocol begins with a DEBUG_AUTH_START request, issued by the debugger to the device, which replies by Authentication Challenge (DAC) message, issued by the device to the debugger. The DAC carries information about current device state to the debugger, inputs from DAC are necessary to find existing or request generation of new Debug Credential (DC). Protocol version 2.x uses ECC for digital signatures, minor version 0 (”2.0”) points to secp256r1 and minor version 1 (“2.1”) points to secp384r1.

Structure of DAC message is shown in following Figure .

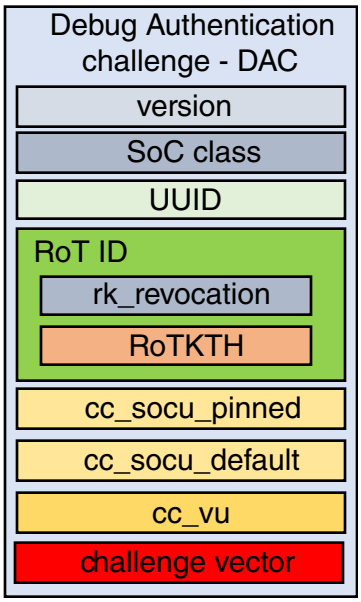

Figure 48. Debug Authentication Challenge (DAC)

- **version** – uint32_t, little endian

  Fixed to value 0x02000000u "2.0" (major =2, minor = 0) -> secp256r1 used as RoTKTH, or fixed to value 0x02000100u "2.1" (major =2, minor = 1) -> secp384r1 used as RoTKTH

- **SoC class** – uint32_t, little endian

  Fixed to 0x5u for this device, identify the device family

- **UUID** – uint32_t[4], little endian

  Unique ID of device.

- **RoT ID** – object

  Identifier of root of trust settings in device.

  — **rk_revocation** – uint32_t, little endian

  1 bit per RoTK (up to 4 RoTK can be defined for device, bit is 1 – RoTK is revoked (not usable for debug auth), bit is 0 – RoTK can be used.

  rk_revocation[bits 31:4] -> reserved for future use.

  rk_revocation[bit 3] -> bit value 0 = RoTK[3] OK / bit value 1 = RoTK[3] revoked

  rk_revocation[bit 2] -> bit value 0 = RoTK[2] OK / bit value 1 = RoTK[2] revoked

rk_revocation[bit 1] -> bit value 0 = RoTK[1] OK / bit value 1 = RoTK[1] revoked

rk_revocation[bit 0] -> bit value 0 = RoTK[0] OK / bit value 1 = RoTK[0] revoked

— **RoTKTH** – uint8_t[32]

RoTKTH (Root of Trust Key Table Hash) value is stored in device fuses. If RoTKTH size is 48 bytes (RoTKTH is SHA384 digest of the RoT Key Table), then this field value carries only leading 32 bytes of RoTKTH full value.

- **cc_socu_pinned** – uint32_t, little endian

  Actual value of CC_SOCU_PINNED in device, which is based on actual device lifecycle, DCFG_CC_SOCU_L1 and DCFG_CC_SOCU_L2 fuses combination. For bit representation of CC_SOCU_PINNED please refer to Table 116.

- **cc_socu_default** – uint32_t, little endian

  Actual value of CC_SOCU_DEFAULT, which is based on actual device lifecycle, DCFG_CC_SOCU_L1 and DCFG_CC_SOCU_L2 fuses combination. For bit representation please refer to Table 116.

- **cc_vu** – uint32_t, little endian

  Vendor usage value, custom value provided by vendor, stored in DBG_AUTH_VU fuse in device, value needs to be the same as value specified present later in debug certificate (DC), used for pairing of corresponding DC.

- **challenge vector** – uint8_t[32]

  Random number generated for each request to be signed in debug authentication response (DAR) to avoid reusing of DAR.

15.2.8.3.3 Debug Credential (DC)

Prior to generating debug credential, it is necessary to generate EC keypair (secp256r1 or secp384r1) for debugger known as Debug Credential Key (DCK). The public key part of DCK (DCK_{public}) is used to represent the identity of the debugger through the creation of a DC, which binds that public key to some usage attributes (UUID, CC_SOCU), and is then authorized/signed by the vendor's Roots of Trust key ($RoTK_{private}$) using ECDSA algorithm. If RoTK is based on secp256r1 then DCK also needs to be based on secp256r1. If RoTK is based on secp384r1then DCK also needs to be based on secp384r1. Combining of EC types is not allowed in DC.

The private part of DCK ($DCK_{private}$) will be used later for signing of Debug Authentication Response (DAR).

The DC structure is illustrated in the following figure.

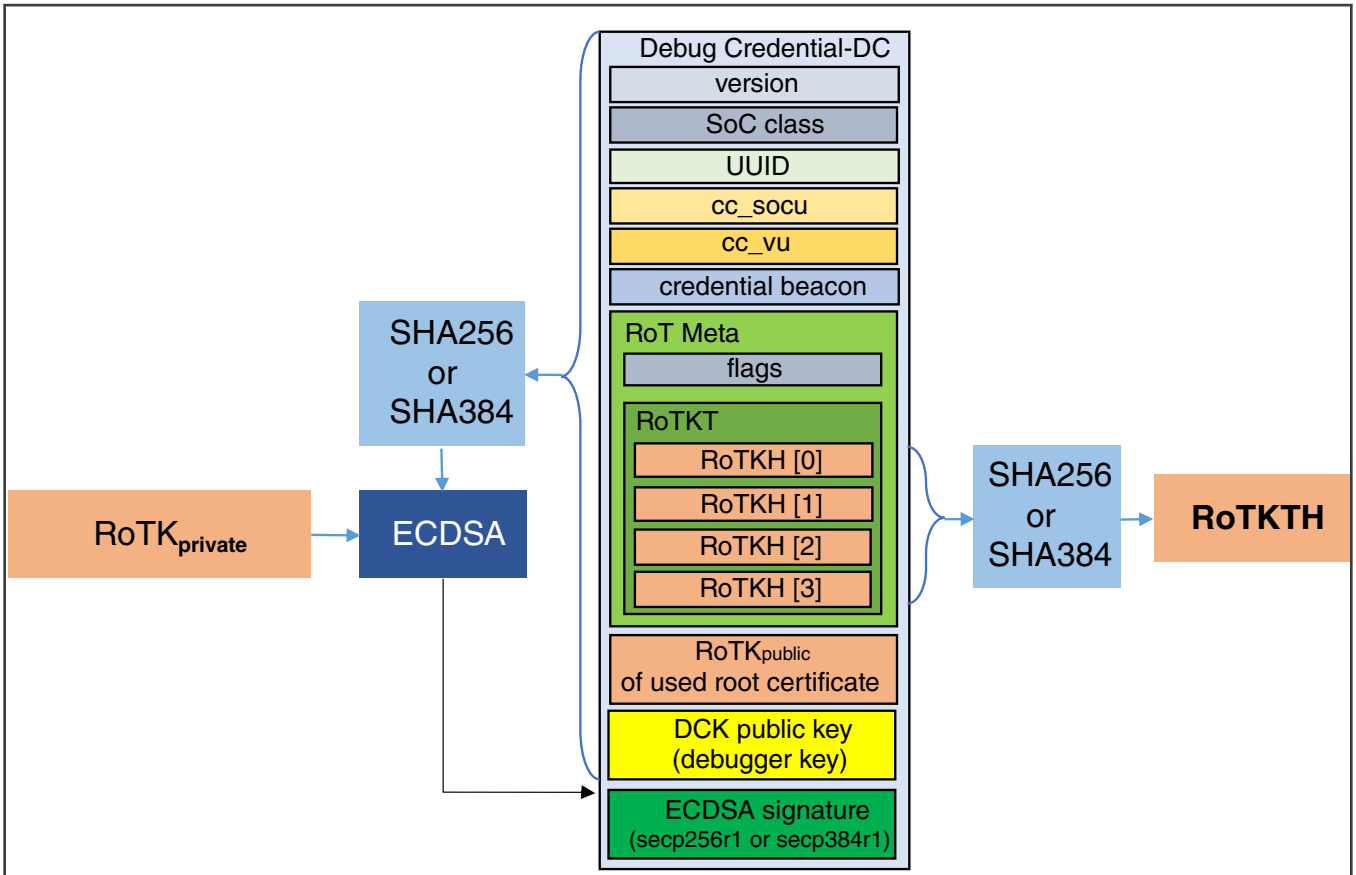

Figure 49. Debug Credential (DC)

The data structure is represented as a packed binary concatenation of its component fields as shown in the list below:

- **version** – uint32_t, little endian

  Fixed to value 0x02000000u “2.0” (major =2, minor = 0) -> secp256r1 used as RoTK or fixed to value 0x02000100u “2.1” (major =2, minor = 1) -> secp384r1 used as RoTK

- **SoC class** – uint32_t, little endian

  Fixed to 0x5u, identify the device family.

- **UUID** – uint32_t[4], little endian

  Unique ID of device. Can be set to 0 when debug credential is used for SoC class matching (one debug credential can be used to open debug ports on all devices with same CTRK and same SoC class, UUID matching in device have to be disabled – default). If UUID matching in device is enabled, then UUID value needs to correspond with UUID value of the device received in DAC.

- **cc_socu** – uint32_t, little endian

  Proposed value of SOCU, will be validated and combined on device with current lifecycle, DCFG_CC_SOCU_L1 and DCFG_CC_SOCU_L2 fuses values to have final state of debug ports, which will be applied on device. Refer to Table 116 for Bit details.

- **cc_vu** – uint32_t, little endian

  Vendor usage value need to be matched with value of DBG_AUTH_VU in device fuses (received on DAC).

- **credential beacon** – uint32_t, little endian

  Value loaded to the beacon register after successful debug authentication. Value is used by application to control debug ports. Mask 0xFFFFu is applied to the value of credential beacon and is connected with authentication beacon value from

DAR as following formula: beacon = (credentialBeacon & 0xFFFFu) | ((authenticationBeacon & 0xFFFFu) << 16). If final beacon value is non zero, debug ports are not enabled by ROM bootloader itself and debug ports configuration is delegated to booted application, which can control debug ports according final beacon value available in register (e.g. third party secondary bootloader will open debug just before jump to loaded application, debug of secondary bootloader can be enabled only by special beacon value of credential beacon).

- **RoT meta** – object

  Device root of trust meta data object.

  - **flags** – uint32_t, little endian

    Configuration details of RoT meta object, needs to be matched with RoT ID received in DAC.

    - **flags[bit 31]**: CA flag, always 1 in DC.
    - **flags[bits 30:12]**: Reserved for future use.
    - **flags[bits 11:8]**: Used root cert number [0-3] (specify RoTK used to DC signature), used only when more than 1 RoTK specified for device.
    - **flags[bits 7:4]**: Number of records in RoTKT [1-4], when equal to 1, then RoTKT not present in DC.
    - **flags[bits 3:0]**: Reserved for future use.

  - **RoTKT** – object

    Root of Trust keys Table, optional object (in case when is specified only one RoTK for device, RoTKT is not present, 1 to 4 RoTK can be specified for device), so if RoTKT is present in DC, then RoTKT table contains at least two RoTKH and maximally 4 RoTKH records.

    - **RoTKH[0-3]** – uint8_t[32] or uint8_t[48]

      Root of Trust Key Hash is SHA256 or SHA384 of RoTKpublic. Hash algorithm is selected based on RoTK EC type (secp256r1 -> SHA256 or secp384r1 -> SHA384). Same RoTKs and RoTKTH values are shared between debug authentication, SB3.1 firmware update container and signed boot image.

- **$RoTK_{public}$** – uint8_t[64] or uint8_t[96]

  X and Y coordinates of public key of selected RoTK, which will be used for signing and verification of DC, field size depends on EC type (secp256r1 or secp384r1)

- **DCK_{public}** – uint8_t[64] or uint8_t[96]

  X and Y coordinates of public key of DCK, field size depends on EC type of DCK key (secp256r1 or secp384r1). DCK and RoTKs must be defined on same EC type, combination of EC types is not allowed.

- **ECDSA signature** – uint8_t[64] or uint8_t[96]

  SHA256 or SHA384 of all Debug Credential data (as described on previous figure) used for ECDSA signature. Hash algorithm selected according to EC type of RoTK (secp256r1 -> SHA256 or secp384r1 -> SHA384). Signature coordinates (r,s) stored in big-endian.

15.2.8.3.4 Debug Authentication Response (DAR)

Debugger will find existing or request generation of new corresponding DC according to the inputs from DAC message. The $DCK_{private}$ key is used as input for calculation of ECDSA signature of the corresponding DC including device UUID and Challenge vector from received DAC (Challenge vector is not part of DAR, but it is used as last input to hash of DAR). For signature used SHA256 or SHA384 hash algorithm based on DCK EC type (secp256r1 or secp384r1), if secp256r1-> SHA256, if secp384r1->SHA384. The DAR structure and generation process is described in following figure.

Because regular debuggers usually don't offer feature for ECDSA signing, some PC tool communicating with debugger is needed. NXP offers tool nxpcertgen.exe for generation of DC and nxpdebugmbox.exe for full debug authentication process. Usage of mentioned tools is described in separate user manual related to them.

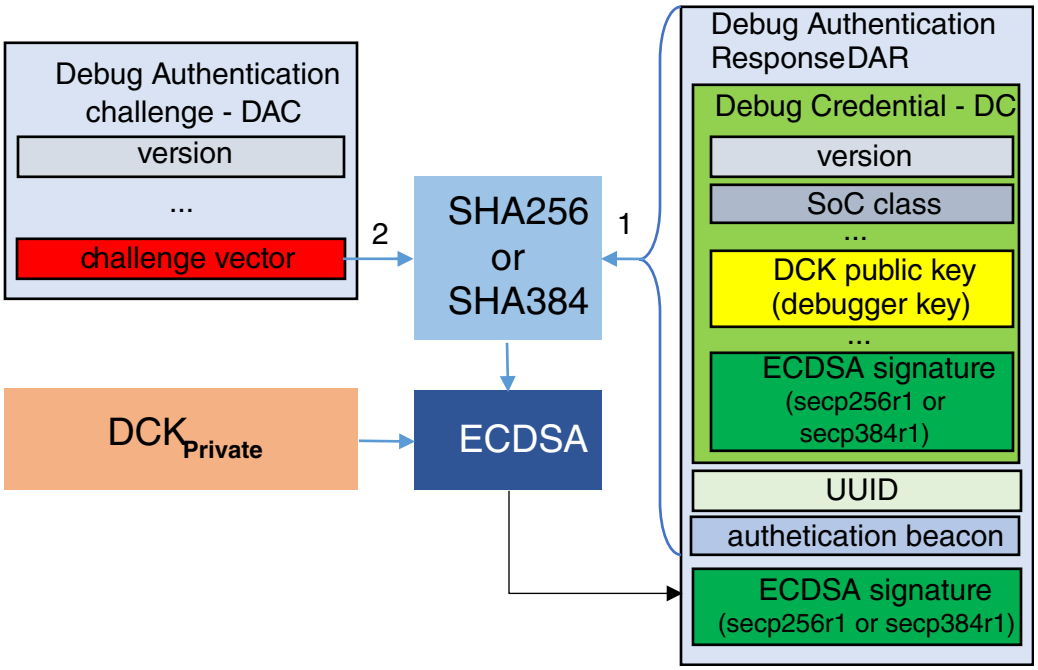

Figure 50. Debug Authentication Response (DAR)

- **Debug credential** – object

  Matched debug credential based on data received from DAC message.

- **authentication beacon** – uint32_t, little endian

  Value loaded to the beacon register after successful debug authentication. Value is used by running application to control debug ports. Mask 0xFFFFu is applied to the value and is connected with credential beacon value from DC as following formula: beacon. Beacon = (credentialBeacon & 0xFFFFu) | ((authenticationBeacon & 0xFFFFu) << 16). If final beacon value is non zero, debug ports are not enabled by ROM bootloader itself and debug ports configuration is delegated to booted application, which can control debug ports according final beacon value available in register (e.g. third party secondary bootloader will open debug just before jump to loaded application, debug of secondary bootloader can be protected by special beacon value).

- **UUID** – uint32_t[4], little endian

  Unique ID of device, must be same as UUID value provided by device in DAC message

15.2.8.3.5 Device processing the DAR

The device BootROM will process DAR received from debugger. As a part of the validation step, device will:

1. Verify DC: Validate DC version, SoC, UUID, RoT, VU, and DC signature.
2. Verify that the DAR has a valid signature that binds it to the CV from the DAC.

If all the steps are successfully completed, it can be deduced that:

- The debugger possesses the private key corresponding to the vendor/RoT-signed credential.
- The credential satisfies the constraints specified in the device configuration.
- The response of the debugger to the challenge from the device is produced and signed in response to the challenge (because of its cryptographic dependency on the challenge vector). The response is not replayed from a previous authentication where a different challenge vector is used.

After completion of processing DAR, if authentication is successful, Debug Access will be granted. If authentication fails, no special response is issued but further debug access request will be ignored, and device will enter in a failure loop (infinite loop waiting for debug attach)

15.2.8.3.6 Debug authentication use cases

15.2.8.3.6.1 Return Material Analysis (RMA) use case

The diagram below shows RMA flow using debug authentication scheme, where a debug credential certificate is issued for each field technician.

1. Vendor generates RoT key pairs and programs the device with SHA256 hash of RoT public key hashes before shipping
2. Field technician generates his own key pair and provides public key to vendor for authorization.
3. Vendor attests the field technician's public key. In the debug credential certificate, vendor assigns the access rights.
4. End customer having issues with a locked product takes it to field technician.
5. Field technician uses his credentials to authenticate with device and un-locks the product for debugging.

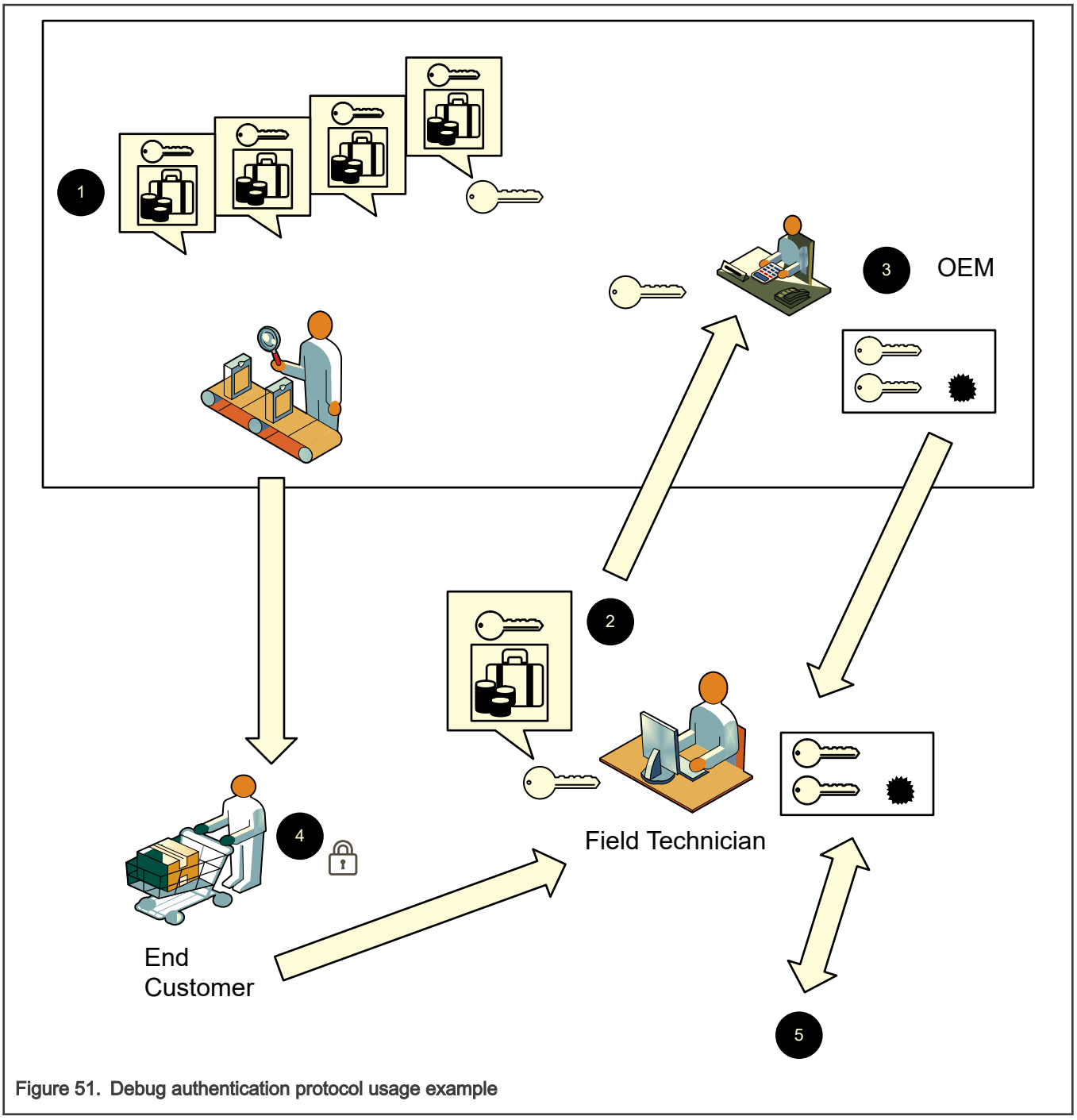

Figure 51. Debug authentication protocol usage example

15.2.8.3.6.2 Module use case with OEM tier1 and tier2 Lifecycle states

The CC_SOCU_PIN_NS & CC_SOCU_DFLT_NS is provided to allow module-maker and OEM using the module to implement tiered protection approach.

- The module maker who is referred as Tier-1 developer can develop secure code and define access rights to his module using CC_SOCU_PIN & CC_SOCU_DFLT.
- Configuration can be such that debug access to secure module is blocked but non-secure debug is always allowed.
- Once the module is ready, Tier-1 developer can release the module to OEM (a.k.a. tier-2 developer), but block debug access to secure mode and enable debug access to non-secure mode.

- Tier-2 developer can develop non-secure module and extend access rights configuration to that module using CC_SOCU_DFLT_NS and CC_SOCU_PIN_NS.

15.2.8.3.7 Fault Analysis (FA) mode

The ROM bootloader offers an FA Mode (Set FA Mode) command handler to enable to delete sensitive information (for example, Keys) before handling over the device to OEM for fault analysis. ROM allows Set FA Mode command only when corresponding flag, FA_CMD_EN, is set. Users must pass an FA request message to Set_FA_Mode command to enter FA mode.

Set FA Mode command will perform the following:

- Erase all OEM Keys in fuse
- Erase the internal flash
- Flush all temporary key registers
- Move the lifecycle to OEM Return

15.2.9 Initiate a debug session

When ROM bootloader is executing (i.e., instructions are fetched from the ROM memory address range), the debug access port (AP) of CM33 is disabled irrespective of device life-cycle state. This mechanism is referred as 'Boot-ROM protection' in this document. Thus, the method to initiate a debug session will vary depending on the device state and intended debug scenario. The scenarios described in the rest of these section are as follows:

- Flash does not contain a valid, bootable image. If the flash does not contain a valid image, the ROM bootloader will proceed to ISP mode and wait to be connected via one of its serial interfaces; in ISP mode the debug interface is disabled.
- ISP mode initiated because the ISP pin was asserted on the device at reset.
- Connection to a device running a valid application, with the intent to update flash with a new application.
- Connection to a device running a valid application in flash, with the intent to debug without updating flash (also called a "debug attach").

15.2.9.1 Debug session with invalid flash image or ISP mode

When the device boots, there may be no valid image in the boot media, at which point the ROM bootloader enters the In-System Programming (ISP) path, and debug access is disabled for security reasons. Another scenario is where the device may be placed into ISP mode because the ISP has been asserted as the device leaves reset.

To start a debug session under these scenarios, users need to enter Debugger Mailbox and send the DM-AP command Start Debug Session. Upon receiving the command, the ROM bootloader ensures any unwanted peripheral interrupts are disabled and secrets managed before enabling debug access. After configuring debug access, the ROM enters a while (1) loop. For lifecycle which does not require debug authentication, once the Start Debug Session has been successfully executed, the AP for CM33 and radio will be accessible and can used to set breakpoints, etc. as with other Cortex-M devices. For lifecycle which requires debug authentication, DM-AP commands Debug Auth Start and Debug Auth Response need to be done successfully before sending Start Debug Session command to ensure AP for CM33 or radio can be accessible.

Example below shows how a debug session is initiated at lifecycle which debug authentication is not required:

```
// Pseudo Code Syntax
// ------------------------------------------------------------------------
// WriteDP <register> <value>
// value = ReadDP <register>
// AP transactions presume the DM AP is selected
// WriteAP <register> <value>
// value = ReadAP <register> <value>
// ------------------------------------------------------------------------
// Read AP ID register to identify DM AP at index 2
WriteDP 2 0x020000F0
// The returned AP ID should be 0x002A0000
```

```
value = ReadAP 3
print "AP ID: ", value
// Select DM AP index 2
WriteDP 2 0x02000000
// Write DM RESYNC_REQ + CHIP_RESET_REQ
WriteAP 0 0x21
// Write DM START_DBG_SESSION to REQUEST register (1)
WriteAP 1 7
// Poll RETURN register (2) for zero return
value = -1
while value != 0 {
        value = (ReadAP 2 & 0xFFFF)
}
print "DEBUG_SESSION_REQ: ", value
```

15.2.9.2 Debug session with valid application in flash

In this scenario, ROM bootloader configures debug access before jumping to the application in flash. If the device is at some lifecycle debug authentication is not required and debug has not been disabled by an application already in flash, the APs of CM33 and radio are accessible, a debug session can be initialized without any other operation. If debug authentication is required, entering Debugger Mailbox, doing the debug authentication successfully and exiting Debugger Mailbox need to be done before ROM bootloader booting the application. By doing so, users can initialize a debug session after ROM bootloader jumping to the application in flash.

15.2.10 Clock

15.2.10.1 Clock gating

The heart of the clocking architecture is the System Clock Generator (SCG) module. The SCG controls multiple clock sources (FIRC/SIRC/SOSC/ROSC/CORECLK/BUSCLK/SLOWCLK) that can then be distributed to the Module Reset and Clock Control (MRCC) module. Clock gating of modules helps users to only consume power for modules that are needed for their end application. The clock to each module can be gated on or off via a programmable register.

Each peripheral has independent clock gating for both the peripheral interface clock and the peripheral functional clock. This clock gating is controlled via MRCC module. MRCC provides a clock select field, a clock disable, a divider of the selected clock source, and a peripheral reset bit that provides independent resetting of the peripheral. MRCC routes interface clocks and functional clocks for all peripherals.

The CPU_CLK, BUS_CLK, and SLOW_CLK are always enabled in the various RUN and Wait modes. If these clocks are not used in low-power stop modes, they will be disabled via the Core Mode Controller (CMC) and System Power Controller (SPC) modules.

15.2.10.2 Module/Peripheral clocking

Most peripheral clocks by default are disabled, ROM will un-gate the peripheral clocks as needed by the boot flow and also enables functional clock.

Here are some of the clocks used by ROM and their setup values:

- TRDC CPU_CLK
- CRC0 BUS_CLK
- LPSPI1 BUS_CLK
- LPUART1 BUS_CLK
- LPI2C1 BUS_CLK
- SSS CPU_CLK
- GPIO{B/C} CPU_CLK

- PORT{A/B} CPU_CLK

15.3 ROM API

ROM bootloader provides several APIs for users. Disabling the interrupts before making any ROM API call is suggested, since API code does not deal with interrupts. Flash APIs are mainly used to manage flash including read, write and erase. Similarly, SPI NOR APIs are mainly used to manage SPI NOR including read, write and erase. nboot APIs are mainly used to do security related operations including image authentication and fuse programming. kb APIs are mainly used to process SB file.

The ROM API table locates at address 0x14816800. See Figure below for the ROM API layout.

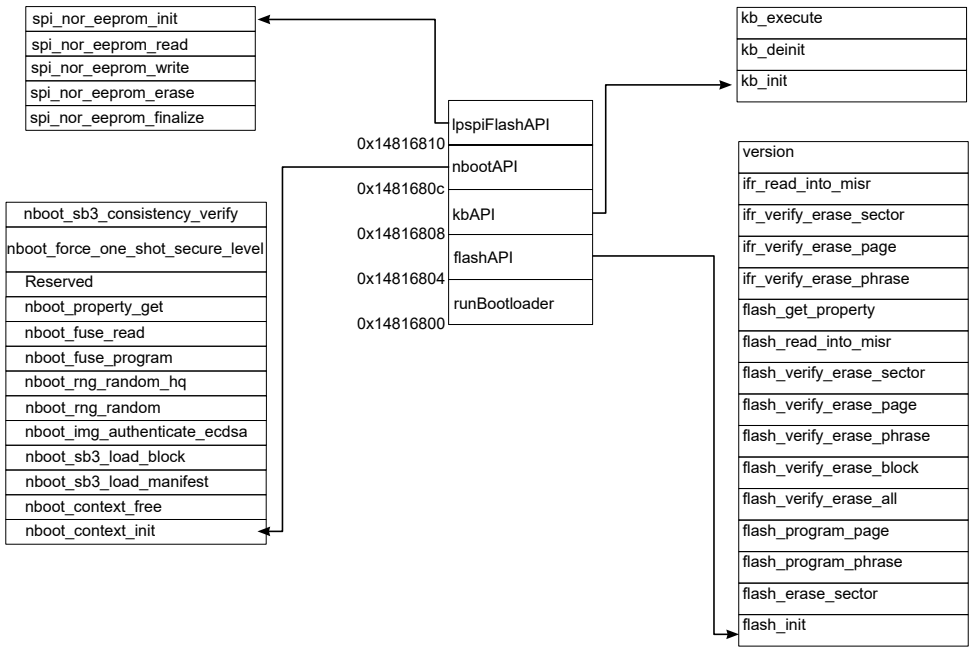

Figure 52. ROM API layout

15.3.1 Flash API

Flash APIs implement all the flash operation supported by CM33 FMU and RF-FMU1. Details of each API is described in this section.

15.3.1.1 flash_init

This API is used for initializing the flash controller and the flash_config context. It must be called before calling other flash APIs.

Prototype

```
status_t flash_init (flash_config_t *config);
```

Parameters

Table 118. flash_init parameters

Parameter	Description
config	Pointer to flash_config_t data structure in memory to store driver runtime state.

flash_config_t is defined as following:

```
typedef struct _flash_mem_descriptor {
    uint32_t blockBase;
    uint32_t totalSize;
    uint32_t blockCount;
} flash_mem_desc_t;

typedef struct _flash_ifr_desc {
    uint32_t pflashIfr0Start;
    uint32_t pflashIfr0MemSize;
} flash_ifr_desc_t;

typedef struct _msf1_config {
    flash_mem_desc_t flashDesc;
    flash_ifr_desc_t ifrDesc;
} msf1_config_t;

typedef struct _flash_config {
    msf1_config_t msf1Config[2];
} flash_config_t;
```

Example:

```
typedef struct
{
    __I void (*runBootloader)(void *arg);           //!< Function to start the bootloader executing.
    __I FLASH_API_Type *flashApiBase;         //!< Internal Flash driver API.
    __I KB_API_Type *kbApiBase;               //!< Bootloader API.
__I NBOOT_API_Type *nbootApiBase;         //!< Image authentication API.
    __I SPI_FLASH_API_Type *spiflashApiBase;             //!< SPI Flash API.

} ROM_API_TYPE;
/** ROM API base address */
#define ROM_API_BASE                        (0x14816800UL)
/** ROM API base pointer */
#define ROM_API                             ((ROM_API_TYPE*) ROM_API_BASE)
/** FLASH API base pointer */
#define FLASH_API                           (ROM_API->flashApiBase)
static flash_config_t flashConfig;
FLASH_API->flash_init(&flashConfig);
```

15.3.1.2 flash_erase_sector

This API is used for erasing specified flash sector (8 KB) in flash or User IFR(IFR0). This API will erase sectors which include the start address and (start + lengthInBytes - 1) address.

Prototype

```
status_t flash_erase_sector (flash_config_t *config, FMU_Type *base, uint32_t start, uint32_t
lengthInBytes, uint32_t key);
```

Parameters

Table 119. flash_erase_sector parameters

Parameter	Description
Config	Pointer to flash_config_t data structure in memory to store driver runtime state.
FMU base	Base pointer to FMU or RF-FMU1
Start	The starting address of the required flash memory to be erased. The starting address must be phrase-aligned (4-word or 16-byte).
lengthInBytes	The length, given in bytes (not words or long words) to be erased.
Key	Key is used to validate erase operation. Must be set to "kFLASH_ApiEraseKey"

Example:

```
#define FOUR_CHAR_CODE(a, b, c, d) (((d) << 24) | ((c) << 16) | ((b) << 8) | ((a)))
#define CM33_FMU                                    ((FMU_Type *)0x40020000u)
enum _flash_driver_api_keys
{
           kFLASH_ApiEraseKey = FOUR_CHAR_CODE('l', 'f', 'e', 'k')
};
result = FLASH_API->flash_erase_sector(&flashConfig, CM33_FMU, 0x0, 4, kFLASH_ApiEraseKey);
```

15.3.1.3 flash_program_phrase

This API is used for programming phrase-aligned data to a previously erased flash or User IFR phrase.

Prototype

```
status_t flash_program_phrase (flash_config_t *config, FMU_Type *base, uint32_t start,
                          uint32_t *src, uint32_t lengthInBytes);
```

Parameters

Table 120. flash_program_phrase parameters

Parameter	Description
config	Pointer to flash_config_t data structure in memory to store driver runtime state.
FMU base	Base pointer to FMU or RF-FMU1
Start	The starting address of the required flash memory to be programmed. The starting address must be phrase-aligned (4-word or 16-byte).
Src	Pointer to the source buffer of data that is to be programmed into flash.
lengthInBytes	The length, given in bytes (not words or long words) to be programmed. The lengthInBytes must be phrase-aligned (4-word or 16-byte).

15.3.1.4 flash_program_page

This API is used for programming page aligned data to a previously erased flash or User IFR page.

Prototype

```
status_t flash_program_page (flash_config_t *config, FMU_Type *base, uint32_t start,
                        uint32_t *src, uint32_t lengthInBytes);
```

Parameters

Table 121. flash_program_page parameters

Parameter	Description
config	Pointer to flash_config_t data structure in memory to store driver runtime state.
FMU base	Base pointer to FMU or RF-FMU1
Start	The starting address of the required flash memory to be programmed. The starting address must be page-aligned (32-word or 128-byte).
Src	Pointer to the source buffer of data that is to be programmed into flash.
lengthInBytes	The length, given in bytes (not words or long words) to be programmed. The lengthInBytes must be page-aligned (32-word or 128-byte).

15.3.1.5 flash_verify_erase_all

This API is used for checking if all flash and IFR space are in the erased state..

Prototype

```
status_t flash_verify_erase_all (FMU_Type *base);
```

Parameters:

Table 122. flash_verify_erase_all parameters

Parameter	Description
FMU base	Base pointer to FMU or RF-FMU1

15.3.1.6 flash_verify_erase_block

This API is used for checking if a flash block is in the erased state.

Prototype

```
status_t flash_verify_erase_block (flash_config_t *config, FMU_Type *base, uint32_t blockaddr);
```

Parameters

Table 123. flash_verify_erase_block parameters

Parameter	Description
config	Pointer to flash_config_t data structure in memory to store driver runtime state.
FMU base	Base pointer to FMU or RF-FMU1
blockaddr	Starting address of a flash block, needs to be block-aligned

15.3.1.7 flash_verify_erase_phrase

This API is used for checking if specified flash phrases are in the erased state.

Prototype

```
status_t flash_verify_erase_phrase (flash_config_t *config, FMU_Type *base, uint32_t start, uint32_t
lengthInBytes);
```

Parameters

Table 124. flash_verify_erase_phrase parameters

Parameter	Description
config	Pointer to flash_config_t data structure in memory to store driver runtime state.
FMU base	Base pointer to FMU or RF-FMU1
Start	The starting address of required flash memory to be checked. The starting address must be phrase-aligned (4-word or 16-byte).
lengthInBytes	The length, given in bytes (not words or long words) to be checked. The lengthInBytes must be phrase-aligned (4-word or 16-byte).

15.3.1.8 flash_verify_erase_page

This API is used for checking if specified flash pages are in the erased state.

Prototype

```
status_t flash_verify_erase_page (flash_config_t *config, FMU_Type *base, uint32_t start, uint32_t
lengthInBytes);
```

Parameters

Table 125. flash_verify_erase_page parameters

Parameter	Description
config	Pointer to flash_config_t data structure in memory to store driver runtime state.
FMU base	Base pointer to FMU or RF-FMU1
Start	The starting address of required flash memory to be checked. The starting address must be page-aligned (32-word or 128-byte).
lengthInBytes	The length, given in bytes (not words or long words) to be checked. The lengthInBytes must be page-aligned (32-word or 128-byte).

15.3.1.9 flash_verify_erase_sector

This API is used for checking if specified IFR0 sectors are in the erased state.

Prototype

```
status_t flash_verify_erase_sector (flash_config_t *config, FMU_Type *base, uint32_t start, uint32_t
lengthInBytes);
```

Parameters

Table 126. flash_verify_erase_sector parameters

Parameter	Description
Config	Pointer to flash_config_t data structure in memory to store driver runtime state.
FMU base	Base pointer to FMU or RF-FMU1
Start	The starting address of required flash memory to be checked. The starting address must be sector-aligned (8192-byte).

Table continues on the next page...

Table 126. flash_verify_erase_sector parameters (continued)

Parameter	Description
lengthInBytes	The length, given in bytes (not words or long words) to be checked. The lengthInBytes must be sector-aligned (8192-byte).

15.3.1.10 flash_read_into_misr

This API is used for generating a signature based on the contents of the selected flash memory using an embedded MISR.

Prototype

```
status_t flash_read_into_misr (flash_config_t *config, FMU_Type *base, uint32_t start, uint32_t end,
uint32_t *seed, uint32_t *signature);
```

Parameters

Table 127. flash_read_into_misr parameters

Parameter	Description
Config	Pointer to flash_config_t data structure in memory to store driver runtime state.
FMU base	Base pointer to FMU or RF-FMU1
Start	The starting address of the selected flash region . The start address must be page-aligned (32-word or 128-byte).
End	The ending address of the selected flash region. Ending address must be flash phrase aligned (4-word or 16-byte) and the last phrase in a page.
Seed	MISR seed
Signature	Pointer to buffer expecting signature after successful generation

15.3.1.11 ifr_verify_erase_phrase

This API is used for checking if specified IFR0 phrases are in the erased state.

Prototype

```
status_t ifr_verify_erase_phrase (flash_config_t *config, FMU_Type *base, uint32_t start, uint32_t
lengthInBytes);
```

Parameters

Table 128. ifr_verify_erase_phrase parameters

Parameter	Description
config	Pointer to flash_config_t data structure in memory to store driver runtime state.
FMU base	Base pointer to FMU or RF-FMU1
Start	The starting address of the required IFR0 memory to be checked. The starting address must be phrase-aligned (4-word or 16-byte).
lengthInBytes	The length, given in bytes (not words or long words) to be checked. The lengthInBytes must be phrase-aligned (4-word or 16-byte).

15.3.1.12 ifr_verify_erase_page

This API is used for checking if specified IFR0 pages are in the erased state.

Prototype

```
status_t ifr_verify_erase_page (flash_config_t *config, FMU_Type *base, uint32_t start, uint32_t
lengthInBytes);
```

Parameters

Table 129. ifr_verify_erase_page parameters

Parameter	Description
config	Pointer to flash_config_t data structure in memory to store driver runtime state.
FMU base	Base pointer to FMU or RF-FMU1
Start	The starting address of the required flash memory to be checked. The start address must be page-aligned (32-word or 128-byte).
lengthInBytes	The length, given in bytes (not words or long words) to be checked. The lengthInBytes must be page-aligned (32-word or 128-byte).

15.3.1.13 ifr_verify_erase_sector

This API is used for checking if specified IFR0 sectors are in the erased state.

Prototype

```
status_t ifr_verify_erase_sector (flash_config_t *config, FMU_Type *base, uint32_t start, uint32_t
lengthInBytes);
```

Parameters

Table 130. ifr_verify_erase_sector parameters

Parameter	Description
config	Pointer to flash_config_t data structure in memory to store driver runtime state.
FMU base	Base pointer to FMU or RF-FMU1
Start	The starting address of the required flash memory to be checked. The start address must be sector-aligned(8192-byte).
lengthInBytes	The length, given in bytes (not words or long words) to be checked. The lengthInBytes must be sector-aligned(8192-byte).

15.3.1.14 ifr_read_into_misr

This API is used for generating a signature based on the contents of the selected IFR0 space using an embedded MISR.

Prototype

```
status_t ifr_read_into_misr (flash_config_t *config, FMU_Type *base, uint32_t start, uint32_t end,
uint32_t *seed, uint32_t *signature);
```

Parameters

Table 131. ifr_read_into_misr parameters

Parameter	Description
Config	Pointer to flash_config_t data structure in memory to store driver runtime state.
FMU base	Base pointer to FMU or RF-FMU1
Start	The starting address of the selected flash region . The start address must be page-aligned (32-word or 128-byte).
End	The ending address of the selected flash region. Ending address must be flash phrase aligned (4-word or 16-byte) and the last phrase in a page.
Seed	MISR seed
Signature	Pointer to buffer expecting signature after successful generation

15.3.1.15 flash_get_property

This API returns the required flash property, which includes base address, block size, and other options.

NOTE

The API returns the status kStatus_FLASH_Unknown, which may appear to indicate a failure. However, this status does not mean the API has failed. The result of the operation is provided through the value parameter.

Prototype

```
status_t flash_get_property (flash_config_t *config, flash_property_tag_t whichProperty, uint32_t
*value);
```

Parameters

Table 132. flash_get_property parameters

Parameter	Description
config	Pointer to flash_config_t data structure in memory to store driver runtime state.
whichProperty	The required property from the list of properties.
Value	Property value return to value pointer

Table 133. Property definition

Property Definition	Value
FMU_SectorSize	0x00
FMU_TotalSize	0x01
FMU_BlockSize	0x02
FMU_BlockCount	0x03
FMU_BlockBaseAddr	0x04
RF-FMU1_TotalSize	0x11
RF-FMU1_BlockSize	0x12
RF-FMU1_BlockCount	0x13
RF-FMU1_BlockBaseAddr	0x14

15.3.1.16 Flash API status code

Table 134. Flash API status code

Status	Code	Description
kStatus_FLASH_Success	0	The flash operation is successful
kStatus_FLASH_InvalidArgument	4	Invalid argument detected during executing a FLASH API.
kStatus_FLASH_SizeError	100	Invalid size detected during executing a FLASH API.
kStatus_FLASH_AlignmentError	101	Alignment error detected during executing a FLASH API.
kStatus_FLASH_AddressError	102	Address error detected during executing a FLASH API.
kStatus_FLASH_AccessError	103	Access error detected during executing a FLASH API.
kStatus_FLASH_ProtectionViolation	104	Command Protection Violation Flag which indicates an attempt was made to modify a protected area of flash memory during a command operation.
kStatus_FLASH_CommandFailure	105	Command failure detected during executing a FLASH API.
kStatus_FLASH_UnknownProperty	106	Unknown property for flash_get_property API.
kStatus_FLASH_EraseKeyError	107	Incorrect EraseKey for flash_erase API.
kStatus_FLASH_CommandAborOption	121	Operation is aborted

15.3.2 nboot API

The ROM API table is located at address 0x1481680c and contains absolute ROM API function addresses which can be called using function pointers. Only secure boot related functions are described in this chapter.

The main purpose of these APIs is to provide access to functions used and implemented in ROM to authenticate the application image and processing sb3 files.

15.3.2.1 nboot_context_init

This API is used for initializing the nboot context data structure. It must be called before calling other nboot APIs which performs authentication and sb3 processing.

Prototype:

```
nboot_status_t nboot_context_init(nboot_context_t *context);
```

Parameters

Table 135. nboot_context_init parameters

Parameter	Description
context	Pointer to nboot_context_t data structure in memory to store runtime state.

15.3.2.2 nboot_context_free

This API is used to release context used by all nboot functions.

Prototype:

```
nboot_status_t nboot_context_free(nboot_context_t *context);
```

Parameters

Parameter	Description
context	Pointer to nboot_context_t data structure in memory used to store runtime state.

15.3.2.3 nboot_sb3_load_manifest

This API is used to verify nboot sb3.1 manifest. It loads keys into the key store so that they can be used for subsequent operations such as nboot_sb3_load_block. NBOOT context must be initialized by the API nboot_context_init before calling this API.

Prototype:

```
nboot_status_t nboot_sb3_load_manifest(nboot_context_t *context, uint32_t *manifest);
```

Parameters

Table 136. nboot_sb3_load_manifest parameters

Parameter	Description
context	Pointer to nboot_context_t data structure in memory to store runtime state.
manifest	Pointer to the input manifest buffer.

15.3.2.4 nboot_sb3_load_block

This API is used to verify and decrypt NBOOT SB3.1 block. Decryption is performed in-place. NBOOT context must be initialized by the API nboot_context_init before calling this API.

Prototype:

```
nboot_status_t nboot_sb3_load_block(nboot_context_t *context, uint32_t *block);
```

Parameters

Table 137. nboot_sb3_load_block parameters

Parameter	Description
context	Pointer to nboot_context_t data structure in memory to store runtime state.
block	Pointer to the input block

15.3.2.5 nboot_img_authenticate_ecdsa

This API is used to authenticate signed image with asymmetric cryptography.

Prototype:

```
nboot_status_t nboot_img_authenticate_ecdsa(nboot_context_t *context, uint8_t imageStartAddress[],
nboot_bool_t *isSignatureVerified);
```

Parameters

Table 138. nboot_img_authenticate_ecdsa

Parameter	Description
context	Pointer to nboot_context_t data structure in memory to store runtime state.

Table continues on the next page...

Table 138. nboot_img_authenticate_ecdsa (continued)

Parameter	Description
imageStartAddress	Pointer to start of the image in memory (32-bit word aligned)
isSignatureVerified	Pointer to memory holding function call result. typedef enum { kNBOOT_TRUE = 0x3C5AC33Cu, kNBOOT_TRUE256 = 0x3C5AC35Au, kNBOOT_TRUE384 = 0x3C5AC3A5u, kNBOOT_FALSE = 0x5AA55AA5u, kNBOOT_OperationAllowed = 0x3c5a33ccU, kNBOOT_OperationDisallowed = 0x5aa5cc33U, } nboot_bool_t;

15.3.2.6 nboot_rng_random

This API is used to get random number(s).

Prototype:

```
nboot_status_t nboot_rng_random(nboot_context_t *context, void *buf, size_t bufLen);
```

Parameters

Table 139. nboot_rng_random

Parameter	Description
context	Pointer to nboot_context_t data structure in memory to store runtime state.
Buf	Pointer to buffer in memory to store random number
bufLen	Buffer length in number of bytes.

15.3.2.7 nboot_rng_random_hq

This API is used to get high quality random number(s).

Prototype:

```
nboot_status_t nboot_rng_random_hq(nboot_context_t *context, void *buf, size_t bufLen);
```

Parameters

Table 140. nboot_rng_random_hq

Parameter	Description
context	Pointer to nboot_context_t data structure in memory to store runtime state.
Buf	Pointer to buffer in memory to store random number
bufLen	Buffer length in number of bytes.

15.3.2.8 nboot_fuse_program

This API is used to program a fuse word at a given address with new data. Before using this API, voltage must be regulated for over-drive and normalize voltage after operation is completed.

Prototype:

```
nboot_status_t nboot_fuse_program(nboot_context_t *context, uint32_t addr, uint32_t *data, uint32_t
systemClockFrequencyMHz);
```

Parameters

Table 141. nboot_fuse_program

Parameter	Description
context	Pointer to nboot_context_t data structure in memory to store runtime state.
Addr	Fuse index
Data	Pointer to data expected to be programmed in fuse
systemClockFrequencyMHz	Boot frequency

15.3.2.9 nboot_fuse_read

This API is used to read a fuse word.

Prototype:

```
nboot_status_t nboot_fuse_read(nboot_context_t *context,
                                    uint32_t addr,
                                    uint32_t *data,
                                    uint32_t systemClockFrequencyMHz);
```

Parameters

Table 142. nboot_fuse_read

Parameter	Description
context	Pointer to nboot_context_t data structure in memory to store runtime state.
Addr	Fuse index
Data	Pointer to data buffer expecting fuse contents after successful read
systemClockFrequencyMHz	Boot frequency

15.3.2.10 nboot_property_get

This API is used to read property. One of the important properties that can be read is the property that last authentication of signed image container has succeeded.

Prototype:

```
nboot_status_t nboot_property_get(nboot_context_t *context,
                                  uint32_t propertyId,
```

```
                                    uint8_t *destData,
                                    size_t *dataLen);
```

Parameters

Table 143. nboot_property_get parameters

Parameter	Description
context	Pointer to nboot_context_t data structure in memory to store runtime state.
propertyId	Property ID must be supported by nboot
destData	Pointer to data buffer for storing returned contents
dataLen	Data buffer length

Property IDs supported are as follows:

Table 144. Supported property IDs

Property	ID	Description
DICE_CDI	0x10	Returns 32 bytes of CDI value.
IMAGE_HASH	0x20	Return 64 bytes (SHA-512) value containing hash of the last authenticated image.
PSA_BOOT_SEED	0x30	Returns 32 bytes boot seed.
LAST_AUTH_STATE	0x40	Returns 4 bytes status of last authentication.
SSS_ROM_VERSION	0x50	Returns 8 bytes of SSS ROM version.
SSS_FW_VERSION	0x51	If SSS FW not loaded successfully, returns 0xFFFFFFFF as 1st word. Else returns 2 words, 1st word: version, 2nd word – commit id.
DTRK_ATTEST_PUBK	0x60	Returns 64 bytes value – public part of the DTRK_ATTEST private key
UUID	0x90	Returns UUID to serve as device unique identifier.

15.3.2.11 nboot API status code

The following table lists the nboot API status code.

Table 145. nboot API status code

Status	Code
kStatus_NBOOT_Success	0x5a5a5a5a
kStatus_NBOOT_Fail	0x5a5aa5a5
kStatus_NBOOT_InvalidArgument	0x5a5aa501
kStatus_NBOOT_RequestTimeout	0x5a5aa502
kStatus_NBOOT_ResourceBusy	0x5a5aa503
kStatus_NBOOT_OperationNotAvaialable	0x5a5aa5e5
kStatus_NBOOT_MemcpyFail	0x5a5a845a

15.3.3 kb API

This set of APIs provides an interface to bootloader functions. The primary purpose of these APIs is to expose ROM-level functionality for processing Secure Binary (SB) files.

NOTE

These APIs are functional when TRDC (Trusted Resource Domain Controller) is disabled. If TRDC is enabled with different configurations, the APIs may encounter issues when attempting to erase or program internal flash memory when using addresses where bit 28 is set to 1.

15.3.3.1 kb_init

This API is used to initialize bootloader and nboot context necessary to process sb3 file format.

Prototype:

```
status_t kb_init(kb_session_ref_t **session_out, const kb_options_t *options)
```

This API is expected to return kStatus_Success (0) on success and kStatus_Fail (1) on failure.

15.3.3.2 kb_deinit

This API is used to release nboot context and finalize sb3 file processing.

Prototype:

```
status_t kb_deinit(kb_session_ref_t *session)
```

15.3.3.3 kb_execute

This API is used to decrypt sb3 file and store signed image contents specified by loader command supported while generating sb3 image through Json configuration. If sb3 file to be processed includes sblaoder command “programFuses” then voltage must be regulated for over-drive and normalize voltage once operation is completed.

Prototype:

```
status_t kb_execute(kb_session_ref_t *session, const uint8_t *data, uint32_t dataLength)
```

Parameters

Table 146. kb_execute parameters

Parameter	Description
data	session pointer obtained from kb_init function
dataLength	sb file data length in bytes
isUpdateExt	Indicator for update(sb) file start address is in internal or external flash. 0x74784578u = External flash Other values = Internal flash

15.3.3.4 kb API status code

Table 147. Flash API status code

Status	Code	Description
kStatus_Success	0	API succesfully finished its operation
kStatus_Fail	1	API failed and it could not finish its operation
kStatus_InvalidArgument	4	API cannot proceed because the input argument value is invalid
kStatus_RomLdrDataUnderrun	10109	API needs to be called again with more data (next data chunk)
kStatus_RomLdrJumpReturned	10110	API finished its execution but the jump to user code returned
kStatus_RomLdrRollbackBlocked	10115	New firmware version is lesser than the present one
kStatus_RomLdrPendingJumpCommand	10119	Returned by kb_execute; Call of kb_finish is needed to do the requested jump
kStatus_RomApiBufferSizeNotEnough	10802	API cannot proceed because the provided buffer (via call of kb_init in options argument) is not large enough
kStatus_RomApiInvalidBuffer	10803	API cannot proceed because the provided buffer pointer is NULL or buffer size is 0

15.3.4 SPI Flash API

15.3.4.1 spi_eeprom_init

This API is used to initialize SPI Flash with requested baud rate and reads JEDEC ID as sanity check.

Prototype:

```
status_t spi_nor_eeprom_init(uint32_t baudRate)
```

Parameters

Table 148. spi_eeprom_init parameters

Parameter	Description
baudRate	Value used to configure SPI NOR flash for subsequent operations.

15.3.4.2 spi_eeprom_read

This API is used to read SPI Flash memory contents.

Prototype:

```
status_t spi_eeprom_read(uint8_t *dest, uint32_t NoOfBytes, uint32_t address, bool
requestFastRead);
```

Parameters

Table 149. spi_eeprom_read parameters

Parameter	Description
dest	Pointer to destination buffer to store memory contents read from SPI flash.
NoOfBytes	Number of bytes to read.
address	Absolute start address of SPI Flash from which read operation should be prformed.
requestFastRead	true = Uses FAST READ (0Bh) false = Uses simple read READ (03h) • User must check AC chacracteristics of Flash memory model and should know SPI functional clock before requesting requestFastRead. Otherwise requestFastRead option can cause a bootleneck in data transaction speed as command buffer involves dummy byte.

15.3.4.3 spi_eeprom_write

This API is used to program data to SPI flash.

Prototype:

```
status_t spi_eeprom_write(uint8_t *data, uint32_t NoOfBytes, uint32_t address);
```

Parameters

Table 150. spi_eeprom_write parameter

Parameter	Description
data	Pointer to the buffer of data that is to be programmed into SPI flash.
NoOfBytes	Number of bytes to be programmed.
Address	Start address of the SPI Flash memory to be programmed.

15.3.4.4 spi_eeprom_erase

This API is used to erase SPI flash contents with specific erase size.

Prototype:

```
status_t spi_eeprom_erase(uint32_t address, eraseOptions_t option);
```

Parameters

Table 151. spi_eeprom_erase parameters

Parameter	Description
address	Start address of the SPI Flash memory to be erased.

option	Following are the options supported for erase operation:
	`typedef enum`
	`{`
	`  kSize_ErasePage = 0x1,`
	`  kSize_Erase4K = 0x2,`

Table continues on the next page...

Table 151. spi_eeprom_erase parameters (continued)

Parameter	Description
	kSize_Erase32K = 0x3, kSize_Erase64K = 0x4, kSize_EraseAll = 0x5, } eraseOptions_t; **NOTE** kSize_ErasePage option is not supported for all memory models. Example: Adesto flash can support page erase commands but not Micron.

15.3.4.5 spi_eeprom_finalize

This API is used de-initialize IOMUX and clock settings used for SPI Flash operations and resets all LPSPI logic and control registers.

Prototype:

```
void spi_eeprom_finalize(void);
```

15.3.4.6 SPI Flash API status code

The following table lists the SPI Flash API status code.

Table 152. SPI Flash API status code

Status	Code
kStatus_Success	0
kStatus_Fail	1

15.3.5 runBootloader API

This API allows to enter the bootloader from the application within the ROM API.

Prototype

```
void (*runBootloader)(uint32_t *arg);
```

Table 153. runBootloader parameter

Parameter	Description
arg	arg Pointer to structure user_app_boot_invoke_option_t

The input argument to the function is a pointer to a 32-bit value which controls how to enter the bootloader:

Table 154. runBootloader API arg fields

Field	Offset	Description
Tag	[31:24]	Fixed value: EBh (enter boot)
Boot mode	[23:20]	• 0: Boot from flash

Table continues on the next page...

Table 154. runBootloader API arg fields (continued)

Field	Offset	Description
		• 1: ISP Mode
Interface	[19:16]	For ISP mode, following interface can be selected • 0: UART • 1: I2C • 2: SPI • 3: CAN • 15: Autodetect
Reserved	[15:0]	-

The function stores the value of the input argument into POR clear register CMC[BSR1] and resets the device, which causes bootloader to run. Bootloader examines the argument value stored in the register and decides what to do:

- ISP Boot mode causes ISP path to be entered like the ISP pin was asserted.
- Master boot mode causes booting the boot image on flash.

Chapter 16
Flash Memory Unit (FMU)

16.1 Chip-specific FMU information

Table 155. Reference links to related information

Topic	Related module	Reference
Full description	FMU	FMU
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

NOTE

For the SoC 32 KB IFR0, the first 8 KB is program once and never allows to be erased.

16.1.1 Module instances

This device has two instances of the FMU module, FMU0 and FMU1.

16.1.2 IFR map

For this device, refer to Table 65 for Table 187.

16.1.3 FCTRL[RWSC]

The configuration of Read Wait-State Control (RWSC) filed of Flash Control Register (FCTRL) is shown in below table.

Table 156. Configuration in different run modes and speed

Mode	Typical Frequency (MHz)	FCTRL[RWSC]
SD - 1.1V	96	0010b
SD - 1.1V	64	0001b
SD - 1.1V	48	0001b
SD - 1.1V	32	0000b
MD - 1.0V	48	0001b
MD - 1.0V	32	0001b
MD - 1.0V	24	0000b

16.1.4 FSTAT[PEWEN]

NOTE

This bit is only writable by accessing it through the test interface.

16.2 Overview

The flash module includes the following accessible memory regions:

- Program flash memory for vector space and code store
- Separate flash memory for parameter store

Flash memory is ideal for single-supply applications, permitting in-the-field erase and reprogramming operations without the need for any external high voltage power sources.

The flash module includes a command controller that executes commands to modify flash memory contents. An erased bit reads '1' and a programmed bit reads '0'. The programming operation is unidirectional; it can only move bits from the '1' state (erased) to the '0' state (programmed). Only the erase operation restores bits from '0' to '1'; bits cannot be programmed from a '0' to a '1'.

CAUTION

A flash memory location must be in the erased state before being programmed. Cumulative programming of bits (back-to-back program operations without an intervening erase) within a flash phrase or page is not allowed. Re-programming of existing 0s to 0 is not allowed as this overstresses the device.

The standard shipping condition for flash memory is erased. Data loss over time may occur due to degradation of the erased ('1') states and/or programmed ('0') states. Therefore, it is recommended that flash memory be re-erased immediately prior to factory programming to ensure that the full data retention capability is achieved.

16.2.1 Block diagram

The block diagram of the flash module is shown in the following figure.

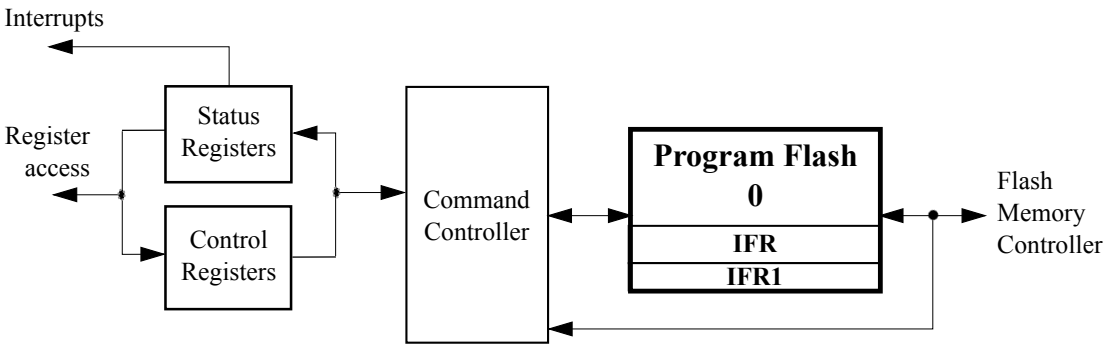

Figure 53. Flash block diagram

16.2.2 Features

The flash memory module provides the following features:

- Sector size of 8 Kbytes
- Single-bit error correction and double-bit error detection for each flash or IFR phrase
- Signature generation for flash contents
- Command-based flash program, erase, and verify operations
- Internal high-voltage supply generator for flash program and erase operations
- Optional interrupt generation upon flash command completion
- Optional interrupt generation upon double-bit error detection during flash reads from the FMC

NOTE

See the chip configuration details for the exact amount of flash memory available.

16.3 Functional description

The following sections describe functional details of the flash module.

16.3.1 Operations

Operations are typically used to modify flash memory contents. The next sections describe:

- Command write sequence used to set flash command parameters and launch execution
- Available flash commands
- Commands impacted by Block Checker and FMC access protection

16.3.1.1 Command write sequence

Flash commands are accomplished using a command write sequence illustrated in Figure 54. The command controller monitors the transaction protection level on writes during the command write sequence, performs various checks on the command (FCCOB) content, and continues with command execution if all requirements are fulfilled.

Before launching a command, the ACCERR, PVIOL, and CMDABT flags in the FSTAT register must be zero and the CCIF flag must be one to verify that any previous command has completed. The FAIL flag in the FSTAT register is cleared by the command controller when a command is launched unless the FAIL flag was set during initialization due to FMU parameters not being loaded from IFR1. If CCIF is clear, the previous command execution is still active, a new command write sequence cannot be started, and all writes to the FCCOB registers are ignored.

16.3.1.1.1 Load the FCCOB Registers

The user must load the FCCOB registers with all parameters required by the specific flash command. The contents of any FCCOB register not used by the specific flash command are ignored except for FCCOB1 (command options) where undefined bits should be cleared. The individual registers that make up the FCCOB data set can be written in any order. All writes to the FCCOB registers in a command write sequence must occur at the same transaction protection level. Any write to the FCCOB registers that violates this rule will be ignored.

Addresses loaded into FCCOB registers assume the flash and IFR spaces start at 0000_0000h.

16.3.1.1.2 Launch the Command by Clearing CCIF

Once all relevant command parameters have been loaded, the user launches the command by clearing the FSTAT[CCIF] bit by writing a '1' to it. The write to clear CCIF must occur at the same transaction protection level as the writes used to load the FCCOB registers. Any write to clear CCIF that violates this rule will be ignored. The CCIF flag remains clear until the flash command completes.

The FSTAT register contains a blocking mechanism which prevents a new flash command from launching (unable to clear CCIF) if the previous command resulted in the setting of an access error (ACCERR), protection violation (PVIOL), or active command abort flag (CMDABT). In error scenarios, two writes to FSTAT are required to initiate the next command: the first write to clear these flags, the second write to clear CCIF. The write to clear these flags can occur at any transaction protection level.

16.3.1.1.3 Command Execution and Error Reporting

Flash command processing contains the following steps:

1. The command controller performs a series of parameter checks, if applicable, which are unique to each command. If the parameter check fails, the FSTAT[ACCERR] flag is set. ACCERR reports invalid instruction codes or options, out of bounds or misaligned addresses, or missing FMU parameters. In the case FMU parameters were not loaded from IFR1 during initialization, the ACCERR flag sets and the FSTAT[FAIL] flag remains set. Command processing never proceeds to execution when the parameter check fails. Instead, command processing is terminated after setting the FSTAT[CCIF] flag. Note that for program and erase operations, PEWEN will not set if FMU parameters were not loaded and PERDY will not set if program or erase related writes to flash or IFR space violate command requirements.
2. If necessary, the command controller performs a protection check to see if the command is allowed to execute on the requested memory space. If the protection check fails, the FSTAT[PVIOL] flag is set. Command processing never

proceeds to execution when the protection check fails. Instead, command processing is terminated after setting the FSTAT[CCIF] flag.

3. If the parameter and protection checks pass, the command proceeds to execution. Run-time errors, such as failure to verify, may occur during the execution phase and are reported in the FAIL flag. A flash command may have access errors, protection violations, and run-time errors, but the run-time errors are not seen until all access errors and protection violations have been corrected.
4. If FCTRL[ABTREQ] sets during command execution, the operation will abort with the FSTAT[CMDABT] flag set.
5. Command execution results, if applicable, are reported back to the user via the FCCOB registers.
6. The command controller sets FSTAT[CCIF] signifying that the command has completed.

CAUTION

If the FAIL flag is set along with ACCERR, FMU parameters were not loaded from IFR1 during initialization. In this case, it is recommended that the flash module be reinitialized. If the issue persists, flash commands will continue to set the ACCERR and FAIL flags.

The flow for a generic command write sequence is illustrated in the following figure.

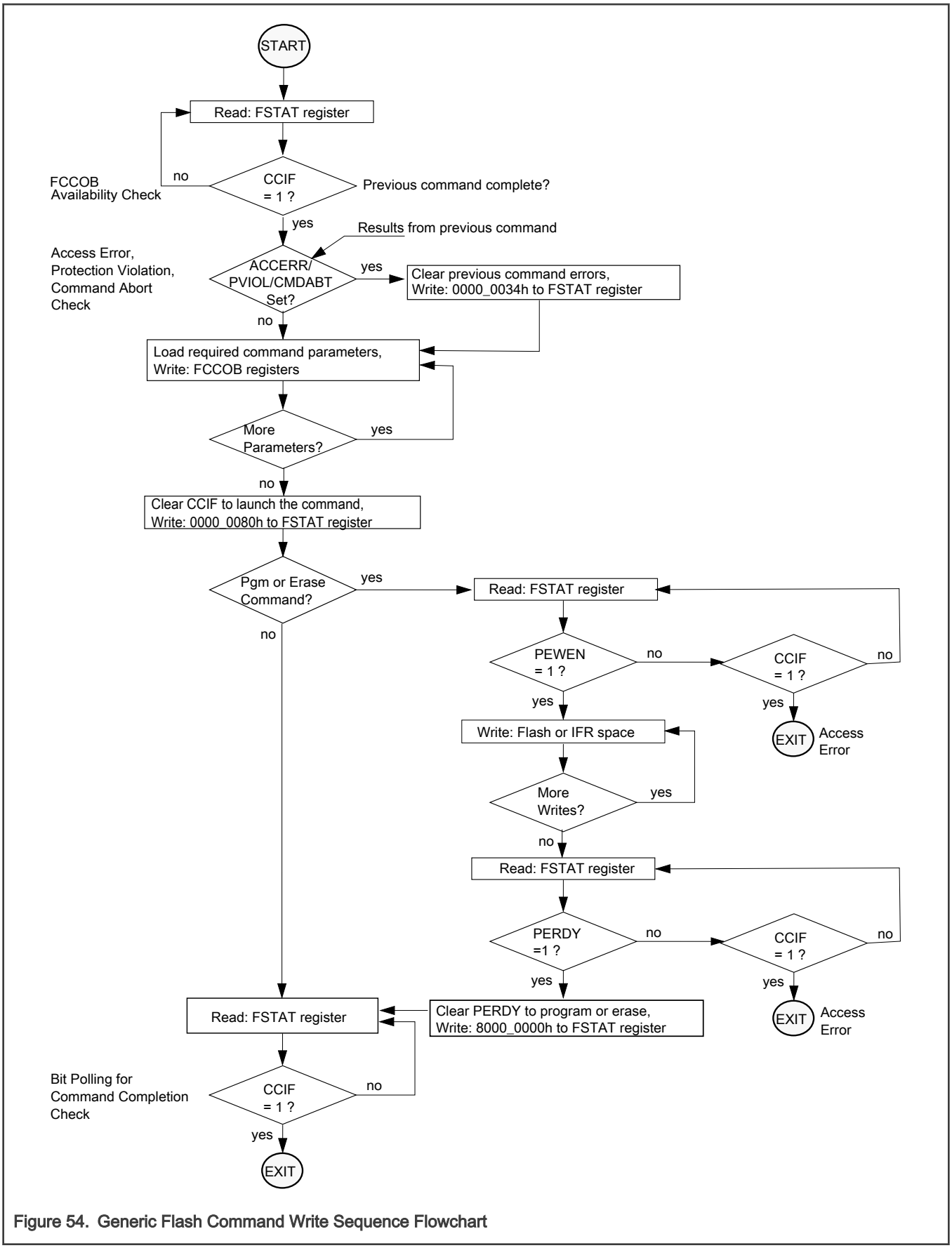

Figure 54. Generic Flash Command Write Sequence Flowchart

16.3.1.1.4 Aborting a Command Write Sequence or Command Operation

FSTAT[CMDP] sets at the start of a command write sequence, typically by writing to one of the FCCOB registers. With CMDP set, setting the FCTRL[ABTREQ] bit allows a user to abort a command write sequence and take control over a new command write sequence. The ABTREQ bit can only be set by a user with the same domain ID as indicated by FSTAT[CMDDID] and at the same or higher security/privilege protection level when compared to FSTAT[CMDPRT], the current owner of the command write sequence. While ABTREQ is set, CCIF cannot be cleared to launch a command.

If FSTAT[CCIF] is high when ABTREQ is set, the command write sequence will abort and ownership transferred to the user setting the ABTREQ bit. The FSTAT[CWSABT] flag will set and the CMDPRT field will be updated based on the write transaction that set the ABTREQ bit. The ABTREQ bit will then be cleared automatically.

If CCIF is low when ABTREQ is set, the command controller will abort execution of the current command operation, set FSTAT[CMDABT], and set CCIF. The CMDPRT field will be updated based on the write transaction that set the ABTREQ bit. The ABTREQ bit will then be cleared automatically. While CMDABT is set, CCIF cannot be cleared to launch a command. Aborting a program or erase operation may leave the flash or IFR space being modified in an indeterminate state.

NOTE

Aborting certain flash commands may take longer to abort than to execute. See the device data sheet for flash command timing specifications.

16.3.1.2 Flash commands

The following table summarizes the function of all flash commands. If any column is marked with an 'X', the flash command is relevant to that particular memory resource.

FCMD	Command	Program flash 0	IFR	Function
00h	Read 1s All (RD1ALL)	x	x	Verify that all flash and IFR space is erased
01h	Read 1s Block (RD1BLK)	x		Verify that a flash block is erased
02h	Read 1s Sector (RD1SCR)	x		Verify that a flash sector is erased
03h	Read 1s Page (RD1PG)	x		Verify that a flash page is erased
04h	Read 1s Phrase (RD1PHR)	x		Verify that a flash phrase is erased
05h	Read into MISR (RDMISR)	x		Generate MISR signature for range of flash pages
12h	Read 1s IFR Sector (RD1ISCR)		x	Verify that an IFR sector is erased
13h	Read 1s IFR Page (RD1IPG)		x	Verify that an IFR page is erased
14h	Read 1s IFR Phrase (RD1IPHR)		x	Verify that an IFR phrase is erased
15h	Read IFR into MISR (RDIMISR)		x	Generate MISR signature for range of IFR pages

Table continues on the next page...

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FCMD	Command	Program flash 0	IFR	Function
23h	Program Page (PGMPG)	x	x	Program data to a flash or IFR page
24h	Program Phrase (PGMPHR)	x	x	Program data to a flash or IFR phrase
40h	Erase All (ERSALL)	x	x	Erase all flash and IFR space if enabled
42h	Erase Sector (ERSSCR)	x	x	Erase a flash sector

16.3.1.3 Flash commands impacted by Block Checker and FMC access protection

The following flash commands are impacted by Block Checker and FMC access protection:

- Program Phrase (PGMPHR)
- Program Page (PGMPG)
- Erase Sector (ERSSCR)

During execution of these flash commands, a sequence of AHB writes to flash or IFR space are required with validity checked by the Block Checker or FMC. When writes are enabled by the FMU, violations detected by the FMC are reported as an access error in the FMU. The other violations are handled by the Block Checker or FMC.

Table 157. Flash Write Access Checks

Flash Write Violation Condition	Block Checker	FMC	FMU
Flash or IFR address out-of-range	X		
Flash or IFR write permission check fails	X		
Write to IFR1 space		X	
Write width not 32-bit		X	
Writes not enabled by FSTAT[PEWEN]		X	
First write in sequence not properly aligned per FSTAT[PEWEN]			X
Non-sequential write after first aligned write in sequence			X
Bus permissions for the AHB write do not match the bus permissions of the APB write that launched the flash command			X

16.3.2 Flash command descriptions

This section describes all flash commands that can be launched by a valid command write sequence. The flash module sets the FSTAT[ACCERR] bit and aborts the command execution if any of the following illegal conditions occur:

- There is an unrecognized command code in the FCCOB FCMD field.
- There is an error in an FCCOB field for the specific command. Refer to the error handling table provided for each command.

The ACCERR, PVIOL, and CMDABT flags in the FSTAT register should be cleared prior to starting a command write sequence. As described in Launch the Command by Clearing CCIF, a new command cannot be launched while these flags are set.

Do not attempt to read a flash block while a flash command is running (CCIF = 0) on that same block. The flash module may return a transfer error to the FMC resulting in a bus fault. The exception to this rule is during program operations where the flash block is still readable after the command is launched up until the time the FSTAT[PERDY] flag is cleared.

CAUTION

Flash data must be in the erased state before being programmed. Cumulative programming of bits (adding more zeros) is not allowed.

16.3.2.1 Read 1s All Command

The Read 1s All command checks if all flash and IFR space are in the erased state.

Table 158. Read 1s All Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	00h (RD1ALL)

Upon clearing CCIF to launch the Read 1s All command, the command controller:

- verifies that all flash and IFR space are in the erased state

If all flash and IFR space are not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s All operation completes.

Table 159. Read 1s All Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

16.3.2.2 Read 1s Block Command

The Read 1s Block command checks if a flash block is in the erased state.

Table 160. Read 1s Block Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	01h (RD1BLK)
2	Block address

Upon clearing CCIF to launch the Read 1s Block command, the command controller:

- verifies that the selected flash block is in the erased state

If the selected flash block is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s Block operation completes.

Table 161. Read 1s Block Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]

Table continues on the next page...

Table 161. Read 1s Block Command Error Handling (continued)

Error Condition	Error Bit
Address is not valid	FSTAT[ACCERR]
Address is not block aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

16.3.2.3 Read 1s Sector Command

The Read 1s Sector command checks if a flash sector is in the erased state.

Table 162. Read 1s Sector Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	02h (RD1SCR)
2	Sector address

Upon clearing CCIF to launch the Read 1s Sector command, the command controller:

- verifies that the selected flash sector is in the erased state

If the selected flash sector is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s Sector operation completes.

Table 163. Read 1s Sector Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Address is not sector aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

16.3.2.4 Read 1s Page Command

The Read 1s Page command checks if a flash page is in the erased state.

Table 164. Read 1s Page Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	03h (RD1PG)
2	Page address

Upon clearing CCIF to launch the Read 1s Page command, the command controller:

- verifies that the selected flash page is in the erased state

If the selected flash page is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s Page operation completes.

Table 165. Read 1s Page Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Address is not page aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

16.3.2.5 Read 1s Phrase Command

The Read 1s Phrase command checks if a flash phrase is in the erased state.

Table 166. Read 1s Phrase Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	04h (RD1PHR)
2	Phrase address

Upon clearing CCIF to launch the Read 1s Phrase command, the command controller:

- verifies that the selected flash phrase is in the erased state

If the selected flash phrase is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s Phrase operation completes.

Table 167. Read 1s Phrase Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Address is not phrase aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

16.3.2.6 Read into MISR command

The Read into MISR operation generates a signature based on the contents of the selected flash memory using an embedded MISR.

Table 168. Read into MISR Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	05h (RDMISR) [7:0]
2	Starting flash page address
3	Ending flash phrase address
4	Word 0 of MISR seed
5	Word 1 of MISR seed
6	Word 2 of MISR seed
7	Word 3 of MISR seed
Returned values	
4	Word 0 of MISR signature
5	Word 1 of MISR signature
6	Word 2 of MISR signature
7	Word 3 of MISR signature

Upon clearing CCIF to launch the Read into MISR command, the command controller:

1. initializes the MISR with the seed provided
2. processes flash data starting with the starting flash page address provided
3. continues until the ending flash phrase address has been processed (must be the last phrase in a page)
4. returns the resulting signature into the FCCOB register bank unless an uncorrectable ECC fault is detected

The CCIF flag sets after the Read into MISR operation completes. If the operation is aborted by setting FCTRL[ABTREQ], a signature will not be returned if the abort occurs prior to the operation writing the signature.

MISR polynomial is $X^{128} + X^{126} + X^{101} + X^{99} + 1$.

Table 169. Read into MISR Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Starting address is not flash page aligned	FSTAT[ACCERR]
Ending address is not flash phrase aligned	FSTAT[ACCERR]
Ending address is not the last phrase in a page	FSTAT[ACCERR]
Starting address is larger than the ending address	FSTAT[ACCERR]
Requested range crosses a flash block boundary	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Uncorrectable ECC error is detected	FSTAT[FAIL]

16.3.2.7 Read 1s IFR Sector Command

The Read 1s IFR Sector command checks if an IFR sector is in the erased state.

Table 170. Read 1s IFR Sector Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	12h (RD1ISCR)
2	IFR sector address

Upon clearing CCIF to launch the Read 1s IFR Sector command, the command controller:

- verifies that the selected IFR sector is in the erased state

If the selected IFR sector is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s IFR Sector operation completes.

Table 171. Read 1s IFR Sector Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Address is not IFR sector aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

16.3.2.8 Read 1s IFR Page Command

The Read 1s IFR Page command checks if an IFR page is in the erased state.

Table 172. Read 1s IFR Page Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	13h (RD1IPG)
2	IFR page address

Upon clearing CCIF to launch the Read 1s IFR Page command, the command controller:

- verifies that the selected IFR page is in the erased state

If the selected IFR page is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s IFR Page operation completes.

Table 173. Read 1s IFR Page Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Address is not IFR page aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]

Table continues on the next page...

Table 173. Read 1s IFR Page Command Error Handling (continued)

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

16.3.2.9 Read 1s IFR Phrase Command

The Read 1s IFR Phrase command checks if an IFR phrase is in the erased state.

Table 174. Read 1s IFR Phrase Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	14h (RD1IPHR)
2	IFR phrase address

Upon clearing CCIF to launch the Read 1s IFR Phrase command, the command controller:

- verifies that the selected IFR phrase is in the erased state

If the selected IFR phrase is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s IFR Phrase operation completes.

Table 175. Read 1s IFR Phrase Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Address is not IFR phrase aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

16.3.2.10 Read IFR into MISR command

The Read IFR into MISR operation generates a signature based on the contents of the selected IFR space using an embedded MISR.

Table 176. Read IFR into MISR Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	15h (RDIMISR) [7:0]
2	Starting IFR page address
3	Ending IFR phrase address
4	Word 0 of MISR seed
5	Word 1 of MISR seed
6	Word 2 of MISR seed

Table continues on the next page...

Table 176. Read IFR into MISR Command FCCOB Requirements (continued)

FCCOB Number	FCCOB Contents
7	Word 3 of MISR seed
Returned values	
4	Word 0 of MISR signature
5	Word 1 of MISR signature
6	Word 2 of MISR signature
7	Word 3 of MISR signature

Upon clearing CCIF to launch the Read IFR into MISR command, the command controller:

1. initializes the MISR with the seed provided
2. processes IFR data starting with the starting IFR page address provided
3. continues until the ending IFR phrase has been processed (must be the last phrase in a page)
4. returns the resulting signature into the FCCOB register bank unless an uncorrectable ECC fault is detected

The CCIF flag sets after the Read IFR into MISR operation completes. If the operation is aborted by setting FCTRL[ABTREQ], a signature will not be returned if the abort occurs prior to the operation writing the signature.

MISR polynomial is $X^{128} + X^{126} + X^{101} + X^{99} + 1$.

Table 177. Read IFR into MISR Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Starting address is not IFR page aligned	FSTAT[ACCERR]
Ending address is not IFR phrase aligned	FSTAT[ACCERR]
Ending address is not the last phrase in a page	FSTAT[ACCERR]
Starting address is larger than the ending address	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Uncorrectable ECC error is detected	FSTAT[FAIL]

16.3.2.11 Program Page command

The Program Page operation programs 32 words of data to a previously erased flash or IFR page.

CAUTION

The page must be in the erased state before being programmed. Cumulative programming of bits (back-to-back program operations without an intervening erase) within a page is not allowed.

Table 178. Program Page Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	23h (PGMPG) [7:0]

Upon clearing CCIF to launch the Program Page command, the command controller:

1. sets FSTAT[PEWEN] to enable writes to the flash and IFR space in the system memory map
2. waits for the user to write 32 consecutive words to the flash or IFR space with the first write being page aligned
3. clears FSTAT[PEWEN] field
4. sets FSTAT[PERDY]
5. waits for the user to clear FSTAT[PERDY]
6. programs the data into the targeted page written to in step 2
7. verifies bits to be programmed are programmed to the program verify level

The CCIF flag sets after the Program Page operation completes. The Program Page operation can be aborted by setting FCTRL[ABTREQ]. If the operation is aborted, the operation terminates with the FSTAT[CMDABT] flag set. Once CCIF is set, the Program Page command may be repeated (same addresses, same data) to complete the program operation without erasing the sector containing the targeted page. Invalid writes to flash or IFR space based on Block Checker or FMC access protection are trapped outside of the flash module.

Table 179. Program Page Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Protection level of the writes to flash or IFR space do not match the protection level of the command write sequence	FSTAT[ACCERR]
Initial address is not page aligned and subsequent addresses phrase aligned	FSTAT[ACCERR]
Number of writes to flash or IFR space is more than expected	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

16.3.2.11.1 Page programming

The standard process of programming one or more flash or IFR pages is as follows:

1. If required, launch the Erase Sector command to erase the flash or IFR sector to be programmed (repeat for additional sectors).
2. Launch the Program Page command to enable writes to the flash space.
3. After the command controller sets FSTAT[PEWEN], write 32 consecutive words to the flash space with the first word page aligned. The data written to the flash space is not readable until the program operation has successfully completed.
4. After the flash page has been written, the command controller will stall and set FSTAT[PERDY].
5. Clear PERDY allowing the command controller to resume and program the 32 words into the flash or IFR space written to in step 3.
6. Wait for CCIF to set indicating the program operation has completed.
7. To program additional flash or IFR pages in previously erased flash memory, repeat steps 2 through 6.

16.3.2.12 Program Phrase command

The Program Phrase operation programs 4 words of data to a previously erased flash or IFR phrase.

CAUTION

The phrase must be in the erased state before being programmed. Cumulative programming of bits (back-to-back program operations without an intervening erase) within a phrase is not allowed.

Table 180. Program Phrase Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	24h (PGMPHR) [7:0]

Upon clearing CCIF to launch the Program Phrase command, the command controller:

1. sets FSTAT[PEWEN] to enable writes to the flash and IFR space in the system memory map
2. waits for the user to write 4 consecutive words to the flash or IFR space with the first write being phrase aligned
3. clears FSTAT[PEWEN] field
4. sets FSTAT[PERDY]
5. waits for the user to clear FSTAT[PERDY]
6. programs the data into the targeted phrase written to in step 2.
7. verifies bits to be programmed are programmed to the program verify level

The CCIF flag sets after the Program Phrase operation completes. The Program Phrase operation can be aborted by setting FCTRL[ABTREQ]. If the operation is aborted, the operation terminates with the FSTAT[CMDABT] flag set. Once CCIF is set and the CMDABT flag is cleared, the Program Phrase command may be repeated (same addresses, same data) to complete the program operation without erasing the sector containing the targeted phrase. Invalid writes to flash or IFR space based on Block Checker or FMC access protection are trapped outside of the flash module.

Table 181. Program Phrase Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Protection level of the writes to flash or IFR space do not match the protection level of the command write sequence	FSTAT[ACCERR]
Address is not phrase aligned	FSTAT[ACCERR]
Number of writes to flash or IFR space is more than expected	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

16.3.2.12.1 Phrase programming

The standard process of programming one or more flash or IFR phrases is as follows:

1. If required, launch the Erase Sector command to erase the flash or IFR sector to be programmed (repeat for additional sectors).
2. Launch the Program Phrase command to enable writes to the flash and IFR space.
3. After the command controller sets FSTAT[PEWEN], write 4 consecutive words to the flash or IFR space with the first word phrase aligned. The data written to the flash or IFR space is not readable until the program operation has successfully completed.
4. After the flash or IFR phrase has been written, the command controller will stall the operation and set FSTAT[PERDY].

5. Clear PERDY allowing the command controller to resume and program the 4 words into the flash or IFR space written to in step 3.
6. Wait for CCIF to set indicating the program operation has completed.
7. To program additional flash or IFR phrases in previously erased flash memory, repeat steps 2 through 6.

16.3.2.13 Erase All command

The Erase All operation erases all flash and IFR space if enabled by the MCU.

Table 182. Erase All Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	40h (ERSALL) [7:0]

Upon clearing CCIF to launch the Erase All command, the command controller:

1. erases flash block 0 sector-by-sector
2. verifies flash block 0 is erased; if not, skips IFR space in block 0
3. erases IFR space in block 0 sector-by-sector
4. verifies IFR space in block 0 is erased
5. clears FSTAT[CMDP] flag

The CCIF flag sets after the Erase All operation completes. If either the flash or IFR space is not in the erased state, FSTAT[FAIL] sets.

Table 183. Erase All Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Command is disabled by the MCU	FSTAT[PVIOL]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

16.3.2.14 Erase Sector command

The Erase Sector operation erases the IFR sector to prepare the sector for programming.

Table 184. Erase Sector Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	42h (ERSSCR) [7:0]

Upon clearing CCIF to launch the Erase Sector command, the command controller:

1. sets FSTAT[PEWEN] to enable writes to the flash and IFR space in the system memory map
2. waits for the user to write 4 consecutive words to the flash or IFR space with the first write being phrase (or sector) aligned
3. clears FSTAT[PEWEN] field
4. sets FSTAT[PERDY]

5. waits for the user to clear FSTAT[PERDY]
6. erases the selected flash or IFR sector
7. verifies the selected flash or IFR sector is erased

If the selected flash or IFR sector is not in the erased state, FSTAT[FAIL] is set. The CCIF flag sets after the Erase Sector operation completes. The Erase Sector operation can be aborted by setting FCTRL[ABTREQ]. If the operation is aborted, the operation terminates with the FSTAT[CMDABT] flag set. Once CCIF is set, the Erase Sector command may be repeated to complete the erase operation. Invalid writes to flash or IFR space based on Block Checker or FMC access protection are trapped outside of the flash module.

Table 185. Erase Sector Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Protection level of the writes to flash or IFR space do not match the protection level of the command write sequence	FSTAT[ACCERR]
Address is not flash or IFR phrase aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
IFR Sector is protected (see FCNFG register)	FSTAT[PVIOL]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

16.3.3 Mass Erase

If enabled by the MCU, MCU resources can be used to launch a mass erase operation without accessing the flash registers.

To know how to enable/disable mass erase for your device, refer the chip-specific section.

The status of the mass erase request is reflected in the FCNFG[ERSREQ] bit. When launched, the mass erase operation occurs regardless of the state of the CMDP, ACCERR, PVIOL, or CMDABT flags in the FSTAT register but requires FSTAT[CCIF] to be set and the MCU to enable mass erase. When mass erase is launched with CCIF set, the CMDP, CCIF, CWSABT, PVIOL, and CMDABT flags in the FSTAT register clear. The ACCERR and FAIL flags also clear unless the FMU parameters were not loaded from IFR1 during initialization in which case the mass erase operation terminates without performing any erase of flash memory.

Upon successful launch of the mass erase operation, the command controller (same steps as the Erase All command):

1. erases flash block 0 sector-by-sector
2. verifies flash block 0 is erased; if not, skips IFR space in block 0
3. erases IFR space in block 0 sector-by-sector
4. verifies IFR space in block 0 is erased

The CCIF flag sets and the ERSREQ bit clears once the operation completes and the FSTAT[FAIL] flag sets if any verify step fails during the mass erase operation. This method of erasing the flash memory cannot be aborted by setting FCTRL[ABTREQ].

16.3.4 Modes

16.3.4.1 Sleep mode

If the CPU enters sleep mode while a flash command is executing, the flash module can wake the CPU via the command complete interrupt (see Interrupts).

16.3.4.2 Non-Active Power mode

If a flash command is active (CCIF = 0) when the MCU requests a non-active power mode, the command execution completes before the MCU is allowed to enter the non-active power mode.

16.3.5 Clocking

This module has no clocking considerations.

16.3.6 Interrupts

The flash module can generate interrupt requests to the MCU upon the occurrence of various flash module events. These interrupt events and their associated status and control bits are shown in the following table.

Table 186. Flash Module Interrupt Sources

Flash Event	Readable Status Bit	Interrupt Enable Bit
Flash Command Complete	FSTAT[CCIF]	FCNFG[CCIE]
Flash ECC Fault Detected	FSTAT[DFDIF]	FCNFG[DFDIE]

NOTE

Vector addresses and their relative interrupt priority are determined at the MCU level.

16.4 External signals

The flash module contains no signals that connect off-chip.

16.5 Initialization

On each reset, the command controller initializes the following based on IFR1 content:

1. FCTRL[RWSC]
2. FMU Parameters (FMUPARM)

The FSTAT[CCIF] flag is cleared throughout the initialization flow. The flash module also holds off all access to flash registers and flash memory during initialization. Completion of the initialization flow is marked by setting FSTAT[CCIF]. If an uncorrectable ECC error is detected during initialization, the FSTAT[FAIL] flag sets. The FAIL flag also sets if FMU parameters are not loaded from IFR1 during initialization. In this case, attempts to launch a flash command terminate with the ACCERR and FAIL flags set. The recommendation is to refrain from launching flash commands if the FAIL flag sets after initialization.

If a reset occurs while any flash command is in progress, that command is immediately aborted. The state of the flash memory or IFR space being programmed or erased is not guaranteed. Command operations do not automatically resume after exiting reset.

16.6 Memory map and registers

This section describes the flash memory map for IFR/IFR1 space and registers. See the MCU system memory map for the location of all flash memory space and registers. Data read from unimplemented memory space in the flash module is undefined.

16.6.1 IFR description

Each flash block contains IFR space separate from the main flash memory. IFR space is memory mapped (see the MCU system memory map). IFR space is divided into IFR pages programmable using the Program Page command. IFR pages are further divided into IFR phrases programmable using the Program Phrase command. Once programmed, IFR phrases can be

reprogrammed after a successful erase using the Erase Sector command operation unless the IFR sector is protected by the FCNFG register.

Table 187. IFR map

Offset Byte Address	IFR Field Size (Bytes)
Block 0 IFR Sector 0	
0000h-1FFFh	8,192
Block 0 IFR Sector 1	
2000h-3FFFh	8,192
Block 0 IFR Sector 2	
4000h-5FFFh	8,192
Block 0 IFR Sector 3	
6000h-7FFFh	8,192

Each flash block also contains IFR1 space separate from the main flash memory. IFR1 space in program flash block 0 is memory mapped for read-only access (see the MCU system memory map). IFR1 space cannot be erased or programmed by the user.

Table 188. IFR1 map

Offset Byte Address	IFR1 Field Size (Bytes)
Block 0 IFR1 Sector	
0000h-15FFh	5,632
1600h-16FFh	256
1700h-1FFFh	2,304

16.6.2 Register descriptions

The flash module contains a set of memory-mapped control and status registers.

NOTE

While a command is running (FSTAT[CCIF]=0), register writes are allowed to FSTAT[PERDY,DFDIF,CWSABT], FCNFG, and FCTRL[ABTREQ,FDFD,RWSC].

16.6.2.1 Flash register descriptions

16.6.2.1.1 Flash memory map

FMU0 base address: 4002_0000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Flash Status Register (FSTAT)	32	RW	See section
4h	Flash Configuration Register (FCNFG)	32	RW	See section
8h	Flash Control Register (FCTRL)	32	RW	See section

Table continues on the next page...

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Offset	Register	Width (In bits)	Access	Reset value
10h	Flash Common Command Object Registers (FCCOB0)	32	RW	0000_0000h
14h	Flash Common Command Object Registers (FCCOB1)	32	RW	0000_0000h
18h	Flash Common Command Object Registers (FCCOB2)	32	RW	0000_0000h
1Ch	Flash Common Command Object Registers (FCCOB3)	32	RW	0000_0000h
20h	Flash Common Command Object Registers (FCCOB4)	32	RW	0000_0000h
24h	Flash Common Command Object Registers (FCCOB5)	32	RW	0000_0000h
28h	Flash Common Command Object Registers (FCCOB6)	32	RW	0000_0000h
2Ch	Flash Common Command Object Registers (FCCOB7)	32	RW	0000_0000h

16.6.2.1.2 Flash Status Register (FSTAT)

Offset

Register	Offset
FSTAT	0h

Function

The FSTAT register reports the operational status of the flash module.

NOTE

When set, ACCERR, PVIOL, and CMDABT flags prevent the launch of any more commands until the flag is cleared (by writing a one to it).

CAUTION

When clearing the DFDIF flag, be careful not to use read-modify-write on the entire FSTAT register and inadvertently clear CCIF to launch a command.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PERDY	0					PEWEN		0						SALV_US...	DFDIF
W	W1C															W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	CMDDID				CMDP	0	CMDPRT		CCIF	CWSABT	ACCERR	PVIOL	0	CMDABT	0	FAIL
W									W1C	W1C	W1C	W1C		W1C		
Reset	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	u

Fields

Field	Function
31 PERDY	Program-Erase Ready Control/Status Flag The PERDY flag is set by the command controller when a program or sector erase command operation has successfully completed the write phase. The command controller will stall the command operation until the user clears the PERDY flag by writing a 1 to PERDY. Failure to clear PERDY will leave the command controller stalled but the flash or IFR space targeted by the command operation will remain readable by the FMC. If FCTRL[ABTREQ] is set while the PERDY flag is set, the command controller will clear PERDY, abort the command operation, and set both CCIF and CMDABT. 0b - Program or sector erase command operation not stalled 1b - Program or sector erase command operation ready to execute
30-26 —	Reserved
25-24 PEWEN	Program-Erase Write Enable Control During program or sector erase command operations, writes are enabled to flash or IFR space in the system memory map. For phrase programming or sector erase, writes are enabled for 4 consecutive words (16 bytes) with address phrase aligned. For page programming, writes are enabled for 8 consecutive phrases (128 bytes) with address page aligned. For programming, data written to erased flash or IFR space for program commands is not available until the program operation has successfully completed. PEWEN will not assert if FMU parameters were not loaded from IFR1 during initialization. 00b - Writes are not enabled 01b - Writes are enabled for one flash or IFR phrase (phrase programming, sector erase) 10b - Writes are enabled for one flash or IFR page (page programming) 11b - Reserved
23-18 —	Reserved

Table continues on the next page...

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Field	Function
17 SALV_USED	Salvage Used for Erase operation This flag indicates salvage was used during the last Erase Sector, Erase All, or Mass Erase operation and is valid at the end of the operation. Salvage involves using ECC to pass erase verify allowing single-bit faults per phrase verified. This flag remains valid until any flash command or Mass Erase operation launches at which time the flag clears. Use of salvage does not guarantee that the erase operation succeeds but only that salvage was used on at least one phrase. 0b - Salvage not used during last operation 1b - Salvage used during the last erase operation
16 DFDIF	Double Bit Fault Detect Interrupt Flag The DFDIF flag indicates an uncorrectable ECC fault was detected during a valid flash read access from the FMC. The DFDIF flag is cleared by writing a 1 to DFDIF. Writing a 0 to DFDIF has no effect. 0b - Double bit fault not detected during a valid flash read access 1b - Double bit fault detected (or FCTRL[FDFD] is set) during a valid flash read access
15-12 CMDDID	Command domain ID While the CMDP flag is set, the CMDDID bits reflect the domain ID of the write transaction controlling a command write sequence or aborting a command operation. Writes to load an FCCOB register, clear CCIF, or clear PERDY must have the same domain ID as the write transaction that started the command write sequence. The CMDDID bits persist after the CMDP flag clears until the CMDP flag sets again at the start of a new command write sequence. Writes to clear the CWSABT, ACCERR, PVIOL, or CMDABT flags are not influenced by the state of the CMDDID bits.
11 CMDP	Command protection status flag The CMDP flag sets when a command write sequence starts with a write to load an existing FCCOB register or clear CCIF while ACCERR, PVIOL, and CMDABT are clear. Clearing the CWSABT, ACCERR, PVIOL, or CMDABT flags as part of a command write sequence will not set the CMDP flag. While the CMDP flag is set, the protection level of any subsequent write transaction to load an FCCOB register, clear CCIF, or clear PERDY must match the CMDPRT bits and the domain ID must match the CMDDID bits. The CMDP flag remains set until cleared when CCIF is set after a command operation or Power Down recovery completes unless the CMDABT flag is set. The CMDP flag is cleared even if the operation ends with ACCERR or PVIOL set. When the CMDP flag is cleared, the CMDPRT and CMDDID bits remain unchanged. The CMDP flag is also cleared by a mass erase request with CCIF set. 0b - Command protection level and domain ID are stale 1b - Command protection level (CMDPRT) and domain ID (CMDDID) are set
10 —	Reserved
9-8 CMDPRT	Command protection level

Table continues on the next page...

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Field	Function
	While the CMDP flag is set, the CMDPRT bits reflect the secure/privilege protection level of the write transaction controlling a command write sequence or aborting a command operation. Writes to load an existing FCCOB register, clear CCIF, or clear PERDY must occur with the same protection level as indicated by the CMDPRT bits. Writes to clear the CWSABT, ACCERR, PVIOL, or CMDABT flags are not influenced by the state of the CMDPRT bits. If FCTRL[ABTREQ] is set while CCIF is high or low, the CMDPRT bits will change to reflect the security/ privilege protection level of the write transaction that set the ABTREQ bit. 00b - Secure, normal access 01b - Secure, privileged access 10b - Nonsecure, normal access 11b - Nonsecure, privileged access
7 CCIF	Command Complete Interrupt Flag The CCIF flag indicates that a flash command has completed. The CCIF flag is cleared by writing a 1 to CCIF to launch a flash command. The CCIF flag stays low until the command completes. The CCIF flag is cleared by a mass erase request with CCIF set. The CCIF flag is also cleared upon entry into Deep Sleep, Power Down, and Deep Power Down modes and stays low until the end of recovery from these non-active power modes. The CCIF flag is reset to 0 but is set to 1 at the end of flash initialization. 0b - Flash command, initialization, or power mode recovery in progress 1b - Flash command, initialization, or power mode recovery has completed
6 CWSABT	Command Write Sequence Abort Flag The CWSABT flag indicates whether a request to abort a command write sequence prior to command launch has been granted. If FCTRL[ABTREQ] is set while CCIF is high, the CWSABT flag will get set. Once CWSABT is set, ABTREQ will get cleared. While the CWSABT flag is set, ABTREQ cannot be set. The CWSABT flag is cleared by writing a 1 to CWSABT while CCIF is set or clear and ABTREQ is clear. Writing a 0 to the CWSABT flag has no effect. The CWSABT flag is cleared by a mass erase request with CCIF set. 0b - Command write sequence not aborted 1b - Command write sequence aborted
5 ACCERR	Command Access Error Flag The ACCERR flag indicates an illegal attempt was made to launch a flash command due to a violation of the command write sequence or by providing invalid command parameters. The ACCERR flag also sets during command execution if FMU parameters were not loaded from IFR1 during initialization. While the ACCERR flag is set, the CCIF flag cannot be cleared to launch a command. The ACCERR flag is cleared by writing a 1 to ACCERR while CCIF is set. Writing a 0 to the ACCERR flag has no effect. The ACCERR flag is cleared by a mass erase request with CCIF set but is not cleared during Power Down recovery.

Table continues on the next page...

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Field	Function
	0b - No access error detected 1b - Access error detected
4 PVIOL	Command Protection Violation Flag The PVIOL flag indicates an attempt was made to modify a protected area of flash memory during a command operation. While the PVIOL flag is set, the CCIF flag cannot be cleared to launch a command. The PVIOL flag is cleared by writing a 1 to PVIOL while CCIF is set. Writing a 0 to the PVIOL flag has no effect. The PVIOL flag is cleared by a mass erase request with CCIF set but is not cleared during Power Down recovery. 0b - No protection violation detected 1b - Protection violation detected
3 —	Reserved
2 CMDABT	Command Abort Flag The CMDABT flag indicates FCTRL[ABTREQ] was set during a command operation while CCIF was clear. This event will result in the termination of the operation unless it occurs during the exit routine of the operation. Once CMDABT is set, ABTREQ will get cleared. While the CMDABT flag is set, ABTREQ cannot be set and the CCIF flag cannot be cleared to launch a command. The CMDABT flag is cleared by writing a 1 to CMDABT while CCIF is set and ABTREQ is clear. Writing a 0 to the CMDABT flag has no effect. The CMDABT flag is cleared by a mass erase request with CCIF set. 0b - No command abort detected 1b - Command abort detected
1 —	Reserved
0 FAIL	Command Fail Flag The FAIL flag is set if an error is detected during execution of a flash command, mass erase operation, or flash initialization. If the FAIL flag sets along with ACCERR after launching a flash command or mass erase operation, FMU parameters were not loaded from IFR1 during initialization and a clean POR where FMU parameters are successfully loaded is required to clear the FAIL flag. As a status flag, this bit cannot (and need not) be cleared by the user like some of the other flags in this register. The value of the FAIL flag for "command-N" is valid only at the end of the "command-N" execution when CCIF=1 and before the next command has been launched. At some point during the execution of "command-N+1," the FAIL flag is cleared unless FMU parameters were not loaded from IFR1 during initialization. The FAIL flag is cleared by a mass erase request with CCIF set unless FMU parameters were not loaded from IFR1 during initialization. The FAIL flag is not cleared during Power Down recovery.

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Field	Function
	0b - Error not detected 1b - Error detected

16.6.2.1.3 Flash Configuration Register (FCNFG)

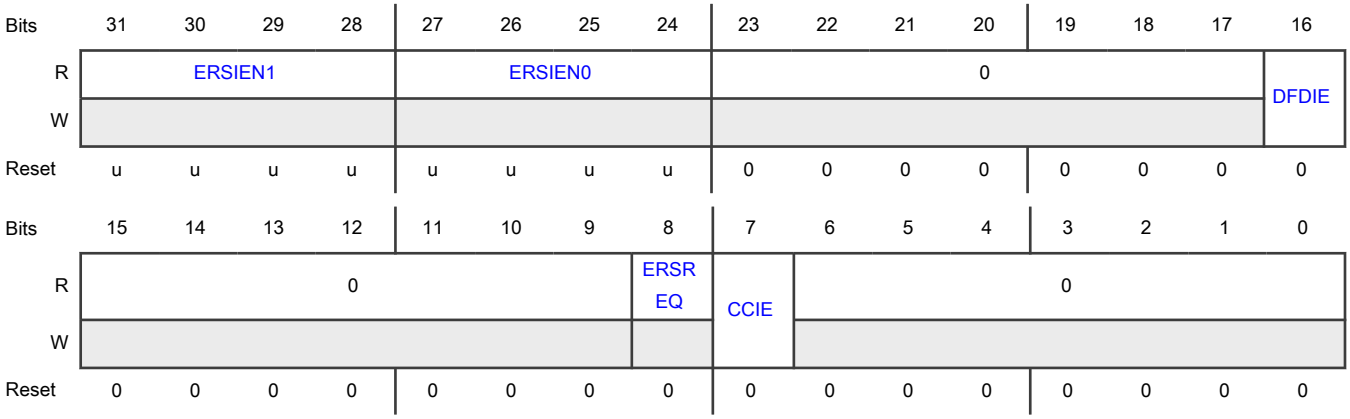
Offset

Register	Offset
FCNFG	4h

Function

This register provides information on the current functional state of the flash module.

Diagram



Fields

Field	Function
31-28 ERSIEN1	Erase IFR Sector Enable - Block 1 (for dual block configs) This field controls the ability to erase the IFR sectors in block 1 using the ERSSCR command. These bits are loaded from sideband signals during initialization and at launch of ERSSCR command. Note: These bits have no effect on single block configurations. Note: The ERSALL command and MCU mass erase request do not adhere to these restrictions. X equals 0, 1, 2, or 3. Any and all bits in the field are independently configured. 0000b - Block 1 IFR Sector X is protected from erase by ERSSCR command 0001b - Block 1 IFR Sector X is not protected from erase by ERSSCR command
27-24	Erase IFR Sector Enable - Block 0

Table continues on the next page...

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Field	Function
ERSIEN0	This field controls the ability to erase the IFR sectors in block 0 using the ERSSCR command. These bits are loaded from sideband signals during initialization and at launch of ERSSCR command. Note: The ERSALL command and MCU mass erase request do not adhere to these restrictions. X equals 0, 1, 2, or 3. Any and all bits in the field are independently configured. 0000b - Block 0 IFR Sector X is protected from erase by ERSSCR command 0001b - Block 0 IFR Sector X is not protected from erase by ERSSCR command
23-17 —	Reserved
16 DFDIE	Double Bit Fault Detect Interrupt Enable The DFDIE bit controls interrupt generation when an uncorrectable ECC fault is detected during a valid flash read access from the platform flash controller. 0b - Double bit fault detect interrupt disabled 1b - Double bit fault detect interrupt enabled. An interrupt request is generated whenever the FSTAT[DFDIF] flag is set.
15-9 —	Reserved
8 ERSREQ	Mass Erase Request This bit indicates whether a sideband request has been received by the command controller to execute the Mass Erase operation. ERSREQ is not directly writable but sets when a Mass Erase request is received by the flash module while CCIF is set. ERSREQ is cleared by the command controller when the operation completes. 0b - No request or request complete 1b - Request to run the Mass Erase operation
7 CCIE	Command Complete Interrupt Enable The CCIE bit controls interrupt generation when a flash command completes. 0b - Command complete interrupt disabled 1b - Command complete interrupt enabled. An interrupt request is generated whenever the FSTAT[CCIF] flag is set.
6-0 —	Reserved

16.6.2.1.4 Flash Control Register (FCTRL)

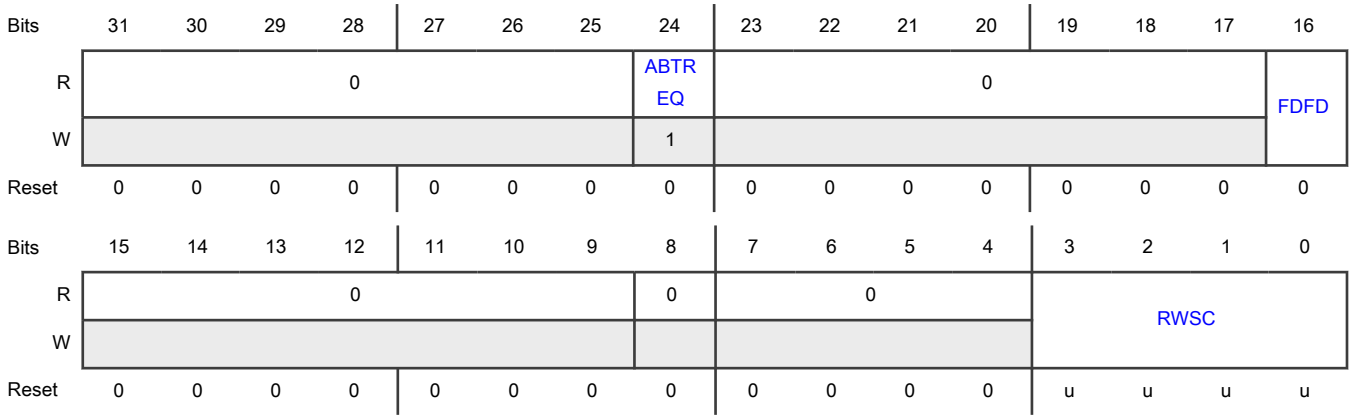
Offset

Register	Offset
FCTRL	8h

Function

The flash control register controls activity associated with flash memory reads and command operations.

Diagram



Fields

Field	Function
31-25 —	Reserved
24 ABTREQ	Abort Request With FSTAT[CMDP] set, setting the ABTREQ bit allows a user to abort a command write sequence or command operation. The ABTREQ bit can only be set by a user with the same domain ID as indicated by FSTAT[CMDDID] and the same or higher security/privilege protection level than is indicated by FSTAT[CMDPRT]. While ABTREQ is set, CCIF cannot be cleared to launch a command. If FSTAT[CCIF] is high when ABTREQ is set, the command write sequence will abort and ownership transferred to the user setting the ABTREQ bit. The FSTAT[CWSABT] flag will set and the CMDPRT field will be updated based on the write transaction that sets the ABTREQ bit. The ABTREQ bit will then be cleared automatically. If FSTAT[CCIF] is low when ABTREQ is set, the command operation will abort and ownership transferred to the user setting the ABTREQ bit. The FSTAT[CMDABT] flag will set and the CMDPRT field will be updated based on the write transaction that sets the ABTREQ bit. The ABTREQ bit will then be cleared automatically. While CWSABT or CMDABT are high, writes to ABTREQ will be ignored. 0b - No request to abort a command write sequence

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Field	Function
	1b - Request to abort a command write sequence
23-17 —	Reserved
16 FDFD	Force Double Bit Fault Detect The FDFD bit enables the user to emulate the setting of the FSTAT[DFDIF] flag to check the associated interrupt routine. The FDFD bit is cleared by writing a 0 to FDFD. 0b - FSTAT[DFDIF] sets only if a double bit fault is detected during a valid flash read access from the platform flash controller 1b - FSTAT[DFDIF] sets during any valid flash read access from the platform flash controller. An interrupt request is generated if the DFDIE bit is set.
15-9 —	Reserved
8 —	Reserved
7-4 —	Reserved
3-0 RWSC	Read Wait-State Control These bits control the number of wait-states added to account for the ratio of system clock period to flash access time during full speed power mode. Ratios greater than one require non-zero settings for the RWSC field for proper flash accesses. The required settings are documented in the device data sheet. 0h - no additional wait-states are added (single cycle access) 1h - 1 additional wait-state is added 2h - 2 additional wait-states are added ... Fh - 15 additional wait-states are added These bits are loaded from IFR1 during initialization. **NOTE** The default FCTRL[RWSC] is set to a value appropriate for the chip's max operating frequency. Refer to the chip-specific section for the default value.

16.6.2.1.5 Flash Common Command Object Registers (FCCOB0 - FCCOB7)

Offset

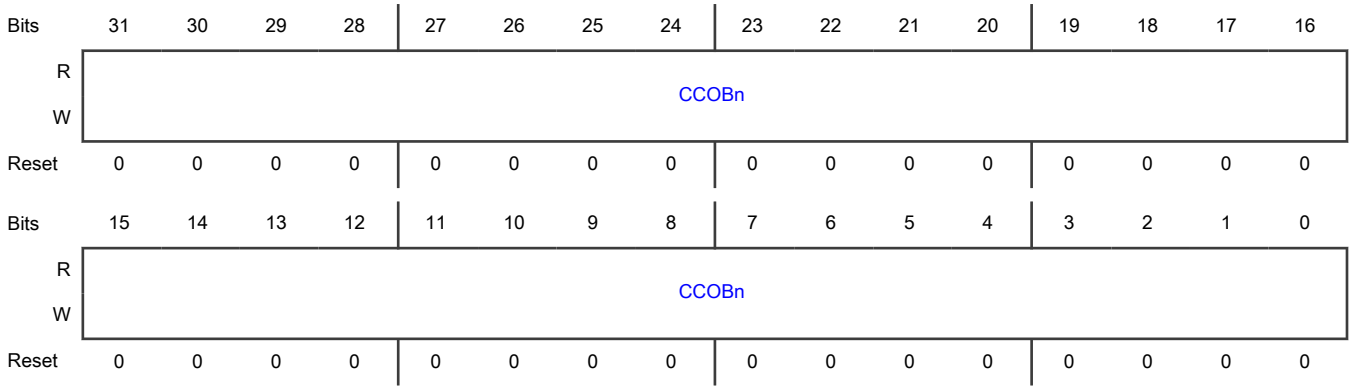
For a = 0 to 7:

Register	Offset
FCCOBa	10h + (a × 4h)

Function

The FCCOB register group provides fields for command codes and parameters. The individual words within the set append a 0-7 hex identifier to the FCCOB register name: FCCOB0, FCCOB1, ..., FCCOB7.

Diagram



Fields

Field	Function
31-0 CCOBn	CCOBn The FCCOB register group provides a command code and relevant parameters to the command controller. The individual registers that compose the FCCOB data set can be written in any order, but you must provide all needed values, which vary from command to command. First, set up all required FCCOB fields and then initiate the command execution by writing a 1 to the FSTAT[CCIF] bit. This clears the CCIF bit, which locks all FCCOB parameter fields and they cannot be changed by the user until the command completes (CCIF returns to 1). No command buffering or queueing is provided; the next command can be loaded only after the current command completes. Some commands return information to the FCCOB registers. Any values returned to FCCOB are available for reading after the FSTAT[CCIF] flag returns to 1. The following table shows a generic flash command format. The first FCCOB register, FCCOB0, always contains the command code. This 8-bit value defines the command to be executed. The command code is followed by the parameters required for this specific flash command, typically an address and/or data values.

NOTE

The command parameter table is written in terms of FCCOB Number (which is equivalent to the word number). This number is a reference to the FCCOB register name and is not the register address.

FCCOB Number[1]	Typical Command Parameter Contents [31:0]
0	FCMD [7:0] (flash command code, bits [31:8] are not writable)

Field	Function	
	FCCOB Number[1]	Typical Command Parameter Contents [31:0]
	1	FCMDOPT [7:0] (flash command options, bits [31:8] are not writable)
	2	Flash address 1 (start)
	3	Flash address 2 (end)
	4	Data Word 0
	5	Data Word 1
	6	Data Word 2
	7	Data Word 3
	1. Refers to FCCOB register name, not register address	

16.7 Glossary

Block Checker — MCU IP that provides a mechanism to set access rights to the flash memory for read and write operations.

Command write sequence — A series of MCU writes to the Flash FCCOB register group and FSTAT[CCIF] that initiates and controls the execution of flash algorithms that are built into the flash module.

Endurance — The number of times that an aligned flash or IFR phrase can be erased and reprogrammed.

FCCOB (Flash Common Command Object Block) — A group of flash registers that are used to pass command, address, data, and any associated parameters to the command controller.

Flash block — A macro within the flash module which provides the nonvolatile memory storage with an aligned block address being the first address in the block.

Flash module — All flash blocks plus a flash management unit providing command control and an interface to MCU buses.

Flash page — 128 bytes of flash main memory with an aligned page having byte-address[6:0] = 00h; represents the largest portion of the flash memory that can be programmed in one operation.

Flash phrase — 16 bytes of flash main memory with an aligned phrase having byte-address[3:0] = 0000b; represents the smallest portion of the flash memory that can be programmed in one operation.

Flash sector — 8 Kbytes of flash main memory with an aligned sector having byte-address[12:0] = 0000h; represents the smallest portion of the flash memory that can be erased in one operation.

FLW — The Flash Logical Window module allows a specific logical address range to access a programmable physical address range in the flash memory with programmable FLW default settings stored in IFR space.

FMC — Flash Memory Controller module manages flash memory reads and writes.

IFR — Information flash region separate from the main flash memory array. Each flash block has 32 Kbytes of user IFR space. Sometimes referred to as IFR0.

IFR1 — Information flash region separate from the main memory array reserved for array trim, MCU trim, and test. Each flash array has 8 Kbytes of IFR1 space.

IFR page — 128 bytes of IFR or IFR1 space with an aligned IFR page having byte-address[6:0] = 00h; represents the largest portion of IFR space that can be programmed.

IFR phrase — 16 bytes of IFR or IFR1 space with an aligned IFR phrase having byte-address[3:0] = 0000b; represents the smallest portion of IFR space that can be programmed in one operation.

IFR sector — 8 Kbytes of IFR or IFR1 space with an aligned IFR sector having byte-address[12:0] = 0000h; represents the smallest portion IFR space that can be erased.

MISR — Multiple-input signature register used to generate a signature based on flash memory contents read.

MSF — Microcontroller Secure Flash.

NVM — Nonvolatile memory. The flash block is an NVM using NOR-type flash memory technology.

Program flash — Program flash memory provides nonvolatile storage for vectors and code store.

Retention — The length of time that data (erased or programmed) can be kept in the NVM without experiencing errors upon readout.

Security/Privilege protection levels — The Flash module supports 4 levels of security/privilege protection for flash commands:

1. Secure (Trusted) / Privileged
2. Secure (Trusted) / User
3. Non-secure (Non-Trusted) / Privileged
4. Non-secure (Non-Trusted) / User

Chapter 17
System Register File (REGFILE)

17.1 Chip-specific REGFILE information

Table 189. Reference links to related information

Topic	Related module	Reference
Full description	REGFILE	REGFILE
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

17.1.1 Module instances

This device has two instances of the REGFILE module, REGFILE0, and REGFILE1. REGFILE0 has no WAR or RAR registers while REGFILE1 has WAR and RAR registers.

17.1.2 Module reset

REGFILE0 retains its contents during low-voltage detect (LVD) events and is only reset during a power-on reset. REGFILE1 can be reset by every reset except wakeup from Power Down and Deep Power Down.

17.1.3 Low-power wakeup booth path

This device embeds a ROM bootloader code resident in the ROM area. Low-power wakeup boot flow requires the usage of REGFILE1 REG0 to store WAKEUP CRC data to verify the ROM wakeup word, therefore, REGFILE1 REG0 should not be used to store application data when low-power wakeup boot is enabled, but it should contain the valid WAKEUP CRC parameter to ensure proper boot sequence. See the Low_power wakeup path for more information about REGFILE1 REG0 usage during low-power boot flow.

17.2 Overview

The REGFILE module is used to store data, which is written to the Register File Registers, to be persistent.

17.3 Memory Map and Registers

17.3.1 REGFILE register descriptions

17.3.1.1 REGFILE memory map

REGFILE0 base address: 4002_1000h

REGFILE1 base address: 4002_2000h

Offset	Register	Width (In bits)	Access	Reset value
0h - 1Ch	Register File Register a (REG0 - REG7)	32	RW	0000_0000h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
100h	Write Access Register (WAR)	32	RW	0000_00FFh
104h	Read Access Register (RAR)	32	RW	0000_00FFh

17.3.1.2 Register File Register a (REG0 - REG7)

Offset

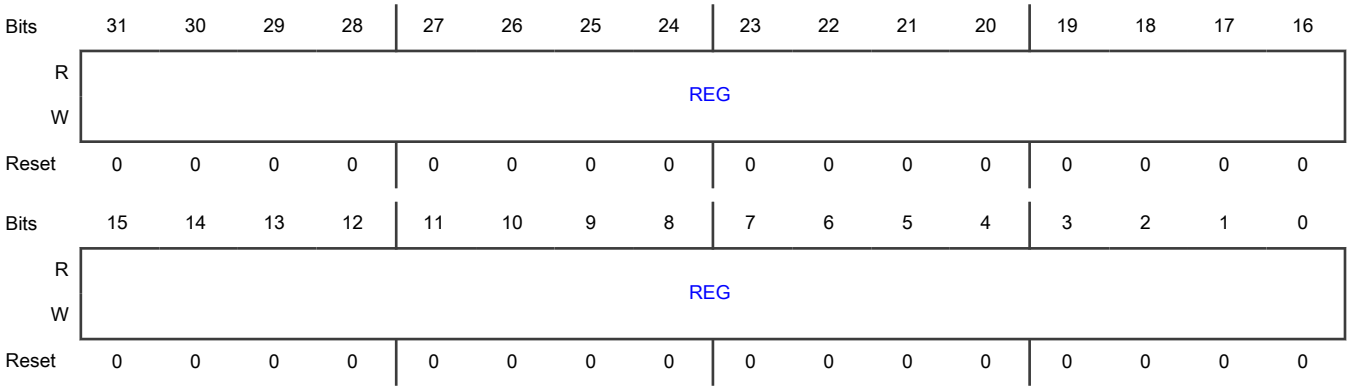
For a = 0 to 7:

Register	Offset
REGa	0h + (a × 4h)

Function

Each register can be accessed as 8-, 16-, or 32-bit.

Diagram



Fields

Field	Function
31-0 REG	Register File

17.3.1.3 Write Access Register (WAR)

Offset

Register	Offset
WAR	100h

Function

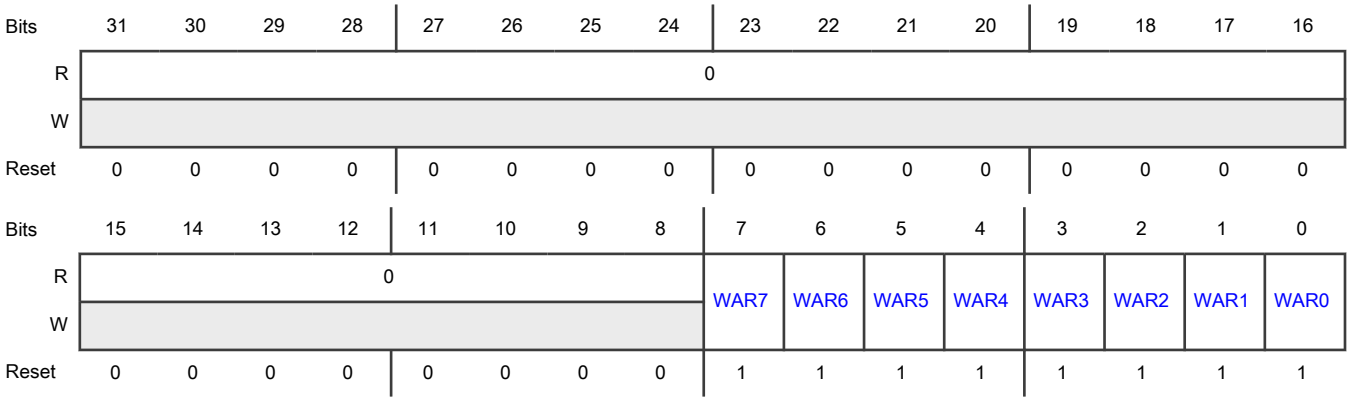
This register controls write access to the REG registers

NOTE

Each module instance supports a different number of registers.

Instance	Register supported	Register not supported
REGFILE0	—	WAR
REGFILE1	WAR	—

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 WARn	REGn Register Write Access 0b - Not allow to write to the REGn register and WARn field until next reset. 1b - Allow to write to the REGn register and WAR0 field.

17.3.1.4 Read Access Register (RAR)

Offset

Register	Offset
RAR	104h

Function

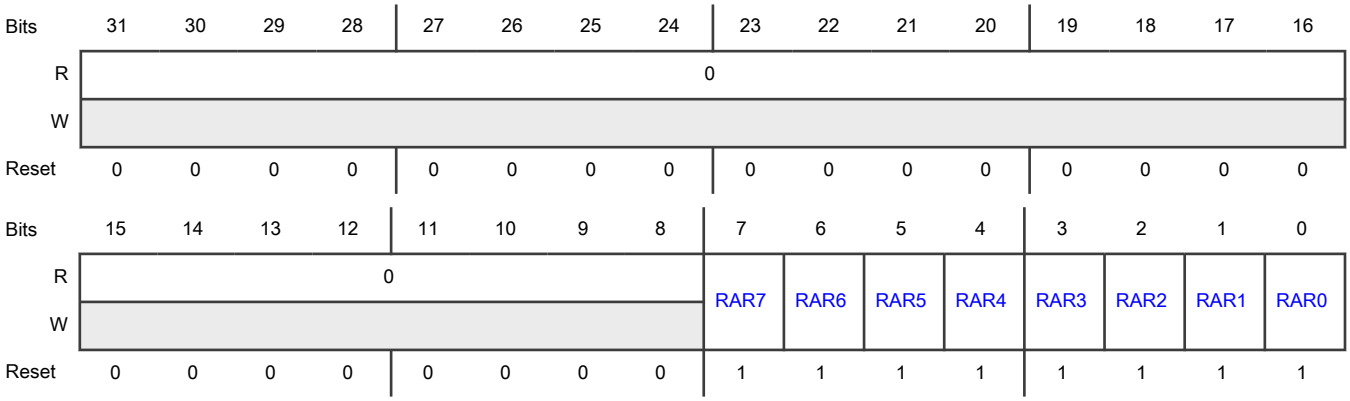
This register controls read access to the REG registers

NOTE

Each module instance supports a different number of registers.

Instance	Register supported	Register not supported
REGFILE0	—	RAR
REGFILE1	RAR	—

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 RARn	REGn Register Read Access 0b - Not allow to read the REGn register until next reset. Reading corresponding REGn register returns all 0. 1b - Allow to read the REGn register.

17.4 Functional description

REGFILE can be used to store data that must be persistent across the low power modes. Write the information into the Register File Registers and read the information back.

If a REGFILE instance supports Write Access Register (WAR) and Read Access Register (RAR), they can lock write and read operations on the Register File Registers until the next reset is performed.

NOTE

Not all the instances support WAR and RAR registers, refer to WAR and RAR registers for instances that support them.

17.4.1 Power mode

The REGFILE module is powered in all power modes unless it is in the VDD_SWITCH domain. In VDD_SWITCH domain, the REGFILE module is only powered down to Deep Power Down mode.

17.4.2 Reset

See chip-specific section for the reset of REGFILE module.

Chapter 18
Signal Muxing and Pinout

18.1 Introduction

To optimize functionality in small packages, pins have several functions available via signal multiplexing. This chapter illustrates which of this device's signals are multiplexed on which external pin.

18.2 Package pinout

Table 190. MCX W72 Package pinout

Pin Name	48QFN	Pinmux Assignment	Alternate Functions
PTB3	1	**ALT0** - ADC0_B13 **ALT1** - PTB3 **ALT2** - LPSPI1_SOUT **ALT3** - LPUART1_RX **ALT5** - TPM1_CH3 **ALT9** - FLEXIO0_D29	**VDD SYS** - WUU0_P14
PTB4	2	**ALT1** - PTB4 **ALT2** - LPSPI1_PCS3 **ALT3** - LPUART1_CTS_b **ALT4** - LPI2C1_SDA **ALT5** - I3C0_SDA **ALT6** - TRGMUX0_IN0 **ALT9** - FLEXIO0_D30	**VDD SYS** - WUU0_P15
PTB5	3	**ALT1** - PTB5 **ALT2** - LPSPI1_PCS2 **ALT3** - LPUART1_RTS_b **ALT4** - LPI2C1_SCL **ALT5** - I3C0_SCL **ALT6** - TRGMUX0_OUT0 **ALT9** - FLEXIO0_D31	
VDD_IO_ABC	4	**ALT0** - VDD_IO_ABC	
SWITCH_WAKEUP_B	5	**ALT0** - SWITCH_WAKEUP_B	
VDD_SWITCH	6	**ALT0** - VDD_SWITCH	
VOUT_SWITCH	7	**ALT0** - VOUT_SWITCH	
PTA0	8	**ALT1** - PTA0 **ALT2** - CMP0_OUT **ALT3** - LPUART0_CTS_b	**VDD SYS** - WUU0_P0

Table continues on the next page...

Table 190. MCX W72 Package pinout (continued)

Pin Name	48QFN	Pinmux Assignment	Alternate Functions
		ALT4 - RF_GPO_11 **ALT5** - TPM0_CH4 **ALT6** - FLEXIO0_D0 **ALT7** - SWD_DIO	
PTA1	9	**ALT1** - PTA1 **ALT2** - CMP1_OUT **ALT3** - LPUART0_RTS_b **ALT4** - RF_GPO_10 **ALT5** - TPM0_CH5 **ALT6** - FLEXIO0_D1 **ALT7** - SWD_CLK	
PTA4	10	**ALT0** - ADC0_A10/CMP0_IN0 **ALT1** - PTA4 **ALT3** - RF_GPO_9 **ALT4** - TPM0_CLKIN **ALT5** - TRACE_SWO **ALT6** - FLEXIO0_D4 **ALT7** - BOOT_CONFIG	**VDD SYS** - WUU0_P2/RF_XTAL_OUT_ENABLE
PTA16	11	**ALT0** - ADC0_A12 **ALT1** - PTA16 **ALT2** - LPSPI0_PCS0 **ALT3** - EWM0_OUT_b **ALT4** - LPI2C0_SCLS **ALT5** - TPM0_CH4 **ALT6** - LPUART0_RX **ALT7** - RF_GPO_8 **ALT9** - FLEXIO0_D5	**VDD SYS** - WUU0_P19/RF_NOT_ALLOWED
PTA17	12	**ALT0** - ADC0_A13 **ALT1** - PTA17 **ALT2** - LPSPI0_SIN **ALT3** - EWM0_IN **ALT4** - LPI2C0_SDAS **ALT5** - TPM0_CH5 **ALT6** - LPUART0_TX **ALT7** - RF_GPO_7 **ALT8** - RF_GPO_8 **ALT9** - FLEXIO0_D6	**VDD SYS** - WUU0_P3/RF_NOT_ALLOWED

Table continues on the next page...

Table 190. MCX W72 Package pinout (continued)

Pin Name	48QFN	Pinmux Assignment	Alternate Functions
		ALT11 - RF_EXT_XTAL_REQUEST/RF_GPO_7	
PTA18	13	**ALT0** - CMP1_IN1 **ALT1** - PTA18 **ALT2** - LPSPI0_SOUT **ALT3** - LPUART0_CTS_b **ALT4** - LPI2C0_SDA **ALT5** - TPM0_CH3 **ALT6** - RF_GPO_0 **ALT10** - LPUART0_RX **ALT11** - SPC0_LPREQ	**VDD SYS** - WUU0_P20
PTA19	14	**ALT0** - CMP1_IN0 **ALT1** - PTA19 **ALT2** - LPSPI0_SCK **ALT3** - LPUART0_RTS_b **ALT4** - LPI2C0_SCL **ALT5** - TPM0_CH2 **ALT6** - RF_GPO_1	**VDD SYS** - WUU0_P4
VSS	49	**ALT0** - VSS	
VDD_LDO_CORE	15	**ALT0** - VDD_LDO_CORE	
VDD_CORE	16	**ALT0** - VDD_CORE	
PTA20	17	**ALT0** - ADC0_A14/CMP0_IN3 **ALT1** - PTA20 **ALT2** - LPSPI0_PCS2 **ALT3** - LPUART0_TX **ALT4** - EWM0_IN **ALT5** - TPM0_CH1 **ALT6** - RF_GPO_2 **ALT8** - FLEXIO0_D7 **ALT11** - LPUART0_RTS_b	
PTA21	18	**ALT0** - ADC0_A15/CMP0_IN2 **ALT1** - PTA21 **ALT2** - LPSPI0_PCS3 **ALT3** - LPUART0_RX **ALT4** - EWM0_OUT_b **ALT5** - TPM0_CH0 **ALT6** - RF_GPO_3	**VDD SYS** - WUU0_P5

Table continues on the next page...

Table 190. MCX W72 Package pinout (continued)

Pin Name	48QFN	Pinmux Assignment	Alternate Functions
		ALT7 - RF_GPO_7 **ALT8** - FLEXIO0_D8 **ALT9** - RF_GPO_10 **ALT11** - LPUART0_CTS_b	
VSS	49		
VSS_DCDC	19	**ALT0** - VSS_DCDC	
DCDC_LX	20	**ALT0** - DCDC_LX	
VDD_IO_D	21	**ALT0** - VDD_IO_D	
VDD_SYS	22	**ALT0** - VDD_SYS	
VSS	49	**ALT0** - VSS	
PTD0	23	**ALT0** - ADC0_A5 **ALT1** - PTD0 **ALT3** - RESET_b	
PTD1	24	**ALT0** - ADC0_B5 **ALT1** - PTD1 **ALT2** - SPC0_LPREQ **ALT3** - NMI_b **ALT4** - RF_GPO_4 **ALT5** - RF_GPO_7 **ALT7** - LPTMR2_TRIG_OUT_b	
PTD2	25	**ALT0** - ADC0_A6 **ALT1** - PTD2 **ALT2** - LPTMR0_ALT3 **ALT3** - TAMPER0 **ALT4** - RF_GPO_5 **ALT5** - TPM2_CH0 **ALT7** - LPTMR1_TRIG_OUT_b	
PTD3	26	**ALT0** - ADC0_B6 **ALT1** - PTD3 **ALT2** - LPTMR1_ALT3 **ALT3** - TAMPER1 **ALT4** - RF_GPO_6 **ALT5** - TPM2_CH1 **ALT6** - TRGMUX0_IN2 **ALT7** - LPTMR0_TRIG_OUT_b	

Table continues on the next page...

Table 190. MCX W72 Package pinout (continued)

Pin Name	48QFN	Pinmux Assignment	Alternate Functions
PTD4	27	**ALT0** - XTAL32K **ALT1** - PTD4 **ALT2** - LPTMR0_ALT2 **ALT3** - TAMPER2	
PTD5	28	**ALT0** - EXTAL32K **ALT1** - PTD5 **ALT2** - LPTMR1_ALT2	
VDD_ANA	29	**ALT0** - VDD_ANA	
VREF_OUT	30	**ALT0** - VREFO	
VSS	49	**ALT0** - VREFL	
VSS	49	**ALT0** - VSS_ANA	
XTAL_OUT	31	**ALT0** - XTAL_OUT	
XTAL	32	**ALT0** - XTAL	
EXTAL	33	**ALT0** - EXTAL	
VDD_RF	34	**ALT0** - VDD_RF	
VSS_RF	49	**ALT0** - VSS_RF	
ANT_2P4GHZ	35	**ALT0** - ANT_2P4GHZ	
VPA_2P4GHZ	36	**ALT0** - VPA_2P4GHZ	
VSS	49	**ALT0** - VSS	
VDD_IO_ABC	4	**ALT0** - VDD_IO_ABC	
PTC0	37	**ALT1** - PTC0 **ALT2** - LPSPI1_PCS2 **ALT3** - CAN0_TX [1] **ALT4** - I3C0_SDA **ALT5** - TPM1_CH0 **ALT7** - LPI2C1_SCL **ALT9** - FLEXIO0_D16	**VDD SYS** - WUU0_P7
PTC1	38	**ALT1** - PTC1 **ALT2** - LPSPI1_PCS3 **ALT3** - CAN0_RX [1] **ALT4** - I3C0_SCL **ALT5** - TPM1_CH1 **ALT7** - LPI2C1_SDA	**VDD SYS** - WUU0_P8

Table continues on the next page...

Table 190. MCX W72 Package pinout (continued)

Pin Name	48QFN	Pinmux Assignment	Alternate Functions
		ALT9 - FLEXIO0_D17	
PTC2	39	**ALT1** - PTC2 **ALT2** - LPSPI1_SOUT **ALT3** - LPUART1_RX **ALT4** - LPI2C1_SCLS **ALT5** - TPM1_CH2 **ALT7** - I3C0_PUR **ALT9** - FLEXIO0_D18 **ALT11** - CAN1_RX [1]	**VDD SYS** - WUU0_P9
PTC3	40	**ALT1** - PTC3 **ALT2** - LPSPI1_SCK **ALT3** - LPUART1_TX **ALT4** - LPI2C1_SDAS **ALT5** - TPM1_CH3 **ALT9** - FLEXIO0_D19 **ALT11** - CAN1_TX [1]	
VSS	49	**ALT0** - VSS	
VDD_CORE	41	**ALT0** - VDD_CORE	
PTC4	42	**ALT1** - PTC4 **ALT2** - LPSPI1_SIN **ALT3** - CAN0_TX [1] **ALT4** - LPI2C1_SCL **ALT6** - TPM2_CH0 **ALT9** - FLEXIO0_D20	**VDD SYS** - WUU0_P10
PTC5	43	**ALT1** - PTC5 **ALT2** - LPSPI1_PCS0 **ALT3** - CAN0_RX [1] **ALT4** - LPI2C1_SDA **ALT5** - TPM1_CH4 **ALT6** - TPM2_CH1 **ALT9** - FLEXIO0_D21	**VDD SYS** - WUU0_P22
PTC6	44	**ALT0** - ADC0_A8 **ALT1** - PTC6 **ALT2** - LPSPI1_PCS1 **ALT5** - TPM1_CH5 **ALT9** - FLEXIO0_D22	**VDD SYS** - WUU0_P11

Table continues on the next page...

Table 190. MCX W72 Package pinout (continued)

Pin Name	48QFN	Pinmux Assignment	Alternate Functions
		ALT11 - CAN1_RX[1]	
PTC7	45	**ALT0** - DISABLED **ALT1** - PTC7 **ALT2** - TRGMUX0_IN3 **ALT3** - TRGMUX0_OUT3 **ALT4** - SFA0_CLK **ALT5** - TPM1_CLKIN **ALT6** - TPM2_CLKIN **ALT7** - CLKOUT **ALT9** - FLEXIO0_D23 **ALT10** - NMI_b **ALT11** - CAN1_TX [1]	**VDD SYS** - WUU0_P12/ NMI_b/RF_NOT_ALLOWED
PTB0	46	**ALT0** - ADC0_B10 **ALT1** - PTB0 **ALT2** - LPSPI1_PCS0 **ALT3** - CAN1_RX[1] **ALT5** - TPM1_CH0 **ALT9** - FLEXIO0_D26	**VDD SYS** - WUU0_P13
PTB1	47	**ALT0** - ADC0_B11 **ALT1** - PTB1 **ALT2** - LPSPI1_SIN **ALT3** - CAN1_TX[1] **ALT5** - TPM1_CH1 **ALT9** - FLEXIO0_D27	
PTB2	48	**ALT0** - ADC0_B12 **ALT1** - PTB2 **ALT2** - LPSPI1_SCK **ALT3** - LPUART1_TX **ALT5** - TPM1_CH2 **ALT9** - FLEXIO0_D28	

1. This signal is not available for the parts without CAN module.

18.3 Pinouts diagram

The below figure shows the pinout diagram for the devices supported by this document. Many signals may be multiplexed onto a single pin. To determine what signals can be used on which pin, see the previous section.

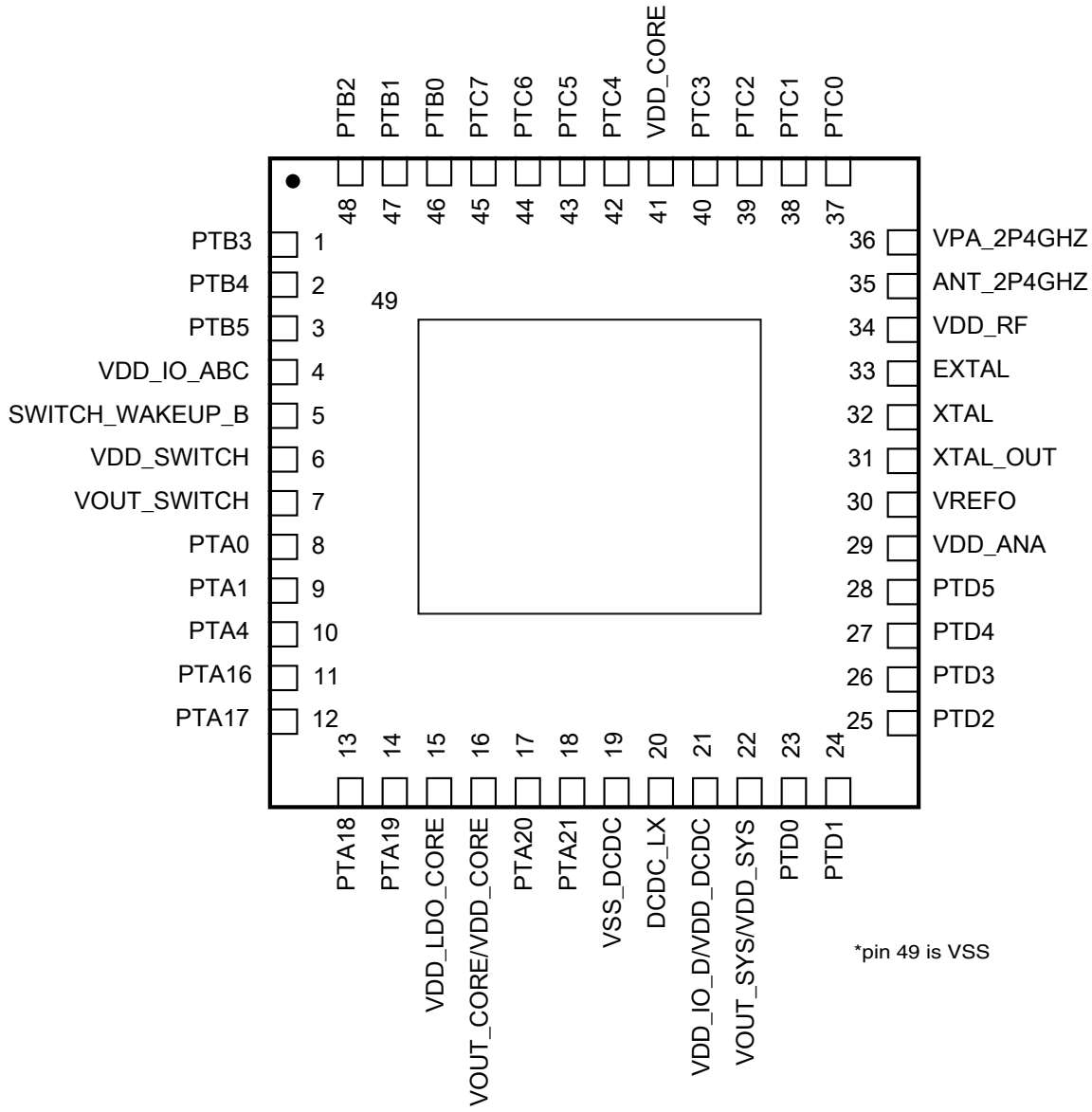


Figure 55. 48-pin HVQFN package pinout diagram

Chapter 19
Port Control (PORT)

19.1 Chip-specific PORT information

Table 191. Reference links to related information

Topic	Related module	Reference
Full description	PORT	PORT
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

19.1.1 Module instances

This device has four instances of the port module, PORTA, PORTB, PORTC, and PORTD.

19.1.2 Port B EFT detect clear (EDCR)

Port B and Port C pins share the same EFT detector clear control from PORTC_EDCR register. Any write to the PORTB_EDCR does not take effect.

19.1.3 Port voltage range (CONFIG[RANGE])

PORTA_CONFIG[RANGE] controls the voltage ranges of Port A, B, and C. Reading or writing PORTB_CONFIG[RANGE] and PORTC_CONFIG[RANGE] does not take effect.

19.1.4 Pads value

Table 192. Pads value

Pin Name	Die Pad Name	I/O Supply	Core Supply	DEFAULT
PTA0	PTA0	VDD_IO_ABC	WAKE	SWD_DIO
PTA1	PTA1	VDD_IO_ABC	WAKE	SWD_CLK
PTA2	PTA2	VDD_IO_ABC	WAKE	DISABLED
PTA3	PTA3	VDD_IO_ABC	WAKE	DISABLED
PTA4	PTA4	VDD_IO_ABC	WAKE	BOOT_CONFIG
PTA5	PTA5	VDD_IO_ABC	WAKE	ADC0_A11/CMP0_IN1
PTA6	PTA6	VDD_IO_ABC	WAKE	DISABLED
PTA7	PTA7	VDD_IO_ABC	WAKE	DISABLED

Table continues on the next page...

Table 192. Pads value (continued)

PTA8	PTA8	VDD_IO_ABC	WAKE	DISABLED
PTA9	PTA9	VDD_IO_ABC	WAKE	DISABLED
PTA10	PTA10	VDD_IO_ABC	WAKE	DISABLED
PTA11	PTA11	VDD_IO_ABC	WAKE	DISABLED
PTA16	PTA16	VDD_IO_ABC	WAKE	ADC0_A12
PTA17	PTA17	VDD_IO_ABC	WAKE	ADC0_A13
PTA18	PTA18	VDD_IO_ABC	WAKE	CMP1_IN1
PTA19	PTA19	VDD_IO_ABC	WAKE	CMP1_IN0
PTA20	PTA20	VDD_IO_ABC	WAKE	ADC0_A14/CMP0_IN3
PTA21	PTA21	VDD_IO_ABC	WAKE	ADC0_A15/CMP0_IN2
PTA22	PTA22	VDD_IO_ABC	WAKE	DISABLED
PTA23	PTA23	VDD_IO_ABC	WAKE	DISABLED
PTA24	PTA24	VDD_IO_ABC	WAKE	DISABLED
PTA25	PTA25	VDD_IO_ABC	WAKE	DISABLED
PTA26	PTA26	VDD_IO_ABC	WAKE	DISABLED
PTA27	PTA27	VDD_IO_ABC	WAKE	DISABLED
PTA30	PTA30	VDD_IO_ABC	VSYS	DISABLED
PTA31	PTA31	VDD_IO_ABC	VSYS	DISABLED
PTB0	PTB0	VDD_IO_ABC	MAIN	ADC0_B10
PTB1	PTB1	VDD_IO_ABC	MAIN	ADC0_B11
PTB2	PTB2	VDD_IO_ABC	MAIN	ADC0_B12
PTB3	PTB3	VDD_IO_ABC	MAIN	ADC0_B13
PTB4	PTB4	VDD_IO_ABC	MAIN	DISABLED
PTB5	PTB5	VDD_IO_ABC	MAIN	DISABLED
PTB6	PTB6	VDD_IO_ABC	MAIN	DISABLED
PTB7	PTB7	VDD_IO_ABC	MAIN	DISABLED

Table continues on the next page...

Table 192. Pads value (continued)

PTB8	PTB8	VDD_IO_ABC	MAIN	DISABLED
PTB9	PTB9	VDD_IO_ABC	MAIN	DISABLED
PTB10	PTB10	VDD_IO_ABC	MAIN	DISABLED
PTB11	PTB11	VDD_IO_ABC	MAIN	DISABLED
PTC0	PTC0	VDD_IO_ABC	MAIN	DISABLED
PTC1	PTC1	VDD_IO_ABC	MAIN	DISABLED
PTC2	PTC2	VDD_IO_ABC	MAIN	DISABLED
PTC3	PTC3	VDD_IO_ABC	MAIN	DISABLED
PTC4	PTC4	VDD_IO_ABC	MAIN	DISABLED
PTC5	PTC5	VDD_IO_ABC	MAIN	DISABLED
PTC6	PTC6	VDD_IO_ABC	MAIN	ADC0_A8
PTC7	PTC7	VDD_IO_ABC	MAIN	DISABLED
PTC8	PTC8	VDD_IO_ABC	MAIN	ADC0_A9
PTC9	PTC9	VDD_IO_ABC	MAIN	ADC0_B9
PTC10	PTC10	VDD_IO_ABC	MAIN	DISABLED
PTC11	PTC11	VDD_IO_ABC	MAIN	DISABLED
PTC12	PTC12	VDD_IO_ABC	MAIN	DISABLED
PTC13	PTC13	VDD_IO_ABC	MAIN	DISABLED
PTC14	PTC14	VDD_IO_ABC	MAIN	DISABLED
PTC15	PTC15	VDD_IO_ABC	MAIN	DISABLED
PTC16	PTC16	VDD_IO_ABC	MAIN	DISABLED
PTC17	PTC17	VDD_IO_ABC	MAIN	DISABLED
PTC18	PTC18	VDD_IO_ABC	MAIN	DISABLED
PTC19	PTC19	VDD_IO_ABC	MAIN	DISABLED
PTD0	PTD0	VDD_IO_D	VSYS	RESET_b
PTD1	PTD1	VDD_IO_D	VSYS	ADC0_B5

Table continues on the next page...

Table 192. Pads value (continued)

PTD2	PTD2	VDD_IO_D	VSYS	ADC0_A6
PTD3	PTD3	VDD_IO_D	VSYS	ADC0_B6
PTD4	PTD4	VDD_IO_D	VSYS	XTAL32K
PTD5	PTD5	VDD_IO_D	VSYS	EXTAL32K
PTD6	PTD6	VDD_IO_D	VSYS	ADC0_A7
PTD7	PTD7	VDD_IO_D	VSYS	ADC0_B7
PTD8	PTD8	VDD_IO_D	VSYS	
PTD9	PTD9	VDD_IO_D	VSYS	
PTD10	PTD10	VDD_IO_D	VSYS	
PTD11	PTD11	VDD_IO_D	VSYS	

19.2 Overview

PORT provides support for pad control functions. You can configure most functions independently for each pin, in the 32-bit port, and affect the pin regardless of its pin multiplexing state.

There exists a single instance of the PORT module for each port, and not all pins within each port are implemented on a specific chip.

19.2.1 Block diagram

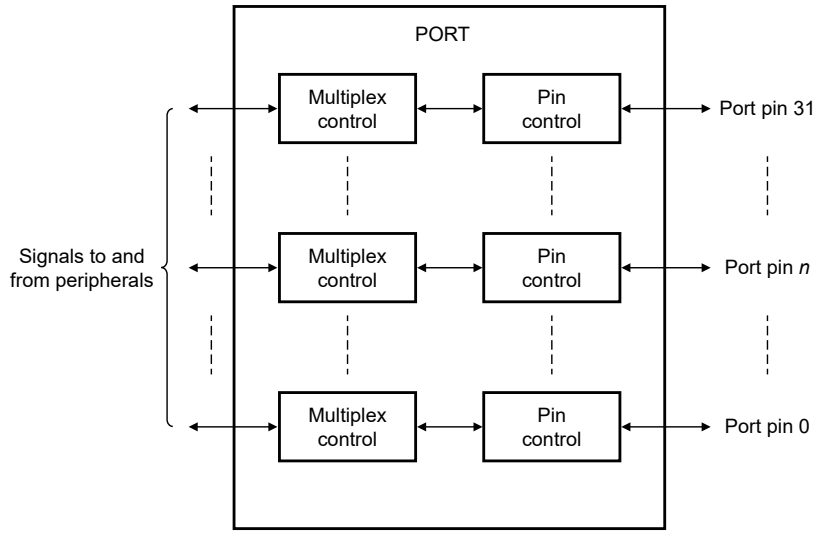


Figure 56. Block diagram

19.2.2 Features

- Individual pull control fields with pullup, pulldown, and pull-disable support

- Individual drive strength fields supporting high and low drive strengths
- Individual slew rate fields supporting fast and slow slew rates
- Individual PCR*n*[PFE] fields that enable and disable individual input passive filters on selected pins
- Individual PCR*n*[ODE] fields that enable and disable individual open drain outputs
- Digital input inversion to optionally invert the digital input
- Individual electrical fast transient (EFT) detect with an EFT detect flag and associated interrupt
- Individual mux control fields supporting analog or pin disabled, GPIO, and up to 10 chip-specific digital functions

19.3 Functional description

19.3.1 Pin control

Each port pin has a corresponding Pin Control Register (PCR) associated with it that helps you configure the following functions for each pin within the 32-bit port:

- Pullup or pulldown enable
- Drive strength configuration
- Slew rate configuration
- Open drain enable
- Passive input filter enable on selected pins
- Digital input inversion
- EFT detection
- Software configuration lock
- Pin multiplexing mode

These functions apply across all digital pin multiplexing modes, and individual peripherals do not override the configuration in PCR*n* unless otherwise noted. For example, if an I^2C function is enabled on a pin, it does not override the pullup or open drain configuration for that pin.

PCR*n*[LK] allows the configuration for each pin to be locked until the next system reset. When locked, writes to the lower half of that PCR*n* are ignored, although a bus error is not generated on an attempted write to a locked register.

The configuration of each PCR*n* is retained when the PORT module is disabled.

When you configure a pin in a digital pin multiplexing mode, the input buffer for that pin is enabled, allowing the pin state to be read via the corresponding GPIO.PDIR or allowing a pin interrupt or DMA request to be generated. If a pin is always floating when its input buffer is enabled, it can cause an increase in power consumption. This situation must be avoided. A pin can be floating because of an input pin that is not connected or an output pin that is tristated (output buffer is disabled).

Enabling the internal pull resistor (or implementing an external pull resistor) ensures that a pin does not float when its input buffer is enabled. The internal pull resistor is automatically disabled whenever the output buffer is enabled, allowing PCR*n*[PE] to remain 1. Configuring Pin Multiplexing mode to disabled or analog (PCR*n*[MUX] = 0) disables the pin's input buffer and results in lowest power consumption.

19.3.2 Global pin control

Global Pin Control Low (GPCLR) and Global Pin Control High (GPCHR) allow a single register write to update the lower 16 bits of PCR*n* for up to 16 pins, all with the same value. You cannot write to locked registers by using Global Pin Control Low (GPCLR) and Global Pin Control High (GPCHR).

Global Pin Control Low (GPCLR) and Global Pin Control High (GPCHR) enable you to quickly configure multiple pins within the same port and with the same peripheral function. These are write-only registers that always read as 0.

19.3.3 EFT detection

The EFT detect circuit is active whenever PORT is powered and EDCR[EDLC] and EDCR[EDHC] are 0.

The EFT high detect circuit for each pin is reset whenever EDCR[EDHC] = 1. Likewise, the EFT low detect circuit for each pin is reset whenever EDCR[EDLC] = 1 and that pin's EFT high detect is not asserted.

19.3.4 Clocking

This module has no clocking considerations.

19.3.5 Interrupt

When EFT on a pin is detected, an interrupt request is generated to indicate the detection of EFT on that pin. This interrupt is enabled when EDIER[EDIE*n*] = 1. Writing 0 to these fields clears the interrupt request but does not affect EFT detection on the corresponding pin (EDFR[EDF*n*]).

19.4 Initialization

To initialize PORT, perform the following procedure:

1. Initialize the pin functions:
   - Initialize single pin functions by writing appropriate values to PCR*n*.
   - Initialize multiple pins (up to 16) with the same configuration by writing appropriate values to Global Pin Control Low (GPCLR) or Global Pin Control High (GPCHR).
2. Lock the configuration for a given pin, by writing 1 to PCR*n*[LK], so that it cannot be changed until the next reset.

19.5 Application information

19.5.1 Determine polarity of an asserted EFT detection

You can determine the polarity of an asserted EFT detect by performing this procedure:

1. Read EFT Detect Flag (EDFR).
2. Write 1 and then write 0 to EDCR[EDLC].
3. Read EFT Detect Flag (EDFR) again. Any field that has now become 0 indicates triggering of the EFT low detector only (no EFT high detector triggering).
4. Write 1 and then write 0 to EDCR[EDHC].
5. Read EFT Detect Flag (EDFR) again. Any field that has now become 0 indicates triggering of the EFT high detector. Any field that did not become 0 indicates triggering of both the EFT high and EFT low detectors.
6. Write 1 and then write 0 to both EDCR[EDLC] and EDCR[EDHC] to ensure that all detectors are reset.

19.6 Memory map and register definition

Any read or write access to the PORT memory space, outside the valid memory map, results in a bus error. All register accesses complete with zero wait states.

19.6.1 PORT register descriptions

19.6.1.1 PORT memory map

PORTA base address: 4004_2000h

PORTB base address: 4004_3000h

PORTC base address: 4004_4000h

PORTD base address: 4004_5000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	0200_0000h
10h	Global Pin Control Low (GPCLR)	32	RW	0000_0000h
14h	Global Pin Control High (GPCHR)	32	RW	0000_0000h
20h	Configuration (CONFIG)	32	RW	0000_0000h
40h	EFT Detect Flag (EDFR)	32	R	0000_0000h
44h	EFT Detect Interrupt Enable (EDIER)	32	RW	0000_0000h
48h	EFT Detect Clear (EDCR)	32	RW	0000_0000h
60h	Calibration 0 (CALIB0)	32	RW	See section
64h	Calibration 1 (CALIB1)	32	RW	See section
80h	Pin Control 0 (PCR0)	32	RW	See section
84h	Pin Control 1 (PCR1)	32	RW	See section
88h	Pin Control 2 (PCR2)	32	RW	See section
8Ch	Pin Control 3 (PCR3)	32	RW	0000_0000h
90h	Pin Control 4 (PCR4)	32	RW	See section
94h	Pin Control 5 (PCR5)	32	RW	0000_0000h
98h - A8h	Pin Control a (PCR6 - PCR10)	32	RW	0000_0000h
ACh	Pin Control 11 (PCR11)	32	RW	0000_0000h
B0h - C4h	Pin Control a (PCR12 - PCR17)	32	RW	See section
C8h - CCh	Pin Control a (PCR18 - PCR19)	32	RW	0000_0000h
D0h - ECh	Pin Control a (PCR20 - PCR27)	32	RW	0000_0000h

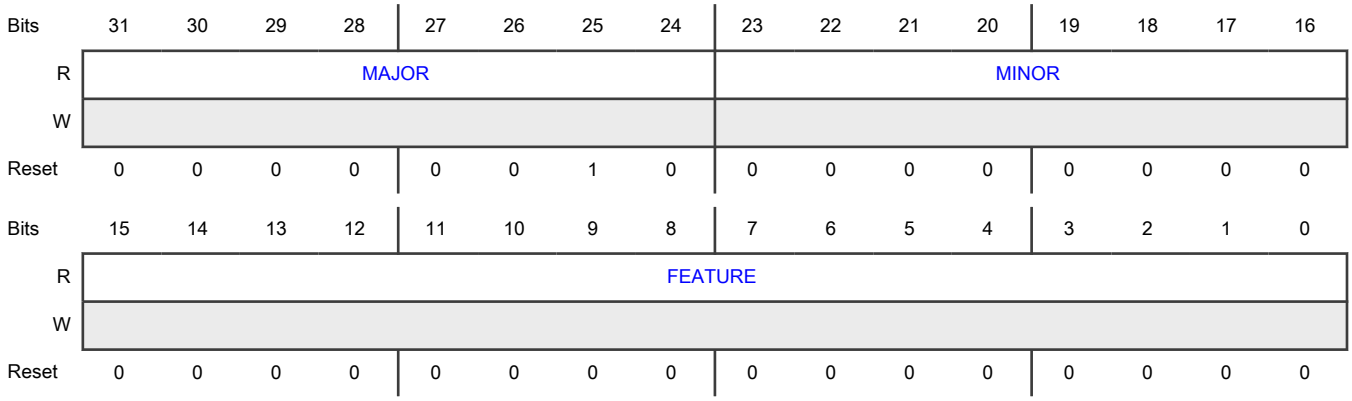
19.6.1.2 Version ID (VERID)

Offset

Register	Offset
VERID	0h

Function
Specifies the version number and feature number of the chip.

Diagram



Fields

Field	Function
31-24 MAJOR	Major Version Number Indicates the major version number for the specification.
23-16 MINOR	Minor Version Number Indicates the minor version number for the specification.
15-0 FEATURE	Feature Specification Number Indicates the feature set number. 0000_0000_0000_0000b - Basic implementation

19.6.1.3 Global Pin Control Low (GPCLR)

Offset

Register	Offset
GPCLR	10h

Function

Controls writes to the PCR15–PCR0 registers.

NOTE

This register supports only 32-bit writes.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W	GPWE 15	GPWE 14	GPWE 13	GPWE 12	GPWE 11	GPWE 10	GPWE 9	GPWE 8	GPWE 7	GPWE 6	GPWE 5	GPWE 4	GPWE 3	GPWE 2	GPWE 1	GPWE 0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W	GPWD															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-16 GPWEn	Global Pin Write Enable Configures the corresponding lower 16-bit field of PCR*n* to be updated with the value in the GPWD field. If a selected PCR is locked, the write to that register is ignored. 0b - Not updated 1b - Updated
15-0 GPWD	Global Pin Write Data Is written to PCR*n*[15:0] if GPWE*n* = 1.

19.6.1.4 Global Pin Control High (GPCHR)

Offset

Register	Offset
GPCHR	14h

Function

Controls writes to the PCR31–PCR16 registers.

NOTE

This register supports only 32-bit writes.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W	GPWE 31	GPWE 30	GPWE 29	GPWE 28	GPWE 27	GPWE 26	GPWE 25	GPWE 24	GPWE 23	GPWE 22	GPWE 21	GPWE 20	GPWE 19	GPWE 18	GPWE 17	GPWE 16
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W	GPWD															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-16 GPWEn	Global Pin Write Enable Configures the corresponding lower 16-bit field of PCR*n* to be updated with the value in the GPWD field. If a selected PCR is locked, write to that register is ignored. 0b - Not updated 1b - Updated
15-0 GPWD	Global Pin Write Data Is written to PCR*n*[15:0] if GPWE*n* = 1.

19.6.1.5 Configuration (CONFIG)

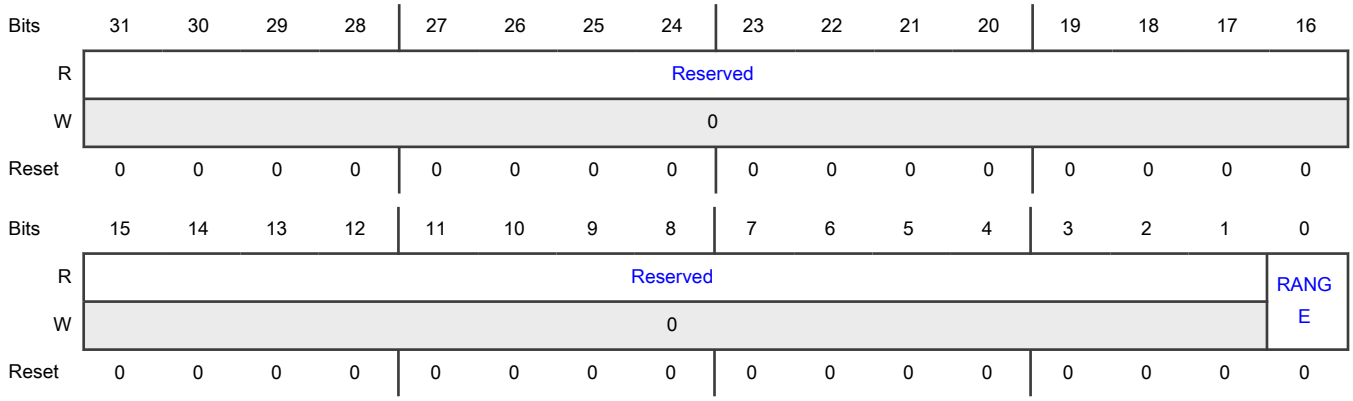
Offset

Register	Offset
CONFIG	20h

Function

Configures the port voltage range.

Diagram



Fields

Field	Function
31-1 —	Reserved
0 RANGE	Port Voltage Range Configures the port voltage range. 0b - 1.71 V–3.6 V 1b - 2.70 V–3.6 V

19.6.1.6 EFT Detect Flag (EDFR)

Offset

Register	Offset
EDFR	40h

Function

Specifies whether an EFT event is detected. The EFT detect logic is active in all pin multiplexing modes.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	0	0	0	EDF27	EDF26	EDF25	EDF24	EDF23	EDF22	EDF21	EDF20	EDF19	EDF18	EDF17	EDF16
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	EDF15	EDF14	EDF13	EDF12	EDF11	EDF10	EDF9	EDF8	EDF7	EDF6	EDF5	EDF4	EDF3	EDF2	EDF1	EDF0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>31
—</td><td>Reserved</td></tr>
<tr><td>30
—</td><td>Reserved</td></tr>
<tr><td>29
—</td><td>Reserved</td></tr>
<tr><td>28
—</td><td>Reserved</td></tr>
<tr><td>27
EDF27</td><td>EFT Detect Flag
Indicates whether high or low EFT is detected on the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>EDFR</td><td>—</td></tr>
<tr><td>PORTB</td><td>—</td><td>EDFR</td></tr>
<tr><td>PORTC</td><td>—</td><td>EDFR</td></tr>
<tr><td>PORTD</td><td>—</td><td>EDFR</td></tr>
</table>
0b - No EFT event detected
1b - High or/and low EFT event detected</td></tr>
</table>

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>26
EDF26</td><td>EFT Detect Flag
Indicates whether high or low EFT is detected on the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>EDFR</td><td>—</td></tr><tr><td>PORTB</td><td>—</td><td>EDFR</td></tr><tr><td>PORTC</td><td>—</td><td>EDFR</td></tr><tr><td>PORTD</td><td>—</td><td>EDFR</td></tr></table>
0b - No EFT event detected
1b - High or/and low EFT event detected</td></tr>
<tr><td>25
EDF25</td><td>EFT Detect Flag
Indicates whether high or low EFT is detected on the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>EDFR</td><td>—</td></tr><tr><td>PORTB</td><td>—</td><td>EDFR</td></tr><tr><td>PORTC</td><td>—</td><td>EDFR</td></tr><tr><td>PORTD</td><td>—</td><td>EDFR</td></tr></table>
0b - No EFT event detected
1b - High or/and low EFT event detected</td></tr>
<tr><td>24
EDF24</td><td>EFT Detect Flag
Indicates whether high or low EFT is detected on the corresponding pin.</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>EDFR</td><td>—</td></tr>
<tr><td>PORTB</td><td>—</td><td>EDFR</td></tr>
<tr><td>PORTC</td><td>—</td><td>EDFR</td></tr>
<tr><td>PORTD</td><td>—</td><td>EDFR</td></tr>
</table>
0b - No EFT event detected
1b - High or/and low EFT event detected
</td></tr>
<tr><td>23
EDF23</td><td>
EFT Detect Flag
Indicates whether high or low EFT is detected on the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>EDFR</td><td>—</td></tr>
<tr><td>PORTB</td><td>—</td><td>EDFR</td></tr>
<tr><td>PORTC</td><td>—</td><td>EDFR</td></tr>
<tr><td>PORTD</td><td>—</td><td>EDFR</td></tr>
</table>
0b - No EFT event detected
1b - High or/and low EFT event detected
</td></tr>
<tr><td>22
EDF22</td><td>
EFT Detect Flag
Indicates whether high or low EFT is detected on the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
</td></tr>
</table>

Table continues on the next page...

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Field	Function

Instance	Field supported in	Field not supported in
PORTA	EDFR	—
PORTB	—	EDFR
PORTC	—	EDFR
PORTD	—	EDFR

0b - No EFT event detected

1b - High or/and low EFT event detected

Field	Function
21 EDF21	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin.

NOTE

This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	EDFR	—
PORTB	—	EDFR
PORTC	—	EDFR
PORTD	—	EDFR

0b - No EFT event detected

1b - High or/and low EFT event detected

Field	Function
20 EDF20	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin.

NOTE

This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	EDFR	—

Table continues on the next page...

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Field	Function

Instance	Field supported in	Field not supported in
PORTB	—	EDFR
PORTC	—	EDFR
PORTD	—	EDFR

0b - No EFT event detected

1b - High or/and low EFT event detected

19

EDF19

EFT Detect Flag

Indicates whether high or low EFT is detected on the corresponding pin.

NOTE

This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	EDFR	—
PORTB	—	EDFR
PORTC	EDFR	—
PORTD	—	EDFR

0b - No EFT event detected

1b - High or/and low EFT event detected

18

EDF18

EFT Detect Flag

Indicates whether high or low EFT is detected on the corresponding pin.

NOTE

This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	EDFR	—
PORTB	—	EDFR

Table continues on the next page...

Table continued from the previous page...

Field	Function

Instance	Field supported in	Field not supported in
PORTC	EDFR	—
PORTD	—	EDFR

0b - No EFT event detected

1b - High or/and low EFT event detected

17

EDF17

EFT Detect Flag

Indicates whether high or low EFT is detected on the corresponding pin.

NOTE

This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	EDFR	—
PORTB	—	EDFR
PORTC	EDFR	—
PORTD	—	EDFR

0b - No EFT event detected

1b - High or/and low EFT event detected

16

EDF16

EFT Detect Flag

Indicates whether high or low EFT is detected on the corresponding pin.

NOTE

This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	EDFR	—
PORTB	—	EDFR
PORTC	EDFR	—

Table continues on the next page...

Table continued from the previous page...

Field	Function
	Instance / Field supported in / Field not supported in PORTD — EDFR 0b - No EFT event detected 1b - High or/and low EFT event detected
15 EDF15	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin. **NOTE** This field is not supported in every instance. The following table includes only supported registers. **Instance / Field supported in / Field not supported in** PORTA — EDFR PORTB — EDFR PORTC EDFR — PORTD — EDFR 0b - No EFT event detected 1b - High or/and low EFT event detected
14 EDF14	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin. **NOTE** This field is not supported in every instance. The following table includes only supported registers. **Instance / Field supported in / Field not supported in** PORTA — EDFR PORTB — EDFR PORTC EDFR — PORTD — EDFR

Table continues on the next page...

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<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
</table>
0b - No EFT event detected
1b - High or/and low EFT event detected
</td></tr>
<tr><td>13
EDF13</td><td>EFT Detect Flag
Indicates whether high or low EFT is detected on the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>—</td><td>EDFR</td></tr>
<tr><td>PORTB</td><td>—</td><td>EDFR</td></tr>
<tr><td>PORTC</td><td>EDFR</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>EDFR</td></tr>
</table>
0b - No EFT event detected
1b - High or/and low EFT event detected
</td></tr>
<tr><td>12
EDF12</td><td>EFT Detect Flag
Indicates whether high or low EFT is detected on the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>—</td><td>EDFR</td></tr>
<tr><td>PORTB</td><td>—</td><td>EDFR</td></tr>
<tr><td>PORTC</td><td>EDFR</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>EDFR</td></tr>
</table>
0b - No EFT event detected
</td></tr>
</table>

Table continues on the next page...

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Field	Function
	1b - High or/and low EFT event detected
11 EDF11	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin. 0b - No EFT event detected 1b - High or/and low EFT event detected
10 EDF10	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin. 0b - No EFT event detected 1b - High or/and low EFT event detected
9 EDF9	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin. 0b - No EFT event detected 1b - High or/and low EFT event detected
8 EDF8	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin. 0b - No EFT event detected 1b - High or/and low EFT event detected
7 EDF7	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin. 0b - No EFT event detected 1b - High or/and low EFT event detected
6 EDF6	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin. 0b - No EFT event detected 1b - High or/and low EFT event detected
5 EDF5	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin. 0b - No EFT event detected 1b - High or/and low EFT event detected
4 EDF4	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - No EFT event detected 1b - High or/and low EFT event detected
3 EDF3	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin. 0b - No EFT event detected 1b - High or/and low EFT event detected
2 EDF2	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin. 0b - No EFT event detected 1b - High or/and low EFT event detected
1 EDF1	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin. 0b - No EFT event detected 1b - High or/and low EFT event detected
0 EDF0	EFT Detect Flag Indicates whether high or low EFT is detected on the corresponding pin. 0b - No EFT event detected 1b - High or/and low EFT event detected

19.6.1.7 EFT Detect Interrupt Enable (EDIER)

Offset

Register	Offset
EDIER	44h

Function
Configures whether to generate an interrupt when an EFT event is detected.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	0	0	0	EDIE27	EDIE26	EDIE25	EDIE24	EDIE23	EDIE22	EDIE21	EDIE20	EDIE19	EDIE18	EDIE17	EDIE16
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	EDIE15	EDIE14	EDIE13	EDIE12	EDIE11	EDIE10	EDIE9	EDIE8	EDIE7	EDIE6	EDIE5	EDIE4	EDIE3	EDIE2	EDIE1	EDIE0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 —	Reserved
30 —	Reserved
29 —	Reserved
28 —	Reserved
27 EDIE27	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. **NOTE** This field is not supported in every instance. The following table includes only supported registers. 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event

Instance	Field supported in	Field not supported in
PORTA	EDIER	—
PORTB	—	EDIER
PORTC	—	EDIER
PORTD	—	EDIER

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>26
EDIE26</td><td>EFT Detect Interrupt Enable
Configures the EFT detect interrupt for the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>EDIER</td><td>—</td></tr><tr><td>PORTB</td><td>—</td><td>EDIER</td></tr><tr><td>PORTC</td><td>—</td><td>EDIER</td></tr><tr><td>PORTD</td><td>—</td><td>EDIER</td></tr></table>0b - Interrupt not generated upon detection of the EFT event
1b - Interrupt generated upon detection of the EFT event</td></tr>
<tr><td>25
EDIE25</td><td>EFT Detect Interrupt Enable
Configures the EFT detect interrupt for the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>EDIER</td><td>—</td></tr><tr><td>PORTB</td><td>—</td><td>EDIER</td></tr><tr><td>PORTC</td><td>—</td><td>EDIER</td></tr><tr><td>PORTD</td><td>—</td><td>EDIER</td></tr></table>0b - Interrupt not generated upon detection of the EFT event
1b - Interrupt generated upon detection of the EFT event</td></tr>
<tr><td>24
EDIE24</td><td>EFT Detect Interrupt Enable
Configures the EFT detect interrupt for the corresponding pin.</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>EDIER</td><td>—</td></tr>
<tr><td>PORTB</td><td>—</td><td>EDIER</td></tr>
<tr><td>PORTC</td><td>—</td><td>EDIER</td></tr>
<tr><td>PORTD</td><td>—</td><td>EDIER</td></tr>
</table>
0b - Interrupt not generated upon detection of the EFT event
1b - Interrupt generated upon detection of the EFT event
</td></tr>
<tr><td>23
EDIE23</td><td>
EFT Detect Interrupt Enable
Configures the EFT detect interrupt for the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>EDIER</td><td>—</td></tr>
<tr><td>PORTB</td><td>—</td><td>EDIER</td></tr>
<tr><td>PORTC</td><td>—</td><td>EDIER</td></tr>
<tr><td>PORTD</td><td>—</td><td>EDIER</td></tr>
</table>
0b - Interrupt not generated upon detection of the EFT event
1b - Interrupt generated upon detection of the EFT event
</td></tr>
<tr><td>22
EDIE22</td><td>
EFT Detect Interrupt Enable
Configures the EFT detect interrupt for the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>EDIER</td><td>—</td></tr>
<tr><td>PORTB</td><td>—</td><td>EDIER</td></tr>
<tr><td>PORTC</td><td>—</td><td>EDIER</td></tr>
<tr><td>PORTD</td><td>—</td><td>EDIER</td></tr>
</table>
0b - Interrupt not generated upon detection of the EFT event
1b - Interrupt generated upon detection of the EFT event</td></tr>
<tr><td>21
EDIE21</td><td>EFT Detect Interrupt Enable
Configures the EFT detect interrupt for the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>EDIER</td><td>—</td></tr>
<tr><td>PORTB</td><td>—</td><td>EDIER</td></tr>
<tr><td>PORTC</td><td>—</td><td>EDIER</td></tr>
<tr><td>PORTD</td><td>—</td><td>EDIER</td></tr>
</table>
0b - Interrupt not generated upon detection of the EFT event
1b - Interrupt generated upon detection of the EFT event</td></tr>
<tr><td>20
EDIE20</td><td>EFT Detect Interrupt Enable
Configures the EFT detect interrupt for the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>EDIER</td><td>—</td></tr>
</table></td></tr>
</table>

Table continues on the next page...

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Field	Function

Instance	Field supported in	Field not supported in
PORTB	—	EDIER
PORTC	—	EDIER
PORTD	—	EDIER

0b - Interrupt not generated upon detection of the EFT event

1b - Interrupt generated upon detection of the EFT event

19

EDIE19

EFT Detect Interrupt Enable

Configures the EFT detect interrupt for the corresponding pin.

NOTE

This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	EDIER	—
PORTB	—	EDIER
PORTC	EDIER	—
PORTD	—	EDIER

0b - Interrupt not generated upon detection of the EFT event

1b - Interrupt generated upon detection of the EFT event

18

EDIE18

EFT Detect Interrupt Enable

Configures the EFT detect interrupt for the corresponding pin.

NOTE

This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	EDIER	—
PORTB	—	EDIER

Table continues on the next page...

Table continued from the previous page...

Field	Function

Instance	Field supported in	Field not supported in
PORTC	EDIER	—
PORTD	—	EDIER

0b - Interrupt not generated upon detection of the EFT event

1b - Interrupt generated upon detection of the EFT event

17

EDIE17

EFT Detect Interrupt Enable

Configures the EFT detect interrupt for the corresponding pin.

NOTE

This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	EDIER	—
PORTB	—	EDIER
PORTC	EDIER	—
PORTD	—	EDIER

0b - Interrupt not generated upon detection of the EFT event

1b - Interrupt generated upon detection of the EFT event

16

EDIE16

EFT Detect Interrupt Enable

Configures the EFT detect interrupt for the corresponding pin.

NOTE

This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	EDIER	—
PORTB	—	EDIER
PORTC	EDIER	—

Table continues on the next page...

Table continued from the previous page...

Field	Function
	<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTD</td><td>—</td><td>EDIER</td></tr></table> 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event
15 EDIE15	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. **NOTE** This field is not supported in every instance. The following table includes only supported registers. <table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>—</td><td>EDIER</td></tr><tr><td>PORTB</td><td>—</td><td>EDIER</td></tr><tr><td>PORTC</td><td>EDIER</td><td>—</td></tr><tr><td>PORTD</td><td>—</td><td>EDIER</td></tr></table> 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event
14 EDIE14	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. **NOTE** This field is not supported in every instance. The following table includes only supported registers. <table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>—</td><td>EDIER</td></tr><tr><td>PORTB</td><td>—</td><td>EDIER</td></tr><tr><td>PORTC</td><td>EDIER</td><td>—</td></tr><tr><td>PORTD</td><td>—</td><td>EDIER</td></tr></table>

Table continues on the next page...

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<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
</table>
0b - Interrupt not generated upon detection of the EFT event
1b - Interrupt generated upon detection of the EFT event
</td></tr>
<tr><td>13
EDIE13</td><td>EFT Detect Interrupt Enable
Configures the EFT detect interrupt for the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>—</td><td>EDIER</td></tr>
<tr><td>PORTB</td><td>—</td><td>EDIER</td></tr>
<tr><td>PORTC</td><td>EDIER</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>EDIER</td></tr>
</table>
0b - Interrupt not generated upon detection of the EFT event
1b - Interrupt generated upon detection of the EFT event</td></tr>
<tr><td>12
EDIE12</td><td>EFT Detect Interrupt Enable
Configures the EFT detect interrupt for the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>—</td><td>EDIER</td></tr>
<tr><td>PORTB</td><td>—</td><td>EDIER</td></tr>
<tr><td>PORTC</td><td>EDIER</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>EDIER</td></tr>
</table>
0b - Interrupt not generated upon detection of the EFT event</td></tr>
</table>

Table continues on the next page...

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Field	Function
	1b - Interrupt generated upon detection of the EFT event
11 EDIE11	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event
10 EDIE10	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event
9 EDIE9	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event
8 EDIE8	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event
7 EDIE7	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event
6 EDIE6	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event
5 EDIE5	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event
4 EDIE4	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event
3 EDIE3	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event
2 EDIE2	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event
1 EDIE1	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event
0 EDIE0	EFT Detect Interrupt Enable Configures the EFT detect interrupt for the corresponding pin. 0b - Interrupt not generated upon detection of the EFT event 1b - Interrupt generated upon detection of the EFT event

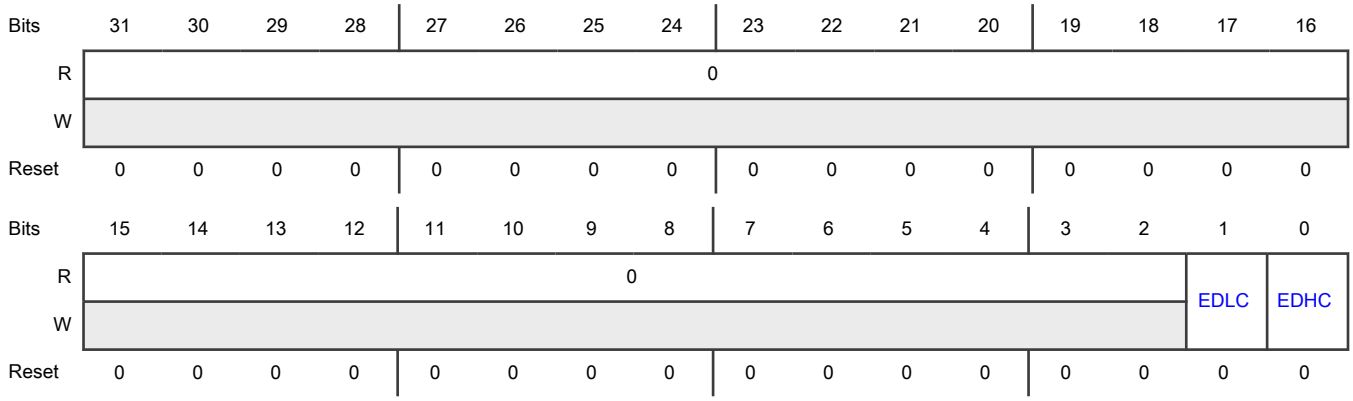
19.6.1.8 EFT Detect Clear (EDCR)

Offset

Register	Offset
EDCR	48h

Function
Clears EFT detectors. The EFT detect logic is cleared per port.

Diagram



Fields

Field	Function
31-2 —	Reserved
1 EDLC	EFT Detect Low Clear Clears low EFT detectors. If this field = 1, all low EFT detectors for which the corresponding high EFT detectors are not asserted are cleared. 0b - Does not clear 1b - Clears
0 EDHC	EFT Detect High Clear Clears high EFT detectors. 0b - Does not clear 1b - Clears

19.6.1.9 Calibration 0 (CALIB0)

Offset

Register	Offset
CALIB0	60h

Function

Stores calibration values for the PMOS and NMOS output drivers when PCR*n*[DSE] = 0.

NOTE

Each module instance supports a different number of registers.

Instance	Register supported	Register not supported
PORTA	—	CALIB0
PORTB	CALIB0	—
PORTC	CALIB0	—
PORTD	—	CALIB0

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0										PCAL					
W																
Reset	0	0	0	0	0	0	0	0	0	0	u[1]	u	u	u	u	u

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0										NCAL					
W																
Reset	0	0	0	0	0	0	0	0	0	0	u[1]	u	u	u	u	u

1. Reset values are loaded out of IFR.

Fields

Field	Function
31-22 —	Reserved
21-16 PCAL	Calibration of PMOS Output Driver
15-6 —	Reserved
5-0 NCAL	Calibration of NMOS Output Driver

19.6.1.10 Calibration 1 (CALIB1)

Offset

Register	Offset
CALIB1	64h

Function

Stores calibration values for the PMOS and NMOS output drivers when PCR*n*[DSE] = 1.

NOTE

Each module instance supports a different number of registers.

Instance	Register supported	Register not supported
PORTA	—	CALIB1
PORTB	CALIB1	—
PORTC	CALIB1	—
PORTD	—	CALIB1

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0										PCAL					
W																
Reset	0	0	0	0	0	0	0	0	0	0	u[1]	u	u	u	u	u

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0										NCAL					
W																
Reset	0	0	0	0	0	0	0	0	0	0	u[1]	u	u	u	u	u

1. Reset values are loaded out of IFR.

Fields

Field	Function
31-22 —	Reserved
21-16 PCAL	Calibration of PMOS Output Driver
15-6 —	Reserved
5-0 NCAL	Calibration of NMOS Output Driver

19.6.1.11 Pin Control 0 (PCR0)

Offset

Register	Offset
PCR0	80h

Function

Configures pin control features on each pin.

NOTE

Do not modify pin configuration registers associated with pins that are unavailable in your selected package. All unbonded pins unavailable in your package default to the Disabled state for lowest power consumption.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	See Register reset values.															

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	LK	0	INV	0	MUX				DSE1	DSE	ODE	PFE	SRE	PV	PE	PS
W																
Reset	See Register reset values.															

Register reset values

Register	Reset value
PCR0	PORTA: 0000_0703h PORTB,PORTC: 0000_0000h PORTD: 0000_0333h

Fields

Field	Function
31-16 —	Reserved
15 LK	Lock Register Locks this PCR. When a PCR*n* is locked, its fields cannot be updated until the next reset.

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>0b - Does not lock
1b - Locks</td></tr>
<tr><td>14
—</td><td>Reserved</td></tr>
<tr><td>13
INV</td><td>Invert Input
Inverts the digital input.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>PCR0</td><td>—</td></tr><tr><td>PORTB</td><td>PCR0</td><td>—</td></tr><tr><td>PORTC</td><td>PCR0</td><td>—</td></tr><tr><td>PORTD</td><td>—</td><td>PCR0</td></tr></table>0b - Does not invert
1b - Inverts</td></tr>
<tr><td>12
—</td><td>Reserved</td></tr>
<tr><td>11-8
MUX</td><td>Pin Multiplex Control
Configures the multiplexing slots on each pin.
Not all pins support all pin multiplexing slots. Unimplemented pin multiplexing slots are reserved.
Unimplemented pin multiplexing slots can result in different behaviors, if the unimplemented slot is phantomed (because the module is phantomed on that die) versus unimplemented on the die.
The corresponding pin is configured according to the following pin multiplexing slots:
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>PCR0[10–8]</td><td>PCR0[11]</td></tr></table></td></tr>
</table>

Table continued from the previous page...

Field	Function

Instance	Field supported in	Field not supported in
PORTB	PCR0	—
PORTC	PCR0	—
PORTD	PCR0[9–8]	PCR0[11–10]

NOTE

The descriptions of the field settings vary by module instance.

Instance	Field value and description
PORTA	000b - Pin disabled (analog) 001b - Alternative 1 (GPIO) 010b - Alternative 2 (chip-specific) 011b - Alternative 3 (chip-specific) 100b - Alternative 4 (chip-specific) 101b - Alternative 5 (chip-specific) 110b - Alternative 6 (chip-specific) 111b - Alternative 7 (chip-specific)
PORTB PORTC	0000b - Pin disabled (analog) 0001b - Alternative 1 (GPIO) 0010b - Alternative 2 (chip-specific) 0011b - Alternative 3 (chip-specific) 0100b - Alternative 4 (chip-specific) 0101b - Alternative 5 (chip-specific) 0110b - Alternative 6 (chip-specific) 0111b - Alternative 7 (chip-specific) 1000b - Alternative 8 (chip-specific) 1001b - Alternative 9 (chip-specific) 1010b - Alternative 10 (chip-specific) 1011b - Alternative 11 (chip-specific)
PORTD	00b - Pin disabled (analog) 01b - Alternative 1 (GPIO)

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<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field value and description</th></tr>
<tr><td></td><td>10b - Alternative 2 (chip-specific)
11b - Alternative 3 (chip-specific)</td></tr>
</table>
</td></tr>
<tr><td>7
DSE1</td><td>Drive Strength Enable
Configures the drive strength on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.
• If this field = 0, normal drive strength is configured on the corresponding pin.
• If this field = 1, double drive strength is configured on the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>—</td><td>PCR0</td></tr>
<tr><td>PORTB</td><td>—</td><td>PCR0</td></tr>
<tr><td>PORTC</td><td>PCR0</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR0</td></tr>
</table>
0b - Normal
1b - Double</td></tr>
<tr><td>6
DSE</td><td>Drive Strength Enable
Configures drive strength, low or high, on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.
• When this field = 0, low drive strength is configured on the corresponding pin, if the pin is configured as a digital output.
• When this field = 1, high drive strength is configured on the corresponding pin, if the pin is configured as a digital output.
NOTE
This field is not supported in every instance. The following table includes only supported registers.</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR0</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR0</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR0</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR0</td></tr>
</table>
0b - Low
1b - High</td></tr>
<tr><td>5
ODE</td><td>Open Drain Enable
Enables open drain output on each pin.
The open drain configuration is valid for all digital pin multiplexing modes.
• When this field = 0, the open drain output is disabled on the corresponding pin.
• When this field = 1, the open drain output is enabled on the corresponding pin, if the pin is configured as a digital output.
0b - Disables
1b - Enables</td></tr>
<tr><td>4
PFE</td><td>Passive Filter Enable
Enables passive input filter on each pin.
The passive filter configuration is valid for all digital pin multiplexing modes.
• When this field = 0, the passive input filter is disabled on the corresponding pin.
• When this field = 1, the passive input filter is enabled on the corresponding pin, if the pin is configured as a digital input.
See the chip's data sheet for filter characteristics.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>—</td><td>PCR0</td></tr>
<tr><td>PORTB</td><td>—</td><td>PCR0</td></tr>
<tr><td>PORTC</td><td>PCR0</td><td>—</td></tr>
</table></td></tr>
</table>

Table continues on the next page...

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Field	Function

Instance	Field supported in	Field not supported in
PORTD	PCR0	—

0b - Disables

1b - Enables

Field	Function
3 SRE	Slew Rate Enable Configures the slew rate feature, fast or slow, on each corresponding pin. The slew rate configuration is valid for all digital pin multiplexing modes. **NOTE** This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	PCR0	—
PORTB	PCR0	—
PORTC	PCR0	—
PORTD	—	PCR0

0b - Fast

1b - Slow

Field	Function
2 PV	Pull Value Selects high or low internal pull resistor value. The pull value configuration is valid for all digital pin multiplexing modes. **NOTE** This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	—	PCR0
PORTB	—	PCR0

Table continues on the next page...

Table continued from the previous page...

Field	Function
	<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTC</td><td>PCR0</td><td>—</td></tr><tr><td>PORTD</td><td>PCR0</td><td>—</td></tr></table> 0b - Low 1b - High
1 PE	Pull Enable Enables the internal pull resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pull resistor is not enabled on the corresponding pin. • When this field = 1, the internal pull resistor is enabled on the corresponding pin, if the pin is configured as a digital input. 0b - Disables 1b - Enables
0 PS	Pull Select Enables the internal pullup or pulldown resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pulldown resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. • When this field = 1, the internal pullup resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. 0b - Enables internal pulldown resistor 1b - Enables internal pullup resistor

19.6.1.12 Pin Control 1 (PCR1)

Offset

Register	Offset
PCR1	84h

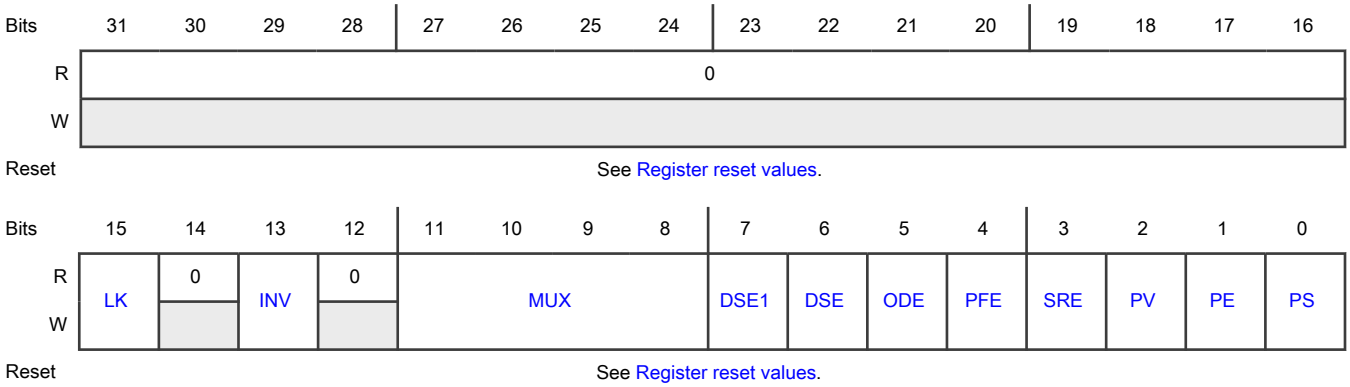
Function

Configures pin control features on each pin.

NOTE

Do not modify pin configuration registers associated with pins that are unavailable in your selected package. All unbonded pins unavailable in your package default to the Disabled state for lowest power consumption.

Diagram



Register reset values

Register	Reset value
PCR1	PORTA: 0000_0702h PORTB–PORTD: 0000_0000h

Fields

Field	Function
31-16 —	Reserved
15 LK	Lock Register Locks this PCR. When a PCR*n* is locked, its fields cannot be updated until the next reset. 0b - Does not lock 1b - Locks
14 —	Reserved
13 INV	Invert Input Inverts the digital input.

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR1</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR1</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR1</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR1</td></tr>
</table>
0b - Does not invert
1b - Inverts
</td></tr>
<tr><td>12
—</td><td>Reserved</td></tr>
<tr><td>11-8
MUX</td><td>
Pin Multiplex Control
Configures the multiplexing slots on each pin.
Not all pins support all pin multiplexing slots. Unimplemented pin multiplexing slots are reserved.
Unimplemented pin multiplexing slots can result in different behaviors, if the unimplemented slot is phantomed (because the module is phantomed on that die) versus unimplemented on the die.
The corresponding pin is configured according to the following pin multiplexing slots:
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR1[10–8]</td><td>PCR1[11]</td></tr>
<tr><td>PORTB</td><td>PCR1</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR1</td><td>—</td></tr>
<tr><td>PORTD</td><td>PCR1</td><td>—</td></tr>
</table>
NOTE
The descriptions of the field settings vary by module instance.
</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function	
	Instance	Field value and description
	PORTA	000b - Pin disabled (analog) 001b - Alternative 1 (GPIO) 010b - Alternative 2 (chip-specific) 011b - Alternative 3 (chip-specific) 100b - Alternative 4 (chip-specific) 101b - Alternative 5 (chip-specific) 110b - Alternative 6 (chip-specific) 111b - Alternative 7 (chip-specific)
	PORTB PORTC	0000b - Pin disabled (analog) 0001b - Alternative 1 (GPIO) 0010b - Alternative 2 (chip-specific) 0011b - Alternative 3 (chip-specific) 0100b - Alternative 4 (chip-specific) 0101b - Alternative 5 (chip-specific) 0110b - Alternative 6 (chip-specific) 0111b - Alternative 7 (chip-specific) 1000b - Alternative 8 (chip-specific) 1001b - Alternative 9 (chip-specific) 1010b - Alternative 10 (chip-specific) 1011b - Alternative 11 (chip-specific)
	PORTD	0000b - Pin disabled (analog) 0001b - Alternative 1 (GPIO) 0010b - Alternative 2 (chip-specific) 0011b - Alternative 3 (chip-specific) 0100b - Alternative 4 (chip-specific) 0101b - Alternative 5 (chip-specific) 0110b - Alternative 6 (chip-specific) 0111b - Alternative 7 (chip-specific) 1000b - Alternative 8 (chip-specific) 1001b - Alternative 9 (chip-specific)

Table continues on the next page...

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<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>7
DSE1</td><td>Drive Strength Enable
Configures the drive strength on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.
• If this field = 0, normal drive strength is configured on the corresponding pin.
• If this field = 1, double drive strength is configured on the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>—</td><td>PCR1</td></tr><tr><td>PORTB</td><td>—</td><td>PCR1</td></tr><tr><td>PORTC</td><td>PCR1</td><td>—</td></tr><tr><td>PORTD</td><td>—</td><td>PCR1</td></tr></table>
0b - Normal
1b - Double</td></tr>
<tr><td>6
DSE</td><td>Drive Strength Enable
Configures drive strength, low or high, on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.
• When this field = 0, low drive strength is configured on the corresponding pin, if the pin is configured as a digital output.
• When this field = 1, high drive strength is configured on the corresponding pin, if the pin is configured as a digital output.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>PCR1</td><td>—</td></tr><tr><td>PORTB</td><td>PCR1</td><td>—</td></tr><tr><td>PORTC</td><td>PCR1</td><td>—</td></tr></table></td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function
	<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTD</td><td>—</td><td>PCR1</td></tr></table> 0b - Low 1b - High
5 ODE	Open Drain Enable Enables open drain output on each pin. The open drain configuration is valid for all digital pin multiplexing modes. • When this field = 0, the open drain output is disabled on the corresponding pin. • When this field = 1, the open drain output is enabled on the corresponding pin, if the pin is configured as a digital output. 0b - Disables 1b - Enables
4 PFE	Passive Filter Enable Enables passive input filter on each pin. The passive filter configuration is valid for all digital pin multiplexing modes. • When this field = 0, the passive input filter is disabled on the corresponding pin. • When this field = 1, the passive input filter is enabled on the corresponding pin, if the pin is configured as a digital input. See the chip's data sheet for filter characteristics. **NOTE** This field is not supported in every instance. The following table includes only supported registers. <table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>—</td><td>PCR1</td></tr><tr><td>PORTB</td><td>—</td><td>PCR1</td></tr><tr><td>PORTC</td><td>PCR1</td><td>—</td></tr><tr><td>PORTD</td><td>PCR1</td><td>—</td></tr></table> 0b - Disables 1b - Enables

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>3
SRE</td><td>Slew Rate Enable
Configures the slew rate feature, fast or slow, on each corresponding pin.
The slew rate configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>PCR1</td><td>—</td></tr><tr><td>PORTB</td><td>PCR1</td><td>—</td></tr><tr><td>PORTC</td><td>PCR1</td><td>—</td></tr><tr><td>PORTD</td><td>—</td><td>PCR1</td></tr></table>
0b - Fast
1b - Slow</td></tr>
<tr><td>2
PV</td><td>Pull Value
Selects high or low internal pull resistor value.
The pull value configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>—</td><td>PCR1</td></tr><tr><td>PORTB</td><td>—</td><td>PCR1</td></tr><tr><td>PORTC</td><td>—</td><td>PCR1</td></tr><tr><td>PORTD</td><td>PCR1</td><td>—</td></tr></table>
0b - Low
1b - High</td></tr>
<tr><td>1</td><td>Pull Enable</td></tr>
</table>

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Table continued from the previous page...

Field	Function
PE	Enables the internal pull resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pull resistor is not enabled on the corresponding pin. • When this field = 1, the internal pull resistor is enabled on the corresponding pin, if the pin is configured as a digital input. 0b - Disables 1b - Enables
0 PS	Pull Select Enables the internal pullup or pulldown resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pulldown resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. • When this field = 1, the internal pullup resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. 0b - Enables internal pulldown resistor 1b - Enables internal pullup resistor

19.6.1.13 Pin Control 2 (PCR2)

Offset

Register	Offset
PCR2	88h

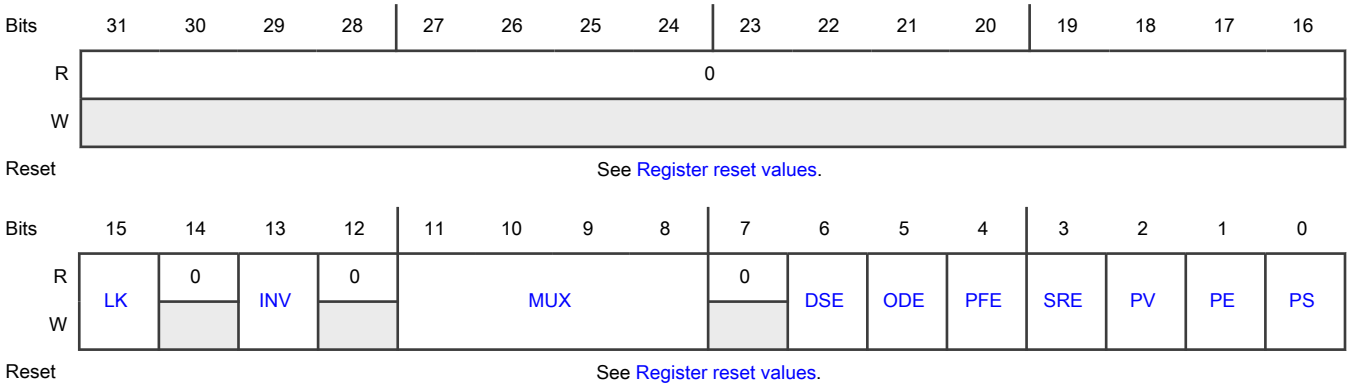
Function

Configures pin control features on each pin.

NOTE

Do not modify pin configuration registers associated with pins that are unavailable in your selected package. All unbonded pins unavailable in your package default to the Disabled state for lowest power consumption.

Diagram



Register reset values

Register	Reset value
PCR2	PORTA: 0000_0040h PORTB–PORTD: 0000_0000h

Fields

Field	Function
31-16 —	Reserved
15 LK	Lock Register Locks this PCR. When a PCR*n* is locked, its fields cannot be updated until the next reset. 0b - Does not lock 1b - Locks
14 —	Reserved
13 INV	Invert Input Inverts the digital input. **NOTE** This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	PCR2	—

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTB</td><td>PCR2</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR2</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR2</td></tr>
</table>
0b - Does not invert
1b - Inverts
</td></tr>
<tr><td>12
—</td><td>Reserved</td></tr>
<tr><td>11-8
MUX</td><td>Pin Multiplex Control
Configures the multiplexing slots on each pin.
Not all pins support all pin multiplexing slots. Unimplemented pin multiplexing slots are reserved.
Unimplemented pin multiplexing slots can result in different behaviors, if the unimplemented slot is phantomed (because the module is phantomed on that die) versus unimplemented on the die.
The corresponding pin is configured according to the following pin multiplexing slots:
NOTE
The descriptions of the field settings vary by module instance.
<table>
<tr><th>Instance</th><th>Field value and description</th></tr>
<tr><td>PORTA
PORTB
PORTC</td><td>0000b - Pin disabled (analog)
0001b - Alternative 1 (GPIO)
0010b - Alternative 2 (chip-specific)
0011b - Alternative 3 (chip-specific)
0100b - Alternative 4 (chip-specific)
0101b - Alternative 5 (chip-specific)
0110b - Alternative 6 (chip-specific)
0111b - Alternative 7 (chip-specific)
1000b - Alternative 8 (chip-specific)
1001b - Alternative 9 (chip-specific)
1010b - Alternative 10 (chip-specific)
1011b - Alternative 11 (chip-specific)</td></tr>
<tr><td>PORTD</td><td>0000b - Pin disabled (analog)</td></tr>
</table>
</td></tr>
</table>

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field value and description</th></tr>
<tr><td></td><td>0001b - Alternative 1 (GPIO)
0010b - Alternative 2 (chip-specific)
0011b - Alternative 3 (chip-specific)
0100b - Alternative 4 (chip-specific)
0101b - Alternative 5 (chip-specific)
0110b - Alternative 6 (chip-specific)
0111b - Alternative 7 (chip-specific)
1000b - Alternative 8 (chip-specific)
1001b - Alternative 9 (chip-specific)</td></tr>
</table>
</td></tr>
<tr><td>7
—</td><td>Reserved</td></tr>
<tr><td>6
DSE</td><td>Drive Strength Enable
Configures drive strength, low or high, on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.
• When this field = 0, low drive strength is configured on the corresponding pin, if the pin is configured as a digital output.
• When this field = 1, high drive strength is configured on the corresponding pin, if the pin is configured as a digital output.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR2</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR2</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR2</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR2</td></tr>
</table>
0b - Low
1b - High</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>5
ODE</td><td>Open Drain Enable
Enables open drain output on each pin.
The open drain configuration is valid for all digital pin multiplexing modes.
• When this field = 0, the open drain output is disabled on the corresponding pin.
• When this field = 1, the open drain output is enabled on the corresponding pin, if the pin is configured as a digital output.
0b - Disables
1b - Enables</td></tr>
<tr><td>4
PFE</td><td>Passive Filter Enable
Enables passive input filter on each pin.
The passive filter configuration is valid for all digital pin multiplexing modes.
• When this field = 0, the passive input filter is disabled on the corresponding pin.
• When this field = 1, the passive input filter is enabled on the corresponding pin, if the pin is configured as a digital input.
See the chip's data sheet for filter characteristics.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>—</td><td>PCR2</td></tr><tr><td>PORTB</td><td>—</td><td>PCR2</td></tr><tr><td>PORTC</td><td>—</td><td>PCR2</td></tr><tr><td>PORTD</td><td>PCR2</td><td>—</td></tr></table>
0b - Disables
1b - Enables</td></tr>
<tr><td>3
SRE</td><td>Slew Rate Enable
Configures the slew rate feature, fast or slow, on each corresponding pin.
The slew rate configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR2</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR2</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR2</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR2</td></tr>
</table>
0b - Fast
1b - Slow
</td></tr>
<tr><td>2
PV</td><td>Pull Value
Selects high or low internal pull resistor value.
The pull value configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>—</td><td>PCR2</td></tr>
<tr><td>PORTB</td><td>—</td><td>PCR2</td></tr>
<tr><td>PORTC</td><td>—</td><td>PCR2</td></tr>
<tr><td>PORTD</td><td>PCR2</td><td>—</td></tr>
</table>
0b - Low
1b - High
</td></tr>
<tr><td>1
PE</td><td>Pull Enable
Enables the internal pull resistor.
This configuration is valid for all digital pin multiplexing modes.
• When this field = 0, the internal pull resistor is not enabled on the corresponding pin.
• When this field = 1, the internal pull resistor is enabled on the corresponding pin, if the pin is configured as a digital input.
0b - Disables</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Enables
0 PS	Pull Select Enables the internal pullup or pulldown resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pulldown resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. • When this field = 1, the internal pullup resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. 0b - Enables internal pulldown resistor 1b - Enables internal pullup resistor

19.6.1.14 Pin Control 3 (PCR3)

Offset

Register	Offset
PCR3	8Ch

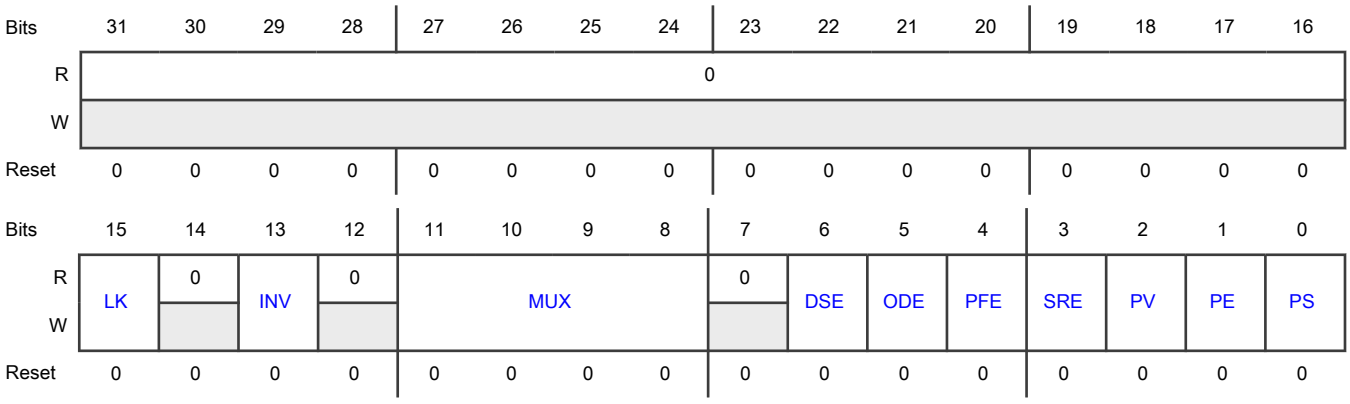
Function

Configures pin control features on each pin.

NOTE

Do not modify pin configuration registers associated with pins that are unavailable in your selected package. All unbonded pins unavailable in your package default to the Disabled state for lowest power consumption.

Diagram



Fields

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>31-16
—</td><td>Reserved</td></tr>
<tr><td>15
LK</td><td>Lock Register
Locks this PCR.
When a PCRn is locked, its fields cannot be updated until the next reset.
0b - Does not lock
1b - Locks</td></tr>
<tr><td>14
—</td><td>Reserved</td></tr>
<tr><td>13
INV</td><td>Invert Input
Inverts the digital input.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR3</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR3</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR3</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR3</td></tr>
</table>
0b - Does not invert
1b - Inverts</td></tr>
<tr><td>12
—</td><td>Reserved</td></tr>
<tr><td>11-8
MUX</td><td>Pin Multiplex Control
Configures the multiplexing slots on each pin.
Not all pins support all pin multiplexing slots. Unimplemented pin multiplexing slots are reserved.
Unimplemented pin multiplexing slots can result in different behaviors, if the unimplemented slot is phantomed (because the module is phantomed on that die) versus unimplemented on the die.
The corresponding pin is configured according to the following pin multiplexing slots:</td></tr>
</table>

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
NOTE
The descriptions of the field settings vary by module instance.
<table>
<tr><th>Instance</th><th>Field value and description</th></tr>
<tr><td>PORTA
PORTB
PORTC</td><td>0000b - Pin disabled (analog)
0001b - Alternative 1 (GPIO)
0010b - Alternative 2 (chip-specific)
0011b - Alternative 3 (chip-specific)
0100b - Alternative 4 (chip-specific)
0101b - Alternative 5 (chip-specific)
0110b - Alternative 6 (chip-specific)
0111b - Alternative 7 (chip-specific)
1000b - Alternative 8 (chip-specific)
1001b - Alternative 9 (chip-specific)
1010b - Alternative 10 (chip-specific)
1011b - Alternative 11 (chip-specific)</td></tr>
<tr><td>PORTD</td><td>0000b - Pin disabled (analog)
0001b - Alternative 1 (GPIO)
0010b - Alternative 2 (chip-specific)
0011b - Alternative 3 (chip-specific)
0100b - Alternative 4 (chip-specific)
0101b - Alternative 5 (chip-specific)
0110b - Alternative 6 (chip-specific)
0111b - Alternative 7 (chip-specific)
1000b - Alternative 8 (chip-specific)
1001b - Alternative 9 (chip-specific)</td></tr>
</table>
</td></tr>
<tr><td>7
—</td><td>Reserved</td></tr>
<tr><td>6
DSE</td><td>Drive Strength Enable
Configures drive strength, low or high, on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>

When this field = 0, low drive strength is configured on the corresponding pin, if the pin is configured as a digital output.
When this field = 1, high drive strength is configured on the corresponding pin, if the pin is configured as a digital output.

NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR3</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR3</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR3</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR3</td></tr>
</table>
0b - Low
1b - High
</td></tr>
<tr><td>5
ODE</td><td>Open Drain Enable
Enables open drain output on each pin.
The open drain configuration is valid for all digital pin multiplexing modes.

When this field = 0, the open drain output is disabled on the corresponding pin.
When this field = 1, the open drain output is enabled on the corresponding pin, if the pin is configured as a digital output.

0b - Disables
1b - Enables</td></tr>
<tr><td>4
PFE</td><td>Passive Filter Enable
Enables passive input filter on each pin.
The passive filter configuration is valid for all digital pin multiplexing modes.

When this field = 0, the passive input filter is disabled on the corresponding pin.
When this field = 1, the passive input filter is enabled on the corresponding pin, if the pin is configured as a digital input.

See the chip's data sheet for filter characteristics.
NOTE
This field is not supported in every instance. The following table includes only supported registers.</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>—</td><td>PCR3</td></tr>
<tr><td>PORTB</td><td>—</td><td>PCR3</td></tr>
<tr><td>PORTC</td><td>—</td><td>PCR3</td></tr>
<tr><td>PORTD</td><td>PCR3</td><td>—</td></tr>
</table>
0b - Disables
1b - Enables
</td></tr>
<tr><td>3
SRE</td><td>Slew Rate Enable
Configures the slew rate feature, fast or slow, on each corresponding pin.
The slew rate configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR3</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR3</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR3</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR3</td></tr>
</table>
0b - Fast
1b - Slow
</td></tr>
<tr><td>2
PV</td><td>Pull Value
Selects high or low internal pull resistor value.
The pull value configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function
	<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>—</td><td>PCR3</td></tr><tr><td>PORTB</td><td>—</td><td>PCR3</td></tr><tr><td>PORTC</td><td>—</td><td>PCR3</td></tr><tr><td>PORTD</td><td>PCR3</td><td>—</td></tr></table> 0b - Low 1b - High
1 PE	Pull Enable Enables the internal pull resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pull resistor is not enabled on the corresponding pin. • When this field = 1, the internal pull resistor is enabled on the corresponding pin, if the pin is configured as a digital input. 0b - Disables 1b - Enables
0 PS	Pull Select Enables the internal pullup or pulldown resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pulldown resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. • When this field = 1, the internal pullup resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. 0b - Enables internal pulldown resistor 1b - Enables internal pullup resistor

19.6.1.15 Pin Control 4 (PCR4)

Offset

Register	Offset
PCR4	90h

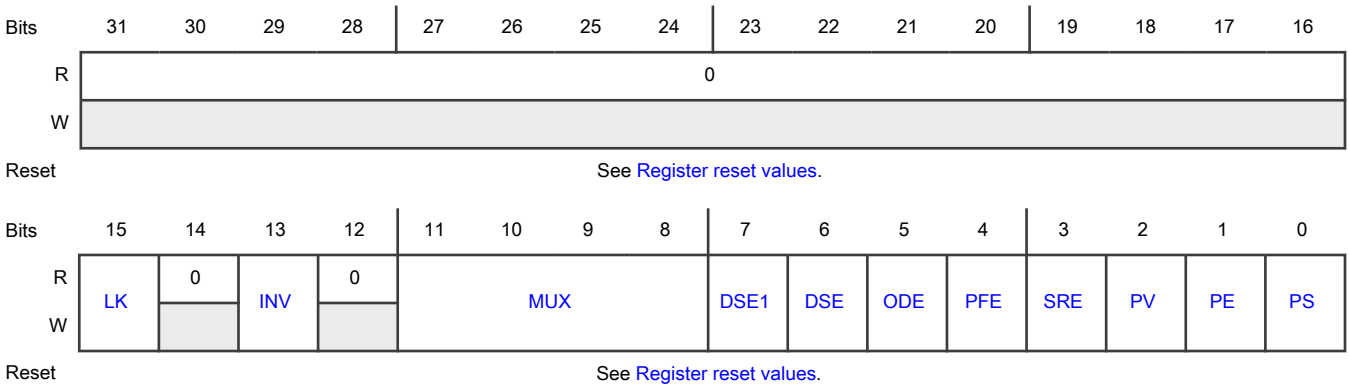
Function

Configures pin control features on each pin.

NOTE

Do not modify pin configuration registers associated with pins that are unavailable in your selected package. All unbonded pins unavailable in your package default to the Disabled state for lowest power consumption.

Diagram



Register reset values

Register	Reset value
PCR4	PORTA: 0000_0702h PORTB–PORTD: 0000_0000h

Fields

Field	Function
31-16 —	Reserved
15 LK	Lock Register Locks this PCR. When a PCR*n* is locked, its fields cannot be updated until the next reset. 0b - Does not lock 1b - Locks
14 —	Reserved
13 INV	Invert Input Inverts the digital input.

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR4</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR4</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR4</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR4</td></tr>
</table>
0b - Does not invert
1b - Inverts
</td></tr>
<tr><td>12
—</td><td>Reserved</td></tr>
<tr><td>11-8
MUX</td><td>
Pin Multiplex Control
Configures the multiplexing slots on each pin.
Not all pins support all pin multiplexing slots. Unimplemented pin multiplexing slots are reserved.
Unimplemented pin multiplexing slots can result in different behaviors, if the unimplemented slot is phantomed (because the module is phantomed on that die) versus unimplemented on the die.
The corresponding pin is configured according to the following pin multiplexing slots:
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR4[10–8]</td><td>PCR4[11]</td></tr>
<tr><td>PORTB</td><td>PCR4</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR4</td><td>—</td></tr>
<tr><td>PORTD</td><td>PCR4</td><td>—</td></tr>
</table>
NOTE
The descriptions of the field settings vary by module instance.
</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function	
	Instance	Field value and description
	PORTA	000b - Pin disabled (analog) 001b - Alternative 1 (GPIO) 010b - Alternative 2 (chip-specific) 011b - Alternative 3 (chip-specific) 100b - Alternative 4 (chip-specific) 101b - Alternative 5 (chip-specific) 110b - Alternative 6 (chip-specific) 111b - Alternative 7 (chip-specific)
	PORTB PORTC	0000b - Pin disabled (analog) 0001b - Alternative 1 (GPIO) 0010b - Alternative 2 (chip-specific) 0011b - Alternative 3 (chip-specific) 0100b - Alternative 4 (chip-specific) 0101b - Alternative 5 (chip-specific) 0110b - Alternative 6 (chip-specific) 0111b - Alternative 7 (chip-specific) 1000b - Alternative 8 (chip-specific) 1001b - Alternative 9 (chip-specific) 1010b - Alternative 10 (chip-specific) 1011b - Alternative 11 (chip-specific)
	PORTD	0000b - Pin disabled (analog) 0001b - Alternative 1 (GPIO) 0010b - Alternative 2 (chip-specific) 0011b - Alternative 3 (chip-specific) 0100b - Alternative 4 (chip-specific) 0101b - Alternative 5 (chip-specific) 0110b - Alternative 6 (chip-specific) 0111b - Alternative 7 (chip-specific) 1000b - Alternative 8 (chip-specific) 1001b - Alternative 9 (chip-specific)

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>7
DSE1</td><td>Drive Strength Enable
Configures the drive strength on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.
• If this field = 0, normal drive strength is configured on the corresponding pin.
• If this field = 1, double drive strength is configured on the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>—</td><td>PCR4</td></tr><tr><td>PORTB</td><td>—</td><td>PCR4</td></tr><tr><td>PORTC</td><td>PCR4</td><td>—</td></tr><tr><td>PORTD</td><td>—</td><td>PCR4</td></tr></table>
0b - Normal
1b - Double</td></tr>
<tr><td>6
DSE</td><td>Drive Strength Enable
Configures drive strength, low or high, on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.
• When this field = 0, low drive strength is configured on the corresponding pin, if the pin is configured as a digital output.
• When this field = 1, high drive strength is configured on the corresponding pin, if the pin is configured as a digital output.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>PCR4</td><td>—</td></tr><tr><td>PORTB</td><td>PCR4</td><td>—</td></tr><tr><td>PORTC</td><td>PCR4</td><td>—</td></tr></table></td></tr>
</table>

Table continues on the next page...

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<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTD</td><td>—</td><td>PCR4</td></tr>
</table>
0b - Low
1b - High
</td></tr>
<tr><td>5
ODE</td><td>Open Drain Enable
Enables open drain output on each pin.
The open drain configuration is valid for all digital pin multiplexing modes.
• When this field = 0, the open drain output is disabled on the corresponding pin.
• When this field = 1, the open drain output is enabled on the corresponding pin, if the pin is configured as a digital output.
0b - Disables
1b - Enables</td></tr>
<tr><td>4
PFE</td><td>Passive Filter Enable
Enables passive input filter on each pin.
The passive filter configuration is valid for all digital pin multiplexing modes.
• When this field = 0, the passive input filter is disabled on the corresponding pin.
• When this field = 1, the passive input filter is enabled on the corresponding pin, if the pin is configured as a digital input.
See the chip's data sheet for filter characteristics.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>—</td><td>PCR4</td></tr>
<tr><td>PORTB</td><td>PCR4</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR4</td><td>—</td></tr>
<tr><td>PORTD</td><td>PCR4</td><td>—</td></tr>
</table>
0b - Disables
1b - Enables
</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>3
SRE</td><td>Slew Rate Enable
Configures the slew rate feature, fast or slow, on each corresponding pin.
The slew rate configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>PCR4</td><td>—</td></tr><tr><td>PORTB</td><td>PCR4</td><td>—</td></tr><tr><td>PORTC</td><td>PCR4</td><td>—</td></tr><tr><td>PORTD</td><td>—</td><td>PCR4</td></tr></table>
0b - Fast
1b - Slow</td></tr>
<tr><td>2
PV</td><td>Pull Value
Selects high or low internal pull resistor value.
The pull value configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>—</td><td>PCR4</td></tr><tr><td>PORTB</td><td>PCR4</td><td>—</td></tr><tr><td>PORTC</td><td>—</td><td>PCR4</td></tr><tr><td>PORTD</td><td>PCR4</td><td>—</td></tr></table>
0b - Low
1b - High</td></tr>
<tr><td>1</td><td>Pull Enable</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function
PE	Enables the internal pull resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pull resistor is not enabled on the corresponding pin. • When this field = 1, the internal pull resistor is enabled on the corresponding pin, if the pin is configured as a digital input. 0b - Disables 1b - Enables
0 PS	Pull Select Enables the internal pullup or pulldown resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pulldown resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. • When this field = 1, the internal pullup resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. 0b - Enables internal pulldown resistor 1b - Enables internal pullup resistor

19.6.1.16 Pin Control 5 (PCR5)

Offset

Register	Offset
PCR5	94h

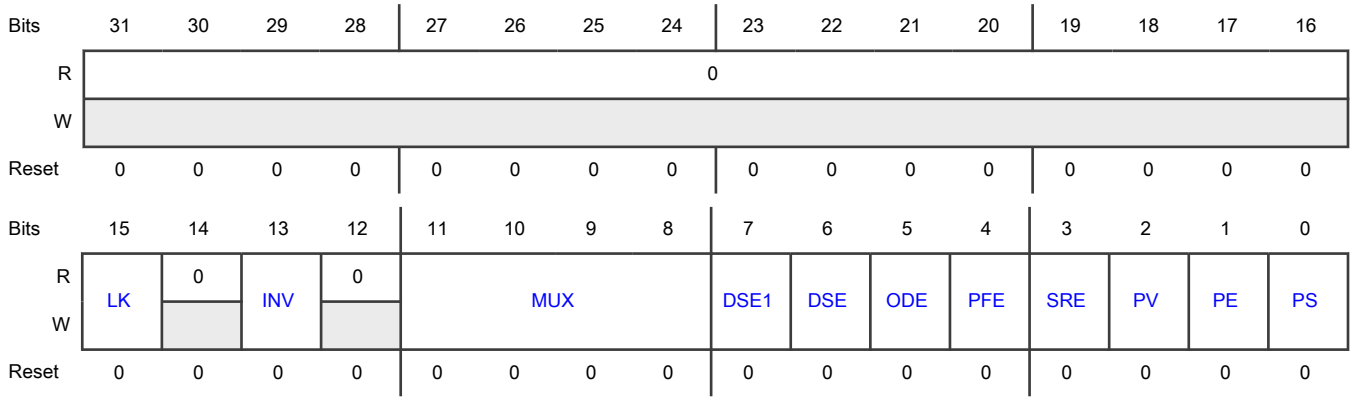
Function

Configures pin control features on each pin.

NOTE

Do not modify pin configuration registers associated with pins that are unavailable in your selected package. All unbonded pins unavailable in your package default to the Disabled state for lowest power consumption.

Diagram



Fields

Field	Function
31-16 —	Reserved
15 LK	Lock Register Locks this PCR. When a PCR*n* is locked, its fields cannot be updated until the next reset. 0b - Does not lock 1b - Locks
14 —	Reserved
13 INV	Invert Input Inverts the digital input. **NOTE** This field is not supported in every instance. The following table includes only supported registers. 0b - Does not invert

Instance	Field supported in	Field not supported in
PORTA	PCR5	—
PORTB	PCR5	—
PORTC	PCR5	—
PORTD	—	PCR5

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>1b - Inverts</td></tr>
<tr><td>12
—</td><td>Reserved</td></tr>
<tr><td>11-8
MUX</td><td>Pin Multiplex Control
Configures the multiplexing slots on each pin.
Not all pins support all pin multiplexing slots. Unimplemented pin multiplexing slots are reserved.
Unimplemented pin multiplexing slots can result in different behaviors, if the unimplemented slot is phantomed (because the module is phantomed on that die) versus unimplemented on the die.
The corresponding pin is configured according to the following pin multiplexing slots:
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR5</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR5</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR5</td><td>—</td></tr>
<tr><td>PORTD</td><td>PCR5[9–8]</td><td>PCR5[11–10]</td></tr>
</table>
NOTE
The descriptions of the field settings vary by module instance.
<table>
<tr><th>Instance</th><th>Field value and description</th></tr>
<tr><td>PORTA
PORTB
PORTC</td><td>0000b - Pin disabled (analog)
0001b - Alternative 1 (GPIO)
0010b - Alternative 2 (chip-specific)
0011b - Alternative 3 (chip-specific)
0100b - Alternative 4 (chip-specific)
0101b - Alternative 5 (chip-specific)
0110b - Alternative 6 (chip-specific)
0111b - Alternative 7 (chip-specific)
1000b - Alternative 8 (chip-specific)</td></tr>
</table>
</td></tr>
</table>

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field value and description</th></tr>
<tr><td></td><td>1001b - Alternative 9 (chip-specific)
1010b - Alternative 10 (chip-specific)
1011b - Alternative 11 (chip-specific)</td></tr>
<tr><td>PORTD</td><td>00b - Pin disabled (analog)
01b - Alternative 1 (GPIO)
10b - Alternative 2 (chip-specific)
11b - Alternative 3 (chip-specific)</td></tr>
</table>
</td></tr>
<tr><td>7
DSE1</td><td>Drive Strength Enable
Configures the drive strength on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.
• If this field = 0, normal drive strength is configured on the corresponding pin.
• If this field = 1, double drive strength is configured on the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>—</td><td>PCR5</td></tr>
<tr><td>PORTB</td><td>—</td><td>PCR5</td></tr>
<tr><td>PORTC</td><td>PCR5</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR5</td></tr>
</table>
0b - Normal
1b - Double</td></tr>
<tr><td>6
DSE</td><td>Drive Strength Enable
Configures drive strength, low or high, on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.
• When this field = 0, low drive strength is configured on the corresponding pin, if the pin is configured as a digital output.</td></tr>
</table>

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<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
When this field = 1, high drive strength is configured on the corresponding pin, if the pin is configured as a digital output.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR5</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR5</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR5</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR5</td></tr>
</table>
0b - Low
1b - High
</td></tr>
<tr><td>5
ODE</td><td>Open Drain Enable
Enables open drain output on each pin.
The open drain configuration is valid for all digital pin multiplexing modes.
When this field = 0, the open drain output is disabled on the corresponding pin.
When this field = 1, the open drain output is enabled on the corresponding pin, if the pin is configured as a digital output.
0b - Disables
1b - Enables</td></tr>
<tr><td>4
PFE</td><td>Passive Filter Enable
Enables passive input filter on each pin.
The passive filter configuration is valid for all digital pin multiplexing modes.
When this field = 0, the passive input filter is disabled on the corresponding pin.
When this field = 1, the passive input filter is enabled on the corresponding pin, if the pin is configured as a digital input.
See the chip's data sheet for filter characteristics.
NOTE
This field is not supported in every instance. The following table includes only supported registers.</td></tr>
</table>

Table continues on the next page...

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<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>—</td><td>PCR5</td></tr>
<tr><td>PORTB</td><td>PCR5</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR5</td><td>—</td></tr>
<tr><td>PORTD</td><td>PCR5</td><td>—</td></tr>
</table>
0b - Disables
1b - Enables
</td></tr>
<tr><td>3
SRE</td><td>Slew Rate Enable
Configures the slew rate feature, fast or slow, on each corresponding pin.
The slew rate configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR5</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR5</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR5</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR5</td></tr>
</table>
0b - Fast
1b - Slow
</td></tr>
<tr><td>2
PV</td><td>Pull Value
Selects high or low internal pull resistor value.
The pull value configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function
	<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>—</td><td>PCR5</td></tr><tr><td>PORTB</td><td>—</td><td>PCR5</td></tr><tr><td>PORTC</td><td>—</td><td>PCR5</td></tr><tr><td>PORTD</td><td>PCR5</td><td>—</td></tr></table> 0b - Low 1b - High
1 PE	Pull Enable Enables the internal pull resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pull resistor is not enabled on the corresponding pin. • When this field = 1, the internal pull resistor is enabled on the corresponding pin, if the pin is configured as a digital input. 0b - Disables 1b - Enables
0 PS	Pull Select Enables the internal pullup or pulldown resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pulldown resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. • When this field = 1, the internal pullup resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. 0b - Enables internal pulldown resistor 1b - Enables internal pullup resistor

19.6.1.17 Pin Control a (PCR6 - PCR10)

Offset

Register	Offset
PCR6	98h
PCR7	9Ch

Table continues on the next page...

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Register	Offset
PCR8	A0h
PCR9	A4h
PCR10	A8h

Function

Configures pin control features on each pin.

NOTE

Do not modify pin configuration registers associated with pins that are unavailable in your selected package. All unbonded pins unavailable in your package default to the Disabled state for lowest power consumption.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	LK	0	INV	0	MUX				0	DSE	ODE	PFE	SRE	PV	PE	PS
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-16 —	Reserved
15 LK	Lock Register Locks this PCR. When a PCR*n* is locked, its fields cannot be updated until the next reset. 0b - Does not lock 1b - Locks
14 —	Reserved
13	Invert Input

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>INV</td><td>Inverts the digital input.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>PCR6–PCR10</td><td>—</td></tr><tr><td>PORTB</td><td>PCR6–PCR10</td><td>—</td></tr><tr><td>PORTC</td><td>PCR6–PCR10</td><td>—</td></tr><tr><td>PORTD</td><td>—</td><td>PCR6–PCR10</td></tr></table>0b - Does not invert
1b - Inverts</td></tr>
<tr><td>12
—</td><td>Reserved</td></tr>
<tr><td>11-8
MUX</td><td>Pin Multiplex Control
Configures the multiplexing slots on each pin.
Not all pins support all pin multiplexing slots. Unimplemented pin multiplexing slots are reserved.
Unimplemented pin multiplexing slots can result in different behaviors, if the unimplemented slot is phantomed (because the module is phantomed on that die) versus unimplemented on the die.
The corresponding pin is configured according to the following pin multiplexing slots:
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>PCR6–PCR10</td><td>—</td></tr><tr><td>PORTB</td><td>PCR6–PCR10</td><td>—</td></tr><tr><td>PORTC</td><td>PCR6–PCR10</td><td>—</td></tr><tr><td>PORTD</td><td>PCR6–PCR10[10–8]</td><td>PCR6–PCR10[11]</td></tr></table></td></tr>
</table>

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<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
NOTE
The descriptions of the field settings vary by module instance.
<table>
<tr><th>Instance</th><th>Field value and description</th></tr>
<tr><td>PORTA
PORTB
PORTC</td><td>0000b - Pin disabled (analog)
0001b - Alternative 1 (GPIO)
0010b - Alternative 2 (chip-specific)
0011b - Alternative 3 (chip-specific)
0100b - Alternative 4 (chip-specific)
0101b - Alternative 5 (chip-specific)
0110b - Alternative 6 (chip-specific)
0111b - Alternative 7 (chip-specific)
1000b - Alternative 8 (chip-specific)
1001b - Alternative 9 (chip-specific)
1010b - Alternative 10 (chip-specific)
1011b - Alternative 11 (chip-specific)</td></tr>
<tr><td>PORTD</td><td>000b - Pin disabled (analog)
001b - Alternative 1 (GPIO)
010b - Alternative 2 (chip-specific)
011b - Alternative 3 (chip-specific)
100b - Alternative 4 (chip-specific)
101b - Alternative 5 (chip-specific)
110b - Alternative 6 (chip-specific)
111b - Alternative 7 (chip-specific)</td></tr>
</table>
</td></tr>
<tr><td>7
—</td><td>Reserved</td></tr>
<tr><td>6
DSE</td><td>Drive Strength Enable
Configures drive strength, low or high, on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.
• When this field = 0, low drive strength is configured on the corresponding pin, if the pin is configured as a digital output.</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
• When this field = 1, high drive strength is configured on the corresponding pin, if the pin is configured as a digital output.

NOTE
This field is not supported in every instance. The following table includes only supported registers.

<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR6–PCR10</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR6–PCR10</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR6–PCR10</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR6–PCR10</td></tr>
</table>

0b - Low
1b - High
</td></tr>
<tr><td>5
ODE</td><td>
Open Drain Enable
Enables open drain output on each pin.
The open drain configuration is valid for all digital pin multiplexing modes.
• When this field = 0, the open drain output is disabled on the corresponding pin.
• When this field = 1, the open drain output is enabled on the corresponding pin, if the pin is configured as a digital output.
0b - Disables
1b - Enables
</td></tr>
<tr><td>4
PFE</td><td>
Passive Filter Enable
Enables passive input filter on each pin.
The passive filter configuration is valid for all digital pin multiplexing modes.
• When this field = 0, the passive input filter is disabled on the corresponding pin.
• When this field = 1, the passive input filter is enabled on the corresponding pin, if the pin is configured as a digital input.
See the chip's data sheet for filter characteristics.

NOTE
This field is not supported in every instance. The following table includes only supported registers.
</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>—</td><td>PCR6–PCR10</td></tr>
<tr><td>PORTB</td><td>—</td><td>PCR6–PCR10</td></tr>
<tr><td>PORTC</td><td>—</td><td>PCR6–PCR10</td></tr>
<tr><td>PORTD</td><td>PCR6–PCR10</td><td>—</td></tr>
</table>
0b - Disables
1b - Enables</td></tr>
<tr><td>3
SRE</td><td>Slew Rate Enable
Configures the slew rate feature, fast or slow, on each corresponding pin.
The slew rate configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR6–PCR10</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR6–PCR10</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR6–PCR10</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR6–PCR10</td></tr>
</table>
0b - Fast
1b - Slow</td></tr>
<tr><td>2
PV</td><td>Pull Value
Selects high or low internal pull resistor value.
The pull value configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function
	<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>—</td><td>PCR6–PCR10</td></tr><tr><td>PORTB</td><td>—</td><td>PCR6–PCR10</td></tr><tr><td>PORTC</td><td>—</td><td>PCR6–PCR10</td></tr><tr><td>PORTD</td><td>PCR6–PCR10</td><td>—</td></tr></table> 0b - Low 1b - High
1 PE	Pull Enable Enables the internal pull resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pull resistor is not enabled on the corresponding pin. • When this field = 1, the internal pull resistor is enabled on the corresponding pin, if the pin is configured as a digital input. 0b - Disables 1b - Enables
0 PS	Pull Select Enables the internal pullup or pulldown resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pulldown resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. • When this field = 1, the internal pullup resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. 0b - Enables internal pulldown resistor 1b - Enables internal pullup resistor

19.6.1.18 Pin Control 11 (PCR11)

Offset

Register	Offset
PCR11	ACh

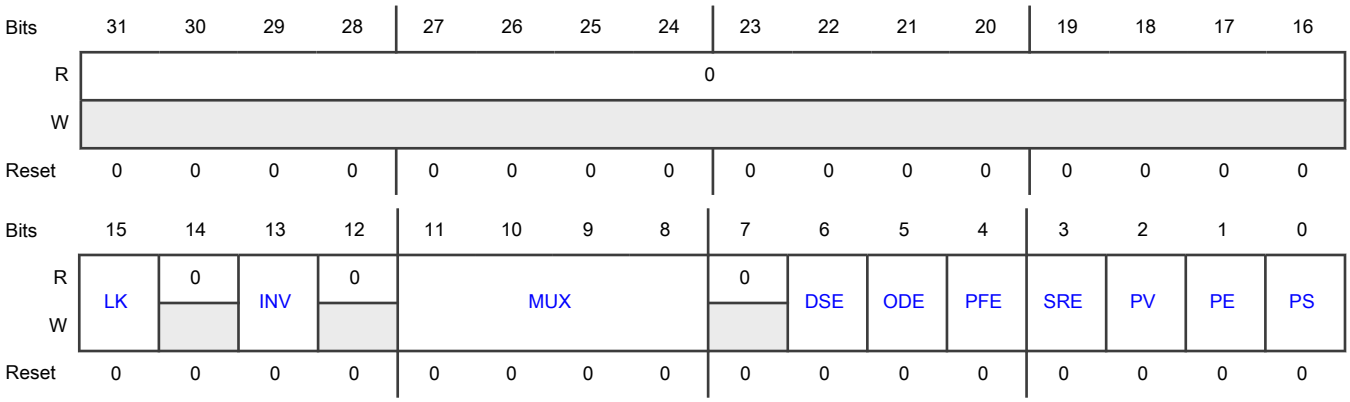
Function

Configures pin control features on each pin.

NOTE

Do not modify pin configuration registers associated with pins that are unavailable in your selected package. All unbonded pins unavailable in your package default to the Disabled state for lowest power consumption.

Diagram



Fields

Field	Function
31-16 —	Reserved
15 LK	Lock Register Locks this PCR. When a PCR*n* is locked, its fields cannot be updated until the next reset. 0b - Does not lock 1b - Locks
14 —	Reserved
13 INV	Invert Input Inverts the digital input. **NOTE** This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
PORTA	PCR11	—

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTB</td><td>PCR11</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR11</td><td>—</td></tr>
<tr><td>PORTD</td><td>—</td><td>PCR11</td></tr>
</table>
0b - Does not invert
1b - Inverts
</td></tr>
<tr><td>12
—</td><td>Reserved</td></tr>
<tr><td>11-8
MUX</td><td>Pin Multiplex Control
Configures the multiplexing slots on each pin.
Not all pins support all pin multiplexing slots. Unimplemented pin multiplexing slots are reserved.
Unimplemented pin multiplexing slots can result in different behaviors, if the unimplemented slot is phantomed (because the module is phantomed on that die) versus unimplemented on the die.
The corresponding pin is configured according to the following pin multiplexing slots:
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR11</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR11</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR11</td><td>—</td></tr>
<tr><td>PORTD</td><td>PCR11[8]</td><td>PCR11[11–9]</td></tr>
</table>
NOTE
The descriptions of the field settings vary by module instance.
<table>
<tr><th>Instance</th><th>Field value and description</th></tr>
<tr><td>PORTA
PORTB
PORTC</td><td>0000b - Pin disabled (analog)
0001b - Alternative 1 (GPIO)</td></tr>
</table>
</td></tr>
</table>

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field value and description</th></tr>
<tr><td></td><td>0010b - Alternative 2 (chip-specific)
0011b - Alternative 3 (chip-specific)
0100b - Alternative 4 (chip-specific)
0101b - Alternative 5 (chip-specific)
0110b - Alternative 6 (chip-specific)
0111b - Alternative 7 (chip-specific)
1000b - Alternative 8 (chip-specific)
1001b - Alternative 9 (chip-specific)
1010b - Alternative 10 (chip-specific)
1011b - Alternative 11 (chip-specific)</td></tr>
<tr><td>PORTD</td><td>0b - Pin disabled (analog)
1b - Alternative 1 (GPIO)</td></tr>
</table>
</td></tr>
<tr><td>7
—</td><td>Reserved</td></tr>
<tr><td>6
DSE</td><td>Drive Strength Enable
Configures drive strength, low or high, on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.
• When this field = 0, low drive strength is configured on the corresponding pin, if the pin is configured as a digital output.
• When this field = 1, high drive strength is configured on the corresponding pin, if the pin is configured as a digital output.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>PCR11</td><td>—</td></tr>
<tr><td>PORTB</td><td>PCR11</td><td>—</td></tr>
<tr><td>PORTC</td><td>PCR11</td><td>—</td></tr>
</table>
</td></tr>
</table>

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<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTD</td><td>—</td><td>PCR11</td></tr>
</table>
0b - Low
1b - High
</td></tr>
<tr><td>5
ODE</td><td>Open Drain Enable
Enables open drain output on each pin.
The open drain configuration is valid for all digital pin multiplexing modes.
• When this field = 0, the open drain output is disabled on the corresponding pin.
• When this field = 1, the open drain output is enabled on the corresponding pin, if the pin is configured as a digital output.
0b - Disables
1b - Enables</td></tr>
<tr><td>4
PFE</td><td>Passive Filter Enable
Enables passive input filter on each pin.
The passive filter configuration is valid for all digital pin multiplexing modes.
• When this field = 0, the passive input filter is disabled on the corresponding pin.
• When this field = 1, the passive input filter is enabled on the corresponding pin, if the pin is configured as a digital input.
See the chip's data sheet for filter characteristics.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>PORTA</td><td>—</td><td>PCR11</td></tr>
<tr><td>PORTB</td><td>—</td><td>PCR11</td></tr>
<tr><td>PORTC</td><td>—</td><td>PCR11</td></tr>
<tr><td>PORTD</td><td>PCR11</td><td>—</td></tr>
</table>
0b - Disables
1b - Enables
</td></tr>
</table>

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<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>3
SRE</td><td>Slew Rate Enable
Configures the slew rate feature, fast or slow, on each corresponding pin.
The slew rate configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>PCR11</td><td>—</td></tr><tr><td>PORTB</td><td>PCR11</td><td>—</td></tr><tr><td>PORTC</td><td>PCR11</td><td>—</td></tr><tr><td>PORTD</td><td>—</td><td>PCR11</td></tr></table>
0b - Fast
1b - Slow</td></tr>
<tr><td>2
PV</td><td>Pull Value
Selects high or low internal pull resistor value.
The pull value configuration is valid for all digital pin multiplexing modes.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>—</td><td>PCR11</td></tr><tr><td>PORTB</td><td>—</td><td>PCR11</td></tr><tr><td>PORTC</td><td>—</td><td>PCR11</td></tr><tr><td>PORTD</td><td>PCR11</td><td>—</td></tr></table>
0b - Low
1b - High</td></tr>
<tr><td>1</td><td>Pull Enable</td></tr>
</table>

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Field	Function
PE	Enables the internal pull resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pull resistor is not enabled on the corresponding pin. • When this field = 1, the internal pull resistor is enabled on the corresponding pin, if the pin is configured as a digital input. 0b - Disables 1b - Enables
0 PS	Pull Select Enables the internal pullup or pulldown resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pulldown resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. • When this field = 1, the internal pullup resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. 0b - Enables internal pulldown resistor 1b - Enables internal pullup resistor

19.6.1.19 Pin Control a (PCR12 - PCR17)

Offset

Register	Offset
PCR12	B0h
PCR13	B4h
PCR14	B8h
PCR15	BCh
PCR16	C0h
PCR17	C4h

Function

Configures pin control features on each pin.

NOTE

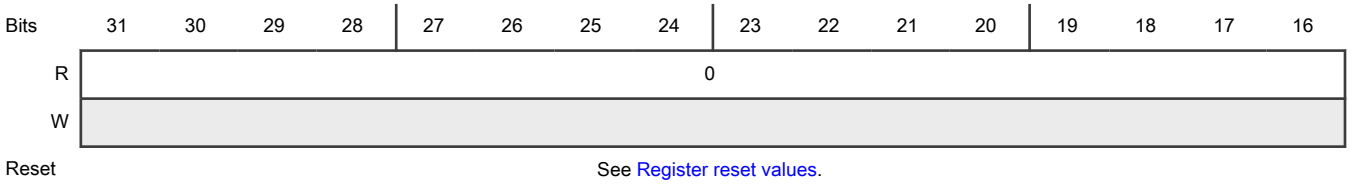
Do not modify pin configuration registers associated with pins that are unavailable in your selected package. All unbonded pins unavailable in your package default to the Disabled state for lowest power consumption.

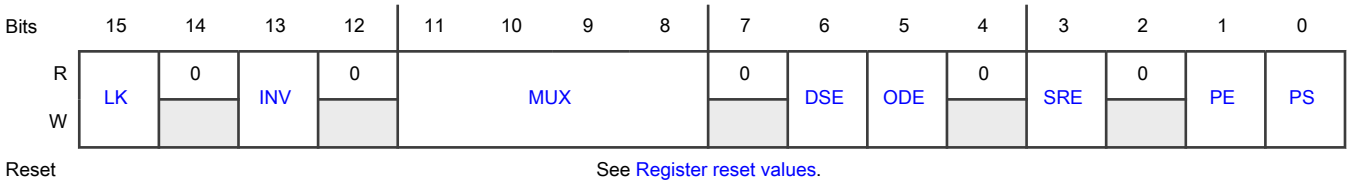
NOTE

Each module instance supports a different number of registers.

Instance	Register supported	Register not supported
PORTA	PCR16–PCR17	PCR12–PCR15
PORTB	—	PCR12–PCR17
PORTC	PCR12–PCR17	—
PORTD	—	PCR12–PCR17

Diagram





Register reset values

Register	Reset value
PCR12–PCR15	0000_0000h
PCR16–PCR17	PORTA: 0000_0000h PORTB: Register not supported PORTC: 0000_0000h PORTD: Register not supported

Fields

Field	Function
31-16 —	Reserved
15 LK	Lock Register Locks this PCR. When a PCR*n* is locked, its fields cannot be updated until the next reset. 0b - Does not lock

Table continues on the next page...

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Field	Function
	1b - Locks
14 —	Reserved
13 INV	Invert Input Inverts the digital input. 0b - Does not invert 1b - Inverts
12 —	Reserved
11-8 MUX	Pin Multiplex Control Configures the multiplexing slots on each pin. Not all pins support all pin multiplexing slots. Unimplemented pin multiplexing slots are reserved. Unimplemented pin multiplexing slots can result in different behaviors, if the unimplemented slot is phantomed (because the module is phantomed on that die) versus unimplemented on the die. The corresponding pin is configured according to the following pin multiplexing slots: 0000b - Pin disabled (analog) 0001b - Alternative 1 (GPIO) 0010b - Alternative 2 (chip-specific) 0011b - Alternative 3 (chip-specific) 0100b - Alternative 4 (chip-specific) 0101b - Alternative 5 (chip-specific) 0110b - Alternative 6 (chip-specific) 0111b - Alternative 7 (chip-specific) 1000b - Alternative 8 (chip-specific) 1001b - Alternative 9 (chip-specific) 1010b - Alternative 10 (chip-specific) 1011b - Alternative 11 (chip-specific)
7 —	Reserved
6 DSE	Drive Strength Enable Configures drive strength, low or high, on each pin. The drive strength configuration is valid for all digital pin multiplexing modes.

Table continues on the next page...

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Field	Function
	• When this field = 0, low drive strength is configured on the corresponding pin, if the pin is configured as a digital output. • When this field = 1, high drive strength is configured on the corresponding pin, if the pin is configured as a digital output. 0b - Low 1b - High
5 ODE	Open Drain Enable Enables open drain output on each pin. The open drain configuration is valid for all digital pin multiplexing modes. • When this field = 0, the open drain output is disabled on the corresponding pin. • When this field = 1, the open drain output is enabled on the corresponding pin, if the pin is configured as a digital output. 0b - Disables 1b - Enables
4 —	Reserved
3 SRE	Slew Rate Enable Configures the slew rate feature, fast or slow, on each corresponding pin. The slew rate configuration is valid for all digital pin multiplexing modes. 0b - Fast 1b - Slow
2 —	Reserved
1 PE	Pull Enable Enables the internal pull resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pull resistor is not enabled on the corresponding pin. • When this field = 1, the internal pull resistor is enabled on the corresponding pin, if the pin is configured as a digital input. 0b - Disables 1b - Enables
0 PS	Pull Select Enables the internal pullup or pulldown resistor.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pulldown resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. • When this field = 1, the internal pullup resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. 0b - Enables internal pulldown resistor 1b - Enables internal pullup resistor

19.6.1.20 Pin Control a (PCR18 - PCR19)

Offset

Register	Offset
PCR18	C8h
PCR19	CCh

Function

Configures pin control features on each pin.

NOTE

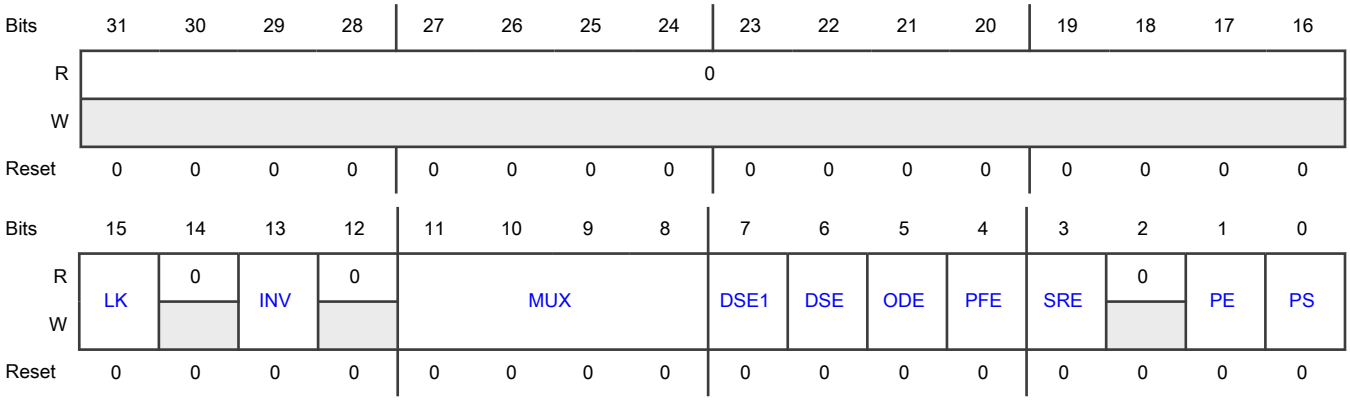
Do not modify pin configuration registers associated with pins that are unavailable in your selected package. All unbonded pins unavailable in your package default to the Disabled state for lowest power consumption.

NOTE

Each module instance supports a different number of registers.

Instance	Register supported	Register not supported
PORTA	PCR18–PCR19	—
PORTB	—	PCR18–PCR19
PORTC	PCR18–PCR19	—
PORTD	—	PCR18–PCR19

Diagram



Fields

Field	Function
31-16 —	Reserved
15 LK	Lock Register Locks this PCR. When a PCR*n* is locked, its fields cannot be updated until the next reset. 0b - Does not lock 1b - Locks
14 —	Reserved
13 INV	Invert Input Inverts the digital input. 0b - Does not invert 1b - Inverts
12 —	Reserved
11-8 MUX	Pin Multiplex Control Configures the multiplexing slots on each pin. Not all pins support all pin multiplexing slots. Unimplemented pin multiplexing slots are reserved. Unimplemented pin multiplexing slots can result in different behaviors, if the unimplemented slot is phantomed (because the module is phantomed on that die) versus unimplemented on the die. The corresponding pin is configured according to the following pin multiplexing slots:

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>0000b - Pin disabled (analog)
0001b - Alternative 1 (GPIO)
0010b - Alternative 2 (chip-specific)
0011b - Alternative 3 (chip-specific)
0100b - Alternative 4 (chip-specific)
0101b - Alternative 5 (chip-specific)
0110b - Alternative 6 (chip-specific)
0111b - Alternative 7 (chip-specific)
1000b - Alternative 8 (chip-specific)
1001b - Alternative 9 (chip-specific)
1010b - Alternative 10 (chip-specific)
1011b - Alternative 11 (chip-specific)</td></tr>
<tr><td>7
DSE1</td><td>Drive Strength Enable
Configures the drive strength on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.
• If this field = 0, normal drive strength is configured on the corresponding pin.
• If this field = 1, double drive strength is configured on the corresponding pin.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>PCR18–PCR19</td><td>—</td></tr><tr><td>PORTC</td><td>—</td><td>PCR18–PCR19</td></tr></table>
0b - Normal
1b - Double</td></tr>
<tr><td>6
DSE</td><td>Drive Strength Enable
Configures drive strength, low or high, on each pin.
The drive strength configuration is valid for all digital pin multiplexing modes.
• When this field = 0, low drive strength is configured on the corresponding pin, if the pin is configured as a digital output.
• When this field = 1, high drive strength is configured on the corresponding pin, if the pin is configured as a digital output.</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>0b - Low
1b - High</td></tr>
<tr><td>5
ODE</td><td>Open Drain Enable
Enables open drain output on each pin.
The open drain configuration is valid for all digital pin multiplexing modes.
• When this field = 0, the open drain output is disabled on the corresponding pin.
• When this field = 1, the open drain output is enabled on the corresponding pin, if the pin is configured as a digital output.
0b - Disables
1b - Enables</td></tr>
<tr><td>4
PFE</td><td>Passive Filter Enable
Enables passive input filter on each pin.
The passive filter configuration is valid for all digital pin multiplexing modes.
• When this field = 0, the passive input filter is disabled on the corresponding pin.
• When this field = 1, the passive input filter is enabled on the corresponding pin, if the pin is configured as a digital input.
See the chip's data sheet for filter characteristics.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>PORTA</td><td>PCR18–PCR19</td><td>—</td></tr><tr><td>PORTC</td><td>—</td><td>PCR18–PCR19</td></tr></table>
0b - Disables
1b - Enables</td></tr>
<tr><td>3
SRE</td><td>Slew Rate Enable
Configures the slew rate feature, fast or slow, on each corresponding pin.
The slew rate configuration is valid for all digital pin multiplexing modes.
0b - Fast
1b - Slow</td></tr>
<tr><td>2</td><td>Reserved</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
1 PE	Pull Enable Enables the internal pull resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pull resistor is not enabled on the corresponding pin. • When this field = 1, the internal pull resistor is enabled on the corresponding pin, if the pin is configured as a digital input. 0b - Disables 1b - Enables
0 PS	Pull Select Enables the internal pullup or pulldown resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pulldown resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. • When this field = 1, the internal pullup resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. 0b - Enables internal pulldown resistor 1b - Enables internal pullup resistor

19.6.1.21 Pin Control a (PCR20 - PCR27)

Offset

For a = 20 to 27:

Register	Offset
PCRa	80h + (a × 4h)

Function

Configures pin control features on each pin.

NOTE

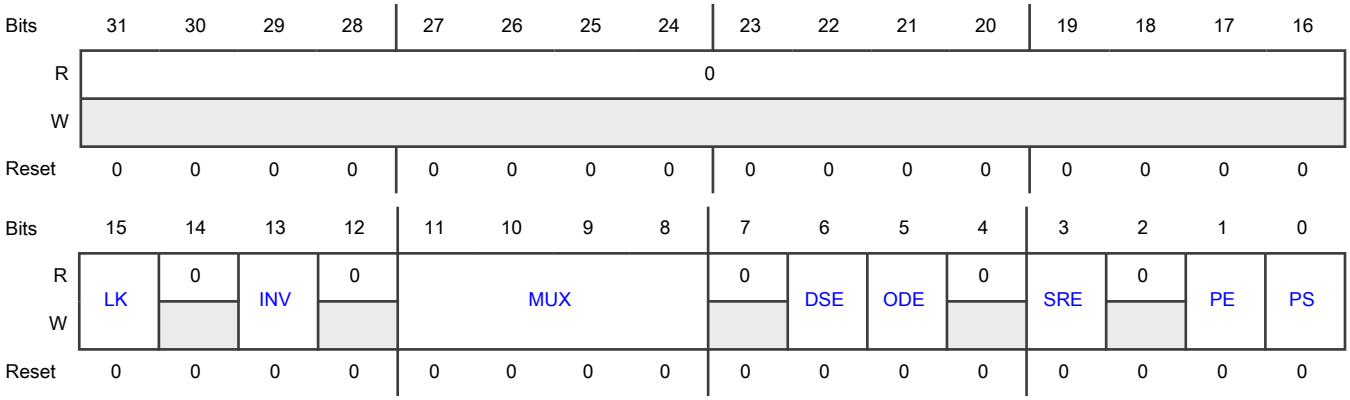
Do not modify pin configuration registers associated with pins that are unavailable in your selected package. All unbonded pins unavailable in your package default to the Disabled state for lowest power consumption.

NOTE

Each module instance supports a different number of registers.

Instance	Register supported	Register not supported
PORTA	PCR20–PCR27	—
PORTB	—	PCR20–PCR27
PORTC	—	PCR20–PCR27
PORTD	—	PCR20–PCR27

Diagram



Fields

Field	Function
31-16 —	Reserved
15 LK	Lock Register Locks this PCR. When a PCR*n* is locked, its fields cannot be updated until the next reset. 0b - Does not lock 1b - Locks
14 —	Reserved
13 INV	Invert Input Inverts the digital input. 0b - Does not invert 1b - Inverts
12	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
11-8 MUX	Pin Multiplex Control Configures the multiplexing slots on each pin. Not all pins support all pin multiplexing slots. Unimplemented pin multiplexing slots are reserved. Unimplemented pin multiplexing slots can result in different behaviors, if the unimplemented slot is phantomed (because the module is phantomed on that die) versus unimplemented on the die. The corresponding pin is configured according to the following pin multiplexing slots: 0000b - Pin disabled (analog) 0001b - Alternative 1 (GPIO) 0010b - Alternative 2 (chip-specific) 0011b - Alternative 3 (chip-specific) 0100b - Alternative 4 (chip-specific) 0101b - Alternative 5 (chip-specific) 0110b - Alternative 6 (chip-specific) 0111b - Alternative 7 (chip-specific) 1000b - Alternative 8 (chip-specific) 1001b - Alternative 9 (chip-specific) 1010b - Alternative 10 (chip-specific) 1011b - Alternative 11 (chip-specific)
7 —	Reserved
6 DSE	Drive Strength Enable Configures drive strength, low or high, on each pin. The drive strength configuration is valid for all digital pin multiplexing modes. • When this field = 0, low drive strength is configured on the corresponding pin, if the pin is configured as a digital output. • When this field = 1, high drive strength is configured on the corresponding pin, if the pin is configured as a digital output. 0b - Low 1b - High
5 ODE	Open Drain Enable Enables open drain output on each pin. The open drain configuration is valid for all digital pin multiplexing modes.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	• When this field = 0, the open drain output is disabled on the corresponding pin. • When this field = 1, the open drain output is enabled on the corresponding pin, if the pin is configured as a digital output. 0b - Disables 1b - Enables
4 —	Reserved
3 SRE	Slew Rate Enable Configures the slew rate feature, fast or slow, on each corresponding pin. The slew rate configuration is valid for all digital pin multiplexing modes. 0b - Fast 1b - Slow
2 —	Reserved
1 PE	Pull Enable Enables the internal pull resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pull resistor is not enabled on the corresponding pin. • When this field = 1, the internal pull resistor is enabled on the corresponding pin, if the pin is configured as a digital input. 0b - Disables 1b - Enables
0 PS	Pull Select Enables the internal pullup or pulldown resistor. This configuration is valid for all digital pin multiplexing modes. • When this field = 0, the internal pulldown resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. • When this field = 1, the internal pullup resistor is enabled on the corresponding pin, if the corresponding PCR*n*.PE field = 1. 0b - Enables internal pulldown resistor 1b - Enables internal pullup resistor

Chapter 20
General-purpose Input and Output (GPIO)

20.1 Chip-specific GPIO information

Table 193. Reference links to related information

Topic	Related module	Reference
Full description	GPIO	GPIO
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

20.1.1 Module instances

This device has four instances of the GPIO module, GPIOA, GPIOB, GPIOC, and GPIOD.

20.1.2 GPIO interrupts

For each GPIO module, two interrupt channels have been assigned. Refer to Interrupt channel assignments for more details.

20.2 Overview

GPIO communicates to the processor core via a zero wait-state interface for maximum pin performance.

20.2.1 Block diagram

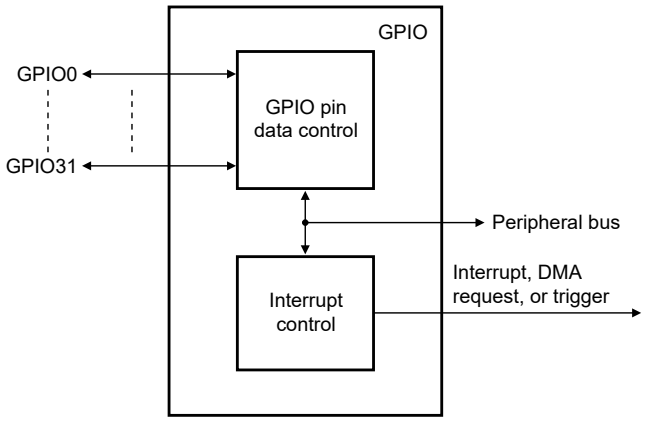


Figure 57. Block diagram

20.2.2 Features

- Port Data Input (PDIR) displays the logic value on each pin when the pin is configured for any digital function, provided the corresponding Port Control and Interrupt modules for that pin are enabled.
- Port Data Output (PDOR), with corresponding set, clear, and toggle registers, controls the output data of each pin when the pin is configured for the GPIO function.
- Port Data Direction (PDDR) controls the direction of each pin when the pin is configured for the GPIO function.

- Port Input Disable (PIDR) controls disabling of the input for each general-purpose pin.
- Pin interrupts:
  - Interrupt flags and enable registers for each pin are functional in all digital pin muxing modes.
  - Support for interrupt, peripheral trigger, or DMA request is configured for each pin.
  - Support for edge-sensitive (rising, falling, or both) or level-sensitive (low, high) interrupts is configured for each pin.
  - Asynchronous wake-up in Low-Power mode.
  - GPIO generates a total of 2 interrupts, 2 output triggers, and 2 DMA requests.
  - Each pin can be used to generate a single interrupt, output trigger, or DMA request.
- Protection registers:
  - Each pin is configured for secure or nonsecure and privileged or nonprivileged access.
  - Each interrupt, trigger, and DMA request domain is configured for secure or nonsecure and privileged or nonprivileged access.

20.3 Functional description

20.3.1 Low-Power mode

You can configure GPIO to exit Low-Power mode via an asynchronous wake-up signal if an enabled interrupt is detected.

20.3.2 Debug mode

GPIO remains functional in Debug mode.

20.3.3 General-purpose input

The logic state of each pin is available via Port Data Input (PDIR) if:

- The corresponding field in Port Input Disable (PIDR) is 0.
- The pin is configured for a digital function.

20.3.4 General-purpose output

The logic state of each pin is controlled via Port Data Output (PDOR) and Port Data Direction (PDDR), provided the pin is configured for the GPIO function. The following table depicts the conditions for a pin to be configured as input or output.

Table 194. General-purpose output

If	Then
A pin is configured for the GPIO function and the corresponding PDDR field is 0	The pin is configured as an input.
A pin is configured for the GPIO function and the corresponding PDDR field is 1	The pin is configured as an output and the logic state of the pin is equal to the corresponding PDOR field.

For efficient bit manipulation on the general-purpose outputs, pin data set, pin data clear, and pin data toggle registers allow one or more outputs within one port to be set, cleared, or toggled from a single register write, eliminating the need for a read-modify-write operation to prevent changing pins accidentally.

20.3.5 Clocking

GPIO receives a single clock, which is used for register access and synchronization with external pin inputs. There are no special considerations.

20.3.6 Reset

GPIO receives a single reset, which resets the peripheral. There are no special considerations.

20.3.7 External interrupts

The external interrupt capability of GPIO is available in all digital pin muxing modes.

GPIO generates a total of 2 interrupts, 2 output triggers, and 2 DMA requests. You can configure each pin individually for interrupt, output trigger, or DMA requests:

- Each output implements a separate interrupt status flag (ISF) register for that domain.
- Each output generates a single interrupt.
- Each output generates a single DMA request.
- Each output generates a single peripheral trigger output.

You can configure each pin individually for any of the external interrupt modes shown in the following table.

Table 195. Available pin configurations for external interrupts

Signal conditions	Software polling using flags	Peripheral triggers	Interrupts	DMA requests
Rising-edge	Yes	—	Yes	Yes
Falling-edge	Yes	—	Yes	Yes
Rising- and falling-edge	Yes	—	Yes	Yes
High-level	—	Yes	Yes	—
Low-level	—	Yes	Yes	—

The interrupt status flag is set when the configured edge or level is detected on the pin. Unless GPIO is in Low-Power mode, the input is first synchronized to the system clock to detect the configured level or edge transition.

GPIO generates a pin interrupt that asserts when the interrupt status flag is set for any enabled interrupt for that output. The interrupt negates after the interrupt status flags for all enabled interrupts are cleared by writing a logic 1 to either ISFR0[ISF*n*] or ICR0[ISF].

GPIO generates a DMA request that asserts when the interrupt status flag is set for any enabled DMA request in that output. The DMA request negates after the DMA transfer is completed because that clears the interrupt status flags for all enabled DMA requests.

In Low-Power mode, the interrupt status flag for any enabled interrupt is asynchronously set if the required level or edge is detected. This also generates an asynchronous wake-up signal to exit Low-Power mode.

GPIO generates a peripheral trigger output that asserts if any pin configured for the active-high trigger is logic 1, or any pin triggered for the active-low trigger is logic 0. The peripheral trigger output asynchronously updates from the value on the configured pins.

20.3.8 Global interrupt control

The two global interrupt control registers (Global Interrupt Control Low (GICLR) and Global Interrupt Control High (GICHR)) allow a single register write to update the upper 16 bits of Interrupt Control a (ICR0 - ICR31) for up to 16 pins, all with the same value.

These global interrupt control registers allow you to quickly configure multiple pins within the same port with the same interrupt configuration.

The global interrupt control registers are write-only registers and always read 0.

20.3.9 DMA

GPIO generates 2 requests. For each pin, you can configure DMA requests to assert for either rising, falling, or both edge detection. See External interrupts for more information.

20.3.10 Access protection

GPIO implements access protection registers (PCNS and PCNP) for each pin, as shown in Table 196.

Table 196. PCNS and PCNP register access protection implementation

Access	Description
Secure	You can write to or read the pins configured for secure access only in the Secure state.
Nonsecure	You can write to or read the pins configured for nonsecure access only in the Nonsecure state.
Privilege	You can write to the pins configured for privilege access only in the Privilege state.
Nonprivilege	You can write to the pins configured for nonprivilege access in both the Privilege and Nonprivilege states.

GPIO implements access protection registers (ICNS and ICNP) for each interrupt, trigger output, and DMA request as shown in Table 197.

Table 197. ICNS and ICNP register access protection implementation

Access	Description
Secure	You can configure the outputs programmed for secure access only in the Secure state.
Nonsecure	You can configure the outputs programmed for nonsecure access only in the Nonsecure state.
Privilege	You can configure the outputs programmed for privilege access only in the Privilege state.
Nonprivilege	You can configure the outputs programmed for nonprivilege access in both the Privilege and Nonprivilege states.

You can write to the access protection registers (PCNS, PCNP, ICNS, and ICNP) only in the Secure-Privilege state; you can optionally lock these registers until the next reset.

Configuring a pin interrupt, trigger output, or DMA request requires the following access permissions:

- Access permission to configure the pin.
- Access permission to either configure to the desired interrupt, trigger output, or DMA request, or writing 0 to ICR*n*[IRQC].
- Access permission to either configure with the existing interrupt, trigger output, or DMA request, or if the current value of ICR*n*[IRQC] is 0.
- The interrupt configuration is not locked.

20.4 External signals

Table 198. External signals

Signal	Description		Direction
GPIO31–GPIO0	General-purpose input/output		I/O
	State meaning	Asserted: The pin is logic 1. Deasserted: The pin is logic 0.	

Table continues on the next page...

Table 198. External signals (continued)

Signal	Description		Direction
	Timing	Assertion: When output, this signal occurs on the rising-edge of the system clock. For input, it may occur at any time and input may be asserted asynchronously to the system clock. Deassertion: When output, this signal occurs on the rising-edge of the system clock. For input, it may occur at any time and input may be asserted asynchronously to the system clock.	

NOTE

Not all pins within each GPIO are implemented on each chip. See the "Signal Multiplexing" chapter for the number of GPIO pins within each port available on this chip.

20.5 Initialization

To initialize GPIO:

1. Initialize the GPIO pins for the output function:
   a. Configure the output logic value for each pin by using Port Data Output (PDOR).
   b. Configure the direction for each pin by using Port Data Direction (PDDR).
2. Initialize the interrupt function by writing to Interrupt Control a (ICR0 - ICR31) for the corresponding pins and desired configuration. If the pin is previously used for a different function, first write 0100_0000h to Interrupt Control a (ICR0 - ICR31) to disable the previous function and clear the flag.

20.6 Application information

GPIO includes the following applications:

- Reading the state of a single pin by performing a byte read of Pin Data (P0DR - P31DR).
- Updating the state of a single pin by performing a byte write to Pin Data (P0DR - P31DR).
- Reading the state of multiple pins by reading Port Data Input (PDIR).
- Updating the state of multiple pins by using the following ways:
  - Writing to Port Data Output (PDOR).
  - Writing to Port Set Output (PSOR) to write 1 to Port Data Output (PDOR).
  - Writing to Port Clear Output (PCOR) to write 0 to Port Data Output (PDOR).
  - Writing to Port Toggle Output (PTOR) to toggle Port Data Output (PDOR).

20.7 Memory map and register definition

The GPIO registers support 8-bit, 16-bit, or 32-bit accesses. Any read or write access to the GPIO memory space that is outside the valid memory map results in a bus error.

NOTE

For simplicity, each GPIO port's register appears with the same width of 32 bits, corresponding to 32 pins. The actual number of pins per port (and therefore the number of usable control bits per port register) is chip-specific. See the "Signal Multiplexing" chapter for the exact control bits of each port.

20.7.1 GPIO register descriptions

20.7.1.1 GPIO memory map

GPIOA base address: 4801_0000h

GPIOB base address: 4802_0000h

GPIOC base address: 4803_0000h

GPIOD base address: 4004_6000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	0201_0001h
4h	Parameter (PARAM)	32	R	0000_0002h
Ch	Lock (LOCK)	32	RW	0000_0000h
10h	Pin Control Nonsecure (PCNS)	32	RW	0000_0000h
14h	Interrupt Control Nonsecure (ICNS)	32	RW	0000_0000h
18h	Pin Control Nonprivilege (PCNP)	32	RW	0000_0000h
1Ch	Interrupt Control Nonprivilege (ICNP)	32	RW	0000_0000h
40h	Port Data Output (PDOR)	32	RW	0000_0000h
44h	Port Set Output (PSOR)	32	RW	0000_0000h
48h	Port Clear Output (PCOR)	32	RW	0000_0000h
4Ch	Port Toggle Output (PTOR)	32	RW	0000_0000h
50h	Port Data Input (PDIR)	32	R	0000_0000h
54h	Port Data Direction (PDDR)	32	RW	0000_0000h
58h	Port Input Disable (PIDR)	32	RW	0000_0000h
60h - 7Fh	Pin Data (P0DR - P31DR)	8	RW	00h
80h - FCh	Interrupt Control a (ICR0 - ICR31)	32	RW	0000_0000h
100h	Global Interrupt Control Low (GICLR)	32	RW	0000_0000h
104h	Global Interrupt Control High (GICHR)	32	RW	0000_0000h
120h - 124h	Interrupt Status Flag (ISFR0 - ISFR1)	32	RW	0000_0000h

20.7.1.2 Version ID (VERID)

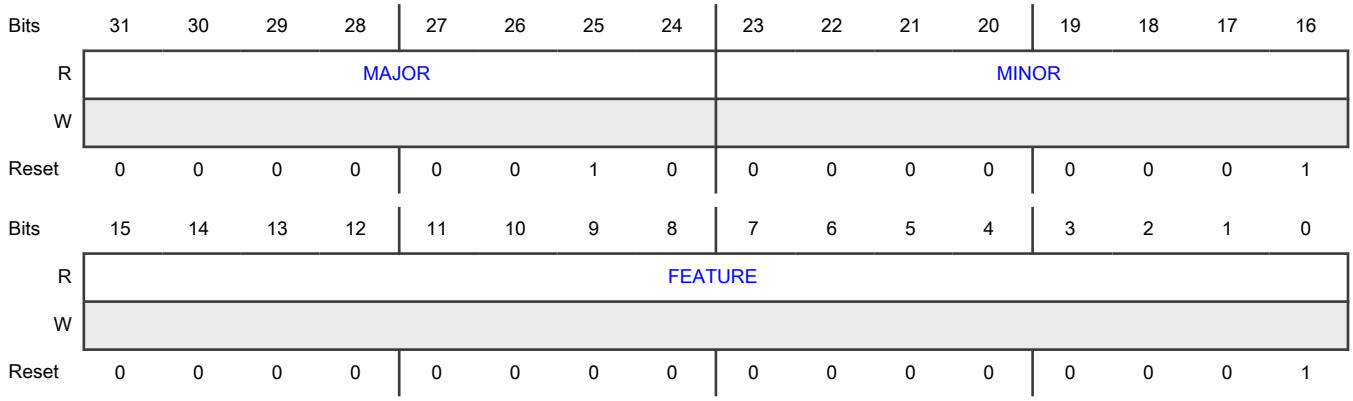
Offset

Register	Offset
VERID	0h

Function

Indicates the version ID number of each GPIO.

Diagram



Fields

Field	Function
31-24 MAJOR	Major Version Number Indicates the major version number for the specification.
23-16 MINOR	Minor Version Number Indicates the minor version number for the specification.
15-0 FEATURE	Feature Specification Number Indicates the feature set number. 0000_0000_0000_0000b - Basic implementation 0000_0000_0000_0001b - Protection registers implemented

20.7.1.3 Parameter (PARAM)

Offset

Register	Offset
PARAM	4h

Function

Indicates the interrupt number of each GPIO.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												IRQNUM			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Fields

Field	Function
31-4 —	Reserved
3-0 IRQNUM	Interrupt Number Indicates the number of interrupt, trigger, or DMA request domains.

20.7.1.4 Lock (LOCK)

Offset

Register	Offset
LOCK	Ch

Function

Locks the nonsecure and nonprivilege access protection registers. You can write to this register only in the Secure-Privilege state.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												ICNP	PCNP	ICNS	PCNS
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-4 —	Reserved
3 ICNP	Lock ICNP Locks Interrupt Control Nonprivilege (ICNP). If this field is 0, you can write to ICNP in the Secure-Privilege state. If this field is 1, you cannot write to ICNP until the next reset. 0b - Writable in Secure-Privilege state 1b - Not writable until the next reset
2 PCNP	Lock PCNP Locks Pin Control Nonprivilege (PCNP). If this field is 0, you can write to PCNP in the Secure-Privilege state. If this field is 1, you cannot write to PCNP until the next reset. 0b - Writable in Secure-Privilege state 1b - Not writable until the next reset
1 ICNS	Lock ICNS Locks Interrupt Control Nonsecure (ICNS). If this field is 0, you can write to ICNS in the Secure-Privilege state. If this field is 1, you cannot write to ICNS until the next reset. 0b - Writable in Secure-Privilege state 1b - Not writable until the next reset
0 PCNS	Lock PCNS Locks Pin Control Nonsecure (PCNS). If this field is 0, you can write to PCNS in the Secure-Privilege state. If this field is 1, you cannot write to PCNS until the next reset. 0b - Writable in Secure-Privilege state 1b - Not writable until the next reset

20.7.1.5 Pin Control Nonsecure (PCNS)

Offset

Register	Offset
PCNS	10h

Function

Configures secure or nonsecure access protection for each pin. You can write to this register only in the Secure-Privilege state if it is not locked (LOCK[PCNS] = 0).

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	NSE31	NSE30	NSE29	NSE28	NSE27	NSE26	NSE25	NSE24	NSE23	NSE22	NSE21	NSE20	NSE19	NSE18	NSE17	NSE16
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	NSE15	NSE14	NSE13	NSE12	NSE11	NSE10	NSE9	NSE8	NSE7	NSE6	NSE5	NSE4	NSE3	NSE2	NSE1	NSE0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 NSEn	Nonsecure Enable Configures secure or nonsecure access protection for each pin. If this field is 0, the pin is configured for secure access. You can read or write to the corresponding pin's registers and fields only in the Secure state. When you access the corresponding pin's registers in the Nonsecure state, all fields in the registers related to that pin are read zero (with writes ignored). If this field is 1, the pin is configured for nonsecure access. You can read or write to the corresponding pin's registers and fields only in the Nonsecure state. When you access the corresponding pin's registers in the Secure state, all fields in the registers related to that pin are read zero (with writes ignored). 0b - Secure access 1b - Nonsecure access

20.7.1.6 Interrupt Control Nonsecure (ICNS)

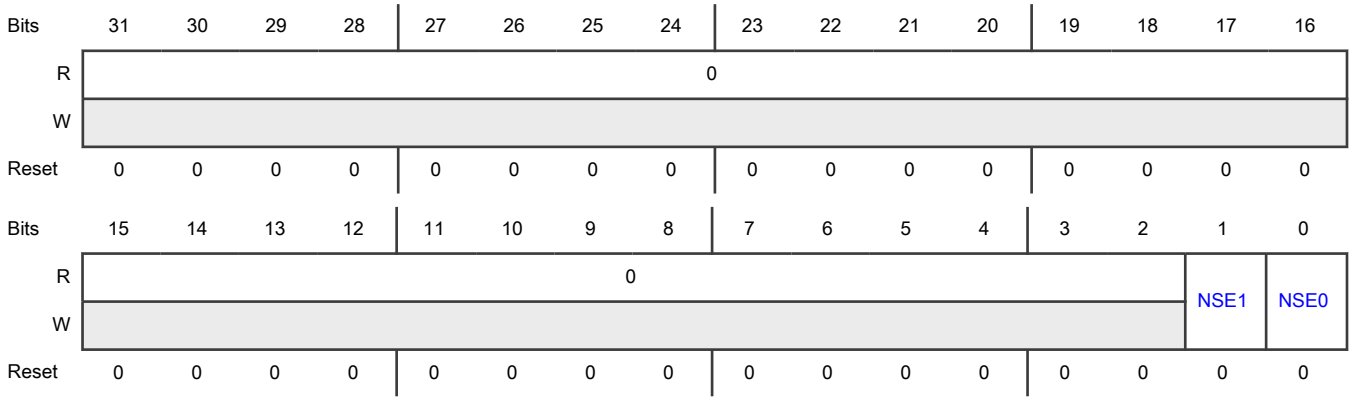
Offset

Register	Offset
ICNS	14h

Function

Configures secure and nonsecure access protection for each interrupt, output trigger, or DMA request. You can update this register only in the Secure-Privilege state if it is not locked (LOCK[ICNS] = 0).

Diagram



Fields

Field	Function
31-2 —	Reserved
1-0 NSEn	Nonsecure Enable Configures secure or nonsecure access protection for each interrupt, output trigger, or DMA request. If this field is 0, the interrupt, output trigger, or DMA request is configured for secure access. You can configure a pin to use the corresponding interrupt, output trigger, or DMA request, or reconfigure a pin that is already configured to use the corresponding interrupt, output trigger, or DMA request only in the Secure state. If this field is 1, the interrupt, output trigger, or DMA request is configured for nonsecure access. You can configure a pin to use the corresponding interrupt, output trigger, or DMA request, or reconfigure a pin that is already configured to use the corresponding interrupt, output trigger, or DMA request only in the Nonsecure state. **NOTE** See the GPIO chip-specific information to determine which GPIO instances support interrupt, DMA request, or trigger capabilities. 0b - Secure access 1b - Nonsecure access

20.7.1.7 Pin Control Nonprivilege (PCNP)

Offset

Register	Offset
PCNP	18h

Function

Configures access protection on each pin either for privilege or for both privilege and nonprivilege accesses. You can update this register only in the Secure-Privilege state if it is not locked (LOCK[PCNP] = 0).

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	NPE31	NPE30	NPE29	NPE28	NPE27	NPE26	NPE25	NPE24	NPE23	NPE22	NPE21	NPE20	NPE19	NPE18	NPE17	NPE16
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	NPE15	NPE14	NPE13	NPE12	NPE11	NPE10	NPE9	NPE8	NPE7	NPE6	NPE5	NPE4	NPE3	NPE2	NPE1	NPE0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 NPEn	Nonprivilege Enable Configures privilege or nonprivilege access protection for each pin. If this field is 0, the pin is configured for privilege access. Write access to the corresponding pin's registers and fields is allowed only in the Privilege state. When you access the corresponding pin's registers and fields in the Nonprivilege state, all fields related to that pin in this GPIO are readable (with writes ignored). If this field is 1, the pin is configured for nonprivilege access; read or write access to the corresponding pin's registers is allowed in both Privilege and Nonprivilege states. 0b - Privilege access 1b - Nonprivilege access

20.7.1.8 Interrupt Control Nonprivilege (ICNP)

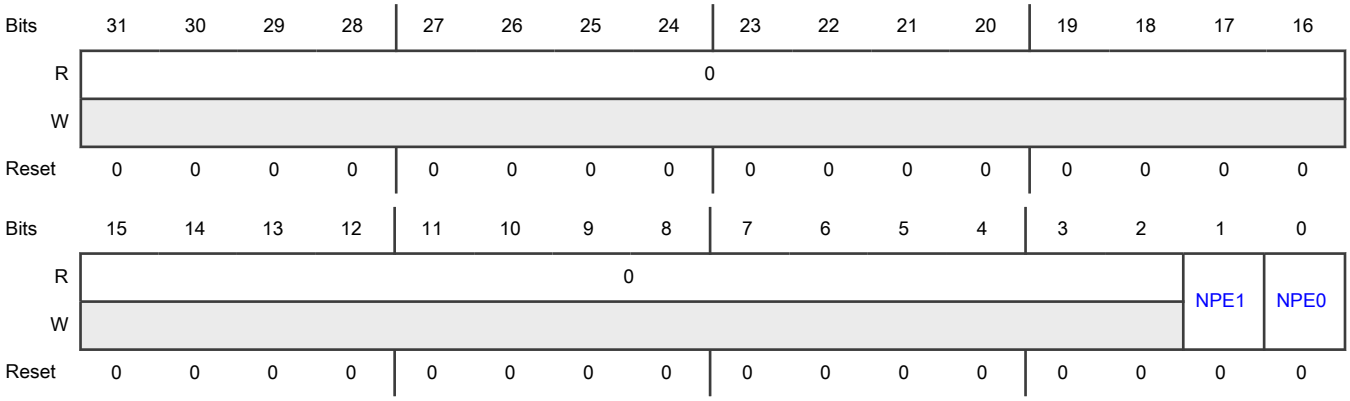
Offset

Register	Offset
ICNP	1Ch

Function

Configures privilege and nonprivilege access protection for each interrupt, trigger output, or DMA request. You can update this register only in the Secure-Privilege state if it is not locked (LOCK[ICNP] = 0).

Diagram



Fields

Field	Function
31-2 —	Reserved
1-0 NPEn	Nonprivilege Enable Configures privilege or nonprivilege access protection for each interrupt, trigger output, or DMA request. If this field is 0, the pin is configured for privilege access. You can configure a pin to use the corresponding interrupt, trigger output, or DMA request, or reconfigure a pin that is already configured to use the corresponding interrupt, trigger output, or DMA request only in the Privilege state. If this field is 1, the pin is configured for nonprivilege access. In either Privilege or Nonprivilege state, you can configure a pin to use the corresponding interrupt, trigger output, or DMA request, or reconfigure a pin that is already configured to use the corresponding interrupt, trigger output, or DMA request. **NOTE** See the GPIO chip-specific information to determine which GPIO instances support interrupt, DMA request, or trigger capabilities. 0b - Privilege access 1b - Nonprivilege access

20.7.1.9 Port Data Output (PDOR)

Offset

Register	Offset
PDOR	40h

Function

Configures the logic levels that are driven on each general-purpose output pin.

NOTE

Do not modify the pin configuration registers associated with pins that are not available in your selected package. By default, these unbonded pins are set to the Disable state for lowest power consumption.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	PDO31	PDO30	PDO29	PDO28	PDO27	PDO26	PDO25	PDO24	PDO23	PDO22	PDO21	PDO20	PDO19	PDO18	PDO17	PDO16
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	PDO15	PDO14	PDO13	PDO12	PDO11	PDO10	PDO9	PDO8	PDO7	PDO6	PDO5	PDO4	PDO3	PDO2	PDO1	PDO0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 PDOn	Port Data Output Configures the logic level on the pin if it is configured for general-purpose output. If this field is 0, logic level 0 is driven on the pin, if the pin is configured for general-purpose output. If this field is 1, logic level 1 is driven on the pin, if the pin is configured for general-purpose output. **NOTE** Reading the fields for unbonded pins returns an undefined value. 0b - Logic level 0 1b - Logic level 1

20.7.1.10 Port Set Output (PSOR)

Offset

Register	Offset
PSOR	44h

Function

Updates the corresponding fields of Port Data Output (PDOR) to become 1.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W	PTSO 31	PTSO 30	PTSO 29	PTSO 28	PTSO 27	PTSO 26	PTSO 25	PTSO 24	PTSO 23	PTSO 22	PTSO 21	PTSO 20	PTSO 19	PTSO 18	PTSO 17	PTSO 16
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W	PTSO 15	PTSO 14	PTSO 13	PTSO 12	PTSO 11	PTSO 10	PTSO 9	PTSO 8	PTSO 7	PTSO 6	PTSO 5	PTSO 4	PTSO 3	PTSO 2	PTSO 1	PTSO 0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 PTSOn	Port Set Output Updates the content of the corresponding field in Port Data Output (PDOR). If this field is 0, the corresponding PDOR field does not change. If this field is 1, the corresponding PDOR field becomes 1. 0b - No change 1b - Corresponding field in PDOR becomes 1

20.7.1.11 Port Clear Output (PCOR)

Offset

Register	Offset
PCOR	48h

Function

Updates the corresponding fields of Port Data Output (PDOR) to become 0.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W	PTCO 31	PTCO 30	PTCO 29	PTCO 28	PTCO 27	PTCO 26	PTCO 25	PTCO 24	PTCO 23	PTCO 22	PTCO 21	PTCO 20	PTCO 19	PTCO 18	PTCO 17	PTCO 16
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W	PTCO 15	PTCO 14	PTCO 13	PTCO 12	PTCO 11	PTCO 10	PTCO 9	PTCO 8	PTCO 7	PTCO 6	PTCO 5	PTCO 4	PTCO 3	PTCO 2	PTCO 1	PTCO 0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 PTCOn	Port Clear Output Updates the content of the corresponding field in Port Data Output (PDOR). If this field is 0, the corresponding PDOR field does not change. If this field is 1, the corresponding PDOR field becomes 0. 0b - No change 1b - Corresponding field in PDOR becomes 0

20.7.1.12 Port Toggle Output (PTOR)

Offset

Register	Offset
PTOR	4Ch

Function

Updates the corresponding fields of Port Data Output (PDOR) to set to the inverse of their current logic states.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W	PTTO 31	PTTO 30	PTTO 29	PTTO 28	PTTO 27	PTTO 26	PTTO 25	PTTO 24	PTTO 23	PTTO 22	PTTO 21	PTTO 20	PTTO 19	PTTO 18	PTTO 17	PTTO 16
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W	PTTO 15	PTTO 14	PTTO 13	PTTO 12	PTTO 11	PTTO 10	PTTO 9	PTTO 8	PTTO 7	PTTO 6	PTTO 5	PTTO 4	PTTO 3	PTTO 2	PTTO 1	PTTO 0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 PTTOn	Port Toggle Output Updates the content of the corresponding field in Port Data Output (PDOR). If this field is 0, the corresponding PDOR field does not change. If this field is 1, the corresponding PDOR field is set to the inverse of its current logic state. 0b - No change 1b - Set to the inverse of its current logic state

20.7.1.13 Port Data Input (PDIR)

Offset

Register	Offset
PDIR	50h

Function

Captures the logic levels of each general-purpose input pin.

NOTE

Do not modify the pin configuration registers associated with the pins that are not available in your selected package. By default, these unbonded pins are set to the Disable state for lowest power consumption.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PDI31	PDI30	PDI29	PDI28	PDI27	PDI26	PDI25	PDI24	PDI23	PDI22	PDI21	PDI20	PDI19	PDI18	PDI17	PDI16
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	PDI15	PDI14	PDI13	PDI12	PDI11	PDI10	PDI9	PDI8	PDI7	PDI6	PDI5	PDI4	PDI3	PDI2	PDI1	PDI0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 PDIn	Port Data Input Indicates the logic level of the pin that is configured for use by a digital function. If this field is 0, the pin logic level is logic 0 or is not configured or implemented for use by a digital function. If this field is 1, the pin logic level is logic 1. 0b - Logic 0 1b - Logic 1

20.7.1.14 Port Data Direction (PDDR)

Offset

Register	Offset
PDDR	54h

Function

Configures the individual port pins for input or output.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	PDD31	PDD30	PDD29	PDD28	PDD27	PDD26	PDD25	PDD24	PDD23	PDD22	PDD21	PDD20	PDD19	PDD18	PDD17	PDD16
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	PDD15	PDD14	PDD13	PDD12	PDD11	PDD10	PDD9	PDD8	PDD7	PDD6	PDD5	PDD4	PDD3	PDD2	PDD1	PDD0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 PDDn	Port Data Direction Configures individual port pins for input or output. If this field is 0, the pin is configured as general-purpose input for the GPIO function. If this field is 1, the pin is configured as general-purpose output for the GPIO function. 0b - Input 1b - Output

20.7.1.15 Port Input Disable (PIDR)

Offset

Register	Offset
PIDR	58h

Function

Disables the input for each general-purpose pin, which prevents the value from being reported in Port Data Input (PDIR).

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	PID31	PID30	PID29	PID28	PID27	PID26	PID25	PID24	PID23	PID22	PID21	PID20	PID19	PID18	PID17	PID16
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	PID15	PID14	PID13	PID12	PID11	PID10	PID9	PID8	PID7	PID6	PID5	PID4	PID3	PID2	PID1	PID0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 PIDn	Port Input Disable Disables a pin for general-purpose input. If this field is 0, the pin is configured for general-purpose input, provided the pin is configured for a digital function. If this field is 1, the pin is disabled for general-purpose input. 0b - Configured for general-purpose input 1b - Disabled for general-purpose input

20.7.1.16 Pin Data (P0DR - P31DR)

Offset

For a = 0 to 31:

Register	Offset
PaDR	60h + (a × 1h)

Function

Configures the data feature of a pin. Pins that are unimplemented or not configured for a digital function read zero.

NOTE

You must not modify Pin Data (P0DR - P31DR) associated with the pins that are not available in your selected package. These unbonded pins are, by default, set to the Disable state for lowest power consumption.

Diagram

Bits	7	6	5	4	3	2	1	0
R	0							PD
W								
Reset	0	0	0	0	0	0	0	0

Fields

Field	Function
7-1 —	Reserved
0 PD	Pin Data (I/O) Specifies the pin logic level. This field updates the corresponding field in Port Data Output (PDOR); reading this field returns the value in the corresponding field of Port Data Input (PDIR). If this field is 0, the pin logic level is logic zero or not configured for use by a digital function. If this field is 1, the pin logic level is logic one. 0b - Logic zero 1b - Logic one

20.7.1.17 Interrupt Control a (ICR0 - ICR31)

Offset

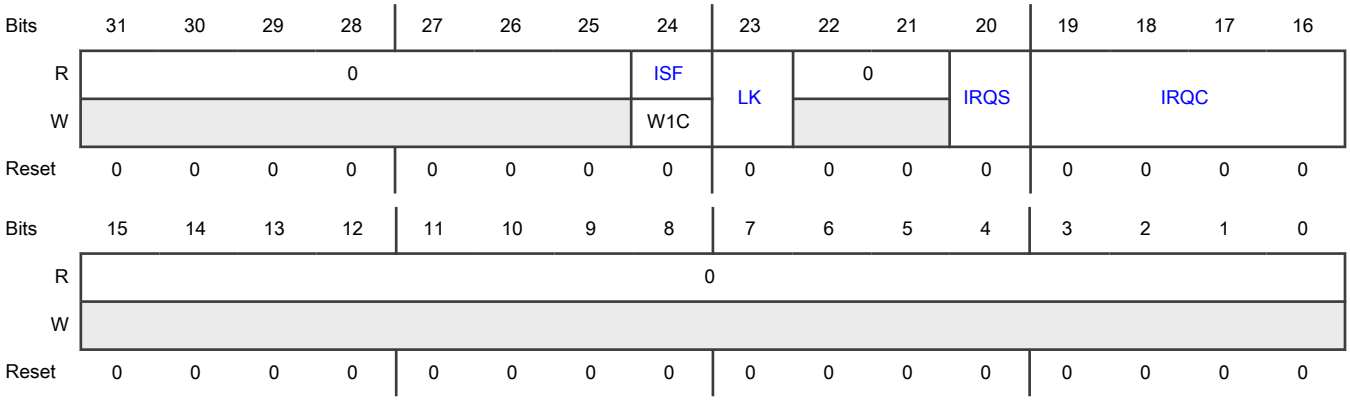
For a = 0 to 31:

Register	Offset
ICRa	80h + (a × 4h)

Function

Configures interrupt features on each pin.

Diagram



Fields

Field	Function
31-25 —	Reserved
24 ISF	Interrupt Status Flag Indicates whether the configured interrupt is detected. The pin interrupt configuration is valid in all digital pin muxing modes. The fields in Interrupt Status Flag (ISFR0 - ISFR1) have the same function. ISF can be cleared with either register field. If the pin is configured to generate a DMA request, then the corresponding flag is cleared automatically at the completion of the requested DMA transfer. Otherwise, the flag remains set until a logic 1 is written to the flag. If the pin is configured for a level-sensitive interrupt and the pin remains asserted, then the flag is set again immediately after it is cleared. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not detected 1b - Detected When writing 0b - No effect 1b - Clear the flag
23 LK	Lock

Table continues on the next page...

Table continued from the previous page...

Field	Function
	Locks ICR[23:0], and you cannot update the locked field until the next system reset. If this field is 0, interrupt configuration by ICR[23:0] is not locked and can be updated. If this field is 1, interrupt configuration by ICR[23:0] is locked and cannot be updated until the next system reset. 0b - Not locked 1b - Locked
22-21 —	Reserved
20 IRQS	Interrupt Select Configures the selected interrupt, trigger output, or DMA request. **NOTE** See the GPIO chip-specific information to determine which GPIO instances support interrupt, DMA request, or trigger capabilities. 0b - Interrupt, trigger output, or DMA request 0 1b - Interrupt, trigger output, or DMA request 1
19-16 IRQC	Interrupt Configuration Specifies the ISF and DMA request configuration. The pin interrupt configuration is valid in all digital pin muxing modes. When changing the interrupt configuration, it is recommended to first disable ISF and then write the new configuration. The corresponding pin is configured to generate interrupt, trigger, or DMA request. **NOTE** See the GPIO chip-specific information to determine the GPIO instances that support interrupt, DMA request, or trigger capabilities. 0000b - ISF is disabled 0001b - ISF and DMA request on rising edge 0010b - ISF and DMA request on falling edge 0011b - ISF and DMA request on either edge 0100b - Reserved 0101b - ISF sets on rising edge 0110b - ISF sets on falling edge 0111b - ISF sets on either edge 1000b - ISF and interrupt when logic 0 1001b - ISF and interrupt on rising edge 1010b - ISF and interrupt on falling edge 1011b - ISF and Interrupt on either edge

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1100b - ISF and interrupt when logic 1 1101b - Enable active-high trigger output; ISF on rising edge (pin state is ORed with other enabled triggers to generate the output trigger for use by other peripherals) 1110b - Enable active-low trigger output; ISF on falling edge (pin state is inverted and ORed with other enabled triggers to generate the output trigger for use by other peripherals) 1111b - Reserved
15-0 —	Reserved

20.7.1.18 Global Interrupt Control Low (GICLR)

Offset

Register	Offset
GICLR	100h

Function

Updates any combination of the lower 16 Interrupt Control registers with the same value. This register supports only 32-bit writes and ignores any 16-bit or 8-bit writes.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W	GIWD															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W	GIWE 15	GIWE 14	GIWE 13	GIWE 12	GIWE 11	GIWE 10	GIWE 9	GIWE 8	GIWE 7	GIWE 6	GIWE 5	GIWE 4	GIWE 3	GIWE 2	GIWE 1	GIWE 0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-16 GIWD	Global Interrupt Write Data

Table continues on the next page...

Table continued from the previous page...

Field	Function
	Indicates the write value that is written to the upper 16 bits of Interrupt Control a (ICR0 - ICR31), selected by GIWE.
15-0 GIWEn	Global Interrupt Write Enable Indicates whether the upper 16 bits of the corresponding Interrupt Control a (ICR0 - ICR31) are updated with the value in GIWD. 0b - Not updated 1b - Updated

20.7.1.19 Global Interrupt Control High (GICHR)

Offset

Register	Offset
GICHR	104h

Function

Updates any combination of the upper 16 Interrupt Control registers with the same value. This register supports only 32-bit writes and ignores any 16-bit or 8-bit writes.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W	GIWD															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W	GIWE 31	GIWE 30	GIWE 29	GIWE 28	GIWE 27	GIWE 26	GIWE 25	GIWE 24	GIWE 23	GIWE 22	GIWE 21	GIWE 20	GIWE 19	GIWE 18	GIWE 17	GIWE 16
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-16 GIWD	Global Interrupt Write Data Indicates the write value that is written to the upper 16 bits of Interrupt Control a (ICR0 - ICR31), selected by GIWE.

Table continues on the next page...

Table continued from the previous page...

Field	Function
15-0 GIWEn	Global Interrupt Write Enable Indicates whether the upper 16 bits of the corresponding Interrupt Control a (ICR0 - ICR31) are updated with the value in GIWD. 0b - Not updated. 1b - Updated

20.7.1.20 Interrupt Status Flag (ISFR0 - ISFR1)

Offset

Register	Offset
ISFR0	120h
ISFR1	124h

Function

Indicates whether the related configured interrupt is detected on each pin. The pin interrupt configuration is valid in all digital pin muxing modes. The ISF for each pin is also visible in the corresponding Interrupt Control register, and each flag can be cleared in either location.

There is a separate ISF register for each interrupt, trigger, or DMA request domain. Each status flag is only visible in the register that corresponds to that flag's domain, as configured in ICR*n*[IRQS].

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	ISF31	ISF30	ISF29	ISF28	ISF27	ISF26	ISF25	ISF24	ISF23	ISF22	ISF21	ISF20	ISF19	ISF18	ISF17	ISF16
W	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	ISF15	ISF14	ISF13	ISF12	ISF11	ISF10	ISF9	ISF8	ISF7	ISF6	ISF5	ISF4	ISF3	ISF2	ISF1	ISF0
W	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 ISFn	Interrupt Status Flag

Table continues on the next page...

Field	Function
	Indicates the detection of the configured interrupt on each pin of the same number. If this field is 0, the configured interrupt is not detected on the pin of the same number. If this field is 1, the configured interrupt is detected on the pin of the same number. If the pin is configured to generate a DMA request, then the corresponding flag is cleared automatically at the completion of the requested DMA transfer. Otherwise, the flag remains set until a logic 1 is written to the flag. If the pin is configured for a level-sensitive interrupt and the pin remains asserted, then the flag is set again immediately after it is cleared. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not detected 1b - Detected When writing 0b - No effect 1b - Clear the flag

Chapter 21
Debug

21.1 Introduction

This chapter describes the debug architecture of this device.

Features:

- The Arm CoreSight™ Architecture is adapted for software trace and debug.
- Serial wire debug (SWD) and Debug Access Port (DAP) to support debugger tools.
- Instrumentation Trace Macrocell (ITM) is supported for the Cortex-M33 core and Radio Cortex-M33 core.
- Data Watchpoint and Trace (DWT) and breakpoint unit (BPU) are supported for the Cortex-M33 and Radio Cortex-M33 core subsystem.
- 1-bit SWO trace port for efficiently accessing Cortex-M33 trace information from the system.

The following figure shows the system level debug architecture.

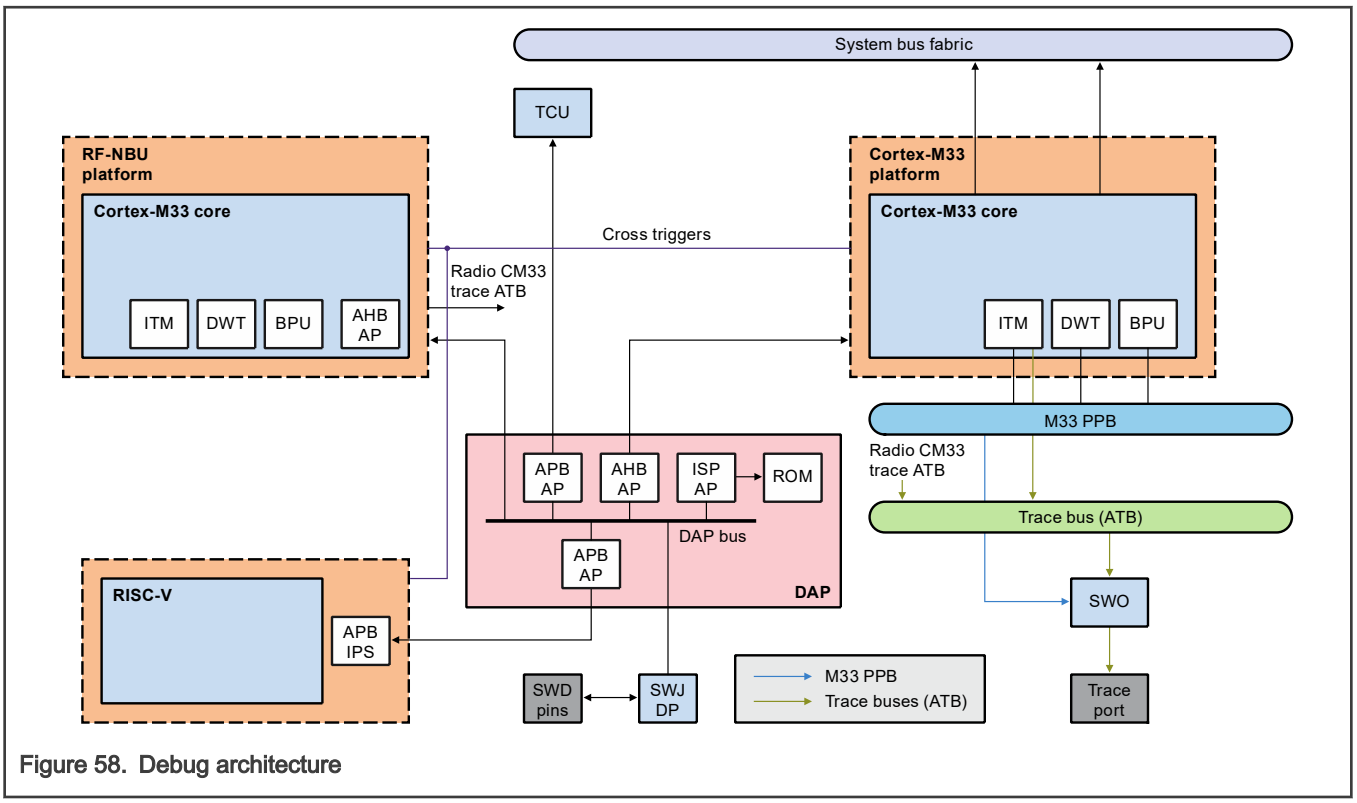


Figure 58. Debug architecture

21.2 Trace component reset sources

The following table show the trace component reset sources.

Table 199. Trace component reset sources

Core	TRACE component	Reset source
CM33	TPIU, Funnel CM33	POR reset or debug reset

Table continues on the next page...

Table 199. Trace component reset sources (continued)

Core	TRACE component	Reset source
	ITM/DWT/CTI/BPU	Only CM33 POR reset
CM3	CTI CM3	POR reset or debug reset
	ITM/DWT/FPB	Only CM3 POR reset

21.3 Test and debug port connectivity

The following figure shows the connectivity of test and debug port on this device.

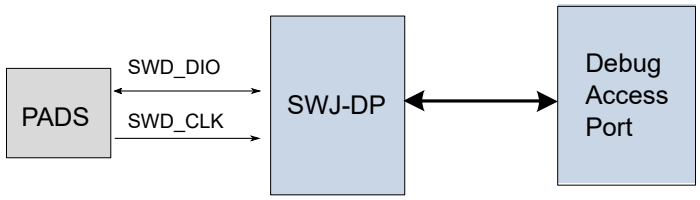


Figure 59. Debug port connectivity

The SWD signals are summarized in the following table.

Table 200. SWD signals summary

Pin Name	SWD		Internal pull up/down
	Type	Description	
SWD_DIO	I/O	Data	Pull-up
SWD_CLK	I	Clock	Pull-down

21.3.1 Serial wire debug (SWD)

The serial wire debug is a 2-pin electrical interface with a clock (SWD_CLK) and a single bi-directional data pin (SWD_DIO) to provide debug and test functionality.

21.3.2 Debug access port

Debug Access Port (DAP) is a standard Arm CoreSight component. The DAP provides multiple master driving ports, all of which are accessible and controlled through a single external interface port to provide system-wide debug. The DAP Instruction Register codes are listed in the following table.

Table 201. DAP IR Codes

Code	DAP IR
4’b1000	ABORT
4’b1010	DPACC
4’b1011	APACC
4’b1110	IDCODE

The DAP offers AHB and APB master interfaces to access system buses. It also exports the internal DAP bus to allow to extend the access ports as per the system requirement. For more information on DAP TAP, refer to Arm Debug Interface v5 Architecture specification on arm.com.

The exported DAP bus is used to host AHB AP, APB AP, MDM AP and ISP AP. The APB-AP implements registers which are used for Test mode control on the device. The MDM-AP hosts system level debug status and control registers (refer to Debug Status and Control Registers) which can be used for low power and other miscellaneous control and status. The ISP AP supports software debug feature at platform level. The selection of different access ports in the DAP is done based on the APSEL value set in the SELECT register of SWJ-DP.

The following figure shows the configuration of the DAP on this device.

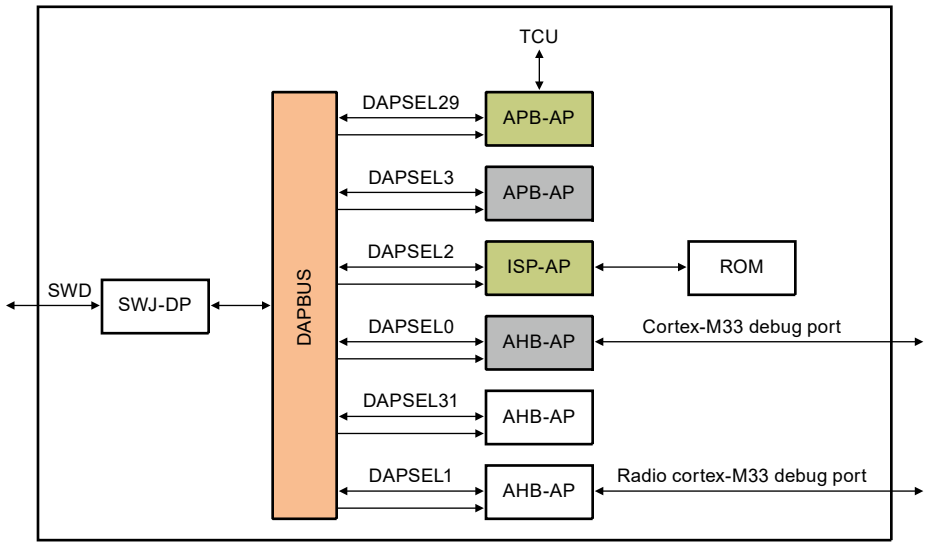


Figure 60. Debug Access Port configuration

21.4 Cortex M33 debug

This section covers the debug mechanisms associated with the CM33 processor.

21.4.1 CM33 software debug and trace

The following figure shows the data flow of software debug and trace information for the Cortex-M33 core on this device.

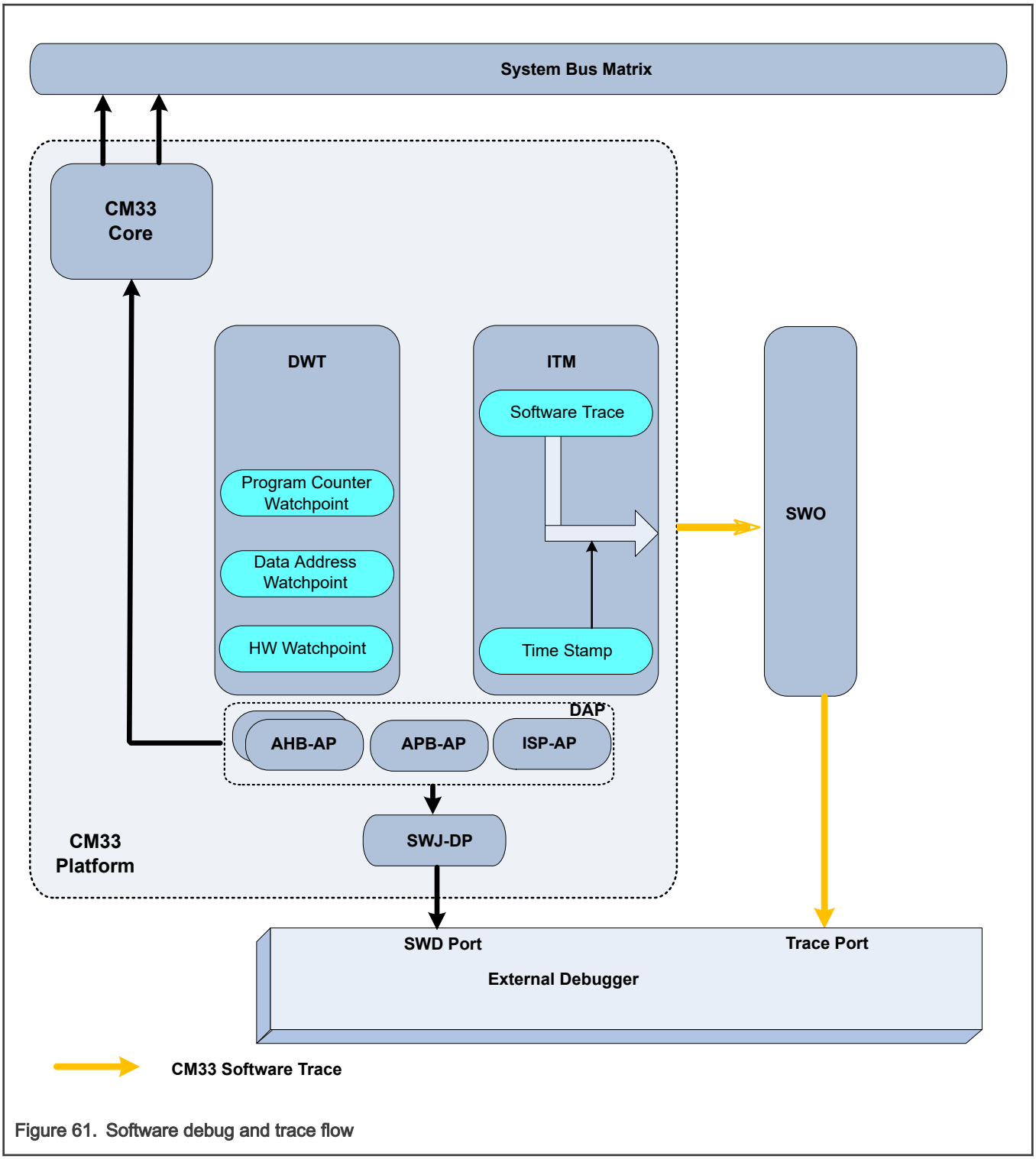


Figure 61. Software debug and trace flow

21.4.2 Data Watchpoint and Trace

The CM33 Data Watchpoint and Trace (DWT) module generates trace information in the core. It has 4 independent watchpoints which can be programmed to compare data, address, or to function as a hardware watchpoint. The DWT can be configured to generate PC samples at defined intervals and to generate interrupt event information. The CM33 DWT also provides periodic requests for protocol synchronization to the ITM and the SWO.

21.4.3 Breakpoint Unit

The CM33 Breakpoint Unit (BPU) module comprises up to 8 instruction address comparators. It provides breakpoint functionality on all instructions fetched across the entire address range in which code can be located.

21.4.4 Instrumentation Trace Macrocell (ITM)

The ITM generates trace information as packets. There are multiple sources that can generate packets. If multiple sources generate packets at the same time, the ITM arbitrates the order in which packets are output. The sources in decreasing order of priority are:

- Software Trace: Application software can write console messages directly to ITM stimulus ports, and output them to the host as trace packets.
- Hardware trace: The DWT generates these packets, and the ITM outputs them.
- Timestamping: ITM can generate timestamp packets that are inserted in to the trace stream, to help the host debugger to find out the timing of events. Timestamps are generated relative to packets. The ITM contains a 21-bit counter to generate the timestamp.

Trace data from ITM will be forwarded to SWO and streamed out via the trace port.

21.5 Cross Trigger Interface (CTI)

Table 202. CTI input triggers

Trigger Bit	Source Signal	Source Module	Description
3	Reserved	Reserved	Reserved
2	Interrupt request	RF Processor core	Acknowledged by writing to the CTIINTACK register in ISR
1	Processor restarted	RF Processor core	Processor core's output indicating that it has restarted.
0	HALTED	RF Processor core	Processor core's output indicating that it has entered the debug mode.

Here the "Source Signal" is the output port of the "Source Module". They are connected to the input triggers of the CTI.

Table 203. CTI output triggers

Trigger Bit	Destination Signal	Destination Module	Description
3	Reserved	Reserved	Reserved
2	cti_irq	NVIC	CTI interrupt
1	Processor Restarted	RF Processor core	Processor core's output indicating that it has restarted.
0	EDBGRQ	Processor core	External request Processor core to enter the debug mode

Here the "Destination Signal" is the input port of the "Destination Module". The output triggers of the CTI are connected to the input port of the destination modules.

21.6 Low power debug

Low power debug is controlled by DBGCTL[SOD] field in the CMC. When set, the debugger is disabled (debug power up acknowledge negates) when the CM33 sleeps and the device fully enters the low power mode. When clear, the clocks to the CM33 remain enabled when the CM33 sleeps and debug is attached (debug power up request is asserted) to maintain the debug connection, and the low power mode is not completely entered. Software can modify DBGCTL[SOD] before each low power entry. There are two modes supported:

- Clock gated mode
- Power gated mode

21.6.1 Clock gated modes

- If the DAP CXXXPWRUPREQ is high and the system attempts to enter STOP mode, the DAP clock and the Core clock continue to run to support core register access and trace, in this case the debug module will have access to core registers but not to modules which are clock gated.
- If the device is in STOP mode (core clock gated), the debugger can assert EDBGRQ (CM33 EDBGRQ) in dap_ctrl_halt_req register, this will wake up the core and will move it into a halted state.

21.6.2 Power gated modes

During power gated modes, the debugger will loose connection and it cannot gather any data in the duration when device stays in low power mode. If the device is expected to go into low power mode and it is desired to gain control of device when it exits low power modes.

Chapter 22
Reset

22.1 Introduction

The following reset sources exist in this device:

Table 204. Reset sources

Reset type	Source
Power	• System Power-On Reset (POR) • System Low-Voltage Detect (LVD) • System High-Voltage Detect (HVD)
External	• External Pin Reset (RESET_b) • Wake-Up Unit (WUU)
Internal	• Watchdog (WDOG) timer • Software (SW) • System Clock Generator (SCG) • Reset Acknowledge timeout (RSTACK) • Low Power Acknowledge (LPACK) • Lockup (LOCKUP) • Debug Access Port (DAP) • EdgeLock Secure Enclave (ELE) • Tamper

Each system reset source has a corresponding bit that is maintained in the System Reset Status register through reset. This information can be used to take appropriate action when coming out of a reset.

22.2 Power reset sources

To ensure predictable operation of the device, the supply voltages must remain in their specified ranges during execution. Because this is not possible during power-up and power-down, the device implements multiple voltage monitors to detect when the supply is outside an acceptable range. When this occurs, the voltage monitor asserts a reset to halt execution and prevent unexpected behavior. The voltage monitors detect power-on events as well as low and high voltage events.

22.2.1 Power-on reset (POR)

The POR voltage monitor is used to ensure that the voltage applied to the system is high enough for other analog modules such as the bias circuits and low voltage monitors to operate correctly. When voltage is initially applied to the device or when the supply voltage drops below the POR falling threshold, the POR monitor triggers the POR reset condition to the device.

The POR reset condition asserts POR reset to all power domains. A POR reset sets the appropriate bits in the CMC registers so that software can determine that a POR reset has occurred.

22.2.2 Low-voltage detect (LVD)

The LVD monitors are used to ensure that the voltage supplies to the device are high enough for the logic and memories to operate correctly. When voltage is initially applied to the device, the POR voltage monitor holds the LVD monitors in reset until the voltages are high enough. The LVD monitors continue to hold the device in reset until all monitoring voltages have risen above the respective default LVD Low thresholds (VLVDL). The LVD monitors are enabled by default.

When enabled, the LVD monitor generates a reset when the voltage drops below the V_{LVD} threshold. The voltage threshold at which the LVD reset asserts is programmable. This ensures that the device halts operation and remains in reset while the monitored voltage is not within the desired range.

The reset sources triggered by individual LVD monitors are combined into a single LVD reset. The LVD reset condition asserts a POR reset in all power domains with only the POR/LVD/HVD detection logic remaining operational. An LVD reset sets the appropriate bits in the CMC registers so that software can determine that an LVD reset has occurred.

22.2.3 High-voltage detect (HVD)

The HVD monitors are used to ensure that the voltage supplies to the device are within operation range for the logic and memories using those power supplies. The HVD monitors are disabled by default, but when an HVD circuit is enabled, the HVD monitor generates a reset when the voltage rises above the V_{HVD} threshold. This ensures that the device halts operation and remains in reset while the monitored voltage is not within the desired range.

The reset source triggered by individual HVD monitors are combined into a single HVD reset. The HVD reset condition asserts a reset to all power domains with only the POR/LVD/HVD detection logic remaining operational. An HVD reset sets the appropriate bits in the CMC registers so that software can determine that an HVD reset has occurred.

22.3 External reset sources

External resets are provided so that the device can be reset or awakened from very low power states. This allows the device to start at the correct time from a known state.

22.3.1 External pin reset (RESET_b)

The RESET_b pin is a bi-directional open-drain pin with internal pull-up resistor. The RESET_b pin is functional in two modes:

- During active and low power modes, the RESET_b pin can be asserted externally to force the device into Pin reset condition.
- During reset, the RESET_b drives low until the device has completed hardware initialization, at which point the RESET_b pin is released. If the RESET_b pin is asserted externally, then the device will remain in reset until the RESET_b input is pulled high.

The RESET_b pin implements a digital filter that software can configure to filter out glitches on the RESET_b pin that are less than 1-32 CMC clock cycles. The filter is bypassed in low power modes if the CMC clock is disabled. The CMC reset filter clock source is the SLOW_CLK.

The RESET_b is multiplexed on PTD0 pin on this device. RESET_b is the default function of this GPIO pin. Asserting RESET_b wakes the device from any mode.

The PIN reset condition triggers the CMC to assert a WARM reset to all power domains. A PIN reset sets the appropriate fields in the CMC registers so that software can determine that a PIN reset has occurred.

22.3.2 Wake-up unit (WAKEUP)

The Wake-Up Unit (WUU) provides for a number of external pins and on-chip peripherals to wake the device from Power Down or Deep Power Down modes. See the WUU chapter for a list of external and internal reset sources connected to the WUU.

On a wakeup from Power Down or Deep Power Down modes, the power management logic triggers a WAKEUP reset in the power domains that had been powered off.

The WAKEUP reset condition triggers the CMC to assert a POR reset to the power domains that were powered down. The system voltage domain is not affected by a WAKEUP reset. A WAKEUP reset sets the appropriate fields in the CMC registers so that software can determine that a WAKEUP reset has occurred.

22.4 Internal reset sources

Internal resets are provided so that the device can be reset when certain erroneous conditions are detected. This allows the device to recover from the erroneous conditions and restart from a known state.

22.4.1 Watchdog (WDOG) timer

The WDOG reset is generated by one of the WDOG modules.

The WDOG monitors the operation of the system by receiving periodic communication from software, known as servicing or refreshing the WDOG. If this periodic servicing does not occur, then the Watchdog triggers a WDOG reset condition.

The WDOG reset condition triggers the CMC to assert a WARM reset to all power domains. A WDOG reset sets the appropriate fields in the CMC registers so that software can determine that a WDOG reset has occurred.

22.4.2 Software (SW)

During execution, if the software detects erroneous operation, the software can initiate a reset to restart the device from a known state.

The SW reset condition triggers the CMC to assert a WARM reset to all power domains. A SW reset sets the appropriate fields in the CMC registers so that software can determine that a SW reset has occurred.

22.4.3 System Clock Generation (SCG)

The SCG module contains a clock monitor, which, if enabled, detects a loss of the external clock. A loss of external clock triggers the SCG reset condition.

The SCG reset condition will assert a WARM reset in all power domains. The CMC_SRS[SCG] and CMC_SRS[WARM] status bits are set on a SCG reset condition.

For details on enabling the clock monitor, see the SCG chapter. To prevent unexpected reset events, clock monitors must be disabled before entering any low-power modes that the external clocks are not present.

22.4.4 Reset Acknowledge timeout (RSTACK)

The reset state machine includes a timeout counter that is triggered by the reset state machine not progressing, this will trigger the RSTACK reset condition.

The reset state machine includes a timeout counter that is triggered by the reset state machine not progressing. This triggers the RSTACK reset condition. The RSTACK reset condition asserts a warm reset in all power domains. SRS[RSTACK], SRS[FATAL], and SRS[WARM] become 1 on an RSTACK reset condition.

The RSTACK reset condition triggers the CMC to assert a WARM reset to all power domains. An RSTACK reset sets the appropriate fields in the CMC registers so that software can determine that an RSTACK reset has occurred.

22.4.5 Low Power Acknowledge timeout (LPACK)

The low power entry state machine includes a timeout counter that is triggered if a module does not acknowledge entry into a low power mode, this will trigger the LPACK reset condition.

The low-power entry state machine includes a timeout counter that triggers if a module does not acknowledge entry into low-power mode. This triggers the LPACK reset condition. The LPACK reset condition asserts a warm reset in all power domains. SRS[LPACK] and SRS[WARM] become 1 on an LPACK reset condition.

The LPACK reset condition triggers the CMC to assert a WARM reset to all power domains. An LPACK reset sets the appropriate fields in the CMC registers so that software can determine that an LPACK reset has occurred.

22.4.6 Lock up (LOCKUP)

The Cortex-M33 core will enter the lockup state as a result of certain illegal operations, this will trigger the LOCKUP reset condition.

The LOCKUP reset condition triggers the CMC to assert a WARM reset to all power domains. A LOCKUP reset sets the appropriate fields in the CMC registers so that software can determine that a LOCKUP reset has occurred.

22.4.7 Debug Port (DAP)

Any debug access port that can initiate a reset request from a connected debugger triggers the DAP reset condition.

The DAP reset condition triggers the CMC to assert a WARM reset to all power domains. A DAP reset sets the appropriate fields in the CMC registers so that software can determine that a DAP reset has occurred.

22.4.8 EdgeLock secure enclave (ELE)

Internal EdgeLock enclave resets are provided so that the security module can be reset when security violation or certain erroneous conditions are detected. This allows security module to recover from the erroneous conditions. The reset sources in the security module available in this device are as follows.

- Security violation
- Security Watchdog timer
- Security software
- Security CPU lockup
- Security debug
- eFuse loading error

Whenever the security module detects a security violation or an erroneous condition, this will trigger the EdgeLock enclave reset condition.

The EdgeLock enclave reset condition will trigger the Core Mode Controller (CMC) to assert a WARM reset to all power domains. An EdgeLock enclave reset will set the appropriate bits in the CMC registers so that software can determine that an EdgeLock enclave reset has occurred.

22.4.9 Tamper detect (TAMPER)

Whenever a tamper detection module detects a tamper event, this will trigger the TAMPER reset condition.

The TAMPER reset condition triggers the CMC to assert a WARM reset to all power domains. A TAMPER reset sets the appropriate fields in the CMC registers so that software can determine that a TAMPER reset has occurred.

22.4.10 Radio reset request

Radio reset request could happen when NBU CM33 meet timeout or NBU system hang. It should be configured in advance to decide reset Radio subsystem or whole chip.

Radio reset can be triggered for system hang using the WDOG timer or radio AHB timeout interrupt.

22.5 Reset type

This section describes the different resets that can be generated on this device and their respective reset sequences. Reset conditions on this device are categorized into two types, POR and WARM resets.

The VBAT is only reset on the VDD_SWITCH domain POR, this is independent from the rest of the device.

The RTC, CCM32K, PORTD, GPIOD are only reset on POR (VDD_SYS).

The LPTMR are reset on POR/LVD/HVD.

The WUU is reset on any reset except wakeup from PD/DPD.

Peripherals generally reset both on POR and WARM reset but here are exceptions please refer to the peripheral section. For example CAN interrupt mask bits in CTRL1, and they are only reset by the global hard reset.

An LVD will reset the regulators to their default setting (voltage level, etc). Most of the SPC is reset on POR/LVD/HVD, there are few registers that reset on the VDD_SYS POR only (mainly voltage monitors).

22.5.1 POR reset

Each power domain generates a POR that is used to reset the entire device, including debug logic and mode control logic. The POR for each power domain can assert as a result of the following events.

- Initial power-up of MCU
- Low or High Voltage Detect
- Power domain wakeup from Power Down or Deep Power Down (varies per domain)

A POR does not guarantee the contents of on-chip SRAM, except for a Power Down wakeup and then only for the SRAM that is configured to retain state.

22.5.1.1 POR reset sequence

The following steps are performed as part of the POR (or LVD/HVD) sequence:

1. RESET_b pin is driven low and internal reset signals assert.
2. POR and LVD signals negate and clocks are enabled in their default configuration.
3. Internal reset remains asserted for 15 clock cycles.
4. Internal reset to Flash and Fuse controller negate and their initialization sequences commence.
5. Initialization sequences for Flash and Fuse complete.
6. Internal trim registers are loaded and RESET_b pin is tri-stated.
7. Reset state machine waits for RESET_b pin input to pull high or drive high externally.
8. Internal reset signals negate.
9. Core exits reset and fetches the initial program counter and stack pointer from Boot ROM.

When the device wakes up from Deep Power Down or Power Down mode, the reset sequence is slightly different from the POR reset sequence. They are described in the subsequent sections.

22.5.1.2 Deep Power Down (DPD) reset sequence

The following steps are performed as part of the Deep Power Down wakeup sequence:

1. Internal reset signals assert.
2. Wakeup signal negates and clocks are enabled in their default configuration.
3. Internal reset remains asserted for 15 clock cycles.
4. Internal reset to Flash and Fuse controller negate and their initialization sequences commence.
5. Initialization sequences for Flash and Fuse complete.
6. Internal trim registers are loaded.
7. Internal reset signals negate.
8. Core exits reset and fetches the initial program counter and stack pointer from Boot ROM.

The RESET_b pin is not driven low by a Deep Power Down reset sequence unless the RESET_b pin was used as the wake up source.

A wakeup from Deep Power Down via the RESET_b pin will follow the warm reset sequence.

22.5.1.3 Power Down (PD) reset sequence

The following steps are performed as part of the Power Down wakeup sequence:

1. Internal reset signals assert.
2. Clocks are enabled in their default configuration.
3. Internal reset remains asserted for 15 clock cycles.
4. Internal trim registers are loaded.
5. Internal reset signals negate.
6. Core exits reset and fetches the initial program counter and stack pointer from Boot ROM.

The RESET_b pin is not driven low by a Power Down reset sequence unless the RESET_b pin was used as the wake up source.

A wakeup from Power Down via the RESET_b pin will follow the warm reset sequence.

22.5.2 Warm reset

A WARM reset re-initializes the device to a known state once it has already been running for a period of time.

A WARM reset resets most of the logic in each power domain. Warm resets are divided into fatal reset sources and non-fatal reset sources. See the CMC chapter for which reset sources are fatal resets.

Non-fatal reset sources can be configured to generate an interrupt instead of the WARM reset. If software can clear the non-fatal reset source (including status flag) then the WARM reset is averted. Non-fatal resets retain the contents of on-chip SRAM.

Fatal reset sources cannot be configured to generate an interrupt, and do not guarantee the contents of on-chip SRAM.

The following steps are performed as part of the warm reset sequence:

1. RESET_b pin drives low and internal reset signals assert.
2. Clocks are enabled in their default configuration.
3. Internal reset remains asserted for 15 clock cycles.
4. Internal reset to Flash and Fuse controller negate and their initialization sequences commence.
5. Initialization sequences for Flash and Fuse complete.
6. Internal trim registers are loaded and RESET_b pin is tri-stated.
7. Reset state machine waits for RESET_b pin input to pull high or drive high externally.
8. Internal reset signals negate.
9. Core exits reset and fetches the initial program counter and stack pointer from Boot ROM.

Chapter 23
Clocking

23.1 Introduction

The heart of the clocking architecture is the System Clock Generator (SCG) module. The SCG controls multiple clock sources that are distributed to the main CPU platform, the memory modules and the peripheral modules. The peripheral modules have an *interface* clock that is used by the CPU/DMA to interface with each module's registers. When applicable, modules may also have *functional* clocks to provide the main timing function of the module's application. For example, functional clocks can be used to source the baud rate for a serial communications peripheral or to clock the counter of a timer peripheral.

Each module's interface clock comes directly from the SCG. The SCG provides functional clock options via the Module Reset and Clock Control (MRCC) module. Software configures the MRCC module to select a module's functional clock. The MRCC module also provides functional clock dividers as needed.

The following diagram shows the clock sources and clock trees.

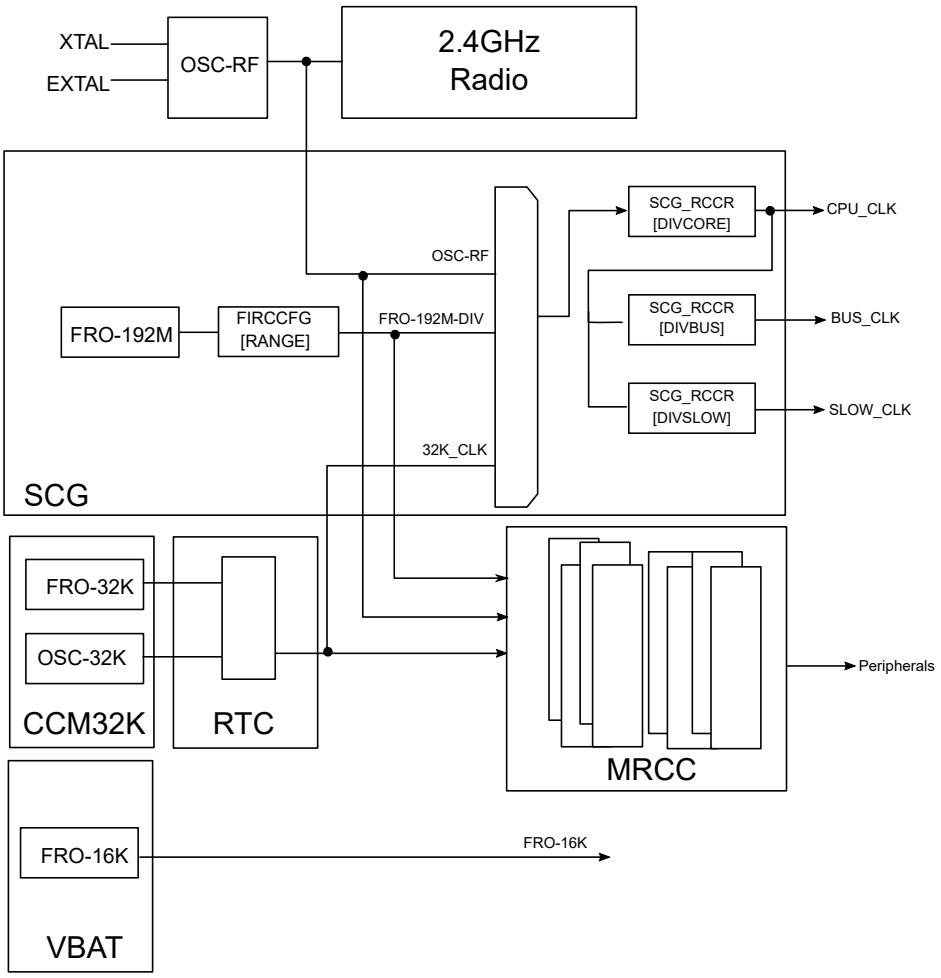


Figure 62. Device clock sources and trees

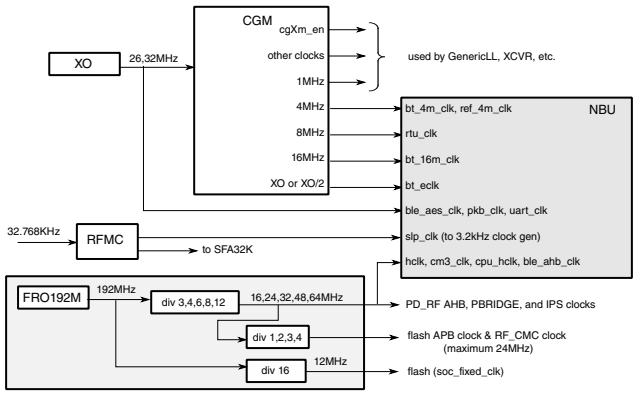


Figure 63. Radio clocking

The CPU_CLK can be sourced directly from the following:

- FRO-192M-DIV (96 MHz) – general default
- 32K_CLK
- OSC-RF

Each of the above clock sources can be divided via the SCG_RCCR[DIVCORE] divider to avoid clocking above the max CPU frequency or to reduce the CPU frequency for lower power consumption.

Other major clock trees are fed from the CPU_CLK for the on-chip peripheral and memory interfaces that are required to be either equal to the CPU_CLK frequency or an integer divide or multiple of the CPU_CLK.

The BUS_CLK and the SLOW_CLK are both sourced from the CPU_CLK. Each of this clock tree has its own independent clock divider to provide frequencies that are an integer divide of the CPU_CLK.

Modules that are required to function at a faster frequency than the CPU_CLK obtain a functional clock via the MRCC.

23.2 Clock definitions

The following table describes the clocks in the device.

Table 205. Clock definitions

Clock name	Description
CPU_CLK[1]	The main CPU clock. The CPU_CLK can be provided by one of the clock sources within the SCG, and also from the clock sources not specifically configured by the SCG. The selected clock source is fed through the DIVCORE divider stage prior to clocking the CPU. The CPU_CLK can be gated off, while other clock trees are allowed to function.
BUS_CLK[1]	The BUS_CLK provides synchronization between the CPU and the peripherals. The BUS_CLK is an integer divide or equal to the CPU_CLK. It is fed via the SCG_RCCR[DIVBUS] divider stage. The BUS_CLK can be gated off, while other clock trees are allowed to function.
SLOW_CLK	The SLOW_CLK provides synchronization between the CPU and peripherals that operate at lower frequencies. The SLOW_CLK is an integer divide of the CPU_CLK. The SLOW_CLK is fed from the CPU_CLK via the SCG_RCCR[DIVSLOW] divider stage. The SLOW_CLK can be gated off, while other clock trees are allowed to function.
OSC-32K	Oscillator with external crystal resonator of 32 kHz

Table continues on the next page...

Table 205. Clock definitions (continued)

Clock name	Description
OSC-RF	External crystal oscillator (26 MHz or 32 MHz) used by the Radio Frequency modules
FRO-32K	32 kHz Free Running Oscillator clock reference
32K_CLK	32 kHz clock source from either OSC-32K or FRO-32K
FRO-192M-DIV	192 MHz Free Running Oscillator clock source with dividers that can be used for high speed operation

1. The maximum frequency of this clock is different depending on VDD_CORE, see data sheet for details.

23.3 MRCC clock outputs

The SCG provides output clock trees for peripheral modules that require functional clocks. Functional clocks are used as the fundamental timing for applications of a module, providing asynchronous clocking from the CPU main clock. This allows modules to operate at different rates compared to the CPU platform. Examples of how functional clocks are used include:

- Clocking the reference counter of a timer module
- Sourcing the baud rate for the external communication of a serial communications peripheral

Each module that needs functional clocking has its own MRCC register that provides a clock select field, a clock disable, a divider of the selected clock source, and a peripheral reset bit that provides independent resetting of the peripheral.

23.4 Clock gating

Clock gating of modules helps consume power only for modules needed for their end application. The clock to each module can be gated on or off via a programmable register.

Each peripheral has independent clock gating for both the peripheral interface clock and the peripheral functional clock. This clock gating is controlled via the peripheral's MRCC register. Clearing MRCC[CC] disables both the interface clock and functional clock of a peripheral.

The CPU_CLK, BUS_CLK, and SLOW_CLK are always enabled in the Active modes. If these clocks are not used in low-power modes, they are disabled via the CMC and SPC modules.

23.5 Module/Peripheral clocking

The following tables detail the various clocks associated with a specific module/peripheral.

Table 206. Module/Peripheral clocking options

Peripheral/Module	Interface clock	Module/Peripheral condition out of POR/ reset condition [1]	External/Alternative input clocks	External output clocks
CPU and system modules				
EWM0	SLOW_CLK	Disabled	—	—
WDOG0	SLOW_CLK	Enabled[2]	—	—
WDOG1	SLOW_CLK	Disabled	—	—
WUU0	SLOW_CLK	Disabled	—	—
M33 CPU	CPU_CLK	Enabled	—	—

Table continues on the next page...

Table 206. Module/Peripheral clocking options (continued)

Peripheral/Module	Interface clock	Module/Peripheral condition out of POR/ reset condition [1]	External/Alternative input clocks	External output clocks
DMAx	CPU_CLK	Disabled	—	—
LCE	CPU_CLK	Disabled	—	—
TRDC	CPU_CLK	Disabled[3]	—	—
SCG0	SLOW_CLK	Enabled	—	Outputs from SCG: CPU_CLK, BUS_CLK, SLOW_CLK, 32K_CLK,FRO-192M-DIV, OSC-RF
MRCC	SLOW_CLK	Disabled	—	—
Debug (SWD)	CPU_CLK	Disabled/Enabled if SWD signals applied	SWD_CLK	—
TRGMUX0	SLOW_CLK	Disabled	—	—
CMC0	SLOW_CLK	—	—	—
SFA0	BUS_CLK	Disabled	—	—
SPM0	CPU_CLK	Disabled	—	—
Memory modules				
TCRAM	CPU_CLK	Enabled	—	—
Cache RAM	CPU_CLK	Enabled	—	—
Flash	CPU_CLK[4]	Enabled	—	—
Security modules				
CRC0	BUS_CLK	Disabled	—	—
Communication modules				
FlexIO	BUS_CLK	Disabled	—	—
LPSPI0	SLOW_CLK	Disabled	LPSPI0_CLK	LPSPI0_CLK
LPSPI1	BUS_CLK	Disabled	LPSPI1_CLK	LPSPI1_CLK
LPUART0	SLOW_CLK	Disabled	—	—
LPUART1	BUS_CLK	Disabled	—	—
SEMA42	BUS_CLK	Disabled	—	—
CAN1	BUS_CLK	Disabled	—	—
I3C0	BUS_CLK	Disabled	I3C0_SCL	I3C0_SCL
LPI2C0	SLOW_CLK	Disabled	LPI2C0_SCL	LPI2C0_SCL
LPI2C1	BUS_CLK	Disabled	LPI2C1_SCL	LPI2C1_SCL
Radio modules				

Table continues on the next page...

Table 206. Module/Peripheral clocking options (continued)

Peripheral/Module	Interface clock	Module/Peripheral condition out of POR/ reset condition [1]	External/Alternative input clocks	External output clocks
DSB	CPU_CLK	Disabled	—	—
RF-NBU	CPU_CLK	Disabled	—	—
LPTMR2	SLOW_CLK	Disabled	LPTMR0_ALT0,1,2,3	LPTMR0_ALT0,1,2,3
Timer modules				
LPTMR0	SLOW_CLK	Disabled	LPTMR0_ALT0,1,2,3	LPTMR0_ALT0,1,2,3
LPTMR1	SLOW_CLK	Disabled	LPTMR1_ALT0,1,2,3	LPTMR1_ALT0,1,2,3
LPIT0	BUS_CLK	Disabled	—	—
TPM0	SLOW_CLK	Disabled	TPM0_CLKIN	—
TPM1	BUS_CLK	Disabled	TPM1_CLKIN	—
HMI modules				
GPIOA/B/C	CPU_CLK	Disabled	—	—
GPIOD	SLOW_CLK	Enabled	—	—
PORTA/B/C	SLOW_CLK	Disabled	—	—
PORTD	SLOW_CLK	Enabled	—	—
Analog modules				
ADC-GP0	BUS_CLK	Disabled	—	—
CMP-GP0	SLOW_CLK	Disabled	—	—
CMP-GP1	SLOW_CLK	Disabled	—	—
VREF	SLOW_CLK	Disabled	—	—
SPC0	SLOW_CLK	Enabled	—	—
Battery domain				
RTC	SLOW_CLK	Enabled	—	RTC_CLKOUT

1. This is the expected status of the module out of reset.
2. Safety to have a WDOG enabled on reset, app code can disable, but provides a mechanism to protect against runaway after reset.
3. BootROM will enable if TZ-M is required, app code will enable if other policy attributes are required.
4. The flash read cycles could be multiple of CPU clock cycle which is configured by FMU_FCTRL[RWSC]

Table 207. Modules/Peripherals with MRCC functional clocking

Peripheral/ Module	Interface clock	Default status	Reset control	Clock gate	Functional alt0 clock	Functional alt1 clock	Functional alt2 clock	Functional alt3 clock	Functional alt4 clock	Functional alt5 clock
CPU and system modules										
EWM0	SLOW_CLK	Disabled	Y	Y	—	—	—	—	—	—

Table continues on the next page...

Table 207. Modules/Peripherals with MRCC functional clocking (continued)

Peripheral/ Module	Interface clock	Default status	Reset control	Clock gate	Functional alt0 clock	Functional alt1 clock	Functional alt2 clock	Functional alt3 clock	Functional alt4 clock	Functional alt5 clock
WDOG0	SLOW_CLK	Enabled	—	Y	—	—	—	—	—	—
WDOG1	SLOW_CLK	Disabled	—	Y	—	—	—	—	—	—
WUU0	SLOW_CLK	N/A	—	—	—	—	—	—	—	—
CM33 CPU	CPU_CLK	N/A	—	—	—	—	—	—	—	—
DMAx	CPU_CLK	Disabled	Y	Y	—	—	—	—	—	—
TRDC	CPU_CLK	N/A	—	—	—	—	—	—	—	—
LCE	CPU_CLK	Disabled	Y	Y	—	—	—	—	—	—
SCG0	SLOW_CLK	N/A	—	—	—	—	—	—	—	—
MRCC	SLOW_CLK	N/A	—	—	—	—	—	—	—	—
Debug (SWD)	CPU_CLK	N/A	—	—	—	—	—	—	—	—
TRGMUX0	SLOW_CLK	N/A	—	—	—	—	—	—	—	—
TCU	Test Clock	N/A	—	—	—	—	—	—	—	—
CMC0	SLOW_CLK	N/A	—	—	—	—	—	—	—	—
SFA0	BUS_CLK	Disabled	Y	Y	—	—	—	—	—	—
SEMA42	BUS_CLK	Disabled	Y	Y	—	—	—	—	—	—
SPM0	CPU_CLK	Disabled	—	Y	—	—	—	—	—	—
Memory modules										
TCRAM	CPU_CLK	Enabled	—	Y	—	—	—	—	—	—
Flash	CPU_CLK[1]	Enabled	—	Y	—	—	—	—	—	—
Security modules										
CRC0	BUS_CLK	Disabled	Y	Y	—	—	—	—	—	—
Communication modules										
FlexCAN1	BUS_CLK	Disabled	Y	Y	—	—	—	FRO-192M-DIV	OSC-RF	—
FlexIO0	BUS_CLK	Disabled	Y	Y	—	—	—	—	FRO-192M-DIV	OSC-RF
LPSPI0	SLOW_CLK	Disabled	Y	Y	—	—	—	FRO-192M-DIV	OSC-RF	—
LPSPI1	BUS_CLK	Disabled	Y	Y	—	—	—	FRO-192M-DIV	OSC-RF	—
LPUART0	SLOW_CLK	Disabled	Y	Y	—	—	—	FRO-192M-DIV	OSC-RF	32K_CLK

Table continues on the next page...

Table 207. Modules/Peripherals with MRCC functional clocking (continued)

Peripheral/ Module	Interface clock	Default status	Reset control	Clock gate	Functional alt0 clock	Functional alt1 clock	Functional alt2 clock	Functional alt3 clock	Functional alt4 clock	Functional alt5 clock
LPUART1	BUS_CLK	Disabled	Y	Y	—	—	—	FRO-192M-DIV	OSC-RF	32K_CLK
I3C0	BUS_CLK	Disabled	Y	Y	—	—	—	FRO-192M-DIV	OSC-RF	—
LPI2C0	SLOW_CLK	Disabled	Y	Y	—	—	—	FRO-192M-DIV	OSC-RF	—
LPI2C1	BUS_CLK	Disabled	Y	Y	—	—	—	FRO-192M-DIV	OSC-RF	—
Radio modules										
DSB	CPU_CLK	Disabled	Y	Y	—	—	—	—	—	—
RF-NBU	CPU_CLK	N/A	—	—	—	—	—	—	—	—
Timers modules										
LPTMR0	SLOW_CLK	N/A	—	—	—	—	—	—	—	—
LPTMR1	SLOW_CLK	N/A	—	—	—	—	—	—	—	—
LPIT0	BUS_CLK	Disabled	Y	Y	—	—	—	FRO-192M-DIV	OSC-RF	—
TPM0	SLOW_CLK	Disabled	Y	Y	—	—	—	FRO-192M-DIV	OSC-RF	32K_CLK
TPM1	BUS_CLK	Disabled	Y	Y	—	—	—	FRO-192M-DIV	OSC-RF	32K_CLK
Battery domain										
RTC	SLOW_CLK	N/A	—	—	—	—	—	—	—	—
HMI modules										
GPIOA/B/C	CPU_CLK	Disabled	Y	Y	—	—	—	—	—	—
GPIOD	SLOW_CLK	N/A	—	—	—	—	—	—	—	—
PORTA/B/C	SLOW_CLK	Disabled	Y	Y	—	—	—	—	—	—
PORTD	SLOW_CLK	N/A	—	—	—	—	—	—	—	—
Analog modules										
ADC-GP0	BUS_CLK	Disabled	Y	Y	—	—	—	FRO-192M-DIV	OSC-RF	—
CMP-GP0	SLOW_CLK	Disabled	Y	Y	—	—	—	—	—	—
CMP-GP1	SLOW_CLK	Disabled	Y	Y	—	—	—	—	—	—
VREF	SLOW_CLK	Disabled	Y	Y	—	—	—	—	—	—
SPC0	SLOW_CLK	N/A	—	—	—	—	—	—	—	—

1. The flash read cycles could be multiple of CPU clock cycle which is configured by FMU_FCTRL[RWSC]

Chapter 24
System Clock Generator (SCG)

24.1 Chip-specific SCG information

Table 208. Reference links to related information

Topic	Related module	Reference
Full description	SCG	SCG
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

24.1.1 Module instances

This device has one instance of the SCG module, SCG0.

24.1.2 Clock naming

Each device that has an SCG module generally has a few differences from SCG modules in different devices. This section describes those differences.

Signal name differences

Table 209. Device signal names = SCG signal names

Device signal		SCG chapter signal	
Free-Running Oscillator – 192 MHz	FRO_192M	FIRC	Fast internal reference clock
Free-Running Oscillator – 6 MHz	FRO_6M	SIRC	Slow internal reference clock
FRO-32K or OSC-32K is selected to become the 32K_CLK (See note below)	32K_CLK	ROSC	Real-time clock oscillator clock
OSC-RF	OSC_RF	RFOSC, SOSC	External RF clock, system oscillator clock
Not available		LPFLL	Low power FLL clock

NOTE

Separate Power Domain: The FRO-32K and the OSC-32K clocks are generated in a separate module CCM32K (32 kHz Clock Control Module) within a different power domain. The different power domain can be powered independently, allowing the RTC module (also in this separate power domain) to be clocked by one of these clock sources (FRO-32K or OSC-32K). The input to the SCG from this separate power domain is called 32K_CLK. The OSC-RF is generated in the RF module within a different power domain. The input to the SCG from this power domain is called OSC-RF.

24.1.3 SCG clock section CLKOUTCNFG[CLKOUTSEL]

The SCG can select the system clock from the following source by CLKOUTCNFG[CLKOUTSEL]:

- 0001b - System OSC (SOSC_CLK)

- 0010b - Slow IRC (SIRC_CLK)
- 0011b - Fast IRC (FIRC_CLK)
- 0100b - RTC OSC (ROSC_CLK)

NOTE

The SCG slow clock cannot be selected as SCG system clock.

24.2 Introduction

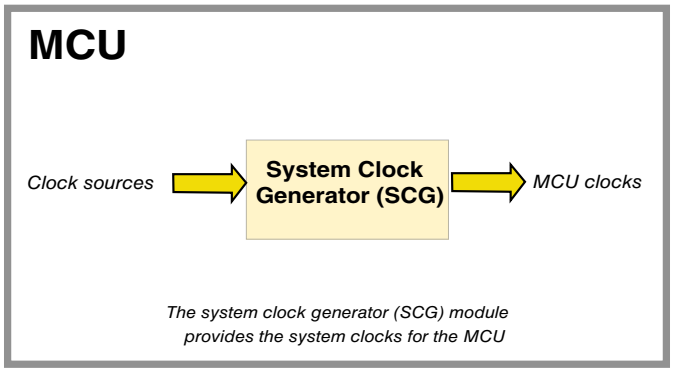


Figure 64. System Clock Generator (SCG) in MCU

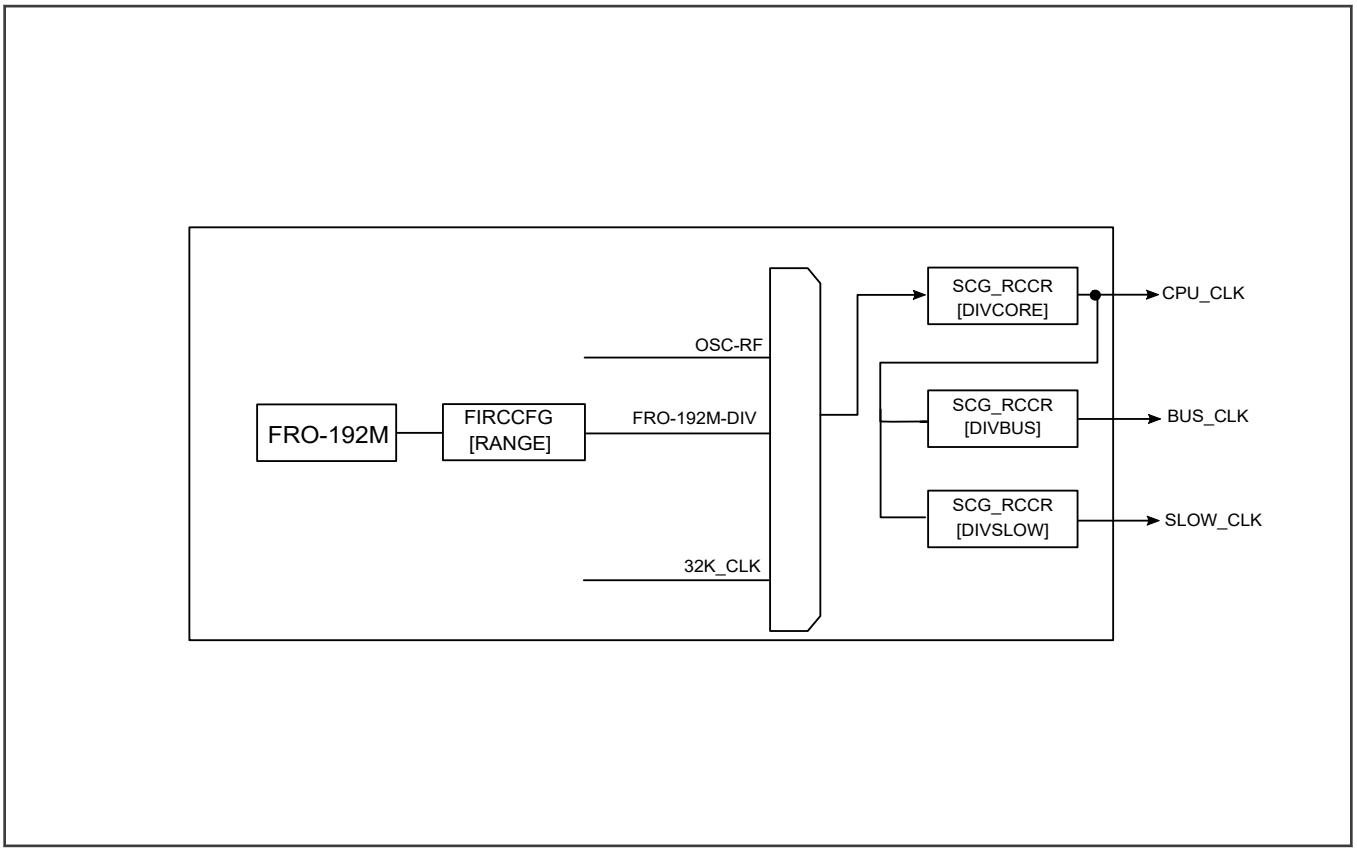
The system clock generator (SCG) module provides the system clocks for the MCU. The SCG takes clock inputs from a variety of sources and generates the types of clocks that the MCU requires.

- Available clock source inputs for the SCG include:
  - System oscillator clock (SOSC)
  - Slow internal reference clock (SIRC)
  - Fast internal reference clock (FIRC)
  - Real-Time Oscillator (ROSC)

Clock dividers are available for:

- core clock (DIVCORE)
- peripheral interface clock (DIVSLOW)
- bus clock (DIVBUS)

24.2.1 Block diagram



NOTE

To identify the oscillators used in your specific device, see the chip-specific SCG information or clocking chapters.

24.2.2 Features

Key features of the SCG module are:

- 2 Internal reference clock (IRC) generators:
  - High frequency free-running oscillator (FRO_192M) with trim capability
  - Free-running oscillator FRO_192M can be selected as the clock source for the system clocks
  - The external clock source (RFOSC) can also be used as a source clock for the systems clocks.
- System Crystal Oscillator:
  - Can be selected as the clock source for the system clocks
- Real Time Oscillator Clock (ROSC):
  - Can be selected as the clock source for the device. See the chip specific sections to ascertain which signal the RTC input maps to.
- Clock monitor with reset and interrupt request capability for SOSC, ROSC clocks

24.3 Functional description

24.3.1 SCG Clock Mode Transitions

The following figure shows the valid clock mode transitions supported by SCG.

Slow IRC (SIRC) boot mode is not supported on this device.

Figure 65. SCG Valid Mode Transitions

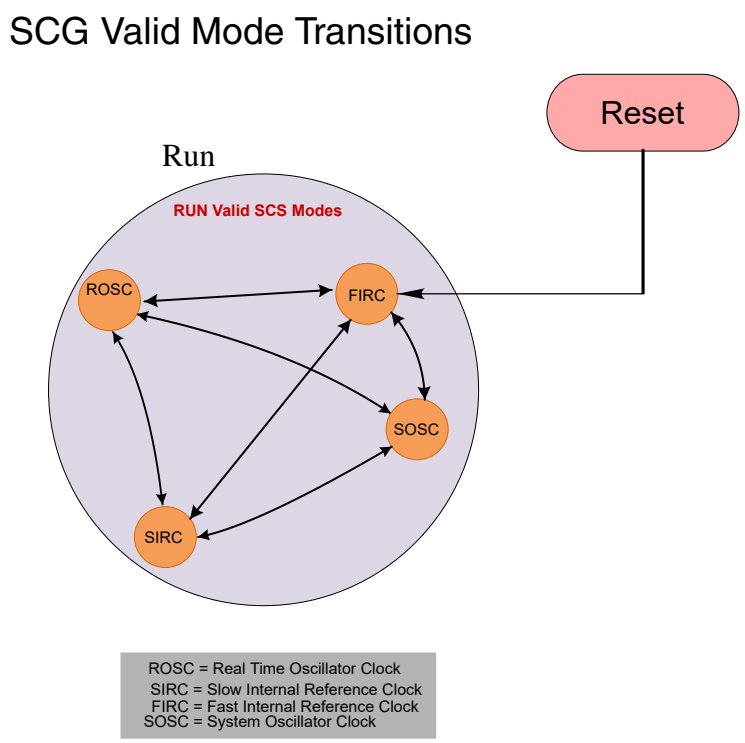


Figure 66. SCG Valid Mode Transitions

The SCG will restrict programming into invalid clock modes and writes to System Clock Source (SCS) bits will be ignored. When a transition between run modes or a transition into wait mode occurs, the SCG completes the switch to the clock mode as defined in the Run Clock Control Register (RCCR). When completed, the system switches to the selected run/wait mode.

The modes of operation listed in the following table are the valid modes for this implementation of the SCG.

Table 210. SCG modes of operation

Mode	Description
System Oscillator Clock (SOSC)	System Oscillator Clock (SOSC) mode is entered when all the following conditions occur: • RUN MODE: — 0001 is written to RCCR[SCS] • SOSCEN = 1 • SOSCVLD = 1 In SOSC mode, SCSCLKOUT and system clocks are derived from the external System Oscillator Clock (SOSC).

Table continues on the next page...

Table 210. SCG modes of operation (continued)

Mode	Description
Slow Internal Reference Clock (SIRC)	Slow Internal Reference Clock (SIRC) mode is entered when all the following conditions occur: • RUN MODE: — 0010 is written to RCCR[SCS] • SIRCVLD = 1 In SIRC mode, SCSCLKOUT and system clocks are derived from the slow internal reference clock.
Fast Internal Reference Clock (FIRC)	Fast Internal Reference Clock (FIRC) mode is the default clock mode of operation and is entered when all the following conditions occur: • RUN MODE: — 0011 is written to RCCR[SCS] • FIRCEN = 1 • FIRCVLD = 1 In FIRC mode, SCSCLKOUT and system clocks are derived from the fast internal reference clock. Two frequency range settings are available for FIRC clock as described in the FIRC[RANGE] register definition. Changes to FIRC range settings will be ignored when FIRC clock is enabled.
Real Time Clock Oscillator (RTCOSC)	Real Time Clock Oscillator (RTCOSC) mode is entered when all the following conditions occur: • RUN MODE: — 0100 is written to RCCR[SCS] • ROSCVLD = 1 In RTCOSC mode, SCSCLKOUT and systems clocks are derived from the external RTC Oscillator Clock (RTCOSC).
Stop	Entered whenever the MCU enters a Stop state. The power modes are chip-specific. For power mode assignments, see the chapter that describes how modules are configured and SCG behaviour during Stop recovery. Entering Stop mode, all SCG clock signals are static, including SCG system clocks (DIVCORE, DIVBUS, DIVSLOW). There are exceptions; the following clocks can continue to run and stay enabled in the following cases: SIRC is available in SLEEP mode when all the following conditions become true: • SIRCCSR[SIRCSTEN] = 1 FIRC is available in SLEEP mode when all the following conditions become true: • FIRCCSR[FIRCEN] = 1 • FIRCCSR[FIRCSTEN] = 1 SOSC is available in SLEEP mode when all the below conditions are true. • SOSCCSR[SOSCEN] = 1 • SOSCCSR[SOSCSTEN] = 1

24.3.2 Clocks

The following table describes the clocks of SCG.

Table 211. Clocks and their description

Clock	Type	Description
Slow Bus Clock	Input	SCG register read/write clock source.
System Oscillating Clock (SOSC)	Input	Reference clock used to generate system clocks when RCCR[SCS]=0001.
Slow Internal Reference Clock (SIRC)	Output	Reference clock used to generate system clocks when RCCR[SCS]=0010.
Fast Internal Reference Clock (FIRC)	Output	Reference clock used to generate system clocks when RCCR[SCS]=0011.
Real Time Clock Oscillator (RTCOSC)	Input	Reference clock used to generate system clocks when RCCR[SCS]=0100.

24.3.3 Interrupts/Resets

SCG includes several sources for interrupt requests. The following table summarizes these sources.

Each of these sources includes a mask control field (such as SOSCCSR[SOSCCMRE], ROSCCSR[ROSCCMRE],

Table 212. Interrupts

Flag	Functionality	Can generate interrupt?	Can generate reset?
SOSCCSR[SOSCERR]	Indicates whether SOSC source clock error has been detected either because of a loss of clock or clock has gone invalid.	Yes, if SOSCCSR[SOSCCMRE] = 0	Yes, if SOSCCSR[SOSCCMRE] = 1
ROSCCSR[ROSCCMRE]	Indicates whether ROSC source clock error has been detected either because of a loss of clock or clock has gone invalid.	Yes, if ROSCCSR[ROSCCMRE] = 0	Yes, if ROSCCSR[ROSCCMRE] = 1

24.4 External signals

SCG has no external signals.

24.5 Initialization

SCG is enabled by default and its default clock mode will be FIRC clock mode. SCG Modes of operation table describes how to configure SCG into a different clocking mode.

24.6 Memory Map/Register Definition

This section includes the memory map and register definition.

The SCG registers can only be written when in supervisor mode. Write accesses when in user mode will result in a bus transfer error. Read accesses may be performed in both supervisor and user mode.

24.6.1 SCG register descriptions

- For any writeable SCG registers, only 32-bit writes are allowed. 8-bit or 16-bit writes will result in transfer errors.

24.6.1.1 SCG memory map

SCG0 base address: 4001_E000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID Register (VERID)	32	R	0100_0000h
4h	Parameter Register (PARAM)	32	R	9800_001Eh
10h	Clock Status Register (CSR)	32	R	0302_0001h
14h	Run Clock Control Register (RCCR)	32	RW	0302_0001h
20h	SCG CLKOUT Configuration Register (CLKOUTCNFG)	32	RW	See section
100h	System OSC Control Status Register (SOSCCSR)	32	RW	See section
200h	Slow IRC Control Status Register (SIRCCSR)	32	RW	0000_0000h
300h	Fast IRC Control Status Register (FIRCCSR)	32	RW	0300_0001h
308h	Fast IRC Configuration Register (FIRCCFG)	32	RW	0000_0002h
30Ch	Fast IRC Trim Configuration Register (FIRCTCFG)	32	RW	0000_0000h
318h	Fast IRC Status Register (FIRCSTAT)	32	RW	See section
400h	RTC OSC Control Status Register (ROSCCSR)	32	RW	See section

24.6.1.2 Version ID Register (VERID)

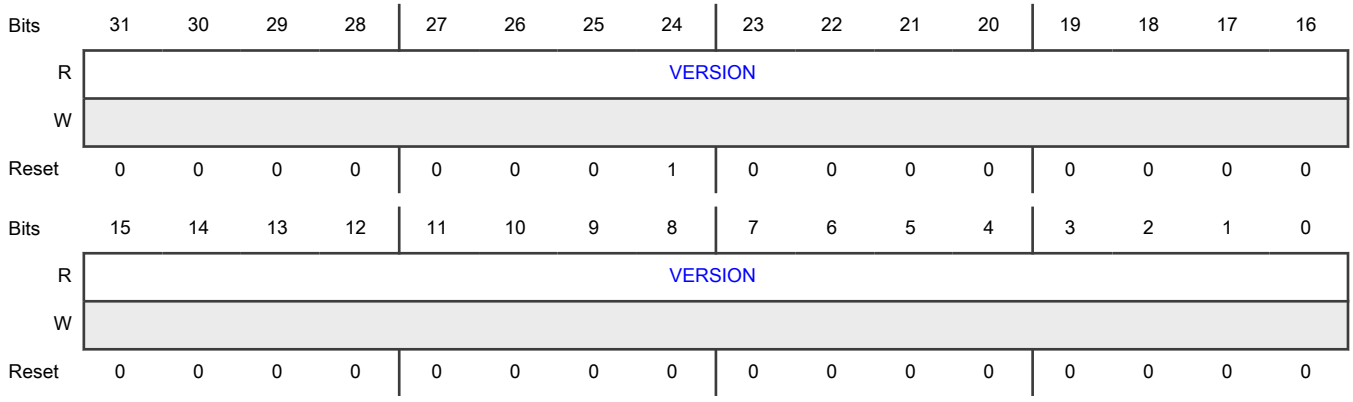
Offset

Register	Offset
VERID	0h

Function

Note: Writing to this register will result in a transfer error.

Diagram



Fields

Field	Function
31-0 VERSION	SCG Version Number

24.6.1.3 Parameter Register (PARAM)

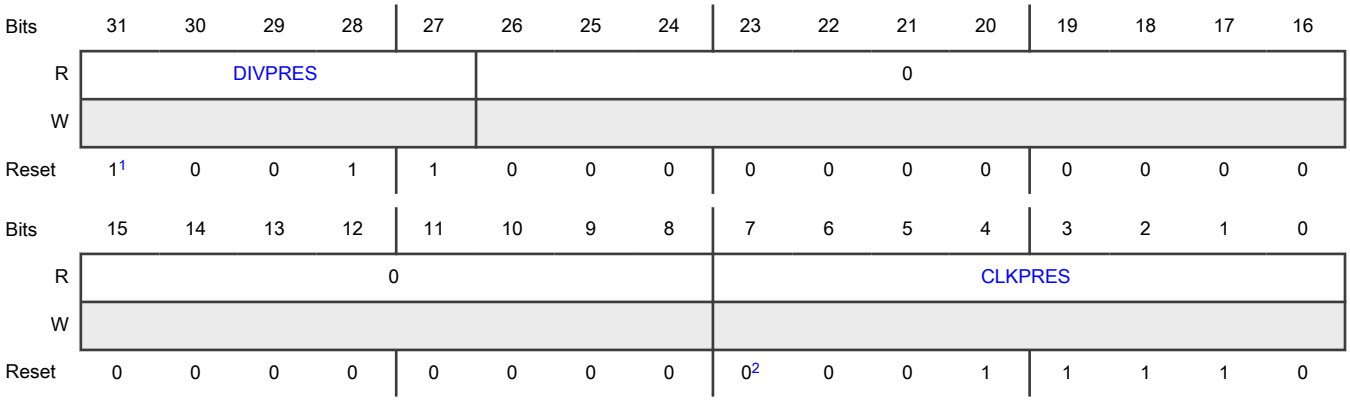
Offset

Register	Offset
PARAM	4h

Function

Note: Writing to this register will result in a transfer error.

Diagram



1. The reset value is controlled by which SCG System Dividers are used by the SoC.
2. The reset value is controlled by which SCG Clock Sources are used by the SoC. Please reference the Reference manual clocking chapter.

Fields

Field	Function
31-27 DIVPRES	Divider Present Indicates which system clock dividers are present in this instance of SCG. 1_xxxxb - System DIVCORE is present. x_xx1xb - System DIVBUS is present. x_xxx1b - System DIVSLOW is present.
26-16	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
15-8 —	Reserved
7-0 CLKPRES	Clock Present Indicates which clock sources are present in this instance of SCG. Any bits not defined in this bit field are Reserved and always has the value 0 when read. 0000_0000b-0000_0001b - Reserved xxx1_xxxxb - RTC OSC (ROSC) is present. xxxx_1xxxb - Fast IRC (FIRC) is present. xxxx_x1xxb - Slow IRC (SIRC) is present. xxxx_xx1xb - System OSC (SOSC) is present.

24.6.1.4 Clock Status Register (CSR)

Offset

Register	Offset
CSR	10h

Function

The Clock Status Register (CSR) returns the currently configured system clock source and the system clock dividers for the core (DIVCORE) and peripheral interface clock (DIVSLOW). The SCG_CSR reports the configuration set by one of the clock control registers SCG_RCCR.

Note: Writing to the Clock Status Register (CSR) will result in a transfer error.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				SCS				0				DIVCORE			
W																
Reset	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				0				DIVBUS				DIVSLOW			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Fields

Field	Function
31-28 —	Reserved
27-24 SCS	System Clock Source Returns the currently configured clock source generating the system clock. 0000b - Reserved 0001b - System OSC (SOSC_CLK) 0010b - Slow IRC (SIRC_CLK) 0011b - Fast IRC (FIRC_CLK) 0100b - RTC OSC (ROSC_CLK) 0101b - Reserved 0110b - Reserved 0111b - Reserved
23-20 —	Reserved
19-16 DIVCORE	Core Clock Divide Ratio 0000b - Divide-by-1 0001b - Divide-by-2 0010b - Divide-by-3 0011b - Divide-by-4 0100b - Divide-by-5 0101b - Divide-by-6 0110b - Divide-by-7 0111b - Divide-by-8 1000b - Divide-by-9 1001b - Divide-by-10 1010b - Divide-by-11 1011b - Divide-by-12 1100b - Divide-by-13 1101b - Divide-by-14 1110b - Divide-by-15 1111b - Divide-by-16
15-12	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
11-8 —	Reserved
7-4 DIVBUS	Bus Clock Divide Ratio 0000b - Divide-by-1 0001b - Divide-by-2 0010b - Divide-by-3 0011b - Divide-by-4 0100b - Divide-by-5 0101b - Divide-by-6 0110b - Divide-by-7 0111b - Divide-by-8 1000b - Divide-by-9 1001b - Divide-by-10 1010b - Divide-by-11 1011b - Divide-by-12 1100b - Divide-by-13 1101b - Divide-by-14 1110b - Divide-by-15 1111b - Divide-by-16
3-0 DIVSLOW	Slow Clock Divide Ratio 0000b - Divide-by-1 0001b - Divide-by-2 0010b - Divide-by-3 0011b - Divide-by-4 0100b - Divide-by-5 0101b - Divide-by-6 0110b - Divide-by-7 0111b - Divide-by-8 1000b - Divide-by-9 1001b - Divide-by-10 1010b - Divide-by-11

Table continues on the next page...

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Field	Function
	1011b - Divide-by-12 1100b - Divide-by-13 1101b - Divide-by-14 1110b - Divide-by-15 1111b - Divide-by-16

24.6.1.5 Run Clock Control Register (RCCR)

Offset

Register	Offset
RCCR	14h

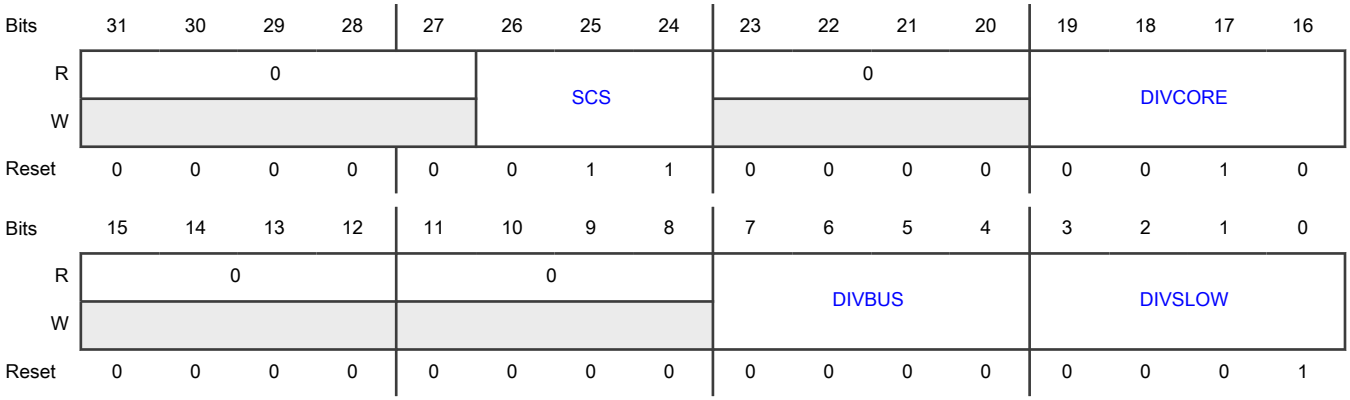
Function

This register controls the system clock source and the system clock dividers for the core, platform, external and bus clock domains when in Run mode only. This register can only be written using a 32-bit write. Selecting a different clock source when in RUN requires that clock source to be enabled first and be valid before system clocks switch to that clock source. If system clock divide ratios also change when selecting a different clock mode when in RUN, new system clock divide ratios will not take affect until a new clock source is valid.

NOTE

Switching to new system clock source and system clock dividers must be done after previous RCCR changes have been completed and the Clock Status Register has updated to match the present RCCR setting.

Diagram



Fields

Field	Function
31-27 —	Reserved
26-24 SCS	System Clock Source Selects the clock source generating the system clock in Run mode. Attempting to select a clock that is not valid will be ignored. Selecting a different clock source when in Run mode requires that clock source to be enabled first and be valid before system clocks are allowed to switch to that clock source. **NOTE** Programming SCS to a different value should only be done after the previous SCS clock switch has finished. 000b - Reserved 001b - System OSC (SOSC_CLK) 010b - Slow IRC (SIRC_CLK) 011b - Fast IRC (FIRC_CLK) 100b - RTC OSC (ROSC_CLK) 101b - Reserved 110b - Reserved 111b - Reserved
23-20 —	Reserved
19-16 DIVCORE	Core Clock Divide Ratio 0000b - Divide-by-1 0001b - Divide-by-2 0010b - Divide-by-3 0011b - Divide-by-4 0100b - Divide-by-5 0101b - Divide-by-6 0110b - Divide-by-7 0111b - Divide-by-8 1000b - Divide-by-9 1001b - Divide-by-10 1010b - Divide-by-11 1011b - Divide-by-12 1100b - Divide-by-13

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1101b - Divide-by-14 1110b - Divide-by-15 1111b - Divide-by-16
15-12 —	Reserved
11-8 —	Reserved
7-4 DIVBUS	Bus Clock Divide Ratio 0000b - Divide-by-1 0001b - Divide-by-2 0010b - Divide-by-3 0011b - Divide-by-4 0100b - Divide-by-5 0101b - Divide-by-6 0110b - Divide-by-7 0111b - Divide-by-8 1000b - Divide-by-9 1001b - Divide-by-10 1010b - Divide-by-11 1011b - Divide-by-12 1100b - Divide-by-13 1101b - Divide-by-14 1110b - Divide-by-15 1111b - Divide-by-16
3-0 DIVSLOW	Slow Clock Divide Ratio 0000b - Divide-by-1 0001b - Divide-by-2 0010b - Divide-by-3 0011b - Divide-by-4 0100b - Divide-by-5 0101b - Divide-by-6 0110b - Divide-by-7

Table continues on the next page...

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Field	Function
	0111b - Divide-by-8 1000b - Divide-by-9 1001b - Divide-by-10 1010b - Divide-by-11 1011b - Divide-by-12 1100b - Divide-by-13 1101b - Divide-by-14 1110b - Divide-by-15 1111b - Divide-by-16

24.6.1.6 SCG CLKOUT Configuration Register (CLKOUTCNFG)

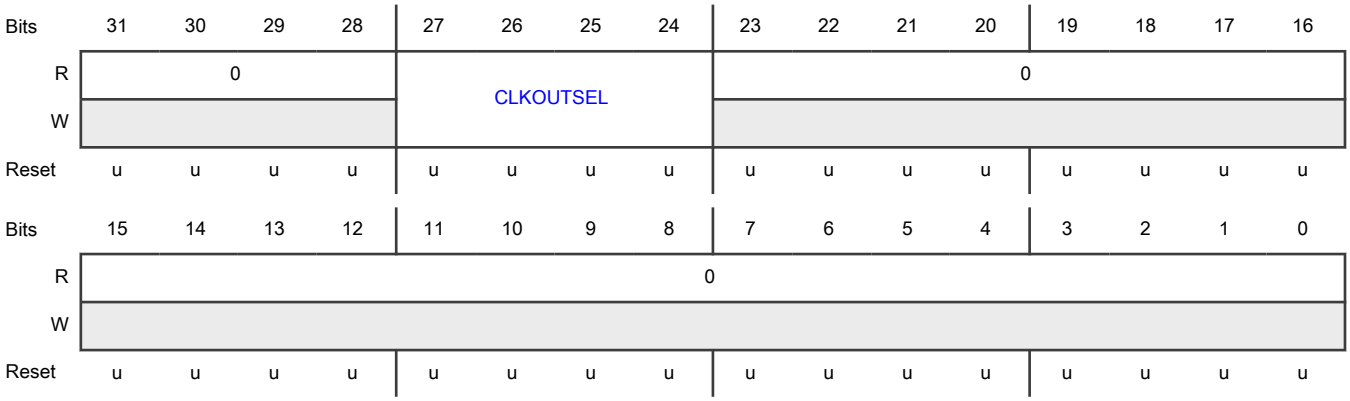
Offset

Register	Offset
CLKOUTCNFG	20h

Function

This register controls which SCG clock source is selected to be ported out to the CLKOUT pin.

Diagram



Fields

Field	Function
31-28 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
27-24 CLKOUTSEL	SCG Clkout Select Selects the SCG system clock. 0000b - SCG SLOW Clock 0001b - System OSC (SOSC_CLK) 0010b - Slow IRC (SIRC_CLK) 0011b - Fast IRC (FIRC_CLK) 0100b - RTC OSC (ROSC_CLK) 0101b - Reserved 0110b - Reserved 0111b - Reserved 1111b - Reserved
23-0 —	Reserved

24.6.1.7 System OSC Control Status Register (SOSCCSR)

Offset

Register	Offset
SOSCCSR	100h

Function

Contains System OSC Clock Error, System OSC Selected, System OSC Valid, Lock Register, System OSC Clock Monitor Reset Enable, System OSC Clock Monitor Enable , System OSC Stop Enable , System OSC Enable.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0					SOSCERR	SOSCSEL	SOSCVLD	LK	0					SOSCCMRE	SOSCCM
W						W1C										
Reset	0	0	0	0	0	u[1]	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0													0	SOSCSTEN	SOSCEN
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

1. This flag is reset on Chip POR only

Fields

Field	Function
31-27 —	Reserved
26 SOSCERR	System OSC Clock Error This flag is reset on Chip POR only, software can also clear this flag by writing a logic one. 0b - System OSC Clock Monitor is disabled or has not detected an error 1b - System OSC Clock Monitor is enabled and detected an error
25 SOSCSEL	System OSC Selected 0b - System OSC is not the system clock source 1b - System OSC is the system clock source
24 SOSCVLD	System OSC Valid 0b - System OSC is not enabled or clock is not valid 1b - System OSC is enabled and output clock is valid
23 LK	Lock Register This bit field can be cleared/set at any time. 0b - This Control Status Register can be written. 1b - This Control Status Register cannot be written.
22-18 —	Reserved
17 SOSCCMRE	System OSC Clock Monitor Reset Enable 0b - Clock Monitor generates interrupt when error detected 1b - Clock Monitor generates reset when error detected
16 SOSCCM	System OSC Clock Monitor Enable Enables the clock monitor when SOSCVLD is set. If the clock is disabled in a low power mode then SOSCCM should be cleared to prevent unexpected SOSC loss of clock. 0b - System OSC Clock Monitor is disabled 1b - System OSC Clock Monitor is enabled
15-3 —	Reserved
2 —	Reserved
1	System OSC Stop Enable

Table continues on the next page...

Table continued from the previous page...

Field	Function
SOSCSTEN	0b - System OSC is disabled in any of the sleep modes 1b - System OSC is enabled in SLEEP mode only if SOSCEN=1. SOSCSTEN must be cleared when its power domain is going to enter Deep Sleep or Power Down mode.
0 SOSCEN	System OSC Enable 0b - System OSC is disabled 1b - System OSC is enabled

24.6.1.8 Slow IRC Control Status Register (SIRCCSR)

Offset

Register	Offset
SIRCCSR	200h

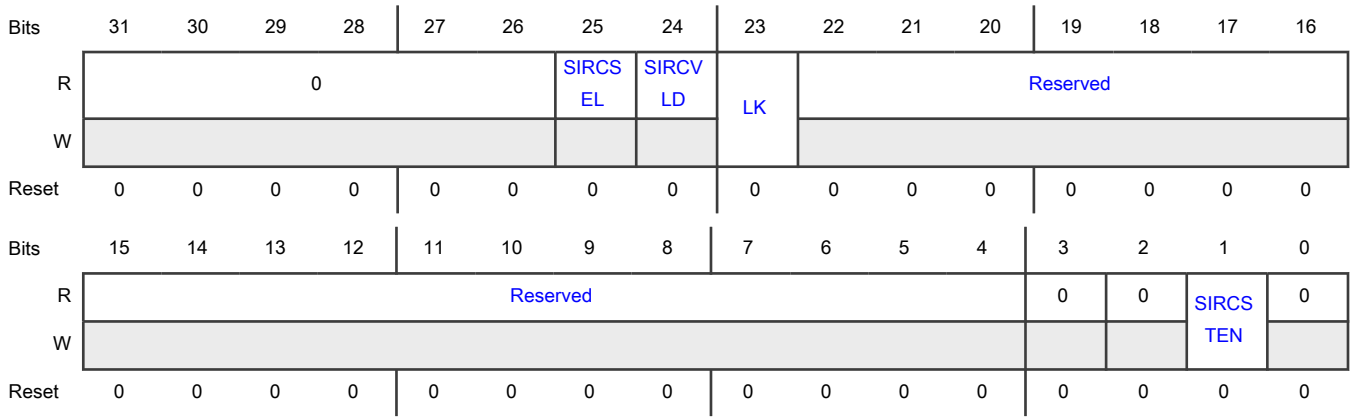
Function

Contains Slow IRC Selected, Slow IRC Valid, Lock Register , Slow IRC Stop Enable , Slow IRC Enable.

NOTE

SIRCVLD is reset only by POR.

Diagram



Fields

Field	Function
31-26 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
25 SIRCSEL	Slow IRC Selected 0b - Slow IRC is not the system clock source 1b - Slow IRC is the system clock source
24 SIRCVLD	Slow IRC Valid 0b - Slow IRC is not enabled or clock is not valid 1b - Slow IRC is enabled and output clock is valid
23 LK	Lock Register This bit field can be cleared/set at any time. The purpose for this bitfield is to prevent runaway code from changing SIRC clock configurations. 0b - Control Status Register can be written. 1b - Control Status Register cannot be written.
22-4 —	This field is reserved and is always has the value 0
3 —	This field is reserved and is always has the value 0
2 —	Reserved
1 SIRCSTEN	Slow IRC Stop Enable 0b - Slow IRC is disabled in sleep modes 1b - Slow IRC is enabled in SLEEP mode
0 —	Reserved

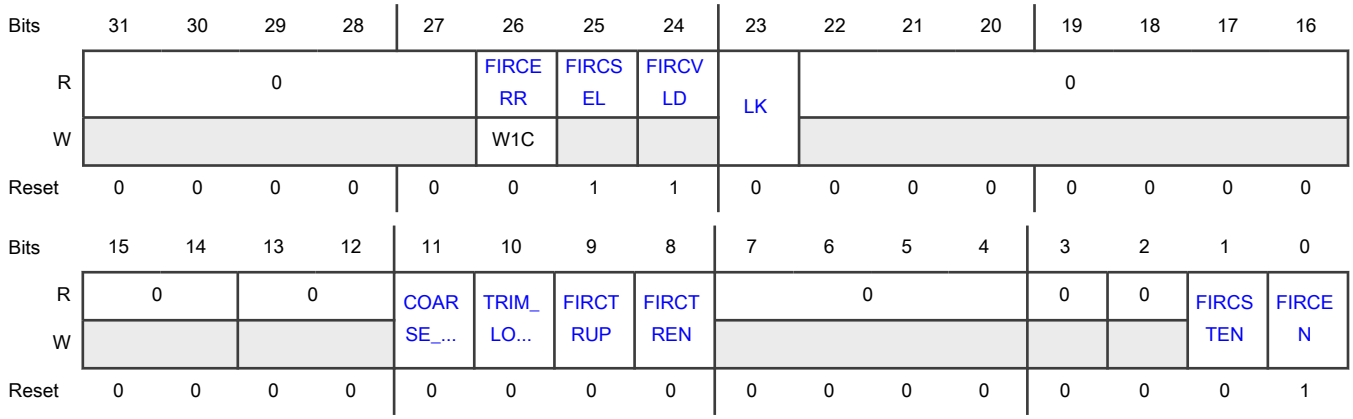
24.6.1.9 Fast IRC Control Status Register (FIRCCSR)

Offset

Register	Offset
FIRCCSR	300h

Function
Contains Fast IRC status bits.

Diagram



Fields

Field	Function
31-27 —	Reserved
26 FIRCERR	Fast IRC Clock Error This flag is reset on Chip POR only, software can also clear this flag by writing a logic one 0b - Error not detected with the Fast IRC trimming. 1b - Error detected with the Fast IRC trimming.
25 FIRCSEL	Fast IRC Selected status 0b - Fast IRC is not the system clock source 1b - Fast IRC is the system clock source
24 FIRCVLD	Fast IRC Valid status 0b - Fast IRC is not enabled or clock is not valid. 1b - Fast IRC is enabled and output clock is valid. The clock is valid after there is an output clock from the FIRC analog.
23 LK	Lock Register This bit field can be cleared/set at any time. 0b - Control Status Register can be written. 1b - Control Status Register cannot be written.
22-14 —	Reserved
13-12 —	Reserved

Table continues on the next page...

Table continued from the previous page...

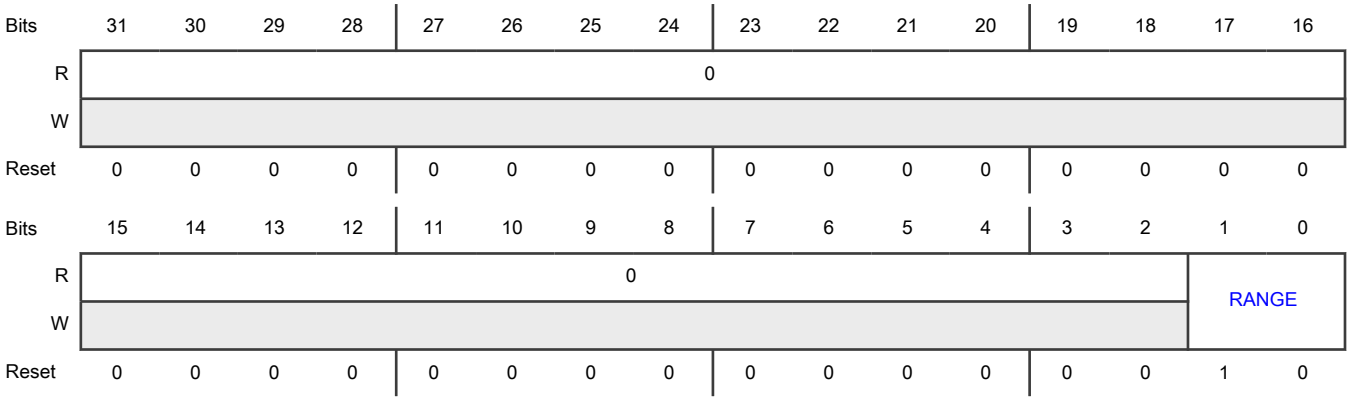
Field	Function
11 COARSE_TRIM_BYPASS	Fast Coarse Auto Trim Bypass 0b - FIRC Coarse Auto Trim NOT Bypassed 1b - FIRC Coarse Auto Trim Bypassed
10 TRIM_LOCK	Fast IRC TRIM LOCK When FIRCTREN and FIRCTRUP are enabled, TRIM_LOCK will indicate when auto trimming is complete and output FIRC frequency has locked to target FIRC range. **NOTE** TRIM_LOCK will automatically get cleared if FIRCTREN and FIRCTRUP are not set. 0b - FIRC auto trim not locked to target frequency range. 1b - FIRC auto trim locked to target frequency range
9 FIRCTRUP	Fast IRC Trim Update 0b - Disable Fast IRC trimming updates 1b - Enable Fast IRC trimming updates
8 FIRCTREN	Fast IRC Trim Enable 0b - Disable trimming Fast IRC to an external clock source 1b - Enable trimming Fast IRC to an external clock source
7-4 —	Reserved
3 —	Reserved
2 —	Reserved
1 FIRCSTEN	Fast IRC Stop Enable 0b - Fast IRC is disabled in sleep modes. 1b - Fast IRC is enabled in SLEEP modes
0 FIRCEN	Fast IRC Enable 0b - Fast IRC is disabled 1b - Fast IRC is enabled

24.6.1.10 Fast IRC Configuration Register (FIRCCFG)

Offset

Register	Offset
FIRCCFG	308h

Diagram



Fields

Field	Function
31-2 —	Reserved
1-0 RANGE	Frequency Range RANGE can be changed while FIRC clock is enabled 00b - 48 MHz FIRC clock selected. 01b - 64 MHz FIRC clock selected. 10b - 96 MHz FIRC clock selected. 11b - 192 MHz FIRC clock selected.

24.6.1.11 Fast IRC Trim Configuration Register (FIRCTCFG)

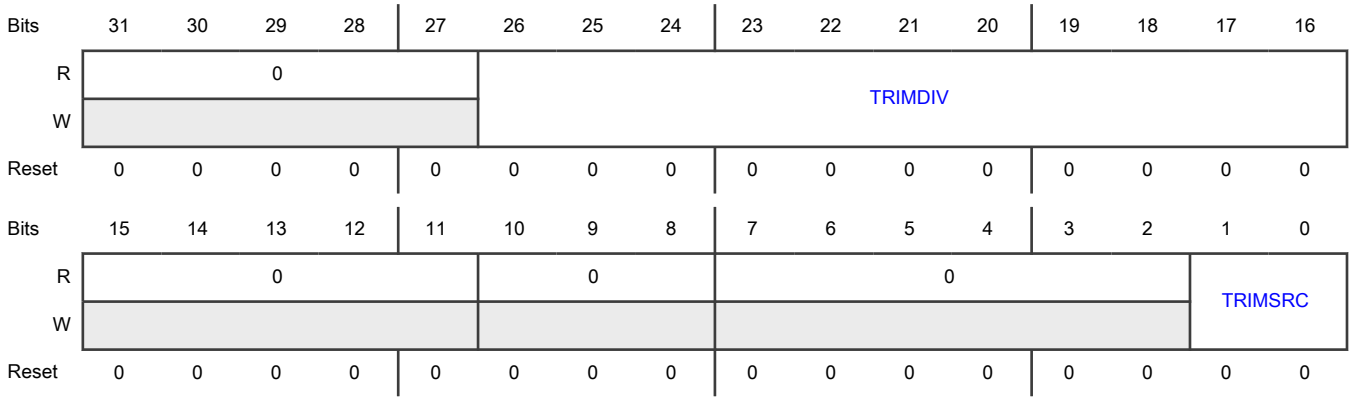
Offset

Register	Offset
FIRCTCFG	30Ch

Function

The FIRCTCFG register cannot be changed when Fast IRC tuning is enabled. When the Fast IRC tuning is enabled, writes to this register are ignored, and there is no transfer error.

Diagram



Fields

Field	Function
31-27 —	Reserved
26-16 TRIMDIV	Fast IRC Trim Predivide Divider of SOSC for FIRC trimming. **NOTE** When selecting SOSC as FIRC trimming source the TRIMDIV register must be set to correct div ratio to generate 1 MHz output reference trimming clock. **NOTE** TRIMDIV is a N-Divider supporting a div ratio of 1 (TRIMDIV=0x000) to a div ratio of 2048 (TRIMDIV=0x7ff).
15-11 —	Reserved
10-8 —	Reserved
7-2 —	Reserved
1-0 TRIMSRC	Trim Source Configures the external clock source to tune the Fast IRC. TRIMSRC must be configured before programming FIRCSTAT register for trim update 00b - Reserved 01b - Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
	10b - System OSC. This option requires that SOSC be divided using the TRIMDIV field to get a frequency of 1 MHz. 11b - RTC OSC (32.768 kHz)

24.6.1.12 Fast IRC Status Register (FIRCSTAT)

Offset

Register	Offset
FIRCSTAT	318h

Function

This register is loaded from IFR during reset. This register is uploaded with the trim values generated by FIRC auto-trimming which is enabled when FIRC is enabled and FIRCTREN=1 and FIRCTRUP=1. When FIRC auto-trimming is enabled and FIRCTRUP is off (Note: TRIMSRC needs to be programmed to TRIMSRC=10 or TRIMSRC=11), writes to this register are allowed and values written to this register are used to trim FIRC clock.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		TRIMCOAR						TRIMFINE							
W																
Reset	0	0	u[1]	u	u	u	u	u	u[1]	u	u	u	u	u	u	u

1. Reset values are loaded out of IFR.

Fields

Field	Function
31-16 —	Reserved
15-14 —	Reserved
13-8	Trim Coarse

Table continues on the next page...

Table continued from the previous page...

Field	Function
TRIMCOAR	TRIMCOAR bits are used to coarsely trim the Fast IRC Clock to within approximately ±TBD% of the target frequency. When FIRC is enabled and auto trimming is enabled (FIRCTREN=1 and FIRCTRUP=1), then TRIMCOAR register gets uploaded with the trimmed coarse value. When FIRCTRUP=0, TRIMCOAR register is writable, to allow user programming of coarse trim values.
7-0 TRIMFINE	Trim Fine See the device's datasheet for the trim values.

24.6.1.13 RTC OSC Control Status Register (ROSCCSR)

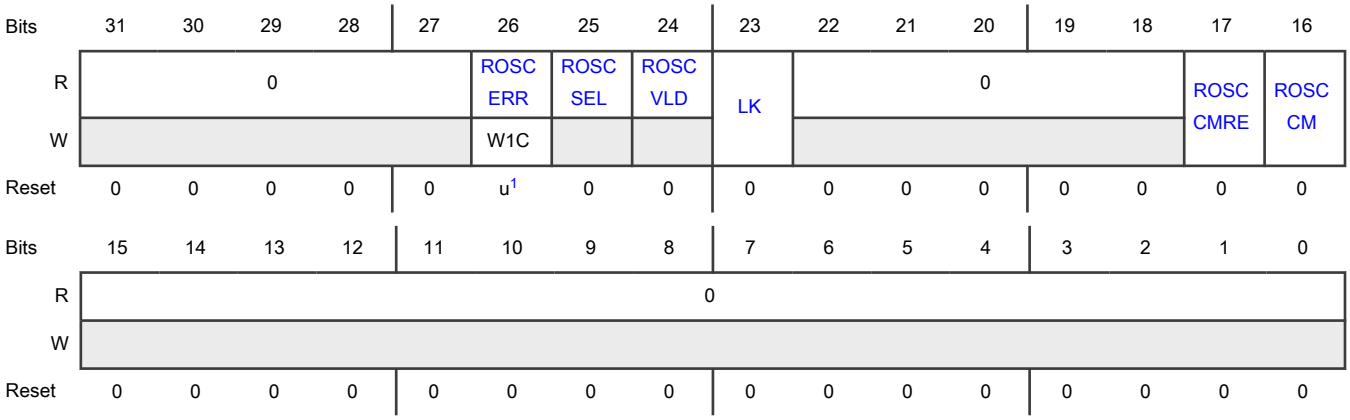
Offset

Register	Offset
ROSCCSR	400h

Function

Contains RTC OSC Clock Error, RTC OSC Selected, RTC OSC Valid, Lock Register, RTC OSC Clock Monitor Reset Enable, RTC OSC Clock Monitor.

Diagram



1. Reset values are loaded out of IFR.

Fields

Field	Function
31-27 —	Reserved
26	RTC OSC Clock Error

Table continues on the next page...

Table continued from the previous page...

Field	Function
ROSCERR	This flag is reset on Chip POR only, software can also clear this flag by writing a logic one 0b - RTC OSC Clock Monitor is disabled or has not detected an error 1b - RTC OSC Clock Monitor is enabled and detected an RTC loss of clock error
25 ROSCSEL	RTC OSC Selected 0b - RTC OSC is not the system clock source 1b - RTC OSC is the system clock source
24 ROSCVLD	RTC OSC Valid 0b - RTC OSC is not enabled or clock is not valid 1b - RTC OSC is enabled and output clock is valid
23 LK	Lock Register This bit field can be cleared/set at any time. 0b - Control Status Register can be written. 1b - Control Status Register cannot be written.
22-18 —	Reserved
17 ROSCCMRE	RTC OSC Clock Monitor Reset Enable 0b - Clock Monitor generates interrupt when error detected 1b - Clock Monitor generates reset when error detected
16 ROSCCM	RTC OSC Clock Monitor Enables the clock monitor when ROSCVLD is set. **NOTE** ROSC clock monitor remains enabled in SLEEP mode only if ROSCCM is enabled. When the clock monitor is disabled in a low power mode, it remains disabled until the clock valid flag is set following exit from the low power mode. **NOTE** The reference clock used to monitor the ROSC is the SIRC. SIRC clock must be programmed to be enabled in order to monitor the ROSC. SIRC is automatically disabled in DSLEEP, PDOWN, and DPDOWN power modes and clock monitor of ROSC will be disabled. 0b - RTC OSC Clock Monitor is disabled 1b - RTC OSC Clock Monitor is enabled
15-0 —	Reserved

Chapter 25
Module Reset and Clock Control (MRCC)

25.1 Chip-specific MRCC information

Table 213. Reference links to related information

Topic	Related module	Reference
Full description	MRCC	MRCC
System memory map		System memory map
Clocking		Clock distribution
Reset		Reset

25.1.1 Peripheral functional clock maximum frequency

The maximum frequency of the modules clock are not all the same in middle mode (MD, VDD_CORE = 1.0 V) and standard mode (SD, VDD_CORE = 1.1 V)).

Table 214. Peripheral clock maximum frequency

Peripherals	Max. frequency in MD (MHz)	Max. frequency in SD (MHz)
TPM0	24	24
TPM1	48	96
TPM2	24	24
LPI2C0	48	48
LPI2C1	96	96
I3C0	96	96
LPSPI0	48	48
LPSPI1	96	96
LPUART0	24	24
LPUART1	96	96
FLEXIO0	48	96
CAN1	48	96
LPIT0	48	96
ADC0	48	64

25.2 Introduction

The Module Reset and Clock Control (MRCC) module provides reset control and clock configuration for on-chip modules. Each module has its own configuration register.

25.3 Features

Per individual module, the MRCC module enables software to:

- Gate all clocks to the module
- Select the source of the functional clock
- Divide the functional clock
- Hold the module in reset

Below is a block diagram of the MRCC module:

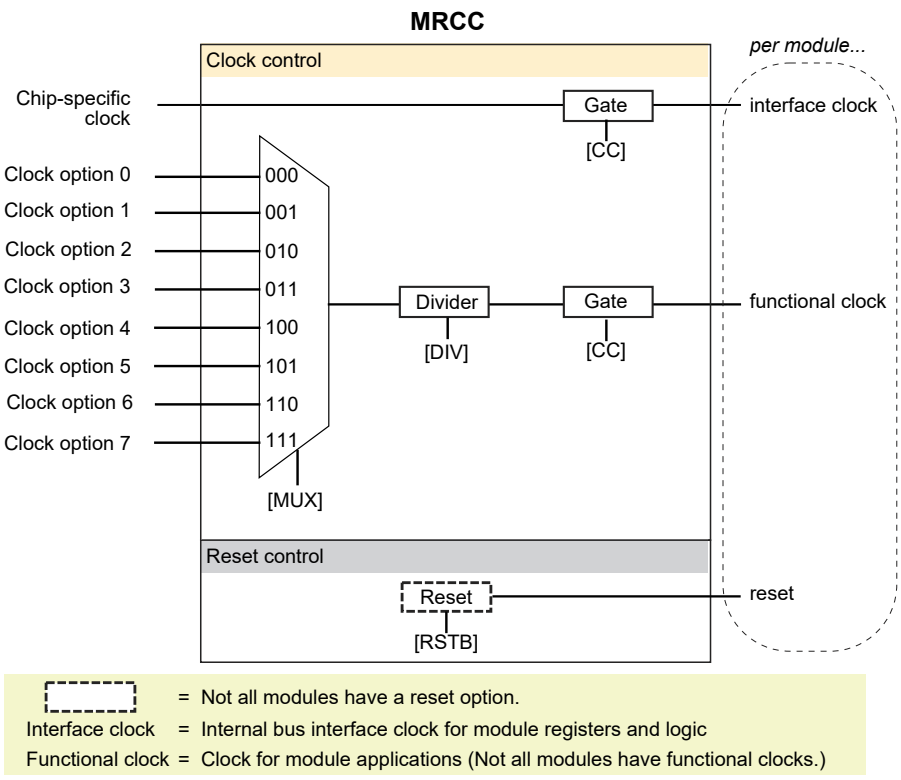


Figure 67. MRCC Block Diagram

25.4 Functional description

The MRCC module provides on-chip modules their own dedicated MRCC registers for clock gating, reset control and configuration options. Generally, each module's MRCC register contains a clock configuration (CC) field for the module's clocks.

NOTE

Before a module can be used, its clocks must be enabled (CC does not equal 00) and it must be released from reset (RSTB = 1). If a module is *not* released from reset (RSTB = 0), an attempt to access a register within that module is terminated with a bus error.

If a module has a functional clock, its MRCC register may provide options for the clock source, selected by programming the mux select (MUX) field. The selected functional clock source can then be divided by programming the divider (DIV) field.The divider factor is given by DIV+1.

NOTE

Before configuring a functional clock, the module's clocks must be disabled (CC = 00).

25.5 Memory map and register definition

Each module has its own dedicated MRCC register. See each module's MRCC register for details.

NOTE

1. To configure the clocking options available to a given module or to modify an existing configuration, first disable the module's clocks by writing 00 to its CC field. 2. For any clock which selected 32k as clock source, it should wait at least 4 clk cycle (4*1/32kHz=125us) to let the CC bit be synced by 32k clk to enable clk out. In this period do not configure MRCC.

25.5.1 IPC register descriptions

25.5.1.1 IPC memory map

MRCC base address: 4001_C000h

Offset	Register	Width (In bits)	Access	Reset value
4Ch	EWM0 reset and clock control (MRCC_EWM0)	32	RW	8000_0000h
5Ch	SYSPM0 reset and clock control (MRCC_SYSPM0)	32	RW	0000_0000h
68h	WDOG0 reset and clock control (MRCC_WDOG0)	32	RW	0000_0002h
6Ch	WDOG1 reset and clock control (MRCC_WDOG1)	32	RW	0000_0000h
74h	SFA0 reset and clock control (MRCC_SFA0)	32	RW	8000_0000h
8Ch	CRC0 reset and clock control (MRCC_CRC0)	32	RW	8000_0000h
90h	SECSUBSYS reset and clock control (MRCC_SECSUBSYS)	32	RW	8000_0000h
BCh	LPIT0 reset and clock control (MRCC_LPIT0)	32	RW	8000_0000h
C4h	TPM0 reset and clock control (MRCC_TPM0)	32	RW	8000_0000h
C8h	TPM1 reset and clock control (MRCC_TPM1)	32	RW	8000_0000h
CCh	LPI2C0 reset and clock control (MRCC_LPI2C0)	32	RW	8000_0000h
D0h	LPI2C1 reset and clock control (MRCC_LPI2C1)	32	RW	8000_0000h
D4h	I3C0 reset and clock control (MRCC_I3C0)	32	RW	8000_0000h
D8h	LPSPI0 reset and clock control (MRCC_LPSPI0)	32	RW	8000_0000h
DCh	LPSPI1 reset and clock control (MRCC_LPSPI1)	32	RW	8000_0000h
E0h	LPUART0 reset and clock control (MRCC_LPUART0)	32	RW	8000_0000h
E4h	LPUART1 reset and clock control (MRCC_LPUART1)	32	RW	8000_0000h
E8h	FLEXIO0 reset and clock control (MRCC_FLEXIO0)	32	RW	8000_0000h
ECh	CAN0 reset and clock control (MRCC_CAN0)	32	RW	8000_0000h
FCh	SEMA0 reset and clock control (MRCC_SEMA0)	32	RW	8000_0000h
104h	DATA_STREAM_2P4 reset and clock control (MRCC_DATA_STREAM_2P4)	32	RW	8000_0000h
108h	PORTA reset and clock control (MRCC_PORTA)	32	RW	8000_0000h
10Ch	PORTB reset and clock control (MRCC_PORTB)	32	RW	8000_0000h

Table continues on the next page...

Table continued from the previous page...

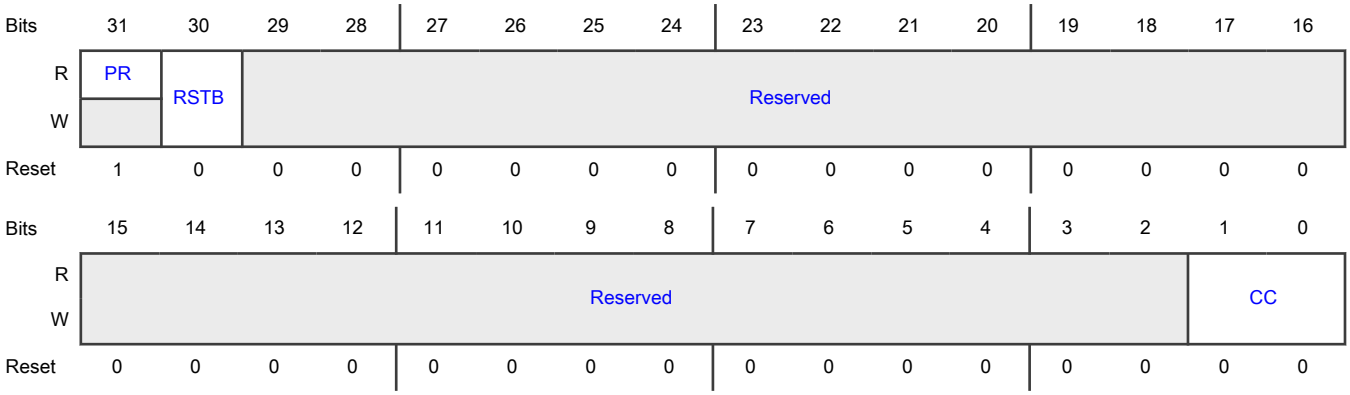
Offset	Register	Width (In bits)	Access	Reset value
110h	PORTC reset and clock control (MRCC_PORTC)	32	RW	8000_0000h
11Ch	LPADC0 reset and clock control (MRCC_LPADC0)	32	RW	8000_0000h
120h	LPCMP0 reset and clock control (MRCC_LPCMP0)	32	RW	8000_0000h
124h	LPCMP1 reset and clock control (MRCC_LPCMP1)	32	RW	8000_0000h
128h	VREF0 reset and clock control (MRCC_VREF0)	32	RW	8000_0000h
134h	MTR_MASTER reset and clock control (MRCC_MTR_MASTER)	32	RW	0000_0000h
13Ch	CAN1 (MRCC_CAN1)	32	RW	8000_0000h
404h	GPIOA reset and clock control (MRCC_GPIOA)	32	RW	8000_0000h
408h	GPIOB reset and clock control (MRCC_GPIOB)	32	RW	8000_0000h
40Ch	GPIOC reset and clock control (MRCC_GPIOC)	32	RW	8000_0000h
410h	DMA0 reset and clock control (MRCC_DMA0)	32	RW	8000_0000h
414h	PFLEXNVM reset and clock control (MRCC_PFLEXNVM)	32	RW	0000_0002h
41Ch	SRAM0 ecc reset and clock control (MRCC_SRAM0)	32	RW	0000_0002h
420h	SRAM1 ecc reset and clock control (MRCC_SRAM1_ecc)	32	RW	0000_0002h
424h	SRAM2 reset and clock control (MRCC_SRAM2)	32	RW	0000_0002h
428h	SRAM3 reset and clock control (MRCC_SRAM3)	32	RW	0000_0002h
42Ch	Clock_Config (MRCC_SRAM0_noecc)	32	RW	0000_0002h
430h	DSP0 reset and clock control (MRCC_DSP0)	32	RW	8000_0000h
434h	DSP0_MUA reset and clock control (MRCC_DSP0_MUA)	32	RW	8000_0000h
438h	SRAM1 reset and clock control (MRCC_SRAM1_noecc)	32	RW	0000_0002h
43Ch	RF_2P4GHZ_BIST reset and clock control (MRCC_RF_2P4GHZ_BIST)	32	RW	0000_0000h
440h	LPTMR0_IPG_CLK_ERCLK_WAKE2VSYS reset and clock control (MRCC_LPTMR0_IPG_CLK_ERCLK_WAKE2VSYS)	32	RW	0000_0000h
444h	LPTMR1_IPG_CLK_ERCLK_WAKE2VSYS reset and clock control (MRCC_LPTMR1_IPG_CLK_ERCLK_WAKE2VSYS)	32	RW	0000_0000h
448h	LPTMR2_IPG_CLK_ERCLK_WAKE2VSYS reset and clock control (MRCC_LPTMR2_IPG_CLK_ERCLK_WAKE2VSYS)	32	RW	0000_0000h

25.5.1.2 EWM0 reset and clock control (MRCC_EWM0)

Offset

Register	Offset
MRCC_EWM0	4Ch

Diagram



Fields

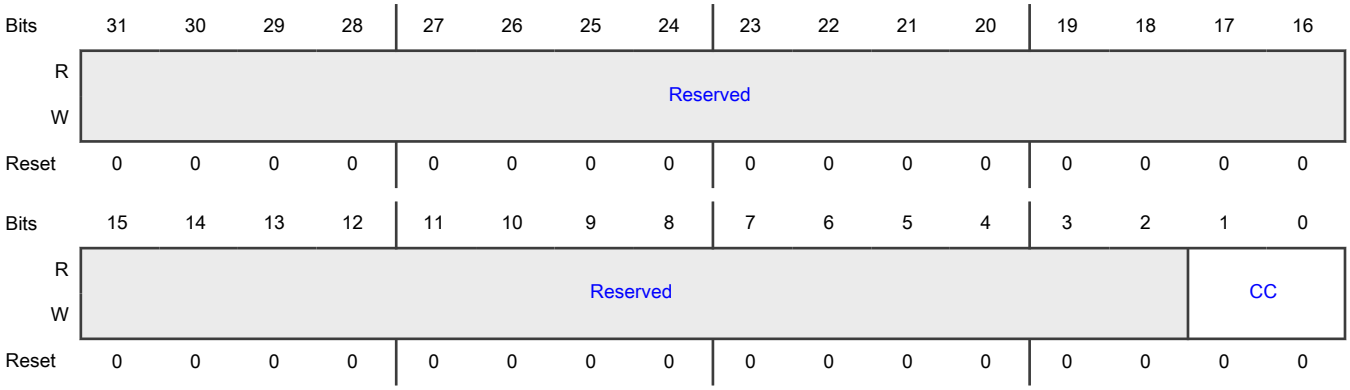
Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.3 SYSPM0 reset and clock control (MRCC_SYSPM0)

Offset

Register	Offset
MRCC_SYSPM0	5Ch

Diagram



Fields

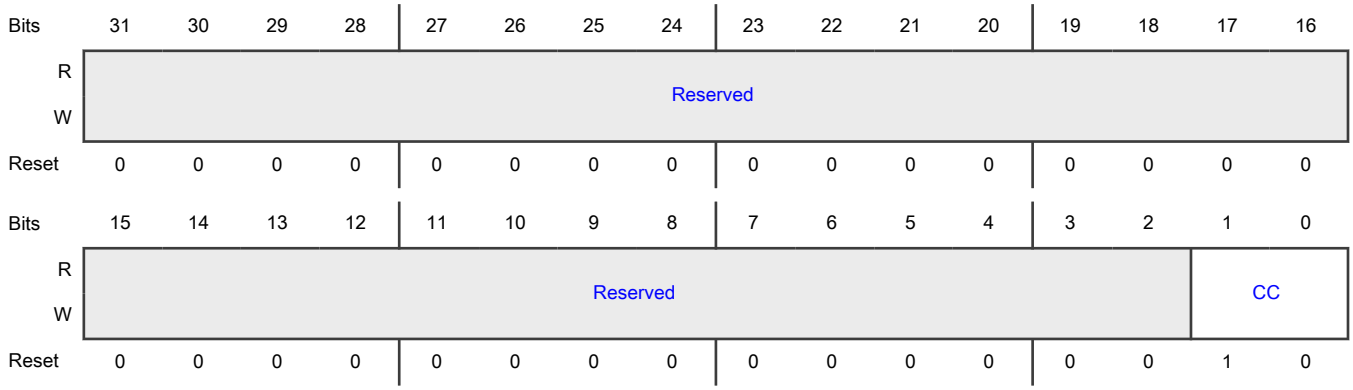
Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.4 WDOG0 reset and clock control (MRCC_WDOG0)

Offset

Register	Offset
MRCC_WDOG0	68h

Diagram



Fields

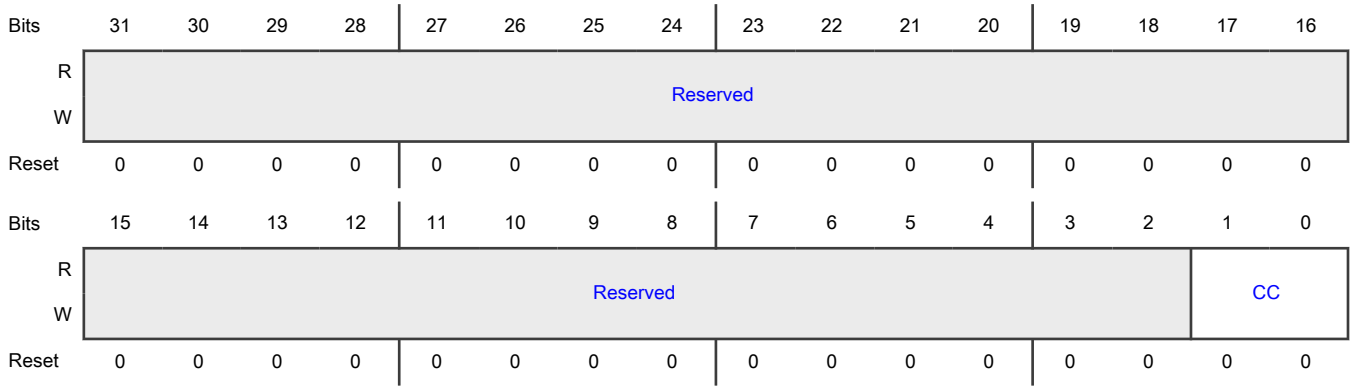
Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.5 WDOG1 reset and clock control (MRCC_WDOG1)

Offset

Register	Offset
MRCC_WDOG1	6Ch

Diagram



Fields

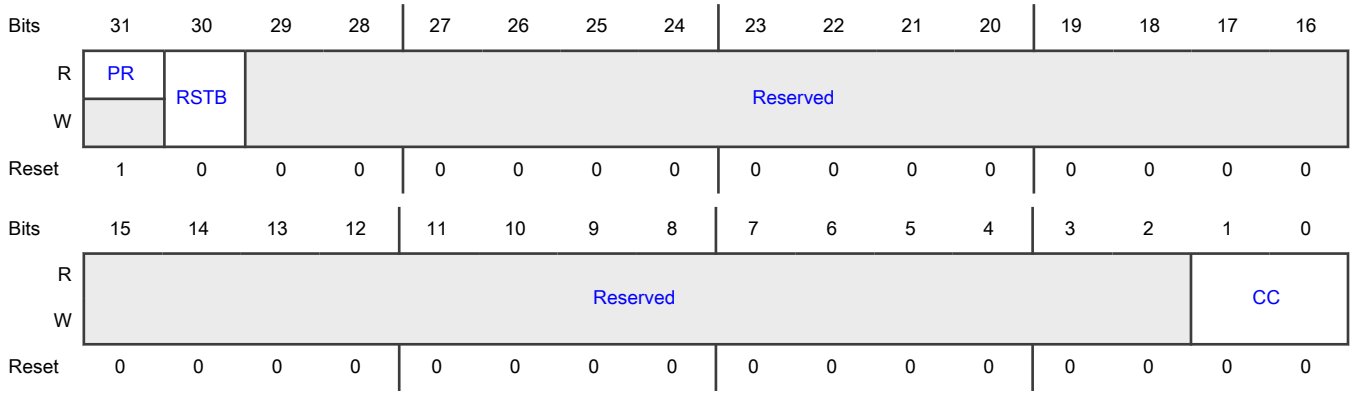
Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.6 SFA0 reset and clock control (MRCC_SFA0)

Offset

Register	Offset
MRCC_SFA0	74h

Diagram



Fields

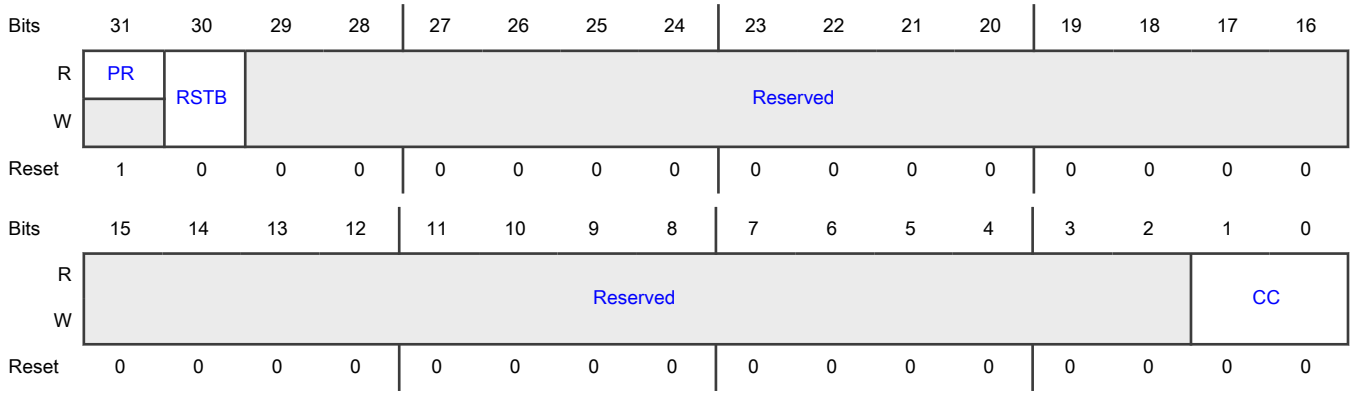
Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.7 CRC0 reset and clock control (MRCC_CRC0)

Offset

Register	Offset
MRCC_CRC0	8Ch

Diagram



Fields

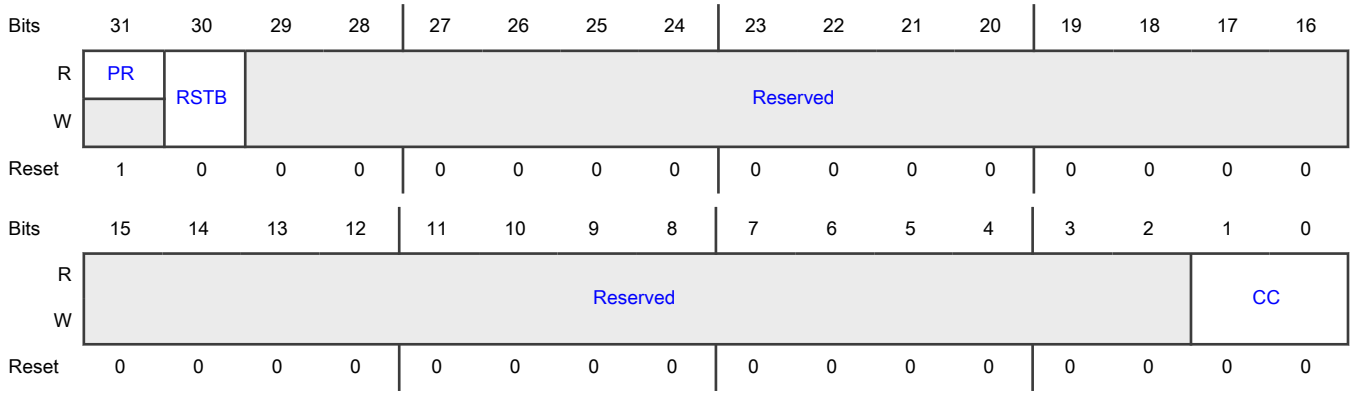
Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.8 SECSUBSYS reset and clock control (MRCC_SECSUBSYS)

Offset

Register	Offset
MRCC_SECSUBSYS	90h

Diagram



Fields

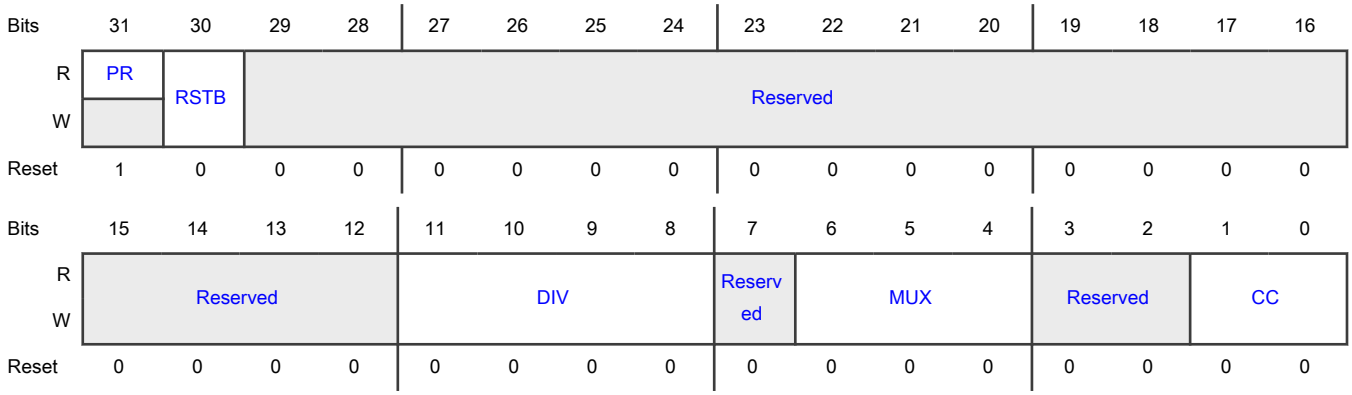
Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.9 LPIT0 reset and clock control (MRCC_LPIT0)

Offset

Register	Offset
MRCC_LPIT0	BCh

Diagram



Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-12 —	reserved reserved
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK
3-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry

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Field	Function
	01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.10 TPM0 reset and clock control (MRCC_TPM0)

Offset

Register	Offset
MRCC_TPM0	C4h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PR	RSTB	Reserved													
W																
Reset	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved				DIV				Reserved	MUX			Reserved		CC	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-12 —	reserved reserved

Table continues on the next page...

Table continued from the previous page...

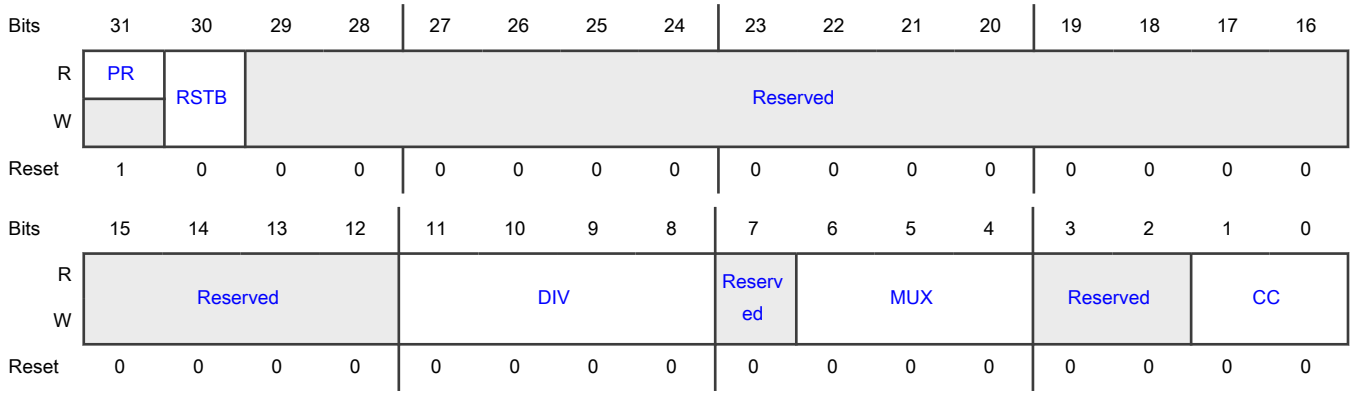
Field	Function
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK 101b - 32K-CLK
3-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.11 TPM1 reset and clock control (MRCC_TPM1)

Offset

Register	Offset
MRCC_TPM1	C8h

Diagram



Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-12 —	reserved reserved
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK 101b - 32K-CLK
3-2 —	reserved reserved
1-0	Clock Config

Table continues on the next page...

Table continued from the previous page...

Field	Function
CC	00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.12 LPI2C0 reset and clock control (MRCC_LPI2C0)

Offset

Register	Offset
MRCC_LPI2C0	CCh

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PR	RSTB	Reserved													
W																
Reset	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved				DIV				Reserved	MUX			Reserved		CC	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-12	reserved

Table continues on the next page...

Table continued from the previous page...

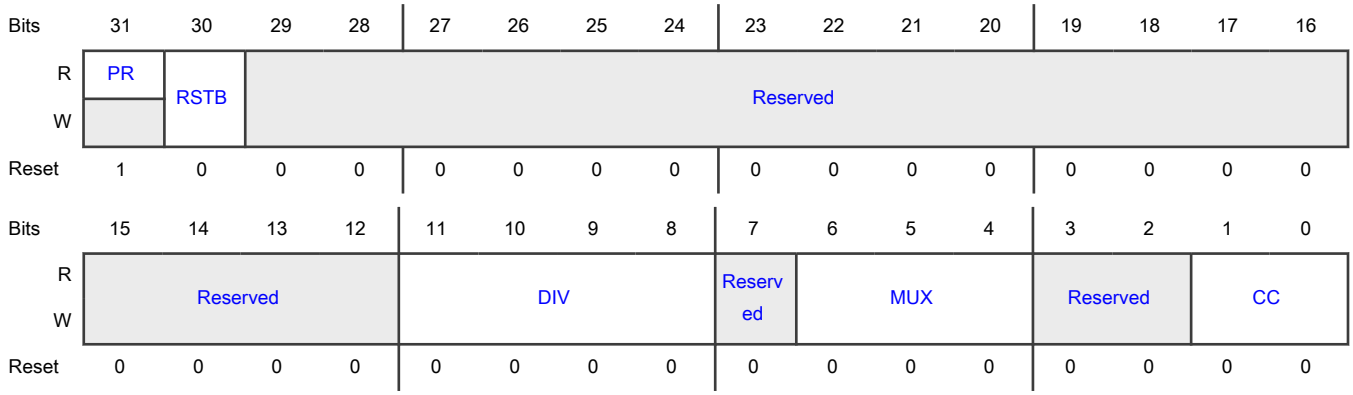
Field	Function
—	reserved
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK
3-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.13 LPI2C1 reset and clock control (MRCC_LPI2C1)

Offset

Register	Offset
MRCC_LPI2C1	D0h

Diagram



Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-12 —	reserved reserved
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK
3-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry

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Field	Function
	01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.14 I3C0 reset and clock control (MRCC_I3C0)

Offset

Register	Offset
MRCC_I3C0	D4h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PR	RSTB	Reserved													
W																
Reset	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved				DIV				Reserved	MUX			Reserved		CC	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-12 —	reserved reserved

Table continues on the next page...

Table continued from the previous page...

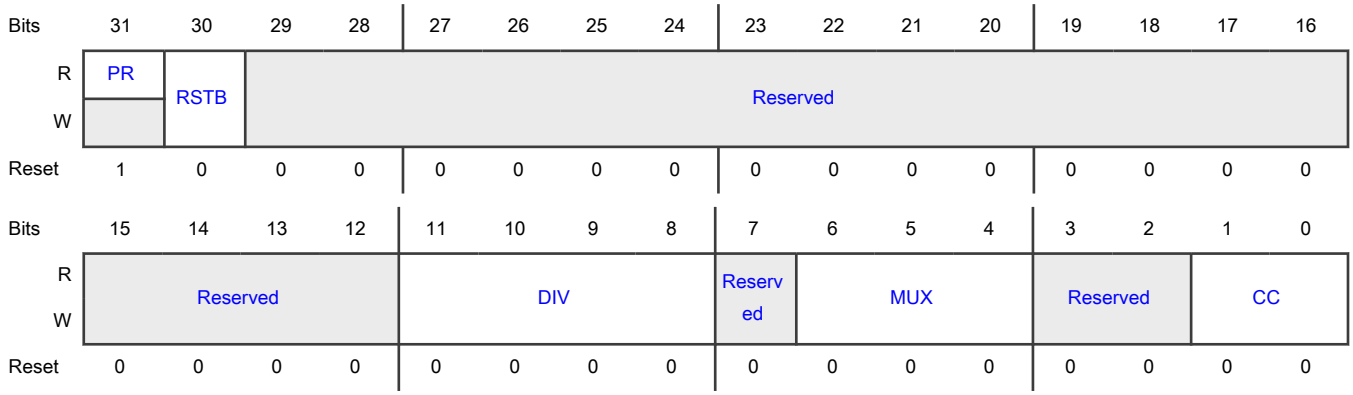
Field	Function
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK
3-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.15 LPSPI0 reset and clock control (MRCC_LPSPI0)

Offset

Register	Offset
MRCC_LPSPI0	D8h

Diagram



Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-12 —	reserved reserved
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK
3-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry

Table continues on the next page...

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Field	Function
	01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.16 LPSPI1 reset and clock control (MRCC_LPSPI1)

Offset

Register	Offset
MRCC_LPSPI1	DCh

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PR	RSTB	Reserved													
W																
Reset	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved				DIV				Reserved	MUX			Reserved		CC	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-12 —	reserved reserved

Table continues on the next page...

Table continued from the previous page...

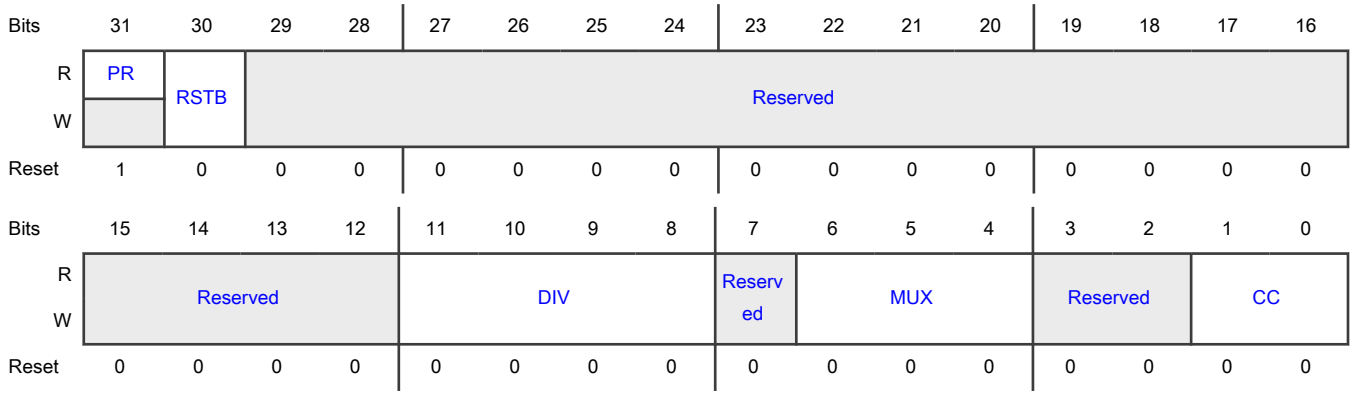
Field	Function
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK
3-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.17 LPUART0 reset and clock control (MRCC_LPUART0)

Offset

Register	Offset
MRCC_LPUART0	E0h

Diagram



Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-12 —	reserved reserved
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK 101b - 32K-CLK
3-2 —	reserved reserved
1-0	Clock Config

Table continues on the next page...

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Field	Function
CC	00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.18 LPUART1 reset and clock control (MRCC_LPUART1)

Offset

Register	Offset
MRCC_LPUART1	E4h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PR	RSTB	Reserved													
W																
Reset	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved				DIV				Reserved	MUX			Reserved		CC	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-12	reserved

Table continues on the next page...

Table continued from the previous page...

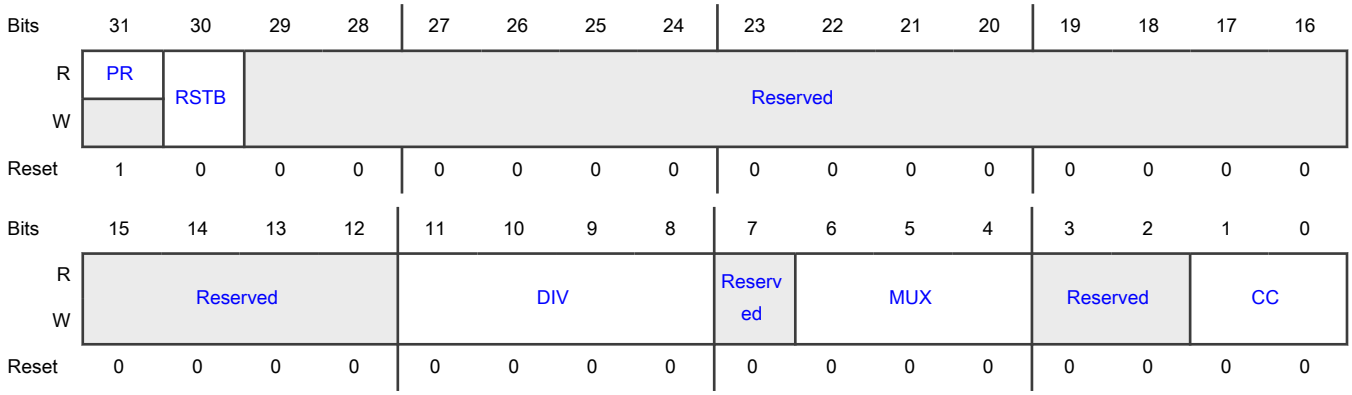
Field	Function
—	reserved
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK 101b - 32K-CLK
3-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.19 FLEXIO0 reset and clock control (MRCC_FLEXIO0)

Offset

Register	Offset
MRCC_FLEXIO0	E8h

Diagram



Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-12 —	reserved reserved
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK
3-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry

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Table continued from the previous page...

Field	Function
	01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.20 CAN0 reset and clock control (MRCC_CAN0)

Offset

Register	Offset
MRCC_CAN0	ECh

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PR	RSTB	Reserved													
W																
Reset	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved				DIV				Reserved	MUX			Reserved		CC	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-12 —	reserved reserved

Table continues on the next page...

Table continued from the previous page...

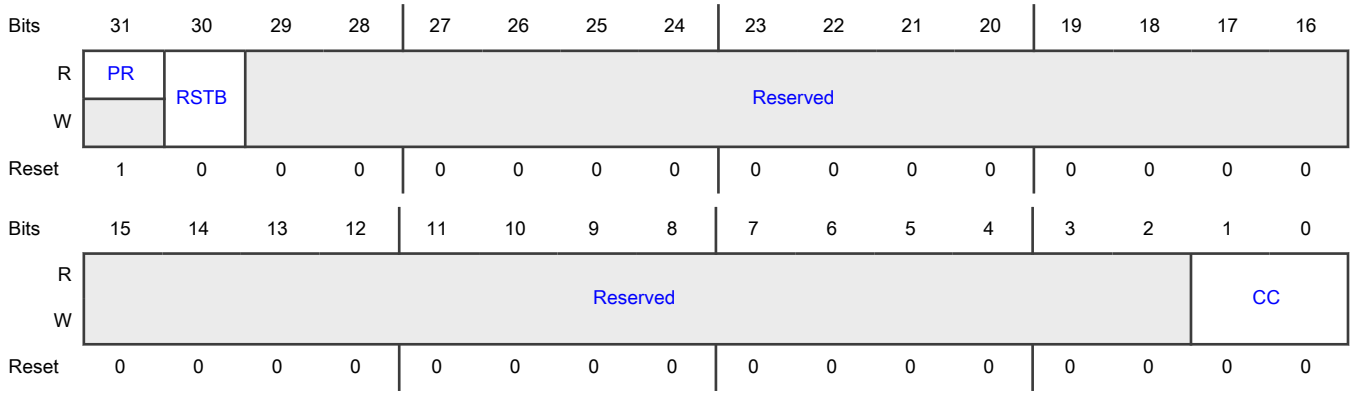
Field	Function
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK
3-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.21 SEMA0 reset and clock control (MRCC_SEMA0)

Offset

Register	Offset
MRCC_SEMA0	FCh

Diagram



Fields

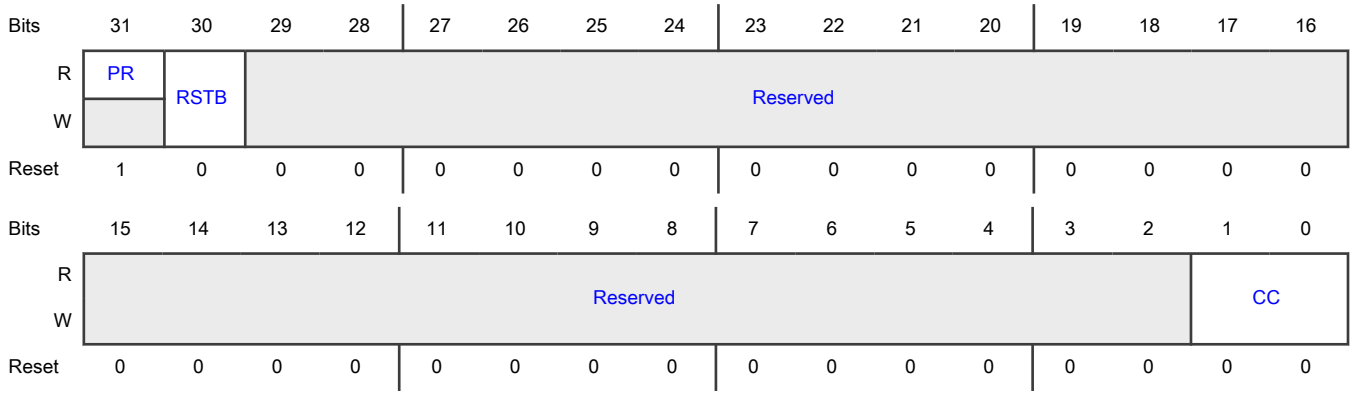
Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.22 DATA_STREAM_2P4 reset and clock control (MRCC_DATA_STREAM_2P4)

Offset

Register	Offset
MRCC_DATA_STREAM_2P4	104h

Diagram



Fields

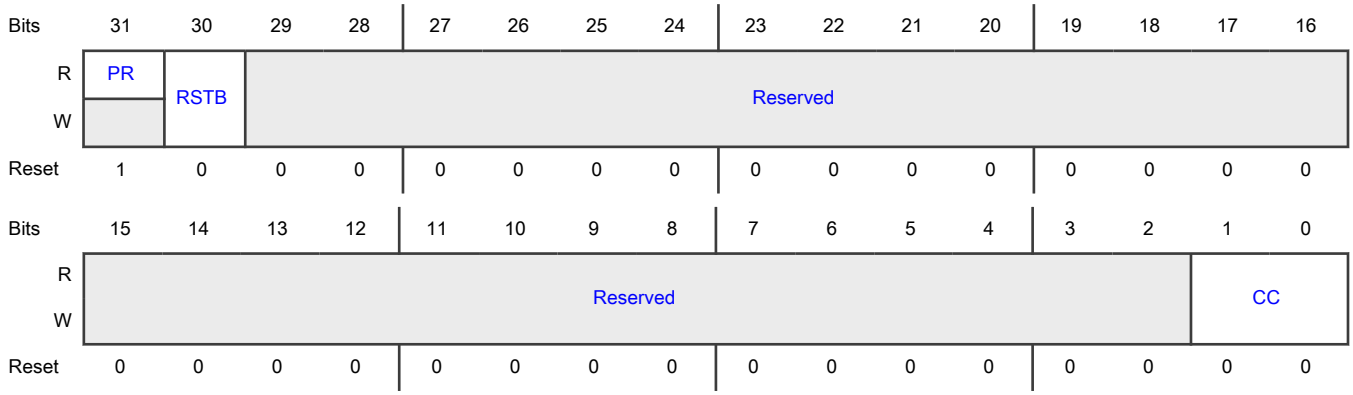
Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.23 PORTA reset and clock control (MRCC_PORTA)

Offset

Register	Offset
MRCC_PORTA	108h

Diagram



Fields

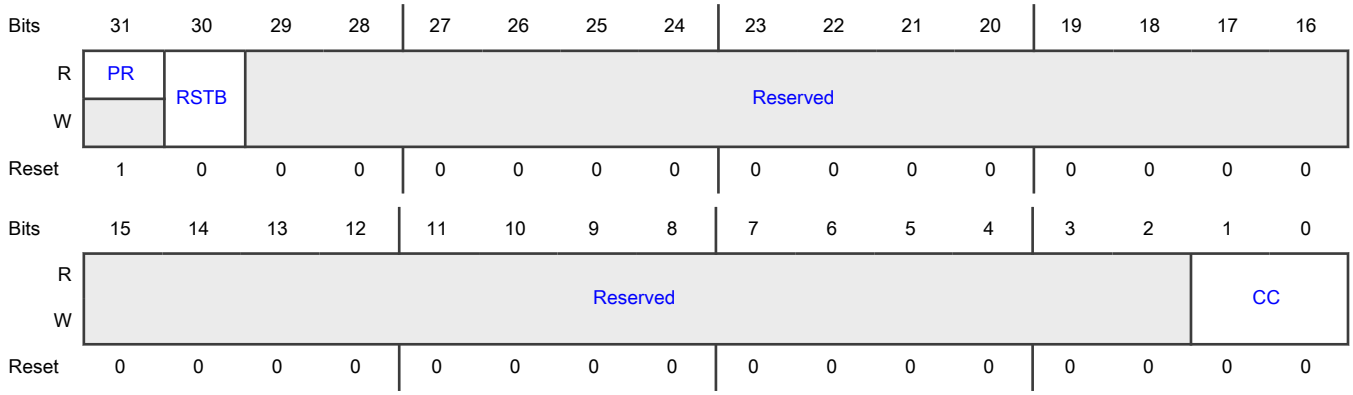
Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.24 PORTB reset and clock control (MRCC_PORTB)

Offset

Register	Offset
MRCC_PORTB	10Ch

Diagram



Fields

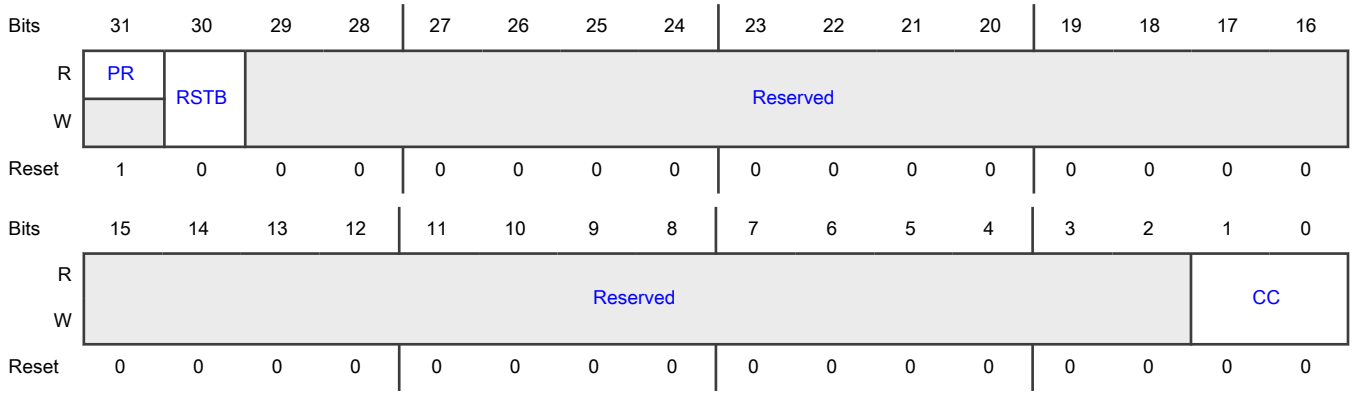
Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.25 PORTC reset and clock control (MRCC_PORTC)

Offset

Register	Offset
MRCC_PORTC	110h

Diagram



Fields

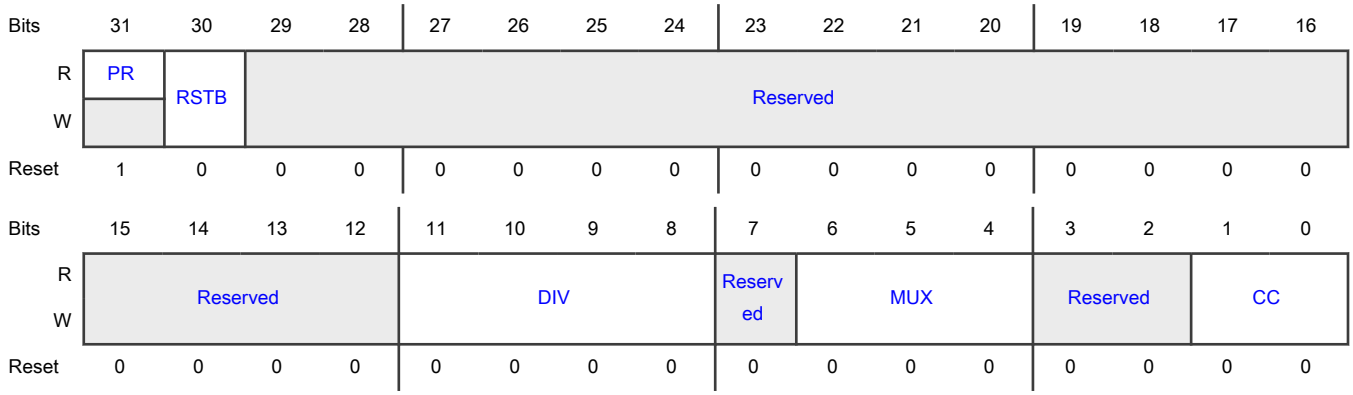
Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.26 LPADC0 reset and clock control (MRCC_LPADC0)

Offset

Register	Offset
MRCC_LPADC0	11Ch

Diagram



Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-12 —	reserved reserved
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK
3-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry

Table continues on the next page...

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Field	Function
	01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.27 LPCMP0 reset and clock control (MRCC_LPCMP0)

Offset

Register	Offset
MRCC_LPCMP0	120h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PR	RSTB	Reserved													
W																
Reset	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved														CC	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.28 LPCMP1 reset and clock control (MRCC_LPCMP1)

Offset

Register	Offset
MRCC_LPCMP1	124h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PR	RSTB	Reserved													
W																
Reset	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved														CC	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset

Table continues on the next page...

Table continued from the previous page...

Field	Function
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.29 VREF0 reset and clock control (MRCC_VREF0)

Offset

Register	Offset
MRCC_VREF0	128h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PR	RSTB	Reserved													
W																
Reset	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved														CC	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30	Reset Negation

Table continues on the next page...

Table continued from the previous page...

Field	Function
RSTB	0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.30 MTR_MASTER reset and clock control (MRCC_MTR_MASTER)

Offset

Register	Offset
MRCC_MTR_MASTER	134h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	Reserved															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	Reserved														CC	
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-2 —	reserved reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.31 CAN1 (MRCC_CAN1)

Offset

Register	Offset
MRCC_CAN1	13Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PR	RSTB	Reserved													
W																
Reset	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved				DIV				Reserved	MUX			Reserved		CC	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 PR	Periphral Present 0b - Module is not present, writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset, register accesses terminate with bus error 1b - Module released from reset, register accesses complete

Table continues on the next page...

Table continued from the previous page...

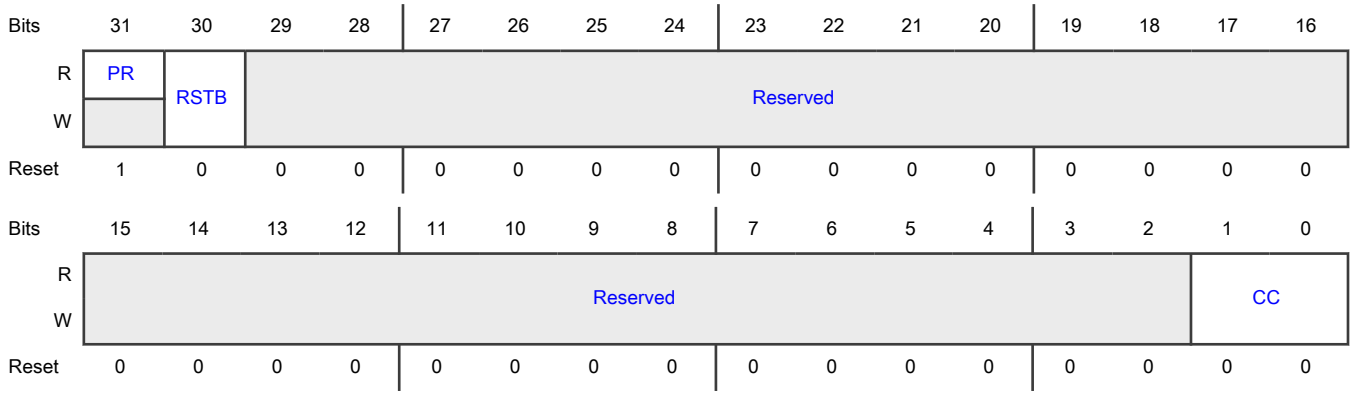
Field	Function
29-12 —	reserved reserved
11-8 DIV	Functional Clock Divider Configure functional clock integer divider when module clock is disabled (CC=00)
7 —	reserved reserved
6-4 MUX	Functional Clock Mux Select Configure functional clock source when module clock is disabled (CC=00) 000b - THE CLOCK IS OFF 011b - FRO-192M 100b - SOSC-CLK
3-2 —	reserved reserved
1-0 CC	Clock Config ipg_clk_s; ipg_clk_pe_nogate 00b - Peripheral clocks are disabled, module does not stall low power mode entry 01b - Peripheral clocks are enabled, module does not stall low power mode entry 10b - Peripherals clocks are enabled unless peripheral is idle, low power mode entry will stall until peripheral is idle 11b - Peripheral clocks are enabled unless in SLEEP mode (or lower), low power mode entry will stall until peripheral is idle Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP mode (or lower)

25.5.1.32 GPIOA reset and clock control (MRCC_GPIOA)

Offset

Register	Offset
MRCC_GPIOA	404h

Diagram



Fields

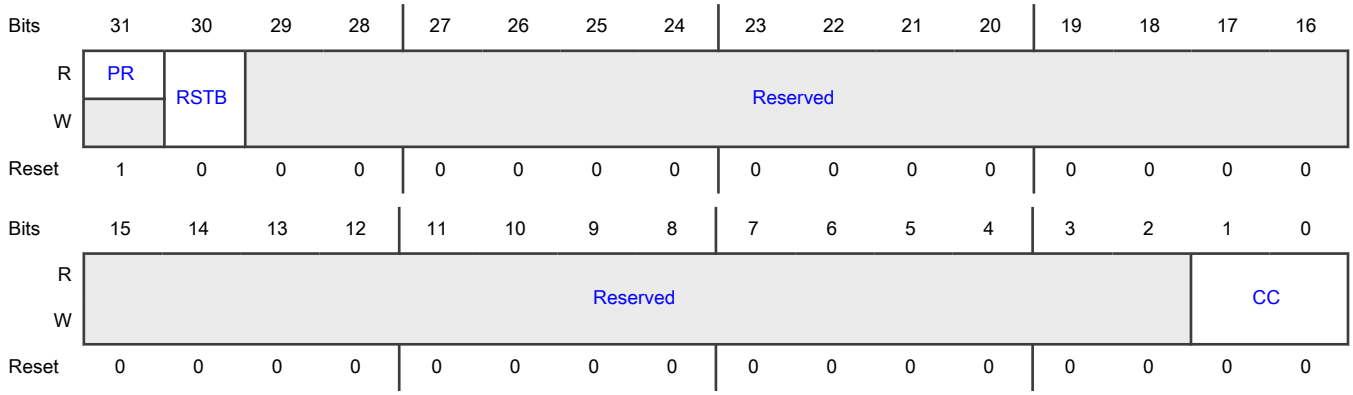
Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.33 GPIOB reset and clock control (MRCC_GPIOB)

Offset

Register	Offset
MRCC_GPIOB	408h

Diagram



Fields

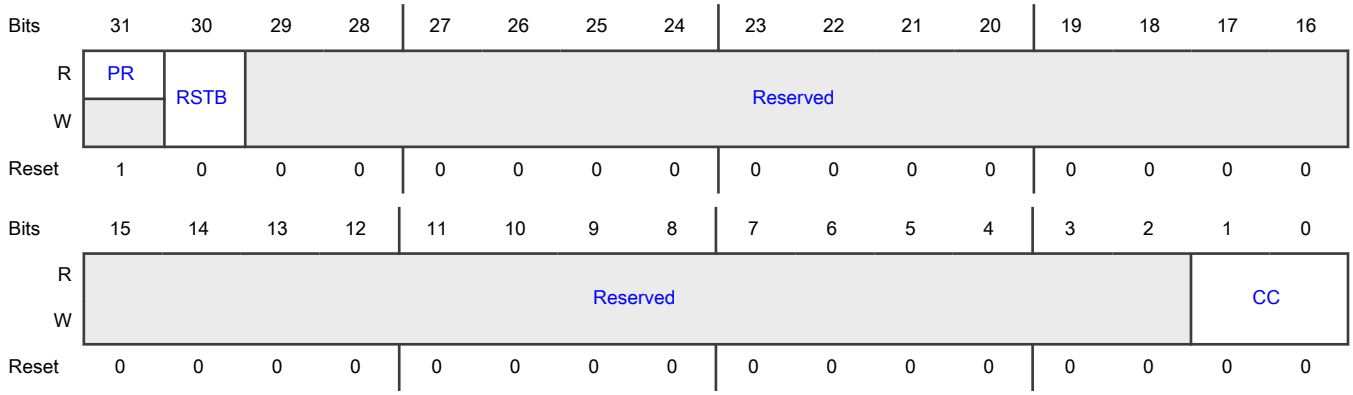
Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.34 GPIOC reset and clock control (MRCC_GPIOC)

Offset

Register	Offset
MRCC_GPIOC	40Ch

Diagram



Fields

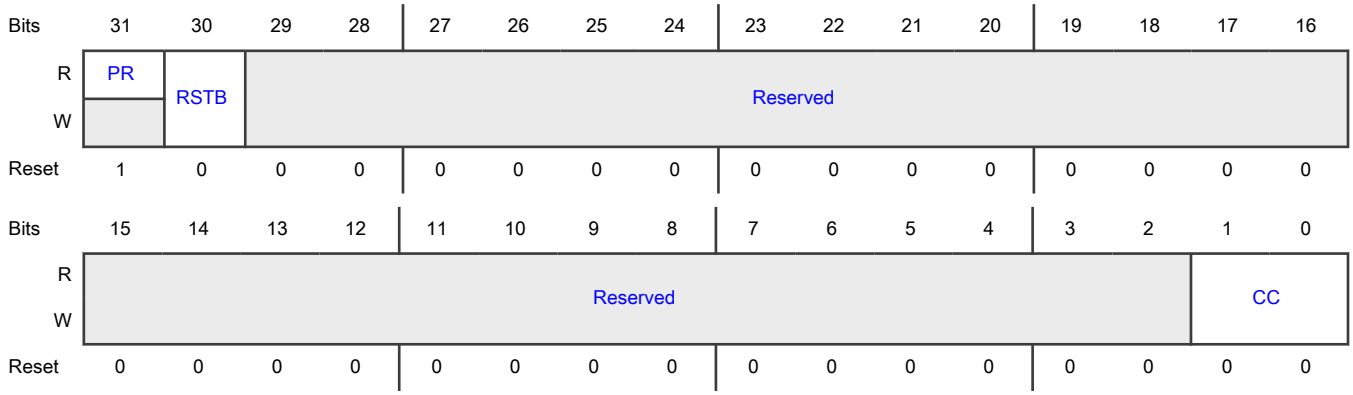
Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.35 DMA0 reset and clock control (MRCC_DMA0)

Offset

Register	Offset
MRCC_DMA0	410h

Diagram



Fields

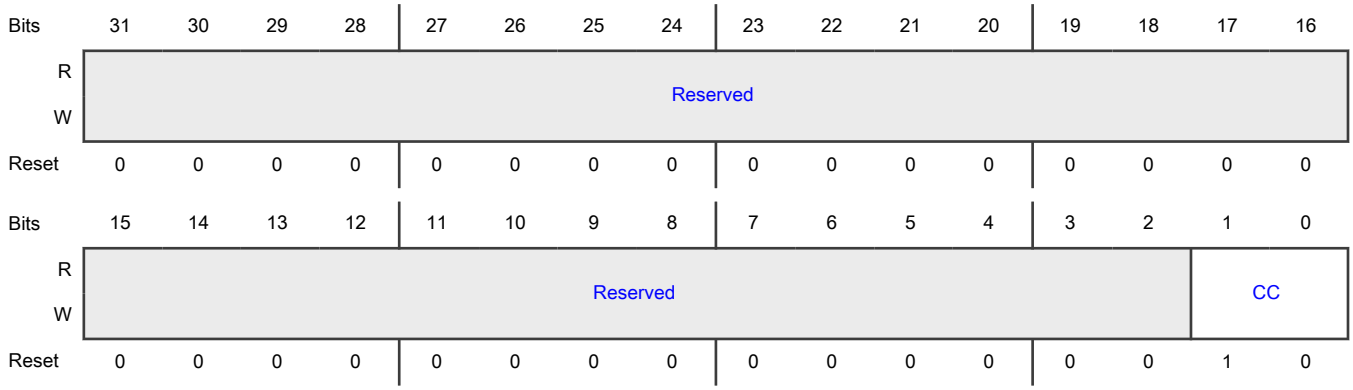
Field	Function
31 PR	Peripheral Present 0b - Module is not present; writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset 1b - Module released from reset
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.36 PFLEXNVM reset and clock control (MRCC_PFLEXNVM)

Offset

Register	Offset
MRCC_PFLEXNVM	414h

Diagram



Fields

Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.37 SRAM0 ecc reset and clock control (MRCC_SRAM0)

Offset

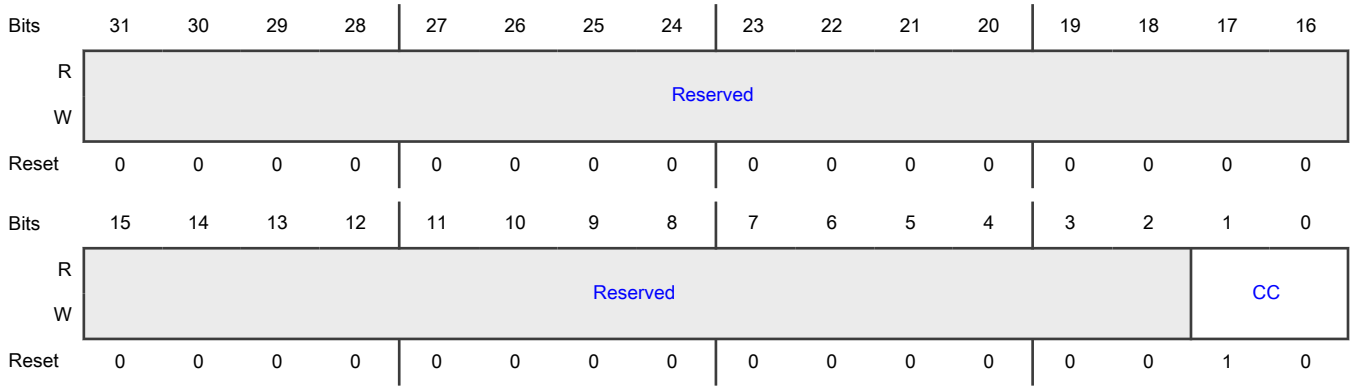
Register	Offset
MRCC_SRAM0	41Ch

Function

NOTE

MRCC_SRAM0 correspond ctcm0

Diagram



Fields

Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.38 SRAM1 ecc reset and clock control (MRCC_SRAM1_ecc)

Offset

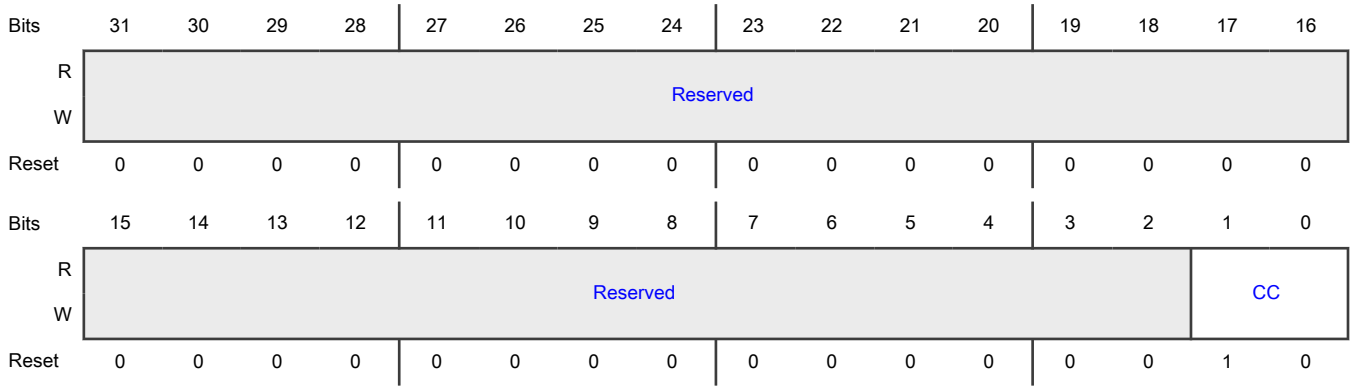
Register	Offset
MRCC_SRAM1_ecc	420h

Function

NOTE

MRCC_SRAM1_ecc correspond stcm0/stcm1/stcm2

Diagram



Fields

Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.39 SRAM2 reset and clock control (MRCC_SRAM2)

Offset

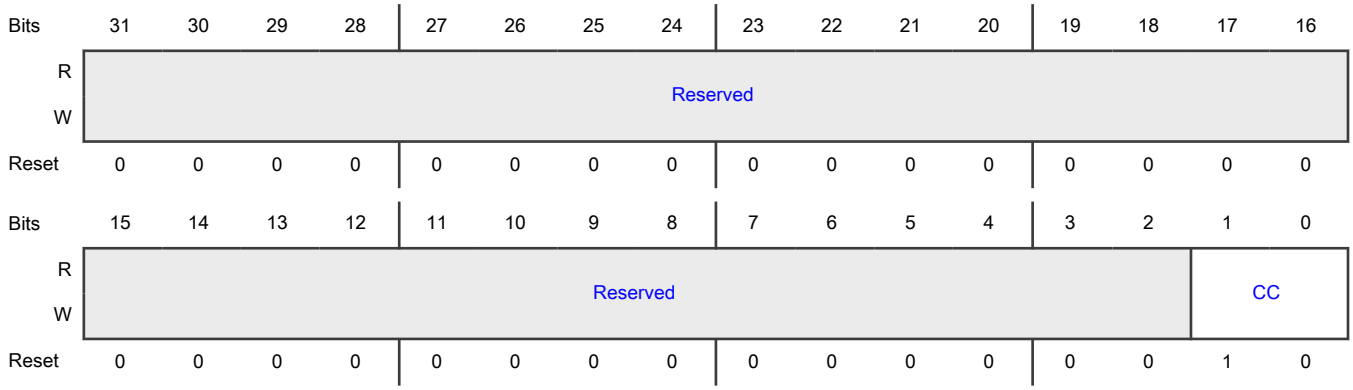
Register	Offset
MRCC_SRAM2	424h

Function

NOTE

MRCC_SRAM2 correspond stcm5/stcm6/stcm7

Diagram



Fields

Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.40 SRAM3 reset and clock control (MRCC_SRAM3)

Offset

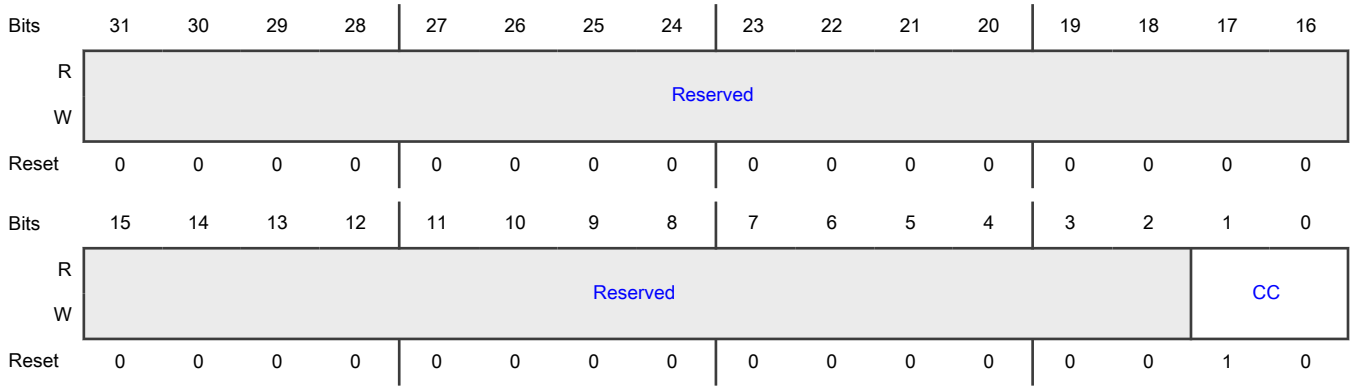
Register	Offset
MRCC_SRAM3	428h

Function

NOTE

MRCC_SRAM3 correspond stcm8

Diagram



Fields

Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.41 Clock_Config (MRCC_SRAM0_noecc)

Offset

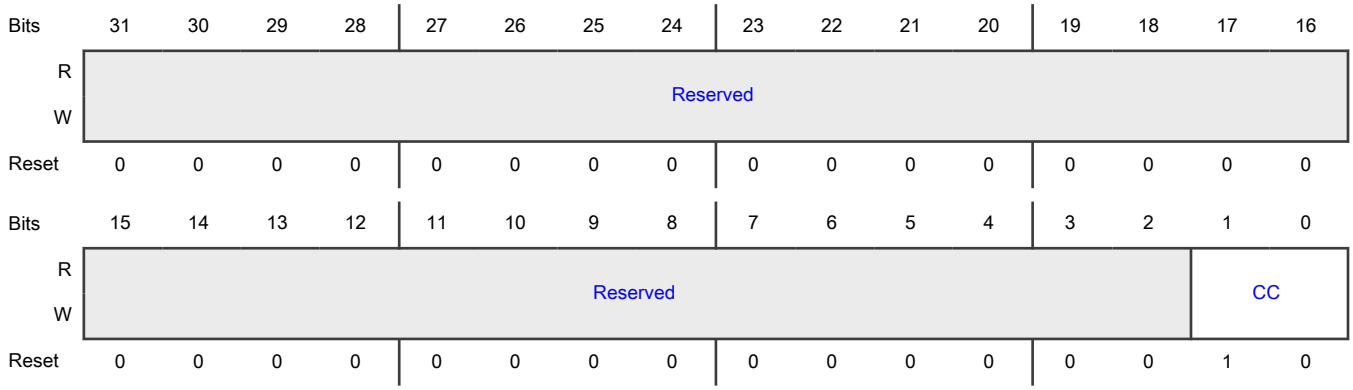
Register	Offset
MRCC_SRAM0_noecc	42Ch

Function

NOTE

MRCC_SRAM0_noecc correspond ctcm1

Diagram



Fields

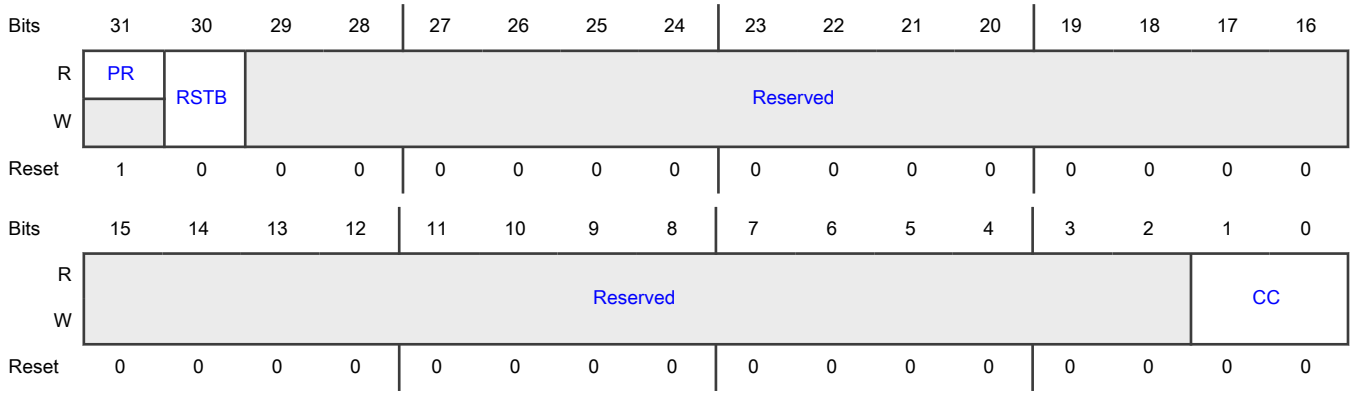
Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config sram0_noecc_hclk 00b - Peripheral clocks are disabled, module does not stall low power mode entry 01b - Peripheral clocks are enabled, module does not stall low power mode entry 10b - Peripherals clocks are enabled unless peripheral is idle, low power mode entry will stall until peripheral is idle 11b - Peripheral clocks are enabled unless in SLEEP mode (or lower), low power mode entry will stall until peripheral is idle Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP mode (or lower)

25.5.1.42 DSP0 reset and clock control (MRCC_DSP0)

Offset

Register	Offset
MRCC_DSP0	430h

Diagram



Fields

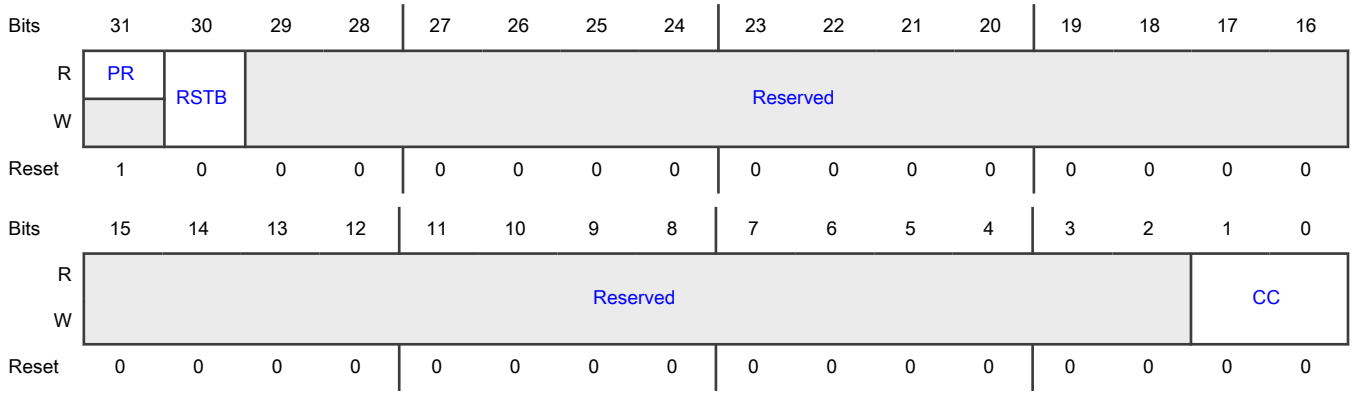
Field	Function
31 PR	Periphral Present 0b - Module is not present, writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset, register accesses terminate with bus error 1b - Module released from reset, register accesses complete
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled, module does not stall low power mode entry 01b - Peripheral clocks are enabled, module does not stall low power mode entry 10b - Peripherals clocks are enabled unless peripheral is idle, low power mode entry will stall until peripheral is idle 11b - Peripheral clocks are enabled unless in SLEEP mode (or lower), low power mode entry will stall until peripheral is idle Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP mode (or lower)

25.5.1.43 DSP0_MUA reset and clock control (MRCC_DSP0_MUA)

Offset

Register	Offset
MRCC_DSP0_MUA	434h

Diagram



Fields

Field	Function
31 PR	Periphral Present 0b - Module is not present, writes to this register are ignored 1b - Module is present
30 RSTB	Reset Negation 0b - Module is held in reset, register accesses terminate with bus error 1b - Module released from reset, register accesses complete
29-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled, module does not stall low power mode entry 01b - Peripheral clocks are enabled, module does not stall low power mode entry 10b - Peripherals clocks are enabled unless peripheral is idle, low power mode entry will stall until peripheral is idle 11b - Peripheral clocks are enabled unless in SLEEP mode (or lower), low power mode entry will stall until peripheral is idle Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP mode (or lower)

25.5.1.44 SRAM1 reset and clock control (MRCC_SRAM1_noecc)

Offset

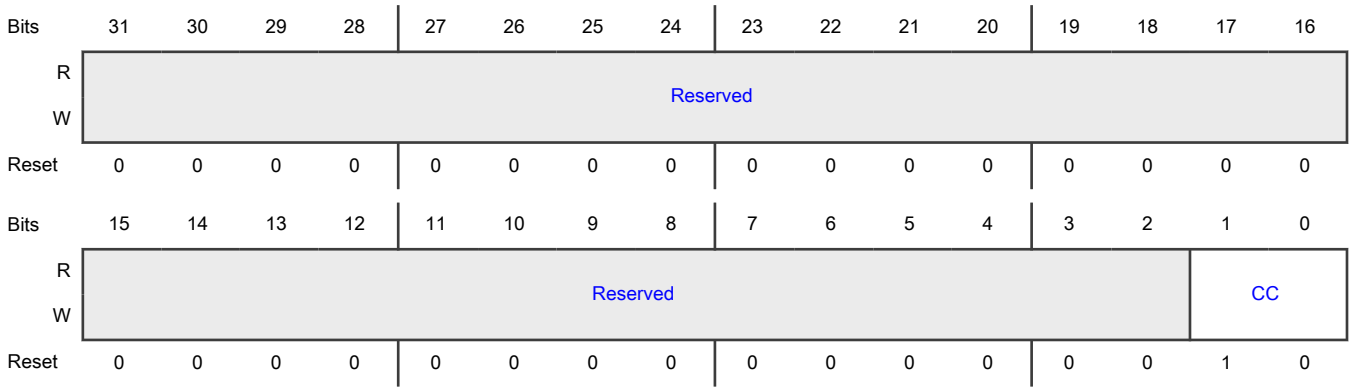
Register	Offset
MRCC_SRAM1_noecc	438h

Function

NOTE

MRCC_SRAM1_noecc correspond stcm3/stcm4

Diagram



Fields

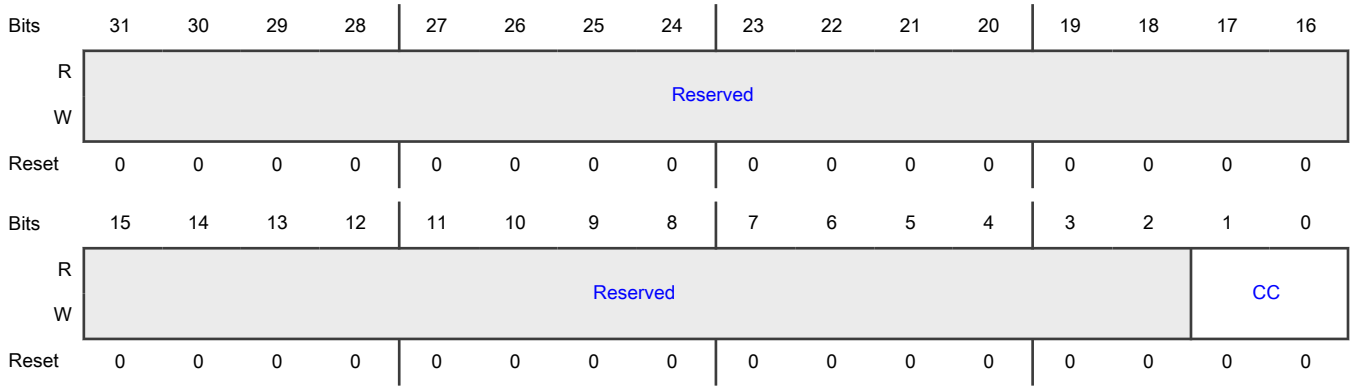
Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config sram1_noecc_hclk 00b - Peripheral clocks are disabled, module does not stall low power mode entry 01b - Peripheral clocks are enabled, module does not stall low power mode entry 10b - Peripherals clocks are enabled unless peripheral is idle, low power mode entry will stall until peripheral is idle 11b - Peripheral clocks are enabled unless in SLEEP mode (or lower), low power mode entry will stall until peripheral is idle Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP mode (or lower)

25.5.1.45 RF_2P4GHZ_BIST reset and clock control (MRCC_RF_2P4GHZ_BIST)

Offset

Register	Offset
MRCC_RF_2P4GHZ_BIST	43Ch

Diagram



Fields

Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.46 LPTMR0_IPG_CLK_ERCLK_WAKE2VSYS reset and clock control (MRCC_LPTMR0_IPG_CLK_ERCLK_WAKE2VSYS)

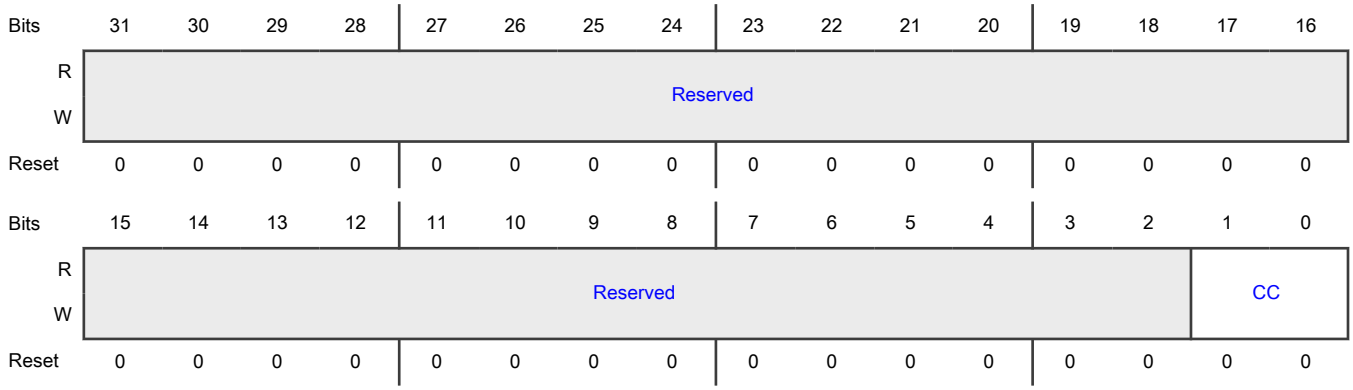
Offset

Register	Offset
MRCC_LPTMR0_IPG_CLK_ERCLK_WAKE2VSYS	440h

Function

The corresponding clock is OSC_RF/2 in the LPTMR section.

Diagram



Fields

Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.47 LPTMR1_IPG_CLK_ERCLK_WAKE2VSYS reset and clock control (MRCC_LPTMR1_IPG_CLK_ERCLK_WAKE2VSYS)

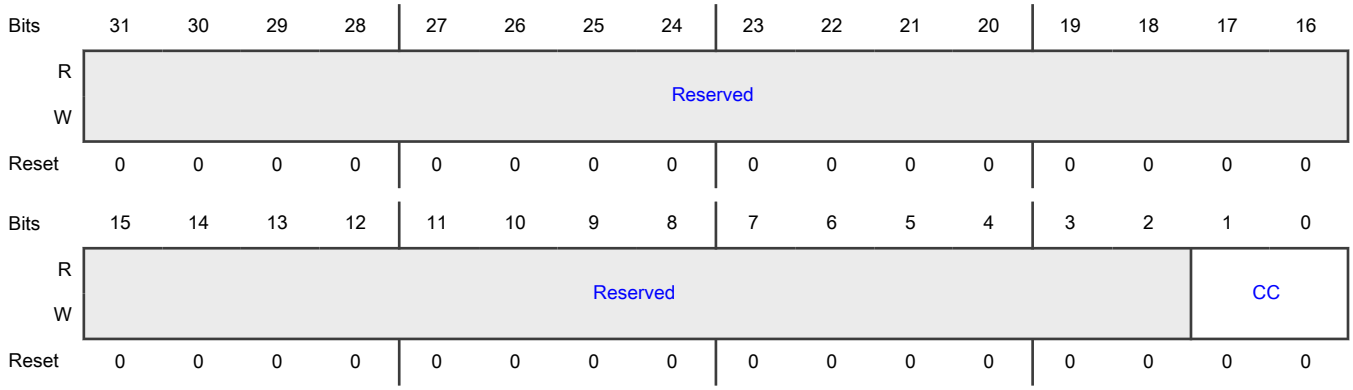
Offset

Register	Offset
MRCC_LPTMR1_IPG_CLK_ERCLK_WAKE2VSYS	444h

Function

The corresponding clock is OSC_RF/2 in the LPTMR section.

Diagram



Fields

Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled; module does not stall low power mode entry 01b - Peripheral clocks are enabled; module does not stall low power mode entry 10b - Peripheral clocks are enabled unless module is idle; low power mode entry stalls until module is idle 11b - Peripheral clocks are enabled unless in SLEEP (or lower) mode; low power mode entry stalls until module is idle. Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP (or lower) mode

25.5.1.48 LPTMR2_IPG_CLK_ERCLK_WAKE2VSYS reset and clock control (MRCC_LPTMR2_IPG_CLK_ERCLK_WAKE2VSYS)

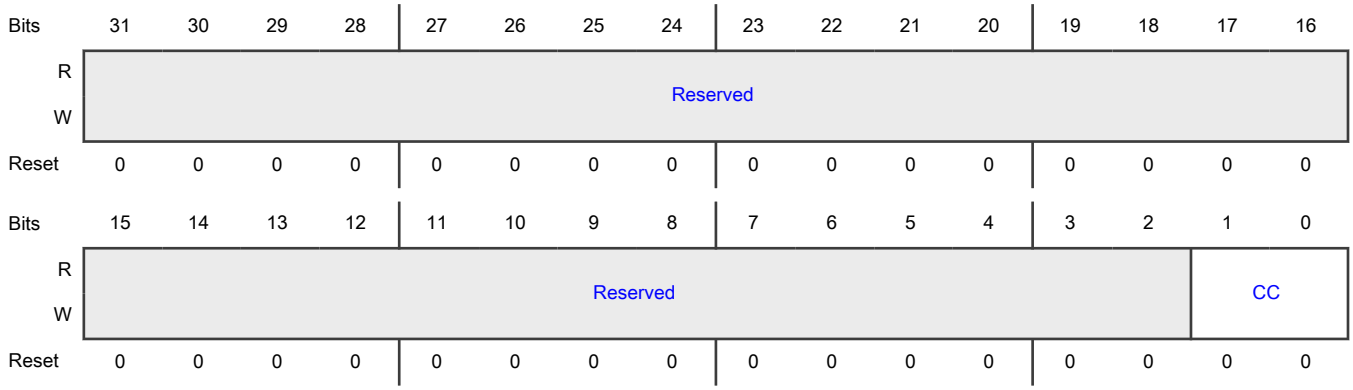
Offset

Register	Offset
MRCC_LPTMR2_IPG_CLK_ERCLK_WAKE2VSYS	448h

Function

The corresponding clock is OSC_RF/2 in the LPTMR section.

Diagram



Fields

Field	Function
31-2 —	reserved reserved
1-0 CC	Clock Config 00b - Peripheral clocks are disabled, module does not stall low power mode entry 01b - Peripheral clocks are enabled, module does not stall low power mode entry 10b - Peripherals clocks are enabled unless peripheral is idle, low power mode entry will stall until peripheral is idle 11b - Peripheral clocks are enabled unless in SLEEP mode (or lower), low power mode entry will stall until peripheral is idle Peripheral functional clocks that remain enabled in SLEEP mode are enabled and do not stall low power mode entry unless entering DEEPSLEEP mode (or lower)

Chapter 26
Signal Frequency Analyser (SFA)

26.1 Chip-specific SFA information

Table 215. Reference links to related information

Topic	Related module	Reference
Full description	SFA	SFA
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

26.1.1 Module instances

This device has two instances of the SFA module, SFA0 and RF_SFA. The SFA0 does not support trigger based measurement function and all the related registers and bit fields are reserved.

26.1.2 SFA register configuration

The following tables list the instance specific configurations.

Table 216. Clock sources connected to the SFA0 clock under test counter

SFA0_CTRL[CUT_SEL]	Clock source
0001	CLKOUT
0110	32K_CLK
1000	OSC-RF
1010	Radio FRO-192M-DIV
1011	FRO-16K
Others	Reserved

Table 217. Clock sources connected to the RF_SFA clock under test counter

RF_SFA_CTRL[CUT_SEL]	Clock source
0/1	32K_CLK

Table 218. Clock sources connected to the SFA0 reference clock

SFA0_CTRL2[REF_CLK_SEL]	Reference clock source
00	OSC-RF
01	CPU_CLK
10	32K-CLK
11	Reserved

Table 219. Clock sources connected to the RF_SFA reference clock

RF_SFA_CTRL2[REF_CLK_SEL]	Reference clock source
0/1	OSC-RF

Table 220. Signals used in RF_SFA trigger based measurement

SFA0_CTRL[TRIG_START_SEL]/ SFA0_CTRL[TRIG_END_SEL]	Trigger source
0	Trigger configured by RFMC_RF2p4GHz_CTRL[SFA_TRIG_EN]
1	Reserved

26.2 Overview

The Signal Frequency Analyser (SFA) provides functionality to perform measurements of clock frequency, clock period, and time between triggers.

26.2.1 Block Diagram

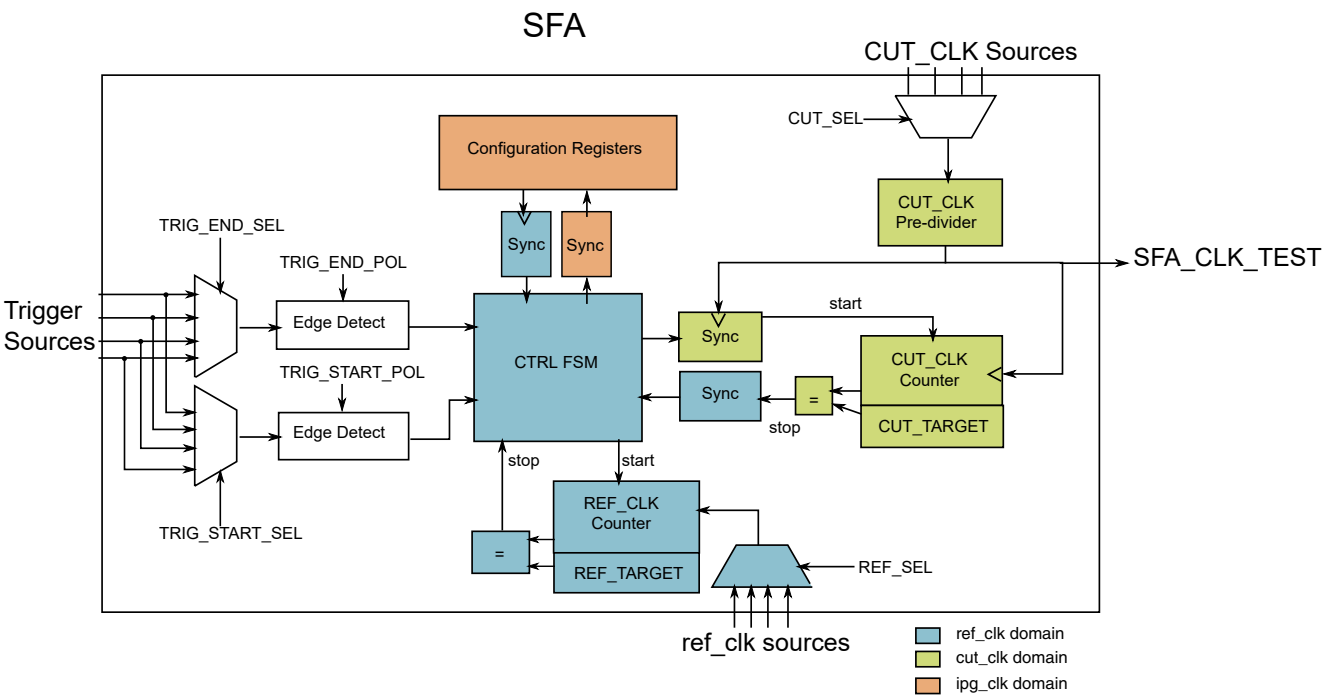


Figure 68. Signal Frequency Analyser Block Diagram

26.2.2 Features

The Signal Frequency Analyser includes the following features.

- Two 32-bit counters, one connected to the bus clock (REF clock), which serves as a reference, and the other connected to the clock under test (CUT).
- An 8-bit predivider is provided to divide down the CUT clock.
- A target count register for both the REF clock and CUT clock are provided to stop the counters.

- Trigger measurement mode to analyse the time between 2 edges (with configurable polarity) of either the same or different triggers. Note, the trigger pulse width must be at least 2 ref_clk cycles long to be properly registered.
- Selectable measurement modes to optimize test time by analysing either the frequency (for fast clocks), or the period (for slow clocks) of the CUT clock.
- Selectable sources for reference clock and CUT clock
- Support interrupt for CUT clk freq exceed setting freq limit

26.3 Functional Description

The Signal Frequency Analyser can be used to measure frequencies, periods, and time between events. The following use cases demonstrate how these capabilities can be used.

26.3.1 Frequency Measurements

The Signal Frequency Analyser can be used to measure the frequency of CUT CLK. The use cases below demonstrate how these capabilities can be used.

In general, either of the following methods may then be used to measure clock frequencies. To measure in frequency mode, register bit CTRL[MODE] must be set to 0x0 or 0x1.

Method 1 (when CUT frequency < REF frequency)(CTRL[MODE] == 0x0):

1. Set CUT and REF count targets
2. Perform a dummy write to REF counter (clears the *COUNT, *STARTED and *STOPPED bits)
3. Poll the CUT_STOPPED bit to make sure it cleared
4. The next step can be completed using 2 different methods depending on the value of CTRL[SFA_TRIG_MEAS_EN]:
    a. SFA_TRIG_MEAS_EN = 0b0

       Perform a dummy write to the CUT counter. This triggers:

        i. REF counter starts counting immediately
        ii. CUT counter starts counting after a ~2 CUT cycle sync delay

    b. SFA_TRIG_MEAS_EN = 0b1

       The SFA will stall processing until the trigger edge selected by CTRL[TRIG_START_SEL] and CTRL[TRIG_START_POL] has been received. Once the trigger has been received, the following sequence will occur:

        i. REF counter starts counting immediately
        ii. CUT counter starts counting after a ~2 CUT cycle sync delay
5. When CUT counter reaches 1, MEAS_STARTED bit asserts after a ~2 REF cycle sync delay
6. Upon assertion of MEAS_STARTED, the REF_COUNT_ST_SAVED (a saved version of the current REF counter, which keeps running) will be written.
7. When CUT counter reaches target, CUT_STOPPED bit asserts after a ~2 REF cycle sync delay
8. Upon assertion of CUT_STOPPED, the REF_COUNT_END_SAVED (which is a saved version of the actual REF counter, which keeps running) will be written.
9. The measurement is considered complete once the REF_STOPPED and CUT_STOPPED bits have been asserted in the CUT_CNT register. The user can either poll the REF_STOPPED and CUT_STOPPED bits or enable SFA_IRQ_EN. If SFA_IRQ_EN is asserted than an interrupt will be issued when the measurement is complete.
10. Calculate CUT frequency by using the difference in the REF_COUNT_END_SAVED and REF_COUNT_ST_SAVED in comparison to the CUT target

11. If the value (REF_COUNT_END_SAVED-REF_COUNT_ST_SAVED) greater than the value setting in REG_HIGH_LIMIT_CNT , it means the measured cut clk frequency is less than minimum limit,if according enable bit is set, the FREQ_LT_MIN_IRQ will be generated
12. If the value (REF_COUNT_END_SAVED-REF_COUNT_ST_SAVED) less than the value setting in REG_LOW_LIMIT_CNT , it means the measured cut clk frequency is greater than maximum limit, if according enable bit is set, the FREQ_GT_MAX_IRQ will be generated

The following two figures represent two possible cases for frequency measurement with CTRL[MODE] = 0x0. The first image illustrates a complete frequency measurement. Note, it is assumed that the user has started the measurement some time before this waveform snapshot was taken. Therefore, the register writes to CUT counter and REF counter are omitted. In this example the CUT target of 0x0000_FFFF is reached before the REF target count is reached. The two significant measurement events occur when MEAS_STARTED is asserted and REF_CNT_STOPPED is asserted.

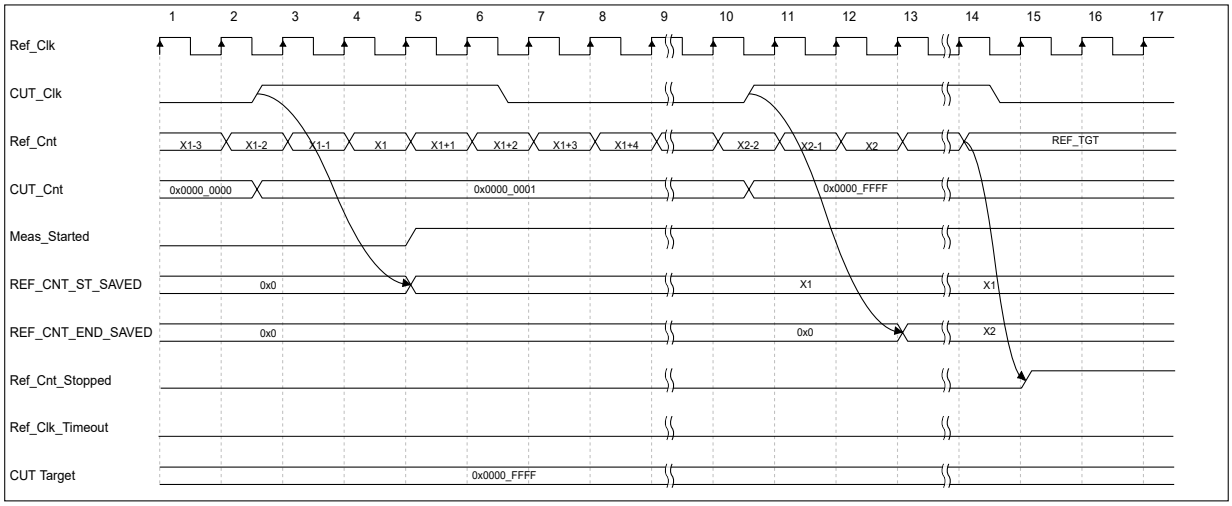


Figure 69. CUT Frequency Measurement with CUT Freq less than REF Freq

The next image illustrates the case when the frequency measurement is unable to be completed before REF_CNT_STOPPED is asserted. This is known as a reference clock timeout. In this example the CUT Target is set to 0x0000_FFFF; however, this value is never reached before REF_CNT = REF_CNT_STOPPED.

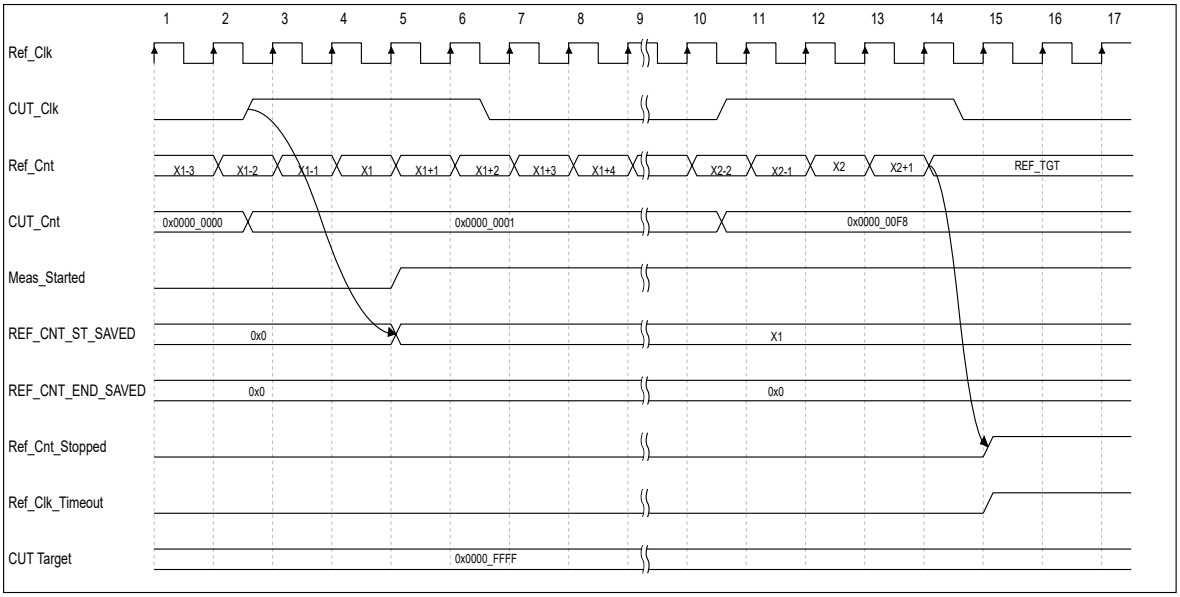


Figure 70. CUT Frequency Measurement Timeout with CUT Freq less than REF Freq

Method 2 (when CUT frequency > REF frequency)(CTRL[MODE] == 0x1):

1. Set CUT and REF count targets (Note: recommend CUT target be set to 0xFFFF_FFFF. There is no CUT_CNT_TIMEOUT flag.)
2. Perform a dummy write to REF counter (clears the *COUNT, *STARTED and *STOPPED bits)
3. Poll the CUT_STOPPED bit to make sure it is clear
4. The next step can be completed using 2 different methods depending on the value of CTRL[SFA_TRIG_MEAS_EN]:
    a. SFA_TRIG_MEAS_EN = 0b0

       Perform a dummy write to the CUT counter. This triggers:

        i. REF counter starts counting immediately

        ii. CUT counter starts counting after a ~2 CUT cycle sync delay

    b. SFA_TRIG_MEAS_EN = 0b1

       The SFA will stall processing until the trigger edge selected by CTRL[TRIG_START_SEL] and CTRL[TRIG_START_POL] has been received. Once the trigger has been received, the following sequence will occur:

        i. REF counter starts counting immediately

        ii. CUT counter starts counting after a ~2 CUT cycle sync delay
5. When REF_COUNT reaches target, the CUT counter stops after a ~2 CUT cycle sync delay, and the CUT_STOPPED bit then sets after a ~2 REF cycle sync delay
6. Calculate CUT frequency by using the CUT_COUNT and REF target
7. To determine when the measurement has been completed, the user can either poll the CUT_STOPPED bit or enable SFA_IRQ_EN. An interrupt will be issued, if SFA_IRQ_EN is asserted and when both CUT_STOPPED and REF_STOPPED are asserted.

8. If the value CUT_CNT is greater than the value setting in CUT_HIGH_LIMIT_CNT , it means the measured cut clk frequency or trigger period is greater than maximum limit. If FREQ_GT_MAX interrupt flag is set, FREQ_GT_MAX IRQ will be generated.
9. If the value CUT_CNT less than the value setting in CUT_LOW_LIMIT_CNT , it means the measured cut clk frequency or trigger period is less than minimum limit, if according enable bit is set, the FREQ_LT_MIN_IRQ will be generated

The following image represents an example frequency measurement with CTRL[MODE] = 0x1. In this case, the CUT frequency should be greater than the REF frequency. This measurement is used to count the number of CUT_CLK cycles that occur in REF_TARGET REF clk cycles. Note that registers REF_CNT_*_SAVED should not be read during this mode. It can be implied that REF_CNT_END_SAVED - REF_CNT_ST_SAVED = REF_TARGET.

When performing a CTRL[MODE] = 0x1 measurement, the CUT_TARGET should be set to the max value to prevent a CUT_TARGET timeout. The measurement will end when REF_CNT reaches the value stored in REF_TARGET. If CUT_TARGET is reached before REF_TARGET is reached, this will indicate an error condition. There is no flag to indicate a CUT_TARGET timeout. This is why CUT_TARGET should be set to the maximum value. The CUT_CNT timeout occurs when CUT_CNT is equal to CUT_TARGET. To detect that the CUT_CNT timeout did not occur, the CUT_CNT register should be less than CUT_TARGET at the end of a CTRL[MODE] = 0x1 measurement. When CUT_CNT is less than CUT_TARGET, the measurement stops when REF_TARGET is met.

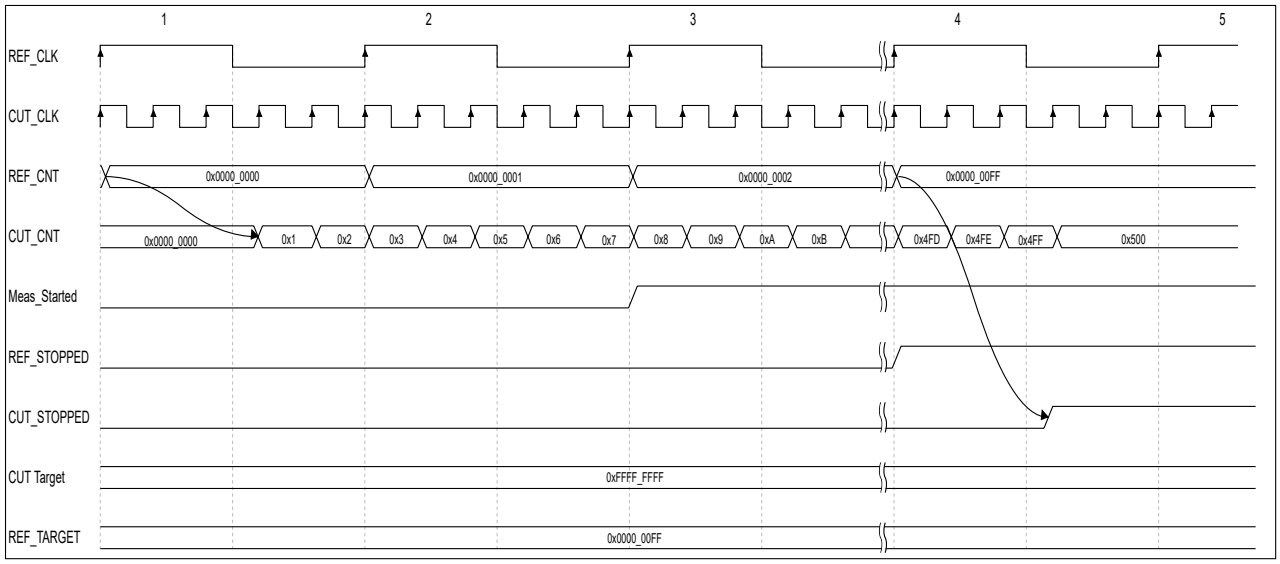


Figure 71. REF Frequency Measurement: CUT Freq greater than REF Freq

Continuous Mode (CTRL[MONITOR_EN] == 0x1):

1. Set CTRL[MONITOR_EN] will enable the continuous mode, this mode only take affect when in frequency mode (CTRL[MODE]= 2'b00 or 2'b01,CTRL[SFA_TRIG_MEAS_EN] = 1'b0)
2. Measurement will keep going on until clock frequency under test exceed the region we set (FREQ_GT_MAX_IRQ/ FREQ_LT_MIN_IRQ is asserted)

26.3.2 Clock Period Measurements

The signal frequency analyser has the capability to measure the period of CUT clock. To operate in clock period mode, the register CTRL[MODE] must be set to 0x2. This mode is used to count the number of REF CLK periods which occur during one period of CUT CLK.

Clock Period Measurement (CTRL[MODE] == 0x2). This mode is used to measure the period of CUT clock. It is assumed that CUT frequency < < REF frequency:

1. Select the source of CUT clock with CTRL[CUT_SEL], and configure any CUT pre-divide with CTRL[CUT_PREDIV].
2. Select a value for REF_TARGET. This value acts as a time-out function. The test will always end when REF_CNT == REF_TARGET.
3. Perform a dummy write to the REF counter. This triggers:
    a. REF counter starts counting immediately
    b. All previous counters will be cleared.
4. The MEAS_STARTED bit will indicate when the measurement sequence has begun.
5. The MEAS_STARTED bit is asserted on the first rising edge of the CUT after the dummy write to the REF counter. Upon assertion of MEAS_STARTED, the REF_COUNT_ST_SAVED (which is a saved version of the actual REF counter, which keeps running) will be written with the current REF_CNT value.
6. The REF_STOPPED bit will indicate when the measurement sequence has been completed.
7. Upon completion of one full period measurement (performed from one rising edge to the next rising edge), the REF_COUNT_END_SAVED (which is a saved version of the actual REF counter, which keeps running) will be written with the current value of REF_CNT.
8. Note that REF_STOPPED may be set before the measurement has been completed. This may indicate the REF_CNT reached REF_TARGET before receiving a full period of CUT CLK. In this case, the CNT_STAT[REF_CNT_TIMEOUT] will be set to 0b1 to indicate that a time-out occurred.
9. Calculate the period width by using the difference between the values of REF_CNT_END_SAVED and REF_COUNT_ST_SAVED.
10. To determine when the measurement has been completed, the user can either poll the REF_STOPPED bit or enable SFA_IRQ_EN. If SFA_IRQ_EN is asserted than an interrupt will be issued when REF_STOPPED is asserted.
11. If the value (REF_COUNT_END_SAVED-REF_COUNT_ST_SAVED) greater than the value setting in REG_HIGH_LIMIT_CNT , it means the measured cut clk frequency is less than minimum limit,if according enable bit is set, the FREQ_LT_MIN_IRQ will be generated
12. If the value (REF_COUNT_END_SAVED-REF_COUNT_ST_SAVED) less than the value setting in REG_LOW_LIMIT_CNT , it means the measured cut clk frequency is greater than maximum limit, if according enable bit is set, the FREQ_GT_MAX_IRQ will be generated

Figure 72 illustrates a CUT Clk period measurement cycle. It is assumed this timing diagram occurs sometime after beginning the measurement (dummy write to REF counter) with CTRL[MODE] == 0x2. In addition, it is assumed that SFA_IRQ_EN is asserted. In Figure 72 , the REF_TARGET register was set sufficiently high to receive a full period of CUT before REF_CNT timeout.

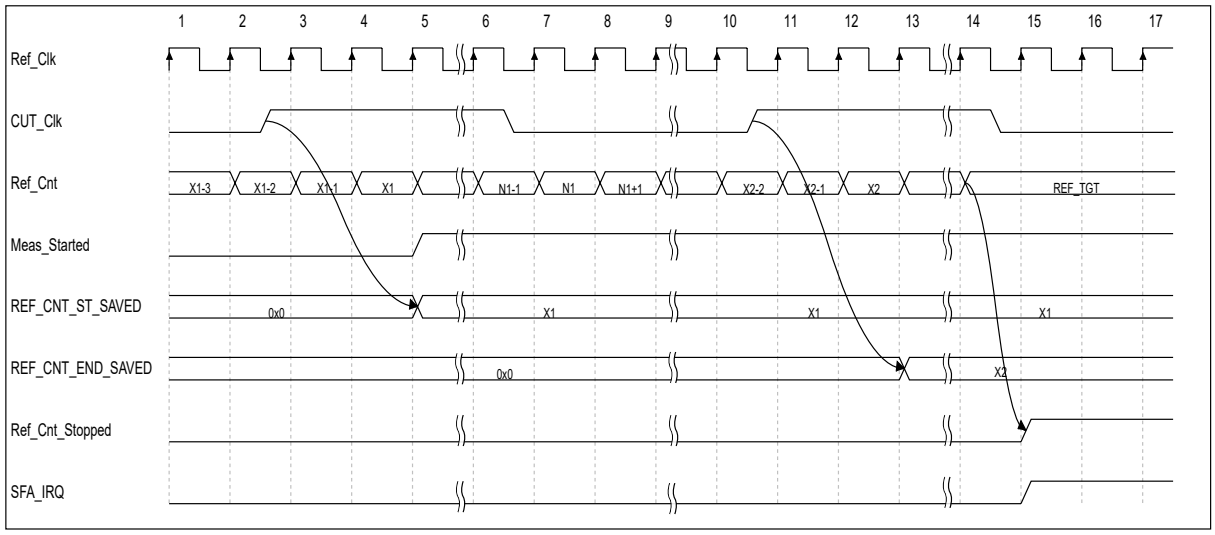


Figure 72. CUT Clk Period Measurement

Figure 73 illustrates what happens when REF_CNT reaches REF_TARGET before the SFA receives a full period of CUT Clk. The result will be an incomplete measurement, and REF_CNT_TIMEOUT will be asserted along with REF_STOPPED.

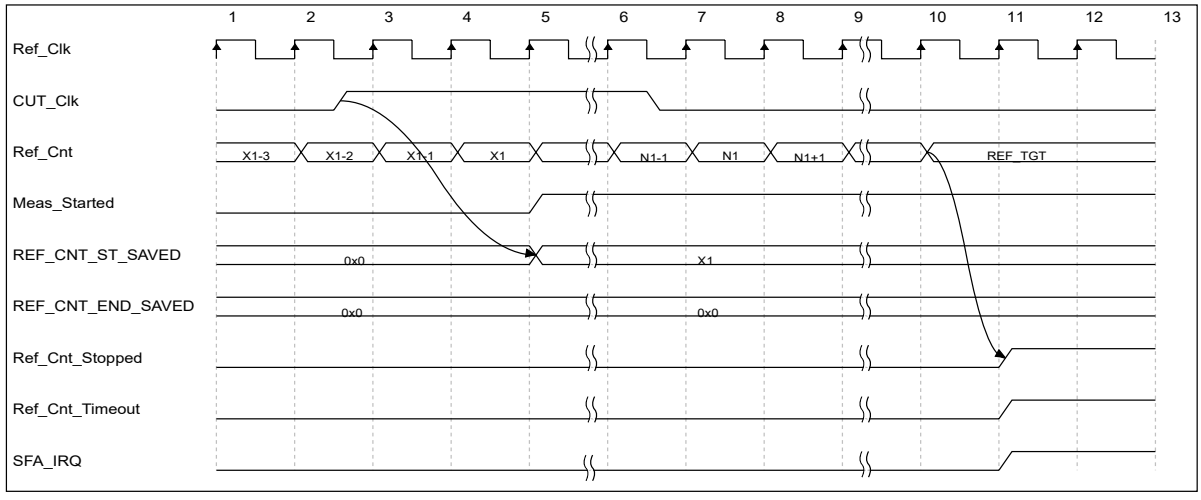


Figure 73. CUT Clk Period Timeout

26.3.3 Trigger Based Measurements

Triggered Measurement (CTRL[MODE] == 0x3). This mode is used to measure the time between two signal events. This measurement will count the number of REF clock periods between two triggers. Both the start trigger and end trigger can be selected from a bus interface. To select the start and end triggers, program the CTRL[TRIG_END_SEL] and CTRL[TRIG_START_SEL] fields. In addition, the polarity of each trigger can be selected to begin on rising or falling edge by programming CTRL[TRIG_END_POL] and CTRL[TRIG_START_POL]. It is assumed that the time between edges will be > > REF clock period:

1. Select the signal source which will begin the measurement with CTRL[TRIG_START_SEL].
2. Select a the polarity for TRIG_START_SEL by programming CTRL[TRIG_START_POL]. This will determine if the sequence begins on a rising or falling edge of TRIG_START_SEL.
3. Select both the signal source and edge polarity that will end the measurement, with CTRL[TRIG_END_SEL] and CTRL[TRIG_END_POL].
4. Select a value for REF_TARGET. This value will act as a time-out feature for the current measurement. The measurement will end when REF_CNT = REF_CNT_TARGET.
5. Perform a dummy write to the REF counter. This triggers:
    a. REF counter starts counting immediately
    b. All previous counters will be cleared.
6. The MEAS_STARTED bit will indicate when the selected TRIG_START_SEL edge has been triggered.
7. Upon assertion of MEAS_STARTED, REF_COUNT_ST_SAVED (which is a saved version of the actual REF counter, which keeps running) will be written.
8. The REF_STOPPED bit will indicate when the selected EDGE_COUNT_END edge has been triggered.
9. Upon assertion of REF_STOPPED, REF_CNT_END_SAVED (which is a saved version of the actual REF counter) will be written.
10. Note that REF_STOPPED may be set before the measurement has been completed. This may indicate the REF_TARGET is too low for the required measurement time. In this case, the CNT_STAT[REF_CNT_TIMEOUT] will be set to 0b1 to indicate that either TRIG_END_SEL or TRIG_START_SEL was never received.
11. Calculate the edge to edge time using the difference between the values of REF_COUNT_END_SAVED and REF_CNT_ST_SAVED.
12. To determine when the measurement has been completed, the user can either poll the REF_STOPPED bit or enable SFA_IRQ_EN. If SFA_IRQ_EN is asserted than an interrupt will be issued when REF_STOPPED is asserted.
13. If the value (REF_COUNT_END_SAVED-REF_COUNT_ST_SAVED) greater than the value setting in REG_HIGH_LIMIT_CNT , it means the measured trigger period is greater than maximum limit,if according enable bit is set, the FREQ_LT_MIN_IRQ will be generated
14. If the value (REF_COUNT_END_SAVED-REF_COUNT_ST_SAVED) less than the value setting in REG_LOW_LIMIT_CNT , it means the measured trigger period is less than minimum limit, if according enable bit is set, the FREQ_GT_MAX_IRQ will be generated

The following two waveforms illustrate two possible cases for trigger based measurements. Note that it is assumed that the user completed the above steps 1 through 5 before these waveforms begin. In addition, it is assumed that SFA_IRQ_EN is asserted. The first waveform shows a completed trigger based measurement. The second waveform illustrates a ref counter timeout when attempting to complete a trigger based measurement. Notice the assertion of Ref_Cnt_Timeout upon completing the measurement cycle.

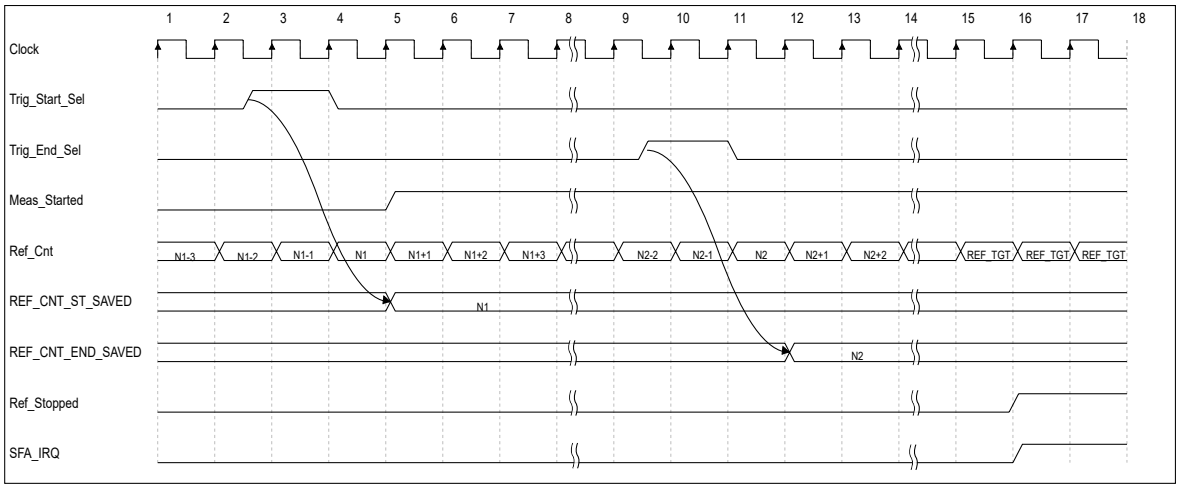


Figure 74. Trigger Based Measurement

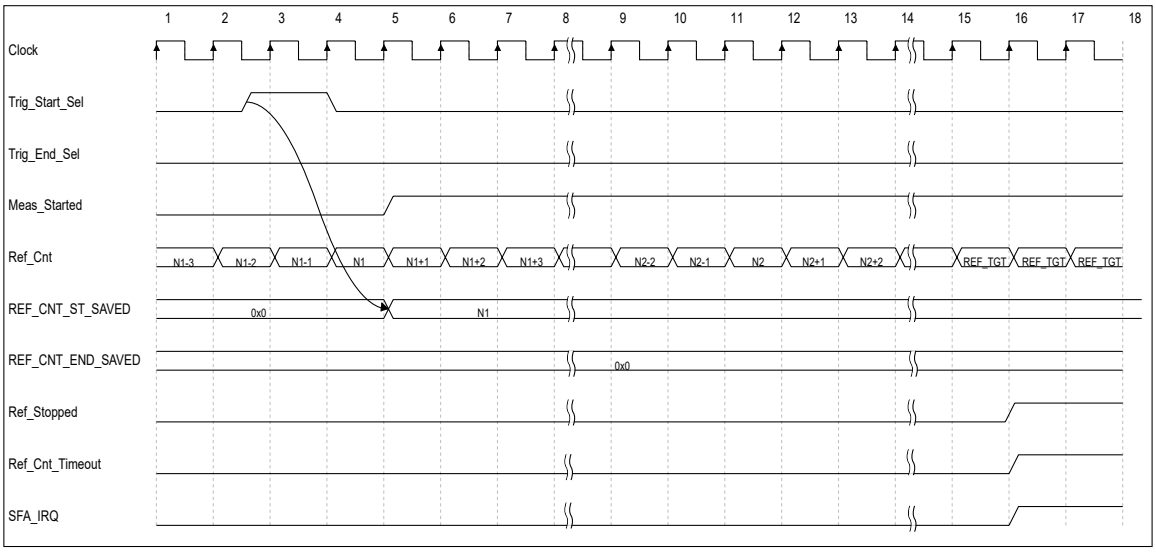


Figure 75. Trigger Based Measurement Timeout

26.3.4 Clocking

The SFA has several clock sources, for internal behaviour, register access, and for frequency measurement. Their role during the frequency measurement is covered in the Functional Description chapter. They are listed in the table below:

Table 221. SFA Clocks

Input	Description
ipg_clk	IPS System Bus Clock
ipg_clk_s	IPS System Bus Clock for pmodel
ipt_clk	High Speed TestClock
sfa_clk_inputs	Clocks under Test
sfa_ref_clk_inputs	Clocks for Reference Clock choices

26.3.5 Interrupts

This module has single interrupt: ipi_init. This interrupt is asserted when:

- CNT_STAT[4] is set and CTRL [5] is enabled
- CNT_STAT[5] is set and CTRL2[16] is enabled
- CNT_STAT[6] is set and CTRL2[17] is enabled

26.4 Memory Map/Register Definition

26.4.1 Signal Frequency Analyser register descriptions

26.4.1.1 Signal_Frequency_Analyser memory map

SFA0 base address: 4001_D000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Signal Frequency Analyser (SFA) Control (CTRL)	32	RW	0000_0000h
4h	Signal Frequency Analyser (SFA) Control Extended (CTRL_EXT)	32	RW	0000_0000h
8h	Signal Frequency Analyser Count Status Register (CNT_STAT)	32	RW	0000_0000h
Ch	Signal Frequency Analyser Clock Under Test Counter (CUT_CNT)	32	RW	0000_0000h
10h	Signal Frequency Analyser Reference Clock Counter (REF_CNT)	32	RW	0000_0000h
14h	Signal Frequency Analyser Clock Under Test Target Count (CUT_TARGET)	32	RW	FFFF_FFFFh
18h	Signal Frequency Analyser Reference Clock Target Count (REF_TARGET)	32	RW	FFFF_FFFFh
1Ch	Signal Frequency Analyser Reference Clock Count Start Saved Register (REF_CNT_ST_SAVED)	32	R	0000_0000h
20h	Signal Frequency Analyser Reference Clock Count End Saved Register (REF_CNT_END_SAVED)	32	R	0000_0000h
24h	Extended control register for SFA (CTRL2)	32	RW	0000_0000h
28h	Record the low limit reference clock count (REF_LOW_LIMIT_CNT)	32	RW	0000_0000h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
2Ch	This register record the low limit of ref clk counter (REF_HIGH_LIMIT_CNT)	32	RW	0000_0000h
30h	Record the CUT clock low limit counter (CUT_LOW_LIMIT_CNT)	32	RW	0000_0000h
34h	Record high limit count of cut clock (CUT_HIGH_LIMIT_CNT)	32	RW	0000_0000h

26.4.1.2 Signal Frequency Analyser (SFA) Control (CTRL)

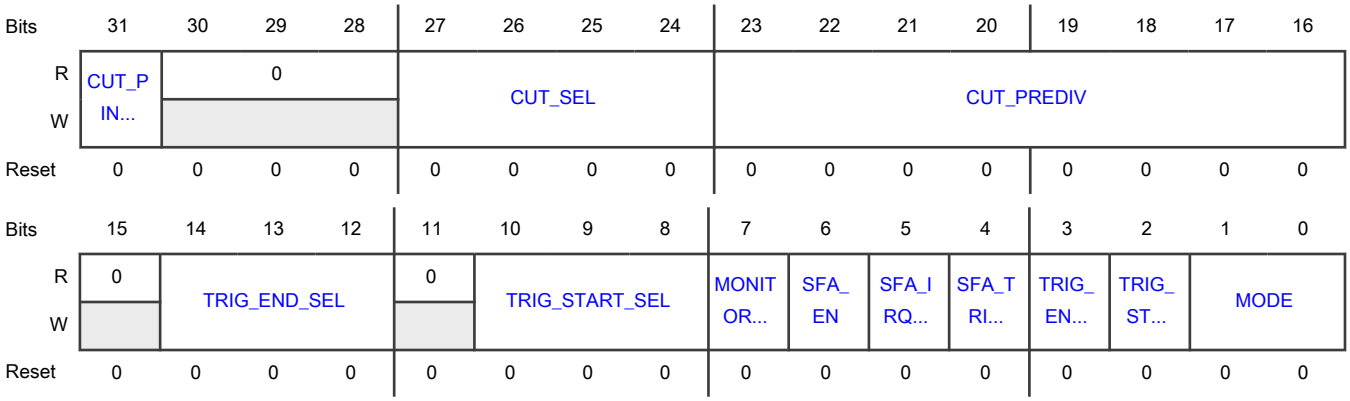
Offset

Register	Offset
CTRL	0h

Function

The SFA Control register contains fields to select both the type of measurement and the signal sources to be measured. The measurement mode will determine whether the SFA performs a frequency, period, or trigger based measurement.

Diagram



Fields

Field	Function
31 CUT_PIN_EN	CUT_PIN_EN This register field controls the connection of the clock under test to an external pin.
30-28 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
27-24 CUT_SEL	CUT_SEL These bits control which SoC clock is connected to the clock under test counter.
23-16 CUT_PREDIV	CUT_PREDIV The CUT_PREDIV 8-bit field provides an integer division of the input CUT signal prior to the CUT counter. Only integer values are implemented and the least significant bit is ignored. 0000_0000b - No Divide 0000_0001b - No Divide 0000_0010b - Divide by 2 0000_0011b - Divide by 2 0000_0100b - Divide by 4 0000_0101b - Divide by 4 0000_0110b - Divide by 6 0000_0111b - Divide by 6 0000_1000b - Divide by 8 0000_1001b - Divide by 8 0000_1010b-1111_1101b - Divide by CUT_PREDIV - CUT_PREDIV%2 1111_1110b - Divide by 254 1111_1111b - Divide by 254
15 —	Reserved
14-12 TRIG_END_SEL	Signal MUX For Trigger Based Measurement End This bit selects which signal will be used to commence a trigger based measurement. An edge of this signal will act as a trigger to end the measurement sequence. Either rising edge or falling edge can be selected by programming TRIG_END_POL.
11 —	Reserved
10-8 TRIG_START_SEL	Signal MUX For Trigger Based Measurement Start This bit selects which signal will be used to start an edge to edge measurement. An edge of this signal will act as a trigger to begin the measurement sequence. Either rising edge or falling edge can be selected by programming EDGE_START_POL.
7 MONITOR_EN	Monitor Enable This bit is used to enable Monitor mode. When in Monitor mode, measure will continue until the measured clk frequency has exceed the target frequency range. This bit ONLY takes affect in Frequecy Measurements(MODE = 00 or MODE=01)

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Not in monitor mode . 1b - In monitor mode.
6 SFA_EN	SFA Enable This bit is the general SFA Enable signal. To run any measurement, this signal must be set to 0b1. This signal must be set to 0b0 when modifying any clock inputs, clock divider values, or trigger selects. For example, prior to writing TRIG_END_POL, TRIG_START_POL, TRIG_START_SEL, TRIG_END_SEL, CUT_PREDIV, or CUT_SEL make sure that this bit is set to 0b0. 0b - The SFA is disabled. 1b - The SFA is enabled.
5 SFA_IRQ_EN	SFA Interrupt Enable This signal determines if interrupts are enabled for the SFA. When enabled, an interrupt will be issued upon completion of a measurement. 0b - Interrupts are disabled. 1b - Interrupts are enabled.
4 SFA_TRIG_MEAS_EN	SFA Triggered Measurement Enable The SFA can be triggered to start a new frequency measurement when operating with either MODE = 0x0 or MODE = 0x1. This register field will be inactive if MODE > 0x1. The start trigger will be selected with TRIG_START_SEL and the measurement will begin when the first edge is received with polarity TRIG_START_POL. Note, SFA_EN bit must be set prior to beginning any measurements. The startup process requires a dummy write to the REF_CNT register to enable trigger detection followed by a trigger from the selected source. Refer to section Frequency Measurements for more information. 0b - The measurement will start by default with a dummy write to the REF and CUT counters. 1b - The measurement will start after receiving a dummy write to the REF_CNT followed by receiving the trigger edge selected by TRIG_START_SEL and TRIG_START_POL.
3 TRIG_END_POL	Trigger End Polarity This signal determines the polarity of the trigger signal which will end a trigger based measurement. 0b - Rising edge of TRIGER[TRIG_END_SEL] will end the measurement sequence. 1b - Falling edge of TRIGGER[TRIG_END_SEL] will end the measurement sequence.
2 TRIG_START_POL	Trigger Start Polarity This signal determines the polarity of the start signal when measuring in trigger mode. 0b - Rising edge of TRIGGER[TRIG_START_SEL] will begin the measurement sequence. 1b - Falling edge of TRIGGER[TRIG_START_SEL] will begin the measurement sequence.
1-0 MODE	MEASUREMENT MODE Measurement mode determines which type of timing measurement is performed.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	00b - Frequency measurement performed with REF frequency > CUT Frequency. 01b - Frequency measurement performed with REF frequency < CUT Frequency. 10b - CUT period measurement performed. 11b - Trigger based measurement performed. Note, each trigger pulse must be held for at least 2 ref_clk cycles.

26.4.1.3 Signal Frequency Analyser (SFA) Control Extended (CTRL_EXT)

Offset

Register	Offset
CTRL_EXT	4h

Function

The SFA CTRL_EXT register contains fields to select

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	CUT_CLK_EN															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-16 —	Reserved
15-0 CUT_CLK_EN	CUT_CLK_EN This register field provides an enable signal for each CUT_CLK source. Each bit corresponds to a single CUT_CLK. Bit 0 corresponds to CUT_CLK0, bit 1 corresponds to CUT_CLK1, and so on. Enabling each bit will enable corresponding CUT_CLK.

26.4.1.4 Signal Frequency Analyser Count Status Register (CNT_STAT)

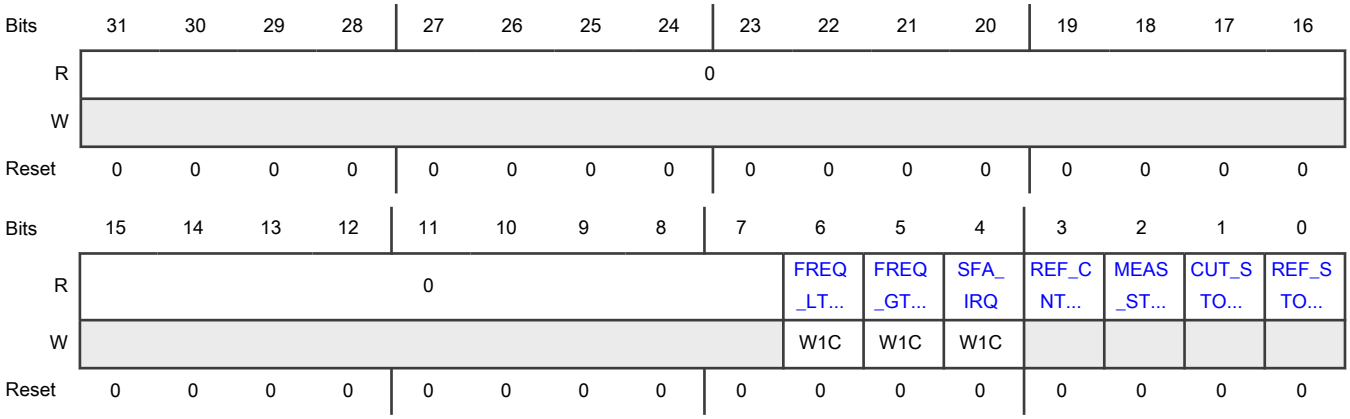
Offset

Register	Offset
CNT_STAT	8h

Function

This register returns status flags to indicate the current state of the REF and CUT counters

Diagram



Fields

Field	Function
31-7 —	Reserved
6 FREQ_LT_MIN_IRQ	FREQ_LT_MIN interrupt flag FREQ_LT_MIN interrupt flag, it means the cut clk frequency is lower than minimum setting,or trigger measurement period is greater than maximum setting
5 FREQ_GT_MAX_IRQ	FREQ_GT_MAX interrupt flag FREQ_GT_MAX interrupt flag, it means the cut clk frequency is greater than maximum setting,or trigger measurement period is less than minimum setting
4 SFA_IRQ	SFA Interrupt Request This flag indicates that REF_CNT has reached REF_TARGET. More generally, this flag indicates that a measurement has been completed and an interrupt has been issued. Writing a 0x1 to this bit position will clear the interrupt request.
3 REF_CNT_TIMEOUT	Reference Counter Time Out This flag indicates the REF counter reached REF_TARGET before the desired measurement was completed. Every test will commence when REF_CNT == REF_TARGET. For measurement accuracy,

Table continues on the next page...

Table continued from the previous page...

Field	Function
	this bit should be equal to 0b0 when REF_STOPPED == 0b1. This bit will be cleared on any write to REF_CNT when not performing a measurement.
2 MEAS_STARTED	Measurement Started Flag In frequency measurement mode, this flag indicates when the CUT counter has started counting. Set when CUT counter increments to 1. In period measurement mode, this flag indicates that the first edge of the CUT has been received for period measurement. In edge to edge signal measurement mode, this flag will indicate when TRIGGER[TRIG_START_SEL] has been received for measurement. This event will also push the REF_CNT to the REF_CNT_ST_SAVED register. This flag is only active during CTRL[MODE] == 0x0, 0x2 or 0x3. Cleared on any write to REF_CNT when not performing a measurement.
1 CUT_STOPPED	CUT_STOPPED This flag indicates the CUT counter has stopped counting. Set when either REF or CUT counter has reached its target. Cleared on any write to REF_CNT when not performing a measurement.
0 REF_STOPPED	REF_STOPPED This flag indicates the REF counter has stopped counting. Set when REF counter has reached its target. Cleared on any write to REF_CNT when not performing a measurement. This bit can be polled to indicate when a measurement is complete.

26.4.1.5 Signal Frequency Analyser Clock Under Test Counter (CUT_CNT)

Offset

Register	Offset
CUT_CNT	Ch

Function

This register contains the current count of the clock under test. Writes to this register will start the clock under test and reference counters. Counting will stop when either the count matches the contents of the clock under test target count register or when reference counter matches the reference target count register. Note, attempts to read this register before the CUT_STOPPED flag has set will return 0x0000_0000

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	CUT_CNT															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	CUT_CNT															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 CUT_CNT	CUT_CNT Current clock under test count. Writes to this register will start the clock under test and reference counters.

26.4.1.6 Signal Frequency Analyser Reference Clock Counter (REF_CNT)

Offset

Register	Offset
REF_CNT	10h

Function

This 32-bit register contains the current count of the reference clock. Writes to this register will clear the clock under test and reference counters. Counting will stop if the count matches the contents of the reference clock target count register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	REF_CNT															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	REF_CNT															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 REF_CNT	REF_CNT Current reference clock count. Writing to this register with any value will clear the clock under test and reference clock count and status flags registers.

26.4.1.7 Signal Frequency Analyser Clock Under Test Target Count (CUT_TARGET)

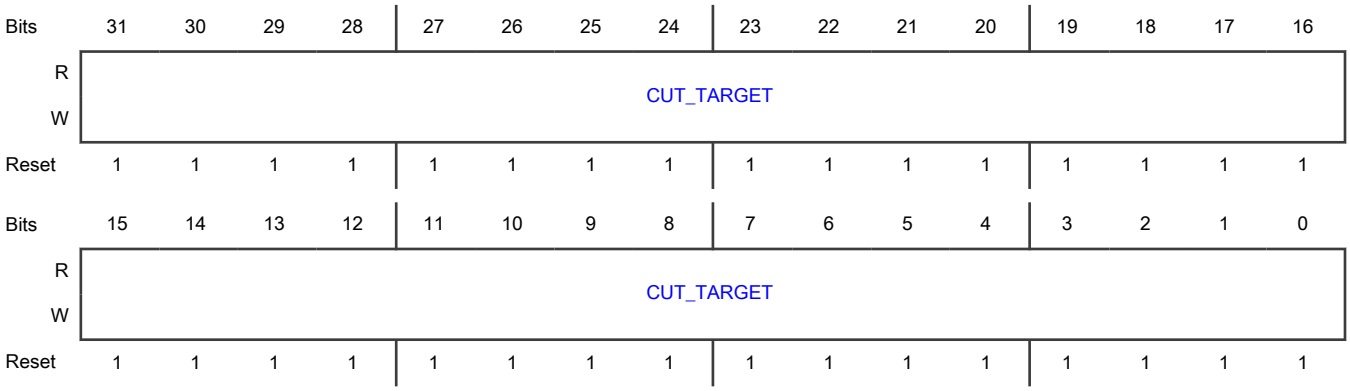
Offset

Register	Offset
CUT_TARGET	14h

Function

This register contains the target count for the clock under test. Both the reference and clock under test count will stop if the clock under test count matches the contents of this register.

Diagram



Fields

Field	Function
31-0 CUT_TARGET	CUT_TARGET Target count for the clock under test. Note, a measurement of type MODE = 0x0 or 0x1 is not valid if CUT_TARGET = 0x00000000. This value must be set to an integer > 0x0 to perform a valid measurement.

26.4.1.8 Signal Frequency Analyser Reference Clock Target Count (REF_TARGET)

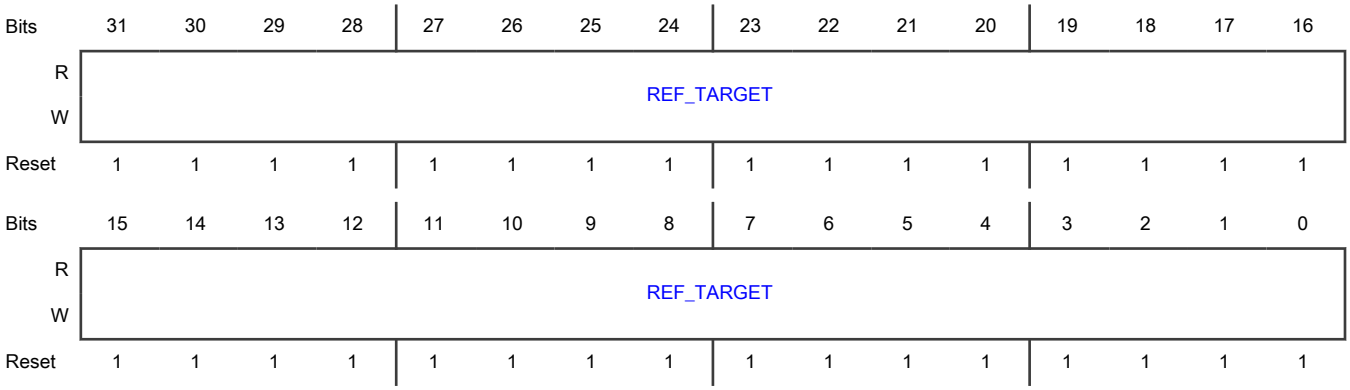
Offset

Register	Offset
REF_TARGET	18h

Function

This register contains the target count for the reference clock. Both the reference and clock under test count will stop if the reference clock count matches the contents of this register.

Diagram



Fields

Field	Function
31-0 REF_TARGET	REF_TARGET Target count for the reference clock. Note, a measurement is not valid if REF_TARGET = 0x00000000. This value must be set to an integer > 0x0 to perform a valid measurement.

26.4.1.9 Signal Frequency Analyser Reference Clock Count Start Saved Register (REF_CNT_ST_SAVED)

Offset

Register	Offset
REF_CNT_ST_SAVED	1Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	REF_CNT_ST_SAVED															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	REF_CNT_ST_SAVED															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 REF_CNT_ST_SAVED	REF_CNT_ST_SAVED Saved reference clock counter. This register is loaded with the current value of REF_CNT on assertion of the MEAS_STARTED flag. Note, during frequency measurements with CTRL[MODE] = 0x1, this register will be unused. It is assumed that the REF CNT start will be 0x0. This register is cleared on any write to REF_CNT when not performing a measurement.

26.4.1.10 Signal Frequency Analyser Reference Clock Count End Saved Register (REF_CNT_END_SAVED)

Offset

Register	Offset
REF_CNT_END_SAVED	20h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	REF_CNT_END_SAVED															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	REF_CNT_END_SAVED															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 REF_CNT_END_SAVED	REF_CNT_END_SAVED Saved reference clock counter. This register is loaded with the current value of REF_CNT on assertion of either the CUT_STOPPED or REF_STOPPED flags. Note, during frequency measurements with CTRL[MODE] = 0x1, this register will be unused. It is assumed that the REF_CNT_END will be equal to REF_TARGET. Cleared on any write to REF_CNT when not performing a measurement.

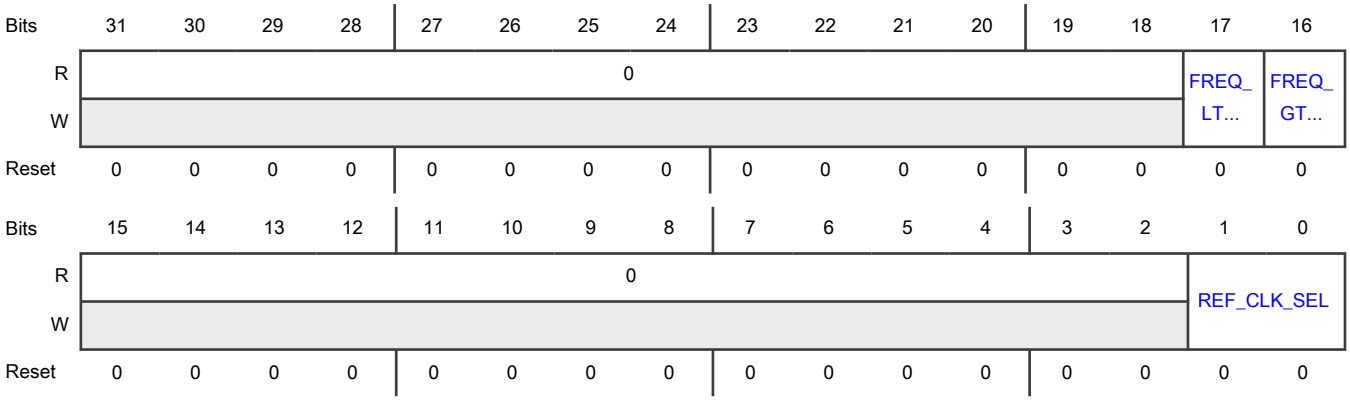
26.4.1.11 Extended control register for SFA (CTRL2)

Offset

Register	Offset
CTRL2	24h

Function
This register an extended control register for SFA

Diagram



Fields

Field	Function
31-18 —	Reserved
17 FREQ_LT_MIN_IRQ_EN	FREQ_LT_MIN interrupt enable This bit used to enable FREQ_LT_MIN interrupt.
16	FREQ_GT_MAX interrupt enable This bit used to enable FREQ_GT_MAX interrupt.

Table continues on the next page...

Table continued from the previous page...

Field	Function
FREQ_GT_MAX_IRQ_EN	
15-2 —	Reserved
1-0 REF_CLK_SEL	Reference clock select These bits control which SoC clock is connected to the reference clock.

26.4.1.12 Record the low limit reference clock count (REF_LOW_LIMIT_CNT)

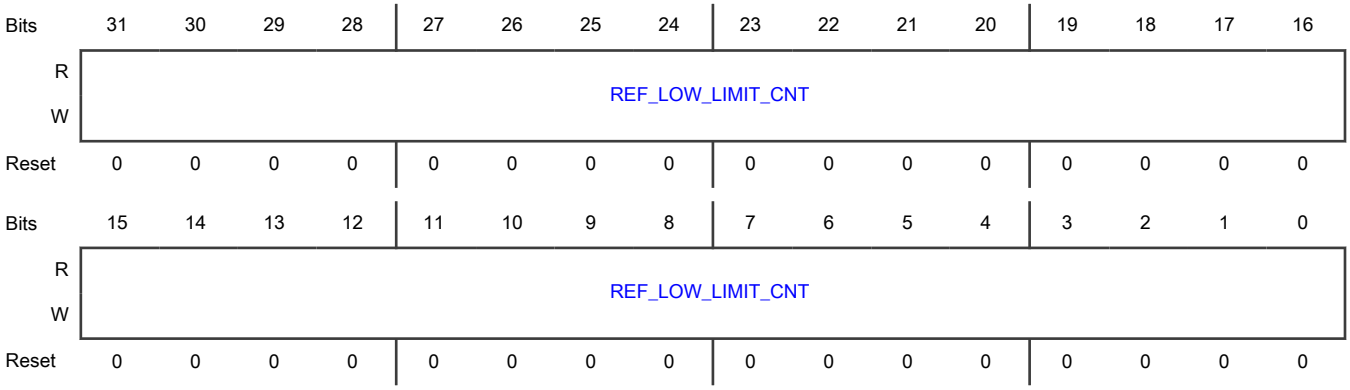
Offset

Register	Offset
REF_LOW_LIMIT_CNT	28h

Function

Record the low limit reference clock count.

Diagram



Fields

Field	Function
31-0 REF_LOW_LIMIT_CNT	Low limit reference clock count value Low limit reference clock count value. If reference clock counter number in measure period is less than this value. Then FREQ_GT_MAX interrupt will generate if according enable bit is set.

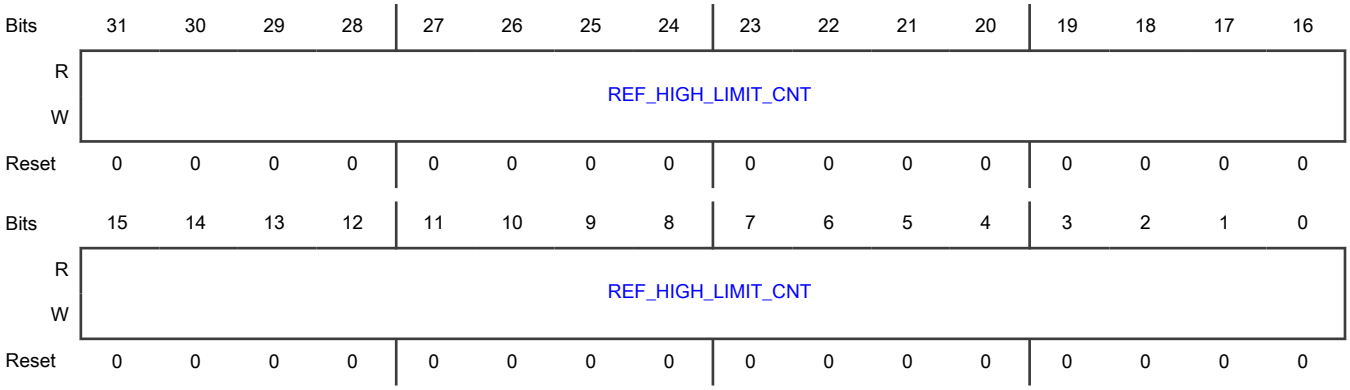
26.4.1.13 This register record the low limit of ref clk counter (REF_HIGH_LIMIT_CNT)

Offset

Register	Offset
REF_HIGH_LIMIT_CNT	2Ch

Function
This register record the low limit of ref clk counter.

Diagram



Fields

Field	Function
31-0 REF_HIGH_LIMIT_CNT	High limit reference clock count value High limit reference clock count value. If reference clock counter number in measure period is greater than this value. Then FREQ_LT_MIN interrupt will generate if according enable bit is set.

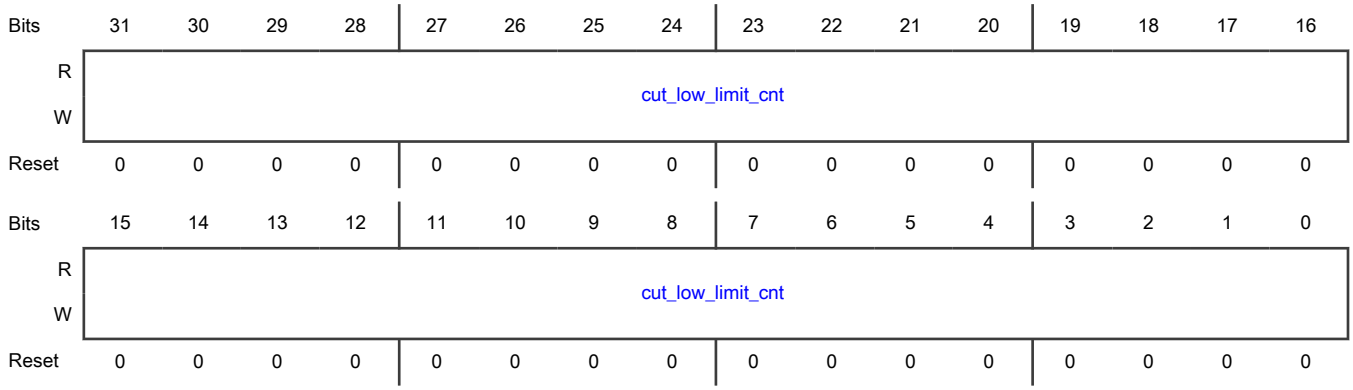
26.4.1.14 Record the CUT clock low limit counter (CUT_LOW_LIMIT_CNT)

Offset

Register	Offset
CUT_LOW_LIMIT_CNT	30h

Function
Record the CUT clock low limit counter. This register is only used when CTRL.MODE=0x01

Diagram



Fields

Field	Function
31-0 cut_low_limit_cnt	Low limit cut clock count value Low limit cut clock count value. If cut clock counter number in measure period is less than this value. Then FREQ_LT_MIN interrupt will generate if according enable bit is set.

26.4.1.15 Record high limit count of cut clock (CUT_HIGH_LIMIT_CNT)

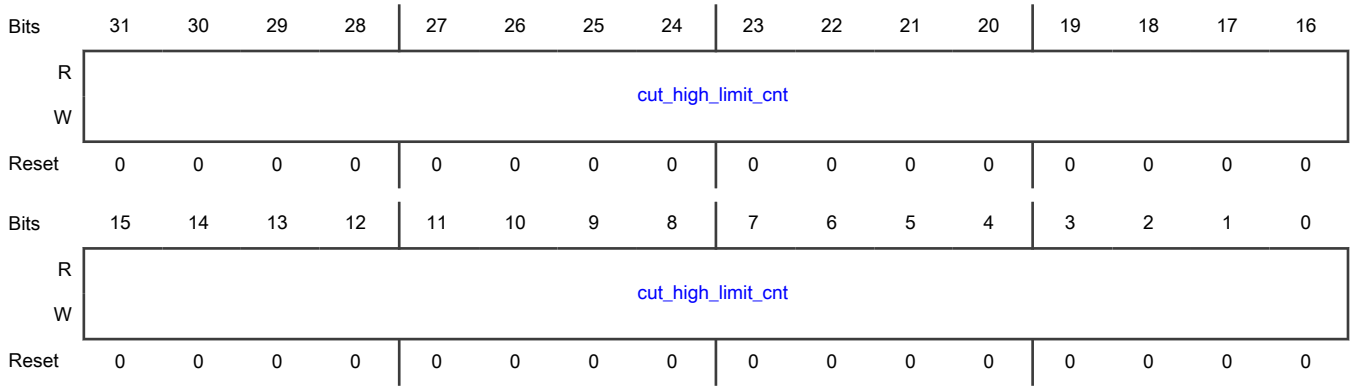
Offset

Register	Offset
CUT_HIGH_LIMIT_CNT	34h

Function

Record high limit count of cut clock. This register is only used when CTRL.MODE=0x01

Diagram



Fields

Field	Function
31-0 cut_high_limit_cnt	High limit cut clock count value High limit cut clock count value. If cut clock counter number in measure period is greater than this value. Then FREQ_GT_MAX interrupt will generate if according enable bit is set.

Chapter 27
32 kHz Clock Control Module (CCM32K)

27.1 Chip-specific CCM32K information

Table 222. Reference links to related information

Topic	Related module	Reference
Full description	CCM32K	CCM32K
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

27.1.1 Module instances

This device has one instance of the CCM32K module.

27.1.2 Reset

The CCM32K module supports only the POR.

27.2 Overview

The 32 kHz Clock Control Module (CCM32K) provides the 32 kHz clock to the device. This module includes the free running oscillator (FRO) and Crystal Oscillator (OSC) which serve as the clock generators of 32 kHz clock. The module has an internal clock validation mechanism to ensure the clock from OSC is stable; and manually switch from the FRO to OSC when clock from OSC is stable or switch back to FRO clock if software disables the OSC. There is also an internal monitor inside OSC to detect whether it is available, and CCM32K can automatically switch back from OSC to FRO immediately if OSC is unavailable.

27.2.1 Block diagram

The following figure shows a block diagram for the CCM32K module.

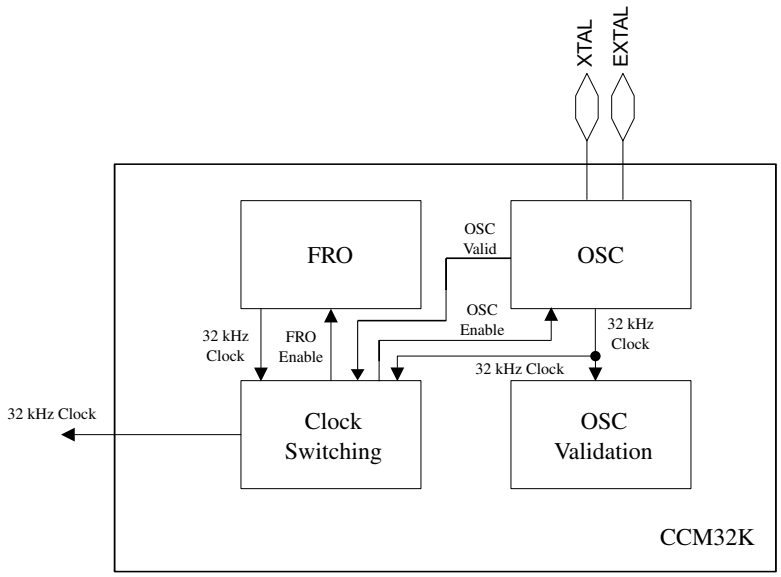


Figure 76. High level block diagram

27.2.2 Features

The CCM32K module has the following features:

- 32-kHz Free Running Oscillator (FRO) that is enabled after POR to provide clock to the device. The FRO can be disabled by software if needed.
- FRO and OSC trim values are loaded from IFR which can be overriden by software if needed.
- 32-kHz Crystal Oscillator (OSC) that is kept disabled after POR. The OSC can be enabled by software when needed. And the OSC has an internal monitor to detect whether it is available.
- Clock validation logic that checks for the quality of clock from OSC and indicates if the clock from the OSC is stable.
- Clock switching logic that switches to OSC clock when it is stable and manually switches back to FRO clock when software disables the OSC.
- Clock automatic switching logic that automatically switches back to FRO clock if OSC internal monitor detect it is unavailable.
- Locking mechanism for all registers for OSC and FRO. Once locked, the registers cannot be unlocked until the next POR. This prevents unwanted modifications to the registers.
- The loss of clock (LOC) monitoring for the quality of external 32-khz crystal oscillator with internal 32-khz FRO as reference clock.

27.3 Functional description

The following sections describe functional details of the CCM32K module.

27.3.1 OSC clock validation

The clock from the external crystal oscillator is not stable immediately after enabling it and takes certain time before it becomes stable and can be used. The clock validation mechanism ensures that sufficient amount of clock cycles have passed before enabling the clock to other modules on the device that require 32 kHz clock. When STATUS[OSC32K_ACTIVE] and STATUS[OSC32K_RDY] are asserted, 32 kHz oscillator clock can be used by other modules.

27.3.2 Clock switching

Clock switching between OSC32K and FRO32K

- Switch FRO32K to OSC32K by configuring CGC32K[CLK_SEL_32K] to 1b if OSC32K clock is available.
- Switch OSC32K to FRO32K by configuring CGC32K[CLK_SEL_32K] to 0b if FRO32K clock is available.
- No clock source active if CGC32K[CLK_SEL_32K] is high and OSC32K is disabled.
- No clock source active if CGC32K[CLK_SEL_32K] is low and FRO32K is disabled.

Clock switching can switch clock source automatically from FRO32K to OSC32K provided OSC32K is as the clock source and FRO32k is available. This logic use the valid flag indicating if the clock of OSC is available, which generated by OSC internal monitor after setting OSC32K_CTRL[OSC_CLKMON_EN] to 1. Enable this function by configuring CLKMON_CTRL[AUTO_SWITCH_EN] to 1b after OSC32K is as clock source.

27.3.3 Clock monitor

CCM32K has two clock monitors. One uses FRO_ 32K as its clock source. The other uses OSC_32K as its clock source. Each monitor checks a divided version of the other clock at the same frequency but divided by 16. The monitor expects a clock edge every 8 cycles, and you can trim the monitor to assert after 10, 12, 14, or 16 cycles with no edge.

Changing the trim makes the clock monitor more sensitive and reduces the latency, but also makes it more susceptible to variation in the duty cycle. The accuracy and latency of the monitor can vary by a cycle due to synchronization differences, so for each trim point:

- At 2 cycles after the expected edge the monitor asserts between 12.5% and 37.5% frequency variation with a maximum latency of 11 cycles
- At 4 cycles after the expected edge the monitor asserts between 37.5% and 62.5% frequency variation with a maximum latency of 13 cycles
- At 6 cycles after the expected edge the monitor asserts between 62.5% and 87.5% frequency variation with a maximum latency of 15 cycles
- At 8 cycles after the expected edge the monitor asserts between 87.5% and 112.5% frequency variation with a maximum latency of 17 cycles

The frequency of the clock monitor can also be trimmed to either 1 kHz or 64 Hz. Configuring to a slower clock increases the detector's latency but reduces power consumption.

NOTE

You must enable both the FR032k and OSC32k and OSC_RDY sets before enabling the clock monitor.

27.3.4 Clock automaitc switching

This section describes the automatic switching function of CCM32K. When selecting OSC32K as clock source, CCM32k will detect the valid signal from OSC32K constantly after setting OSC32K_CTRL[OSC_CLKMON_EN] and CLKMON_CTRL[AUTO_SWITCH_EN] to 1b. This valid signal derives from OSCK32 internal monitor that is used to detect the period of high and low level of the clock. when the frequency is below about 20khz, OSCK32 will de-assert the valid signal and then CCM32K dynamically switch the clock source to FRO32K immediately.

STATUS[AUTO_SWITCH] is 1b to identify clock source has been switched to FRO32K. Software must follow the steps below to further select OSC32K to the clock source again if need.

1. Clear CGC32K[CLK_SEL_32K] to be 0b to select FRO32K as clock source.
2. Wait until the STATUS[FRO32K_ACTIVE] is 1b to identify FRO32K is as clock source.
3. Clear CLKMON_CTRL[AUTO_SWITCH_EN] to 0b to disable clock automatic switching logic.
4. Clear OSC32K_CTRL[OSC_EN] and OSC32K_CTRL[SOX_EN] as 0b to disable OSC32K.
5. Enable OSC32K and configure it as clock source. Refer to initialization section.

27.4 External signals

This table describes the CCM32K signals that are SoC level pins.

Signal	I/O	Description
EXTAL32K	I/O	32-kHz Crystal pin
XTAL32K	I/O	32-kHz Crystal pin

27.5 Initialization

This section describes the initialization of the CCM32K module.

The CCM32K module powers up, loads the default trims from flash and starts up the FRO after Power-On-Reset (POR) is complete. The trim values get loaded after POR into their respective registers. Software must follow the steps below to further configure the module.

- FRO32K as clock source
  1. Enable the FRO32K by setting FRO32K_CTRL[FRO_EN] as 1b. The FRO32K_CTRL[FRO_EN] is reset to 1b by default.
  2. Wait until the STATUS[FRO32K_ACTIVE] is 1b to identify FRO32K available.
  3. Clear CGC32K[CLK_SEL_32K] to be 0b to select FRO32K as clock source. The CGC32K[CLK_SEL_32K] is reset to 0b by default.
- OSC32K as clock source
  1. Set OSC32K_CTRL[OSC_EN] and OSC32K_CTRL[SOX_EN] as 1b.
  2. Set OSC32K_CTRL[OSC_CLKMON_EN] as 1b if need to use automatic switching function.
  3. Select internal capacitance bank value through OSC32K_CTRL[XTAL_CAP_SEL] and OSC32K_CTRL[EXTAL_CAP_SEL] if internal capacitance back is enabled (OSC32K_CTRL[CAP_SEL_EN]).
  4. Wait until theSTATUS[OSC32K_RDY] is 1b to identify OSC32K available.
  5. Set CGC32K[CLK_SEL_32K] as 1b to select OSC32K as clock source.
  6. Wait until the STATUS[OSC32K_ACTIVE] is 1b to identify OSC32K is as clock source.
  7. Set CLKMON_CTRL[AUTO_SWITCH_EN] to 1b optionally to enable clock automatic switching logic.
- OSC32K bypass clock as clock source
  1. Set OSC32K_CTRL[OSC_EN] and OSC32K_CTRL[OSC_BYP_EN] high.
  2. Wait until theSTATUS[OSC32K_RDY] is 1b to identify OSC32K available.
  3. Set CGC32K[CLK_SEL_32K] high , then OSC32K bypass clock is selected as clock source. This clock is treated as same clock on EXTAL32 pad.

NOTE

OSC32K_ACTIVE or FRO32_ACTIVE will be asserted only when related oscillator is selected as clock source and CGC32K[CLK_OE_32K] is not all 0.

27.6 Memory Map and register definition

This section includes the CCM32K module memory map and detailed descriptions of all registers.

27.6.1 CCM32K register descriptions

27.6.1.1 CCM32K memory map

CCM32K base address: 4001_F000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Free Running 32 kHz Oscillator Control Register (FRO32K_CTRL)	32	RW	0088_0001h
4h	Free Running 32 kHz Oscillator Trim Register (FRO32K_TRIM)	32	RW	0000_0400h
8h	32 kHz OSC Control Register (OSC32K_CTRL)	32	RW	0000_0000h
Ch	Status Register (STATUS)	32	R	0000_0010h
14h	Clock Monitor Control Register (CLKMON_CTRL)	32	RW	0000_0000h
18h	Clock Monitor Test Register (CLKMON_TST)	32	RW	0000_0000h
1Ch	32 kHz Clock Gate Control Register (CGC32K)	32	RW	0000_001Fh
24h	32 kHz OSC Internal Monitor Trim Register (OSC32K_MON_TRIM)	32	RW	0000_1F1Fh

27.6.1.2 Free Running 32 kHz Oscillator Control Register (FRO32K_CTRL)

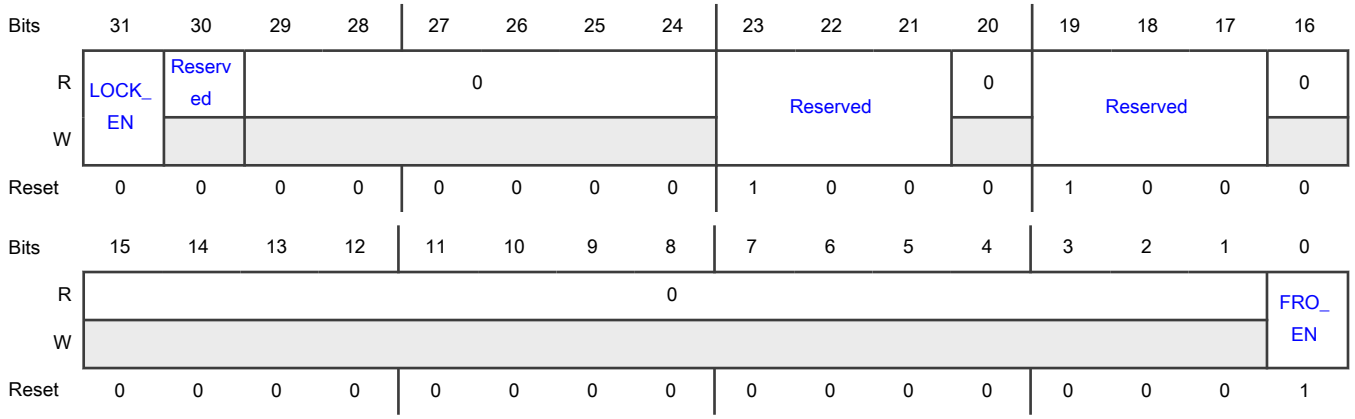
Offset

Register	Offset
FRO32K_CTRL	0h

Function

The Free Running 32 kHz Oscillator Control Register (FRO32K_CTRL) provides control fields for the 32 kHz Free Running Oscillator.

Diagram



Fields

Field	Function
31 LOCK_EN	Write Access Lock When set to '1', this field locks all further write accesses to this register until a POR occurs. Writing '0' after setting this field to '1' has no effect. 0b - Register write access is unlocked 1b - Register write access is locked
30 —	Reserved bits. Reads only zeros.
29-24 —	Reserved bits. Reads only zeros.
23-21 —	Reserved bits. Reads only zeros. Writes have no effect but it is preferred that these bits are not written to.
20 —	Reserved bits. Reads only zeros.
19-17 —	Reserved bits. Reads only zeros. Writes have no effect but it is preferred that these bits are not written to.
16-1 —	Reserved bits. Reads only zeros.
0 FRO_EN	FRO Enable This field enables the FRO analog oscillator. There is a 120 µs typical start-up time before clocks are output from the FRO. 0b - FRO is disabled 1b - FRO is enabled

27.6.1.3 Free Running 32 kHz Oscillator Trim Register (FRO32K_TRIM)

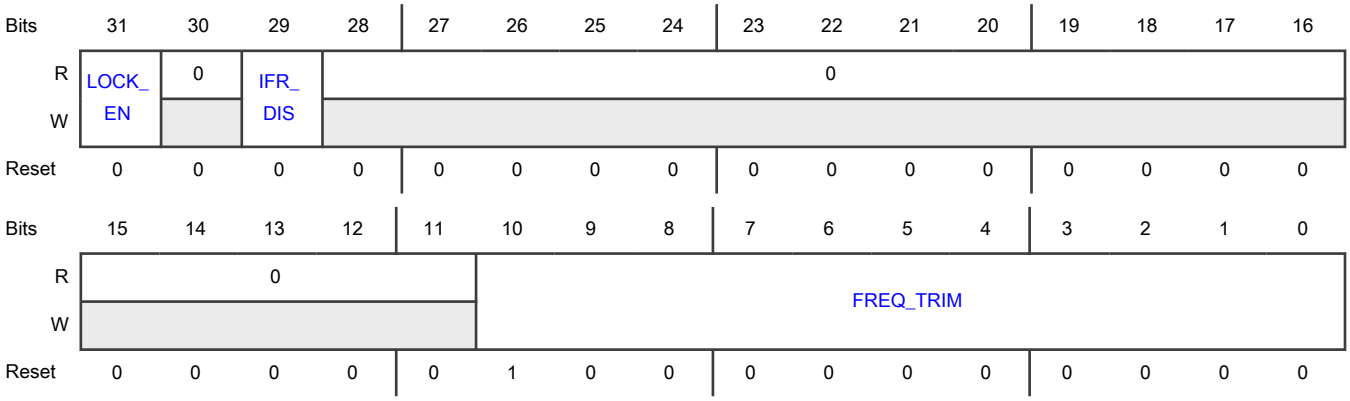
Offset

Register	Offset
FRO32K_TRIM	4h

Function

The Free Running 32 kHz Oscillator Trim Register (FRO32K_TRIM) provides frequency trim configuration for the 32 kHz Free Running Oscillator.

Diagram



Fields

Field	Function
31 LOCK_EN	Write Access Lock When set to '1', this field locks all further write accesses to this register until a POR occurs. Writing '0' after setting this field to '1' has no effect. 0b - Register write access is unlocked 1b - Register write access is locked
30 —	Reserved
29 IFR_DIS	IFR Loading Disable Control This field controls whether the FREQ_TRIM field gets overwritten when IFR value gets loaded in the SoC. Setting this field to '1' blocks the FREQ_TRIM field from being loaded again. If LOCK_EN bit is set to '1', this field is ignored and no IFR values get loaded. 0b - IFR loading is enabled 1b - IFR loading is disabled
28-11 —	Reserved
10-0 FREQ_TRIM	Frequency Trim These field controls the frequncy of the FRO. The frequency is decreased monotonically when this field is changed progressively from 00000000000b to 11111111111b. This field is set from the IFR (Flash) but can be overridden by software. This field can be changed only when the FRO32K_CTRL[FRO_EN] field is '0'. **NOTE** To ensure monotonic change in frequency in a closed loop mode, the bit 0 of this field should always be kept '0'. The IFR_DIS and LOCK_EN fields control how this field gets loaded. If IFR_DIS is '1', this field will not be loaded with IFR value. If LOCK_EN bit is '1', this field will be locked for both IFR load and software writes. 100_0000_0000b - Default trim value

27.6.1.4 32 kHz OSC Control Register (OSC32K_CTRL)

Offset

Register	Offset
OSC32K_CTRL	8h

Function

The 32 kHz OSC Control Register (OSC32K_CTRL) controls the 32 kHz Crystal Oscillator.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LOCK_EN	DLY_TRIM				SUPPLY_DET		SOX_EN	0		COARSE_AMP_GAIN		OSC_HP_...	CMP_TRIM		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	XTAL_CAP_SEL				EXTAL_CAP_SEL				CAP_SEL...	CAP_TRIM		Reserved		OSC_CLK...	OSC_BYP...	OSC_EN
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 LOCK_EN	Write Access Lock bit When set to '1', this bit will lock all further write accesses to this register until a POR occurs. Writing '0' after setting this bit to '1' has no effect. 0b - Register write access is unlocked 1b - Register write access is locked
30-27 DLY_TRIM	SOX Delay Selection Delay selection for SOX mode.
26-25 SUPPLY_DET	Supply Detector Trim Supply detector for sox mode.
24 SOX_EN	Crystal mode enable Enables the crystal oscillator SOX mode. 0b - Not supported for crystal mode operation 1b - Required for crystal mode operation

Table continues on the next page...

Table continued from the previous page...

Field	Function
23-22 —	Reserved
21-20 COARSE_AMP_GAIN	Amplifier gain adjustment bits to allow the use of a wide range of external crystal ESR values. **NOTE** See the device data sheet for the ranges supported by this device. 00b - ESR_Range0 01b - ESR_Range1 10b - ESR_Range2 11b - ESR_Range3
19 OSC_HP_EN	Crystal Oscillator High Power Enable This field enables the crystal oscillator internal clock monitor when set to '1'. The oscillator will start giving the clock output but the clock is not available to the device until the STATUS[OSC_RDY] and STATUS[OSC_ACTIVE] fields are asserted. 0b - Oscillator internal clock monitor is disabled 1b - Oscillator internal clock monitor is enabled
18-16 CMP_TRIM	SOX Comparator trim Comparator selection trim for SOX mode.
15-12 XTAL_CAP_SEL	Crystal load capacitance selection bits Selects the internal capacitance for the XTAL pin from the capacitor bank. The final load capacitance can be calculated as $C_L = ((C_{extal} \cdot C_{xtal})/(C_{extal} + C_{xtal})) + C_{shunt}$ where: • C_{extal} is the selected capacitance on EXTAL pin • C_{xtal} is the selected capacitance on XTAL pin • C_{shunt} is the internal shunt capacitance whose value can be determined from the device's datasheet The selected capacitance value is shown below. 0000b - 0 pF 0001b - 2 pF 0010b - 4 pF 0011b - 6 pF 0100b - 8 pF 0101b - 10 pF 0110b - 12 pF

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Field	Function
	0111b - 14 pF 1000b - 16 pF 1001b - 18 pF 1010b - 20 pF 1011b - 22 pF 1100b - 24 pF 1101b - 26 pF 1110b - 28 pF 1111b - 30 pF
11-8 EXTAL_CAP_SEL	Crystal load capacitance selection bits Selects the internal capacitance for the EXTAL pin from the capacitor bank. The final load capacitance can be calculated as $C_L = ((C_{extal} \cdot C_{xtal})/(C_{extal} + C_{xtal})) + C_{shunt}$ where: • C_{extal} is the selected capacitance on EXTAL pin • C_{xtal} is the selected capacitance on XTAL pin • C_{shunt} is the internal shunt capacitance whose value can be determined from the device's datasheet The selected capacitance value is shown below. 0000b - 0 pF 0001b - 2 pF 0010b - 4 pF 0011b - 6 pF 0100b - 8 pF 0101b - 10 pF 0110b - 12 pF 0111b - 14 pF 1000b - 16 pF 1001b - 18 pF 1010b - 20 pF 1011b - 22 pF 1100b - 24 pF 1101b - 26 pF 1110b - 28 pF 1111b - 30 pF

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Field	Function
7 CAP_SEL_EN	Crystal Load Capacitance Selection Enable Enables the internal capacitor banks on the EXTAL and XTAL pins that vary the load capacitance on these pins. 0b - Internal capacitance bank is not enabled 1b - Internal capacitance bank is enabled
6-5 CAP_TRIM	SOX Capacitor Trim Delay selection (area) for SOX mode.
4-3 —	Reserved bits. Reads only zeros. Writes have no effect but it is preferred that these bits are not written to.
2 OSC_CLKMON_EN	Crystal Oscillator Internal Clock Monitor Enable This field enables the crystal oscillator internal clock monitor when set to '1'. The oscillator internal monitor will start detecting the frequency of clock. 0b - Oscillator internal clock monitor is disabled 1b - Oscillator internal clock monitor is enabled
1 OSC_BYP_EN	Crystal Oscillator Bypass Enable When this field is set to 1b, the crystal oscillator will be bypassed, and the output of the crystal oscillator is the same as that of the external oscillator from the EXTAL pin. Both OSC_EN and this bit must be set together to 1b to enable the bypass mode of the oscillator. To exit bypass mode, both OSC_EN and OSC_BYP_EN bits must be set to '0'. User must not move the OSC from bypass mode directly to normal mode. 0b - Crystal oscillator is not bypassed 1b - Crystal oscillator is bypassed
0 OSC_EN	Crystal Oscillator Enable This field enables the crystal oscillator when set to '1'. The oscillator will start giving the clock output but the clock is not available to the device until the STATUS[OSC_RDY] and STATUS[OSC_ACTIVE] fields are asserted. 0b - Oscillator is disabled 1b - Oscillator is enabled

27.6.1.5 Status Register (STATUS)

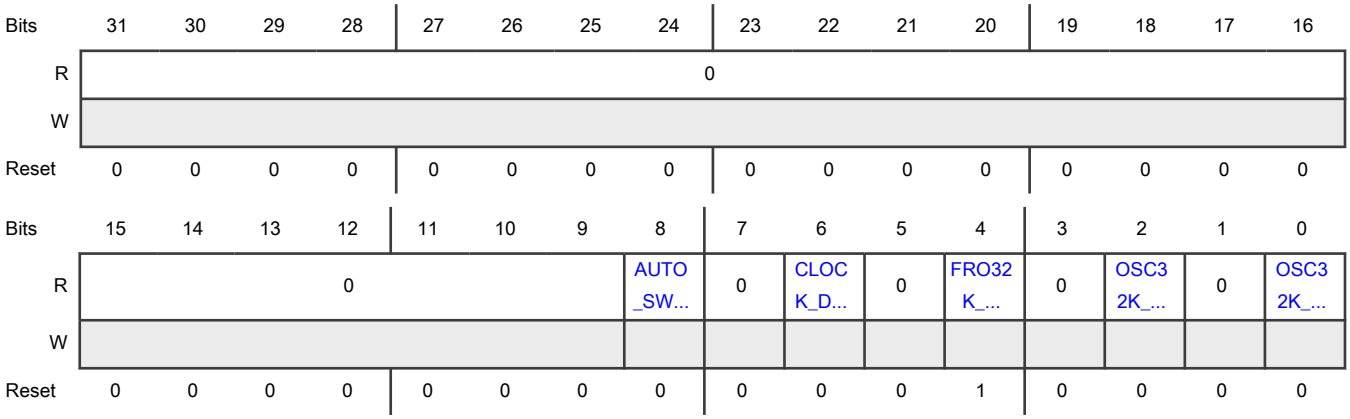
Offset

Register	Offset
STATUS	Ch

Function

This register provides status bits for the CCM32K module.

Diagram



Fields

Field	Function
31-9 —	Reserved bits. Reads only zeros.
8 AUTO_SWITCH	Clock Source Auto switch Switch back from OSC to FRO automatically if OSC is as clock source but unavailable. 0b - Clock source do not switch 1b - Clock source switch back to FRO
7 —	Reserved bits. Reads only zeros.
6 CLOCK_DET	Clock Detect The Clock monitor has detected an error. 0b - Clock error is not detected 1b - Clock error is detected
5 —	Reserved bits. Reads only zeros.
4 FRO32K_ACTIVE	32 kHz FRO active bit Indicates whether the 32 kHz free running oscillator is active and in use as the clock source or not. 0b - FRO32K is not the active clock source 1b - FRO32K is the active clock source
3	Reserved bits. Reads only zeros.

Table continues on the next page...

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Field	Function
—	
2 OSC32K_ACTIVE	32 kHz Oscillator active bit Indicates whether the 32 kHz crystal oscillator is active and in use as the clock source or not. 0b - OSC32K is not the active clock source 1b - OSC32K is the active clock source
1 —	Reserved bits. Reads only zeros.
0 OSC32K_RDY	32 kHz Oscillator ready bit. A '1' on this bit indicates that clock output from the crystal oscillator is stable. The software can decide to switch to the OSC32K clock when this bit is set. However, this bit does not clear when due to any reason the OSC32K stops providing a clock. Other on-chip tamper detection methods might indicate if clock has stopped due to removal of crystal or other reasons. This bit de-asserts during a POR event OR if the OSC32K_CTRL[OSC_EN] bit set to 0. 0b - Clock output from crystal oscillator is not stable. 1b - Clock output from crystal oscillator is stable.

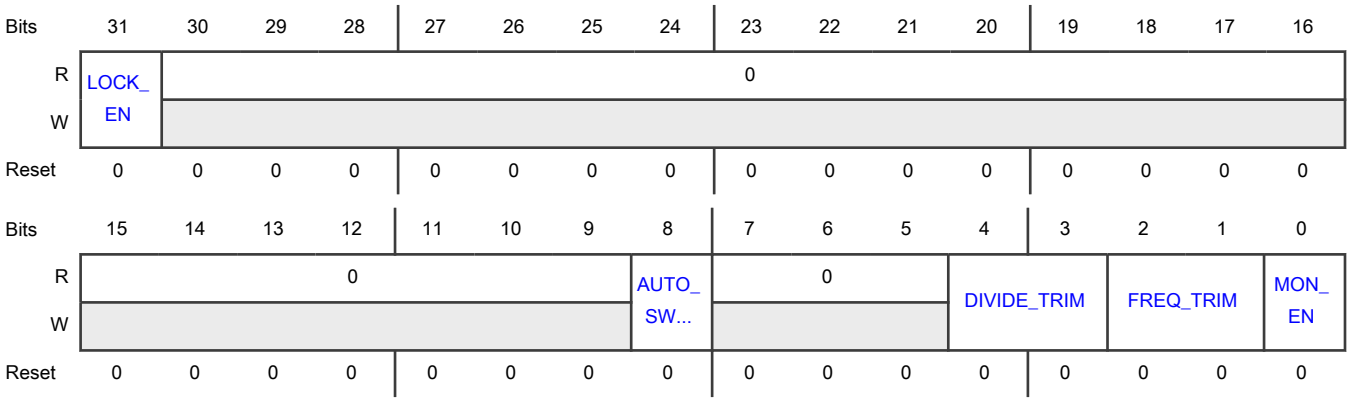
27.6.1.6 Clock Monitor Control Register (CLKMON_CTRL)

Offset

Register	Offset
CLKMON_CTRL	14h

Function
Provides control bits for clock monitor.

Diagram



Fields

Field	Function
31 LOCK_EN	Write Access Lock bit When set to '1', this bit will lock all further write accesses to this register until a POR occurs. Writing '0' after setting this bit to '1' has no effect. 0b - Register write access is unlocked 1b - Register write access is locked
30-9 —	Reserved bits. Reads only zeros.
8 AUTO_SWITCH_EN	Automatic Switch Enable Bit When OSC32K_CTRL[OSC_CLKMON_EN] and this bit set to '1', this bit will enable the automatic switch provided OSC32K is as the clock source and FRO32k is available. 0b - Automatic switch is disable 1b - Automatic switch is enable
7-5 —	Reserved bits. Reads only zeros.
4-3 DIVIDE_TRIM	Divide Trim Clock monitor divide trim 00b - Clock monitor operates at 1 kHz for both FRO32K and OSC32K 01b - Clock monitor operates at 64 Hz for FRO32K and clock monitor operates at 1 kHz for OSC32K (Reserved) 10b - Clock monitor operates at 1 kHz for FRO32K and clock monitor operates at 64 Hz for OSC32K (Reserved) 11b - Clock monitor operates at 64 Hz for both FRO32K and OSC32K
2-1 FREQ_TRIM	Frequency trim bits Clock monitor frequency trim 00b - Clock monitor asserts 2 cycle after expected edge (assert after 10 cycles with no edge) 01b - Clock monitor asserts 4 cycles after expected edge (assert after 12 cycles with no edge) 10b - Clock monitor asserts 6 cycles after expected edge (assert after 14 cycles with no edge) 11b - Clock monitor asserts 8 cycles after expected edge (assert after 16 cycles with no edge)
0 MON_EN	CLKMON Enable Enables the CLKMON when set to '1'. 0b - CLKMON is disabled 1b - CLKMON is enabled

27.6.1.7 Clock Monitor Test Register (CLKMON_TST)

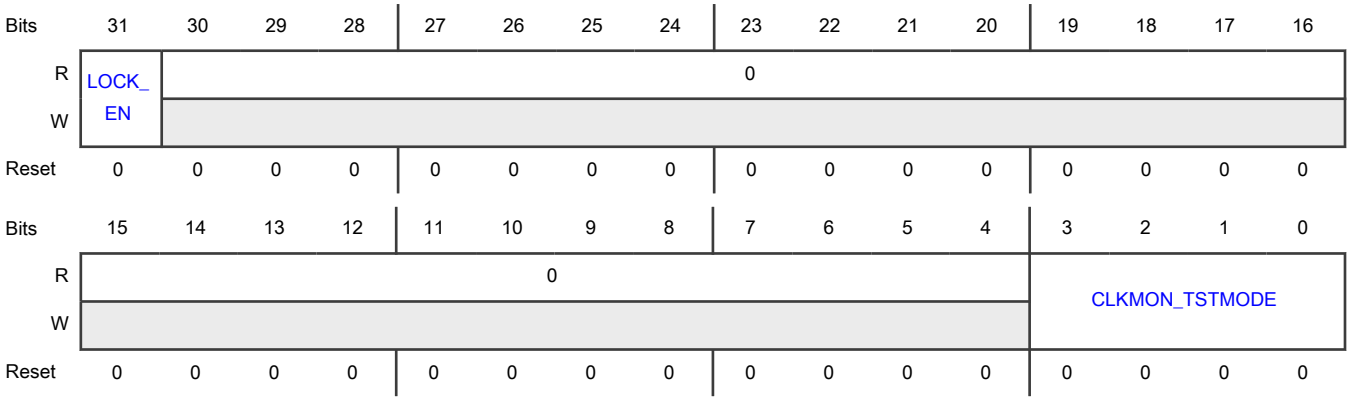
Offset

Register	Offset
CLKMON_TST	18h

Function

Provides control bits for clock monitor test.

Diagram



Fields

Field	Function
31 LOCK_EN	Write Access Lock bit When set to '1', this bit will lock all further write accesses to this register until a POR occurs. Writing '0' after setting this bit to '1' has no effect. 0b - Register write access is unlocked 1b - Register write access is locked
30-4 —	Reserved bits. Reads only zeros.
3-0 CLKMON_TSTMODE	Test Mode Configure the CLKMON test mode. Fields '0' and '1' indicate the reference clock and enable signal respectively after entering test mode. Moreover, fields '2' and '3' are for monitored clock part. When set to '0000' following '0101' after resetting CLKMON_CTRL [MON_EN], these fields can completely turn off clock monitor.

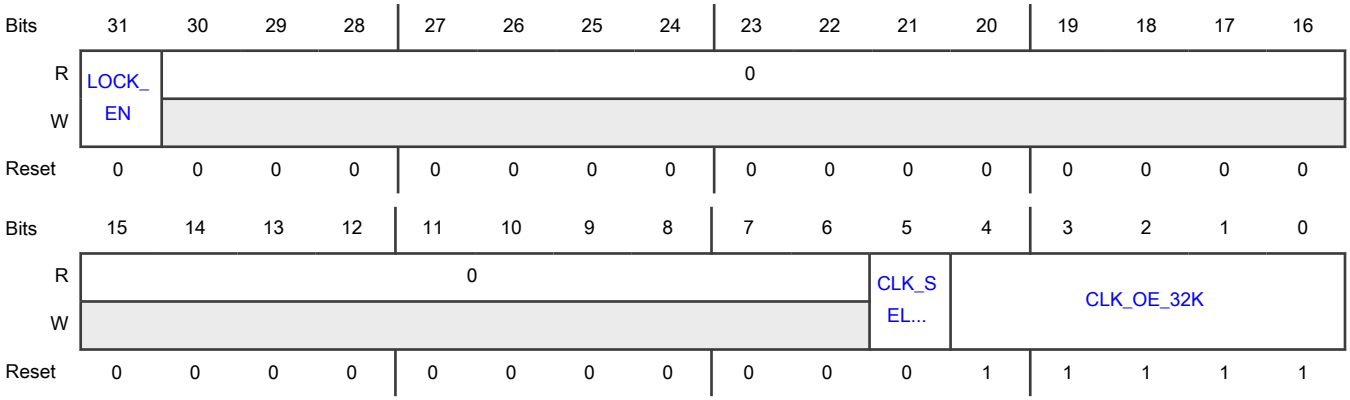
27.6.1.8 32 kHz Clock Gate Control Register (CGC32K)

Offset

Register	Offset
CGC32K	1Ch

Function
Provides 32 kHz clock output gate control bits for peripherals.

Diagram



Fields

Field	Function
31 LOCK_EN	Write Access Lock bit When set to '1', this bit will lock all further write accesses to this register until a POR occurs. Writing '0' after setting this bit to '1' has no effect. 0b - Register write access is unlocked 1b - Register write access is locked
30-6 —	Reserved bits. Reads only zeros.
5 CLK_SEL_32K	32 kHz clock source selection bit 0b - FRO32K clock output is selected as clock source 1b - OSC32K clock output is selected as clock source
4-0 CLK_OE_32K	32 kHz clock output enable bits Each bit is used by different peripherals. • CLK_OE_32K [0]: RTC/Dryice

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Field	Function
	• CLK_OE_32K [1]: RFMC • CLK_OE_32K [2]: NBU • CLK_OE_32K [3]: WUU/RMC/PORTD • CLK_OE_32K [4]: Other modules 0_0000b - Clock output is disabled 0_0001b - Clock output is enabled

27.6.1.9 32 kHz OSC Internal Monitor Trim Register (OSC32K_MON_TRIM)

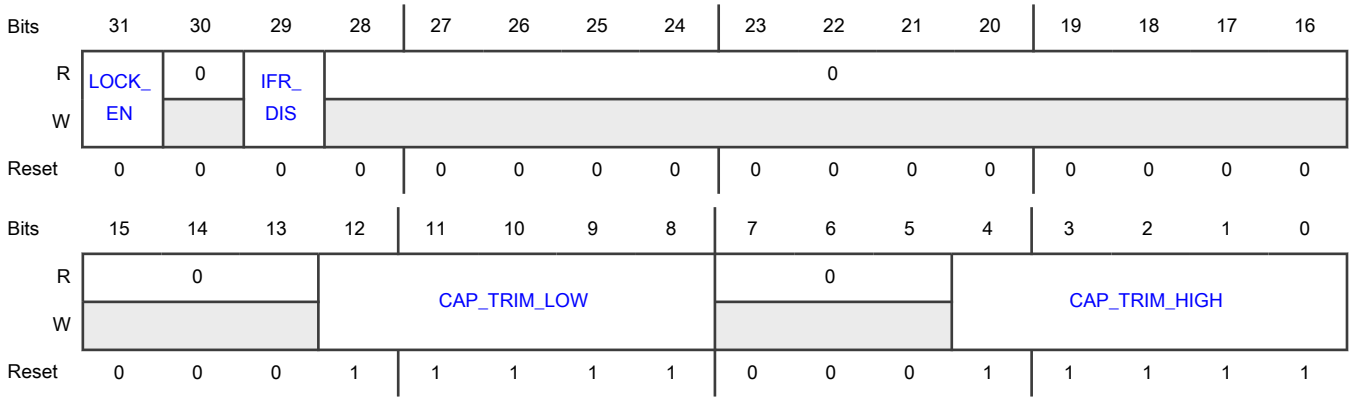
Offset

Register	Offset
OSC32K_MON_TRIM	24h

Function

The 32 kHz OSC Internal Monitor Trim Register (OSC32K_MON_TRIM) provides capacitance trim configuration for the 32 kHz OSC internal monitor.

Diagram



Fields

Field	Function
31 LOCK_EN	Write Access Lock When set to '1', this field locks all further write accesses to this register until a POR occurs. Writing '0' after setting this field to '1' has no effect. 0b - Register write access is unlocked

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Register write access is locked
30 —	Reserved
29 IFR_DIS	IFR Loading Disable Control This field controls whether the CAP_TRIM_HIGH and CAP_TRIM_LOW field gets overwritten when IFR value gets loaded in the SoC. Setting this field to '1' blocks the CAP_TRIM_HIGH and CAP_TRIM_LOW field from being loaded again. If LOCK_EN bit is set to '1', this field is ignored and no IFR values get loaded. 0b - IFR loading is enabled 1b - IFR loading is disabled
28-13 —	Reserved
12-8 CAP_TRIM_LOW	OSC32K Internal Monitor Capacitance Trim for Clock Low Level These field controls the detection of clock low level. The larger trim value indicates to the greater threshold of the clock low level period. This field is set from the IFR (Flash) but can be overridden by software. This field can be changed only when the OSC32K_CTRL[OSC_EN] field is '0'. The IFR_DIS and LOCK_EN fields control how this field gets loaded. If IFR_DIS is '1', this field will not be loaded with IFR value. If LOCK_EN bit is '1', this field will be locked for both IFR load and software writes. 1_1111b - Default trim value
7-5 —	Reserved
4-0 CAP_TRIM_HIGH	OSC32K Internal Monitor Capacitance Trim for Clock High Level Refer to CAP_TRIM_LOW. 1_1111b - Default trim value

Chapter 28
Power Management

28.1 Introduction

This chapter describes the power modes supported with this device. It also describes the power domains and the voltage supply options connected to these power domains.

NOTE

Refer to Radio low power mode for power management of radio sub-system.

28.2 Power domains

A power domain is a collection of circuits that can be powered off even when a voltage source is still supplied. This section shows the power domains within the device and the modules belong to these domains.

NOTE

If a module belongs to several power domains, the module will be powered off when any of the power domain is powered off.

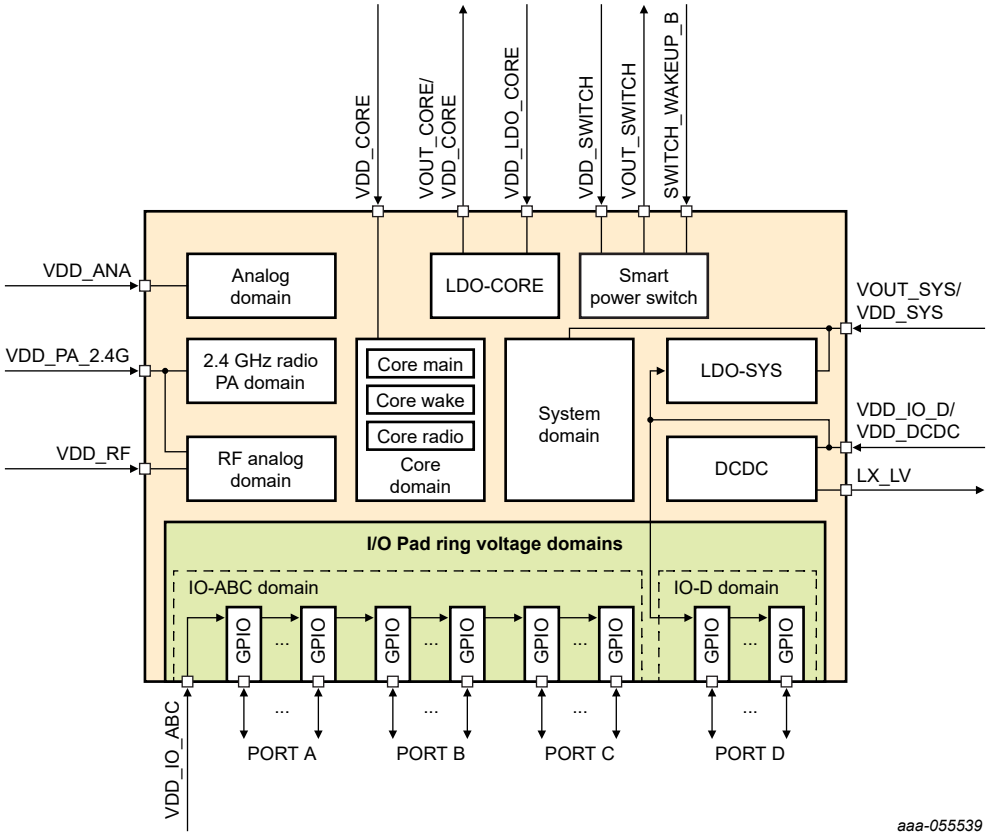


Figure 77. Power domains and voltage supplies

Table 223. Peripheral power domain assignments

Power domain	Voltage supply	Module
Analog Domain	VDD_ANA VSS_ANA	ADC0
		VREF0
Core Main [1]	VDD_CORE_MAIN	CM33
		DSP
		FPU
		MPU
		NVIC
		SYSTICK
		TZM
		DAP
		DWT
		ITM
		TPIU
		AXBS0
		eDMA0
		MSCM
		SMSCM
		PBRIDGE2
		TRGMUX
		MRCC
		SFA0
		CACHE-CODE
		FLASH
		ROM-BOOT
		CRC0
		EdgeLock Secure Enclave
		TRDC0
		LPIT0
		TPM1
		TPM2
		FlexIO0
		LPI2C 1

Table continues on the next page...

Table 223. Peripheral power domain assignments (continued)

Power domain	Voltage supply	Module
		I3C0
		LPSPI 1
		LPUART 1
		GPIOB/C
		SEMA42
		PORTB/C
		ADC0
		VREF0
		TCM-SYS
CORE Wake [3,2]	VDD_CORE_WAKE	SWD
		CMC0
		EWM0
		WDOG0/1
		WRCC
		SCG0
		TPM0
		LPI2C0
		LPSPI0
		LPUART0
		GPIOA
		PORTA
		LPCMP0, LPCMP1
Core Radio [4,2]	VDD_CORE_2.4G	RF-2.4G
		NBU
		RF-FMU
		RF-FRO192M
IO-ABC	VDD_IO_ABC	PORTA
		PORTB
		PORTC
		LPCMP0, LPCMP1
IO-D	VDD_IO_D	LDO-SYS
		PORTD

Table continues on the next page...

Table 223. Peripheral power domain assignments (continued)

Power domain	Voltage supply	Module
Smart Power Switch	VDD_SWITCH	Power switch
		RAM LDO
		FRO16K
		Power Switch Controller
System	VDD_SYSmorerows="38"	RFMC0
		Bluetooth LE LL(from NBU)
		WUU0
		FRO192M
		LPTMR0, LPTMR1
		SPC0
		OSC-RTC
		FRO32K
		REGFILE0/1 -RTC
		TAMPER
		RTC0
		GPIOD
		PORTD
RF Analog	VDD_RF	OSC-RF
		RF-2.4G
2.4GHz Radio PA	VPA_2P4GHZ	RF-PA-2.4G

1. Core main is a subdomain from the core domain.
2. These subdomains belong to the core domain. These subdomain includes optional voltage scaling options associated the voltage supply of each domain for deep sleep and power down modes. See system power control chapter for more information. Core domain is supplied by VDD_CORE voltage supply in the chip package.
3. Core wake is a subdomain from the core domain.
4. Core radio is a subdomain from the core domain.

NOTE

VDD_CORE_MAIN, VDD_CORE_WAKE and VDD_CORE_2.4G are connected to the VDD_CORE voltage supply in the chip package with optional voltage scaling options in deep sleep and power down modes.

28.3 Power modes

The device supports Active, Sleep, Deep Sleep, Power Down, and Deep Power Down modes. Any reset brings the chip back to the Active mode.

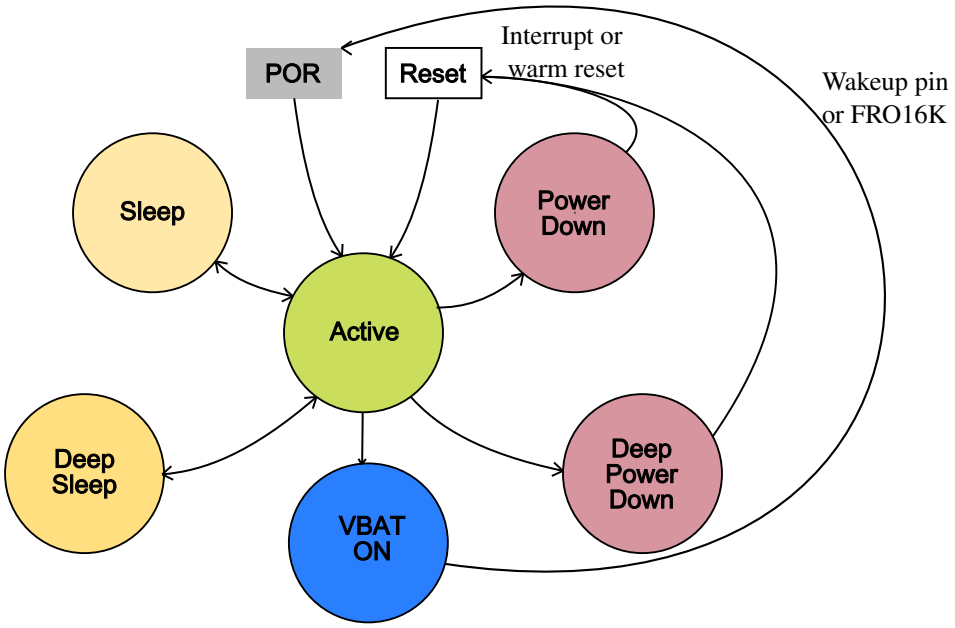


Figure 78. Power modes

28.3.1 Active mode

In Active mode, CPU execution is possible.

To achieve the performance requirements of a given system application while minimizing power consumption, Active mode permits the following power-saving options when possible:

- Configure the VDD_CORE subdomains voltage level to balance power and performance.
- Individually configure SRAM as active/shutdown by software.
- Gate the clocks to unused modules.
- Configure the unused VDD_CORE subdomains to state retention mode.
- Power-gate the unused VDD_CORE subdomains.

28.3.2 Sleep mode

In Sleep mode, CPU execution is halted. The core clock is gated off. The system clock as well as the bus clocks, if enabled, continue to operate.

Sleep mode supports the following behaviors based on different clock configurations:

- CPU clock is OFF. The system clock and bus clock remain ON. Most modules can remain operational.
- CPU clock, system clock and bus clock are all OFF. Some modules can remain operational with low power asynchronous clock sources and serve as wake-up sources.

Wake from Sleep mode is triggered by an interrupt or a wakeup event.

Sleep mode also supports a partial wake-up where a bus master other than the CPU (eg. DMA) is recovered by a wakeup event. The device automatically re-enters sleep mode after this module finishes its task.

To achieve the performance requirements of a given system application while minimizing power consumption, Sleep mode permits the following power-saving options when possible:

- Configure the VDD_CORE subdomains voltage level to balance power and performance.

- Individually configure SRAM as active / deep sleep / shutdown by software.
- Gate the clocks to unused modules.
- Configure the unused VDD_CORE subdomains to state retention mode.
- Power-gate the unused VDD_CORE subdomains.

28.3.3 Deep Sleep mode

Deep Sleep mode places most of the chip into a static state. It is the lowest power mode that can retain all registers.

The device wakes from Deep Sleep mode through the interrupt routine or wake-up event.

The core clock, system clock and the bus clock are gated off.

In Deep Sleep mode, the whole VDD_CORE_MAIN subdomain is put into state retention mode.

In Deep Sleep mode, the peripherals inside the VDD_CORE_WAKE subdomain can remain operational using an asynchronous clock and can wake the device.

Refer to Low Power Mode Controllers for peripherals in the VDD_CORE_2.4G.

External signals via GPIO or VDD_SYS domain peripherals can wake the device.

Subdomains can choose VDD_CORE or IVS scaled voltage to match the required performance or leakage.

SRAM can also be individually configured as deep sleep or shutdown by software.

28.3.4 Power Down mode

Power Down mode places the chip in power off state.

The device wakes from Power Down mode through the reset routine.

In Power Down mode, the whole VDD_CORE_MAIN subdomain is power gated.

In Power Down mode, the peripherals inside the VDD_CORE_WAKE subdomain can optionally remain operational using an asynchronous clock and can wake the device.

Refer to Low Power Mode Controllers for peripherals in the VDD_CORE_2.4G.

External signals via GPIO, VDD_SYS domain peripherals, or the RTC power domain peripherals can wake the device.

SRAM can also be individually configured as retention or off by software.

28.3.5 Vbat on

For VBAT ON, refer to Smart power switch.

28.3.6 Deep Power Down mode

Deep Power Down mode permits the lowest power level.

The device wakes from Deep Power Down mode through the Reset routine.

In Deep Power Down mode, the whole VDD_CORE domain (including all subdomains) is power gated.

In Deep Power Down mode, the on-chip regulator for VDD_CORE is powered off. The VDD_SYS on-chip regulator is powered on , and the VDD_SYS power domain is enabled. The external power supply to any of the on-chip regulators that are disabled should be turned off to avoid extra leakage.

External reset or the VDD_SYS domain peripherals can wake the device.

SRAMs without RAM LDO supplied cannot be retained in Deep Power Down mode.

28.4 Module operation in low power modes

The following table shows module functionality in low power modes.

Table 224. Cortex M33 core module operation in low power modes

Module	Sleep	Deep Sleep	Power Down	Deep Power Down
Core modules				
Cortex M33	Static	Static	OFF	OFF
NVIC	Optional	Static	OFF	OFF
WIC	ON	Static	OFF	OFF
Cache	Static	Static	OFF	OFF
MU (LCE)	Optional	Static	OFF	OFF
MU	Optional	Static	OFF	OFF
MCM	Static	Static	OFF	OFF
System modules				
AXBSx	Optional	Static	OFF	OFF
DMAx	Optional	Static	OFF	OFF
WDOGx	ON	Optional	Optional	OFF
EWM	Optional	Static	Static	OFF
TRDCx	ON	Static	OFF	OFF
CMCx	ON	Optional	Optional	OFF
SPCx	ON	ON	ON	ON
WUUx	ON	ON	ON	ON
SFA0	Optional	Static	OFF	OFF
TRIGMUX	ON	Static	OFF	OFF
Clock modules				
FRO-192M	Optional	Static[1]	OFF	OFF
FRO-32K	ON	ON	Optional	Optional
OSC-RTC	ON	ON	Optional	Optional
OSC-RF	ON	Optional	Optional	OFF
SCGx	ON	Static	Static	OFF
MRCC	ON	Static	OFF	OFF
Memory modules				
Flash[2]	Optional LP	LP	OFF	OFF
SRAM	Optional	Optional	Optional	OFF
RTC Reg File	ON	ON	ON	ON

Table continues on the next page...

Table 224. Cortex M33 core module operation in low power modes (continued)

Module	Sleep	Deep Sleep	Power Down	Deep Power Down
ROM	ON	OFF	OFF	OFF
Security modules				
EdgeLock Secure Enclave	ON	Static	OFF	OFF
PRINCE	ON	Static	OFF/Retained	OFF/Retained
Digital Tamper	ON	ON	ON	ON
CRCx	ON	Static	OFF	OFF
ELEMU	ON	Static	OFF	OFF
Timer modules				
TPM0	ON	Optional	Optional	OFF
TPM1	ON	Static	OFF	OFF
LPITx	ON	Static	OFF	OFF
LPTMRx	ON	ON	ON	ON
RTC	ON	ON	ON	ON
Communication modules				
LPUART0	ON	Optional	Optional	OFF
LPUART1	ON	Static	OFF	OFF
SEMA(or SEMA42)	ON	Static	OFF	OFF
LPSPI0	ON	Optional	Optional	OFF
LPSPI1	ON	Static	OFF	OFF
LPI2C0	ON	Optional	Optional	OFF
LPI2C1	ON	Static	OFF	OFF
I3C0	ON	Static	OFF	OFF
CAN1	ON	Static	OFF	OFF
Human interface modules				
GPIOA	ON	Optional	Optional	Static
GPIOB/C	ON	Static	Static	Static
GPIOD	ON	ON	ON	ON
Analog modules				
ADC-GPx	Optional	Static	OFF	OFF
CMP-GPx	Optional	Optional	Optional	Optional
VREF	Optional	Static	Static	OFF
Radio modules				

Table continues on the next page...

Table 224. Cortex M33 core module operation in low power modes (continued)

Module	Sleep	Deep Sleep	Power Down	Deep Power Down
RF-2.4G[3]	Optional	Optional	Optional	Optional

1. Internally powered down
2. Contents are always retained as this is NVM.
3. See more details about 2.4 GHz radio modules in Low Power Mode Controllers.

Table 225. Power domain module operation in low power modes

Module	Sleep	Deep Sleep	Power Down	Deep Power Down
POWER Modules				
LDO-CORE	Optional LP	ON, LP or OFF	ON, LP or OFF	OFF
LDO-SYS	Optional LP	ON, LP	ON, LP	ON, LP
DCDC	Optional LP	ON, LP or OFF	ON, LP or OFF	OFF
POR	ON	ON	ON	ON
VDD_CORE HVD / LVD	Optional	Optional	Optional	OFF
VDD_IO_ABC HVD / LVD	Optional	Optional	Optional	OFF
VDD_SYS HVD / LVD	Optional	Optional	Optional	Optional

Table 226. Power domain operation in low power modes

Domain	Active	Sleep	Deep Sleep	Power Down	Deep Power Down
VDD_CORE_MAIN	ACT	ACT	RET	OFF	OFF
VDD_CORE_WAKE	ACT	ACT	ACT/RET	ACT/RET/OFF	OFF
VDD_CORE_SRAM [1]	ACT/RET/OFF	ACT/RET/OFF	RET/OFF	RET/OFF	OFF
VDD_CORE_2P4G	ACT/RET/OFF	ACT/RET/OFF	ACT/RET/OFF	ACT/RET/OFF	OFF
VDD_CORE_2P4G_SRAM [2]	ACT/RET/OFF	ACT/RET/OFF	ACT/RET/OFF	ACT/RET/OFF	OFF
VDD_SYS	ACT	ACT	ACT	ACT	ACT

1. System SRAM is partitioned and each part is individually configurable by CMC.
2. Radio SRAM is partitioned into Tx/Rx RAM and each part is individually configurable by Radio.

Since VDD_CORE_MAIN, VDD_CORE_WAKE and VDD_CORE_2P4G are independent power domain, there are various low-power mode combinations among them. The SPC will do the arbitration on their low-power requests and select the highest low-power mode as system power mode.

From system point of view, it has several scenarios:

1. MCU in low-power mode, Radio switch between run and low-power mode (typical case for Bluetooth LE event without CPU involved)
2. Radio wakeup MCU to deal with connectivity upper layer software like Bluetooth LE Host or applications
3. MCU switch between run and low-power mode for general application, Radio in low-power mode (Radio is not enabled)

28.5 Power supply configurations

This section shows some of the most common power supply configurations.

28.5.1 Recommended configuration for tradeoff between cost and power efficiency

The following figure shows a power efficient configuration of the device power supplies.

In this configuration:

- External 3.3 V for DCDC, VDD_IO_D, VDD_IO_ABC, LDO-SYS
- LDO-CORE, VDD_RF come from DCDC output
- Generate VPA_2P4GHZ internally from VDD_RF

NOTE

VPA_2P4GHZ voltage depends on Tx power level. It can be powered internally or externally. When internal supply is used, VDD_RF voltage must be equal to or exceed VPA + 275 mV.

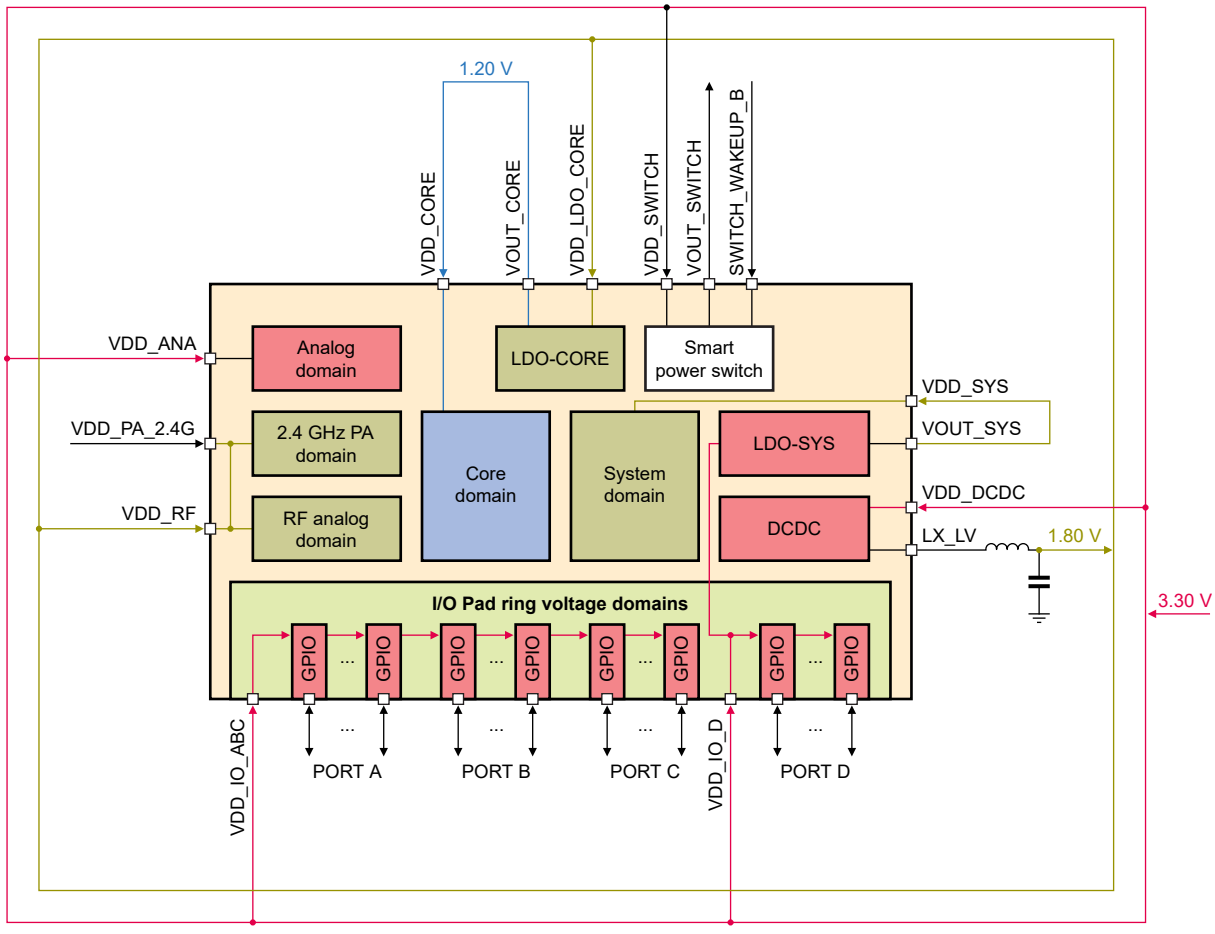


Figure 79. Power efficient schematic

28.5.2 Low cost supply configuration

The following figure shows a low cost configuration of the device power supplies.

In this configuration:

- Bypass DCDC
- External 3.3 V (range: 1.71 – 3.6 V) for LDO-CORE, LDO-SYS, VDD_IO_D, VDD_IO_ABC and VDD_RF
- Generate VPA_2PGHZ internally from VDD_RF

NOTE

VPA_2P4GHZ voltage depends on Tx power level. It can be powered internally or externally. When internal supply is used, VDD_RF voltage must be equal to or exceed VPA + 275 mV.

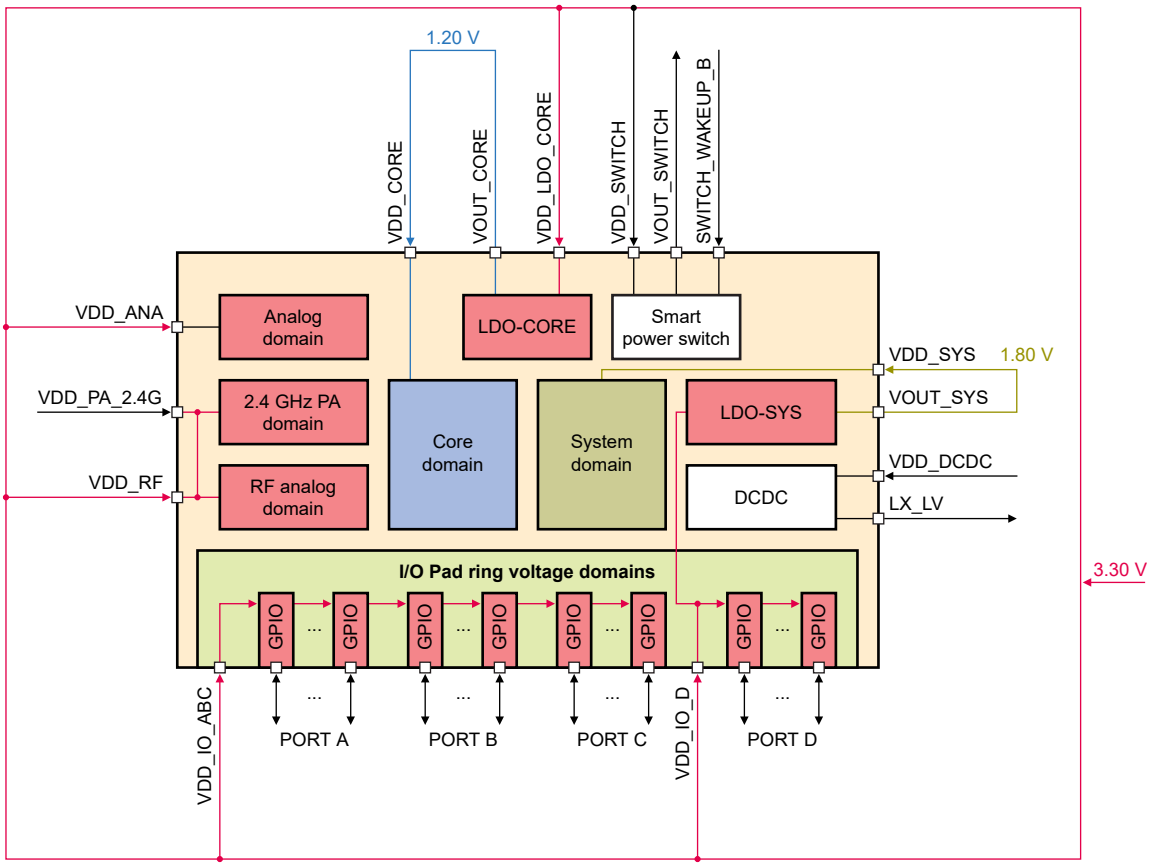


Figure 80. Low cost schematic

28.6 Power optimization

28.6.1 VDD_CORE voltage scaling

This device supports VDD_CORE voltage scaling for different performance and power consumption.

This device supports the following VDD_CORE voltage scaling methods:

- By adjusting VDD_CORE power supply input level directly with internal IVS disabled. This method is available for all power modes. The user must configure VDD_CORE voltage level through SPC registers when VDD_CORE is supplied by on-chip regulators (LDO-CORE). The device power consumption can benefit from the regulator high efficiency when DCDC is used as VDD_CORE source. However, the VDD_CORE voltage needs time to reach new levels for charging or discharging the VDD_CORE pin capacitor.

- By internal IVS (internal voltage scaling) module. This method will apply only to Deep Sleep and Power Down modes. The user should configure the target IVS output voltage level before entering low power modes. The VDD_CORE input voltage will remain unchanged. The IVS manipulates the internal supply voltage directly. The voltage will reach the new target value much faster.

Subdomains can choose VDD_CORE or IVS scaled voltage to match the required performance or leakage.

28.6.2 SRAM Configuration

The SRAM is partitioned, allowing the mode of each SRAM partition to be independently configured:

SRAM power mode	Description
Active	SRAM can be accessed normally.
Deep Sleep	SRAM cannot be accessed, but the data is retained.
Shutdown	SRAM cannot be accessed, and the data is not retained.

Depending on the requirements of the system application, software can optionally configure an individual SRAM partition to be in a lower, power-saving mode relative to the overall device power mode:

When the overall device power mode is...	An SRAM partition may be configured into this mode...
Active	Active or Shutdown
Sleep	Active or Deep Sleep or Shutdown
Deep Sleep or Power Down	Deep Sleep or Shutdown

NOTE

All SRAM partitions are forced into Shutdown mode after the device enters Deep Power Down mode.

28.6.3 Flash low power options

To balance power usage versus performance requirements, the flash module can be configured independent of the overall device power mode:

Flash power mode	Description
Full power	Supports full speed read, program and erase.
Low speed active	Supports reduced frequency read, program, and erase.

The flash module supports low-power feature by configuring CMC_FLASHCR registers. It can configure Flash in low-power mode when MCU is in Active mode or CM33 CORE is sleeping. In parallel, it provide option to automatic wakeup Flash from low-power mode when any flash access.

NOTE

To avoid unexpected access latencies, take care when configuring the flash module to a low power mode when the overall device is in Active mode. The flash module needs time to recover full-speed functionality after entering a low power mode.

28.6.4 Peripheral clock gating

To conserve power, the clocks to modules can be turned off or divided by configuring the MRCC module registers.

28.6.5 Voltage monitor optimization

Depending on the requirements of the system application, software can disable individual voltage monitors (LVD and/or HVD) within the different power domains to save power.

28.6.6 Wake-up time consideration

This device supports different low power modes for power consumption level and wake-up time balance.

The wake-up time from Sleep/Deep Sleep mode is the accumulation of following time:

- VDD_CORE power source recovery time
- The longer of the following:
  - Clock recovery time
  - Flash recovery time
- Interrupt Latency

The wake-up time from Power Down mode is the accumulation of following time:

- VDD_CORE power source recovery time
- The longer of the following:
  - Clock recovery time
  - Flash recovery time
- System Reset Latency

The wake-up time from Deep Power Down mode is:

- The boot-up time required after device released by POR. This includes everything included in a cold power-up, including the Boot ROM latency.

The clock recovery time can be affected by following factors:

- The system clock source status in low power modes. There will be no recovery time needed if the clock remains ON in low power mode.
- The system clock source before entering low power mode.

The flash recovery time depends on the flash status in low power mode.

The VDD_CORE power source recovery time can be affected by following factors:

- The regulator type used. On-chip linear regulator starts up faster than on-chip DCDC.
- The regulator status in low power modes. There will be no recovery time needed if the regulator remains in full-power regulation in low power mode.
- Whether VDD_CORE voltage scaling is enabled before and after entering low power modes
- The VDD_CORE domain voltage scaling method used. Voltage scaling by internal IVS recovers faster.
- The external capacitor on VDD_CORE pin will affect recovery time if scaling is achieved by adjusting VDD_CORE voltage directly.

28.7 Smart power switch

The smart power switch supports two major use-cases:

- It can be used to switch off all or part of MCU power supply to get lower power consumption than deep power down mode. See Figure 81 as an example.

- It can be used to power external device. For example, sensor device will be power off most of time and can keep power when measurement. Figure 79 is the example with the VOUT_SWITCH powering an external sensor, and Figure 82 is another example to power an external sensor and an I/O rail.

It has several ways to turn on power switch

- The POR of power switch input supply
- external SWITCH_WAKEUP_B pin. Once driven low, it can turn on power switch;
- internal wakeup logic from SPC if VSYS is powered ON;
- internal timer using internal FRO16K

NOTE

To support standby RAM LDO and RAM power switch, smart power switch input supply (VDD_SWITCH) is required to be powered permanently.

In Figure 81:

- External 3.3 V supply to Smart Power Switch
- Power switch output connected to DCDC, LDO-SYS, VDD_ANA, VDD_IO_D and VDD_IO_ABC
- DCDC output connected to LDO-CORE, VDD_RF

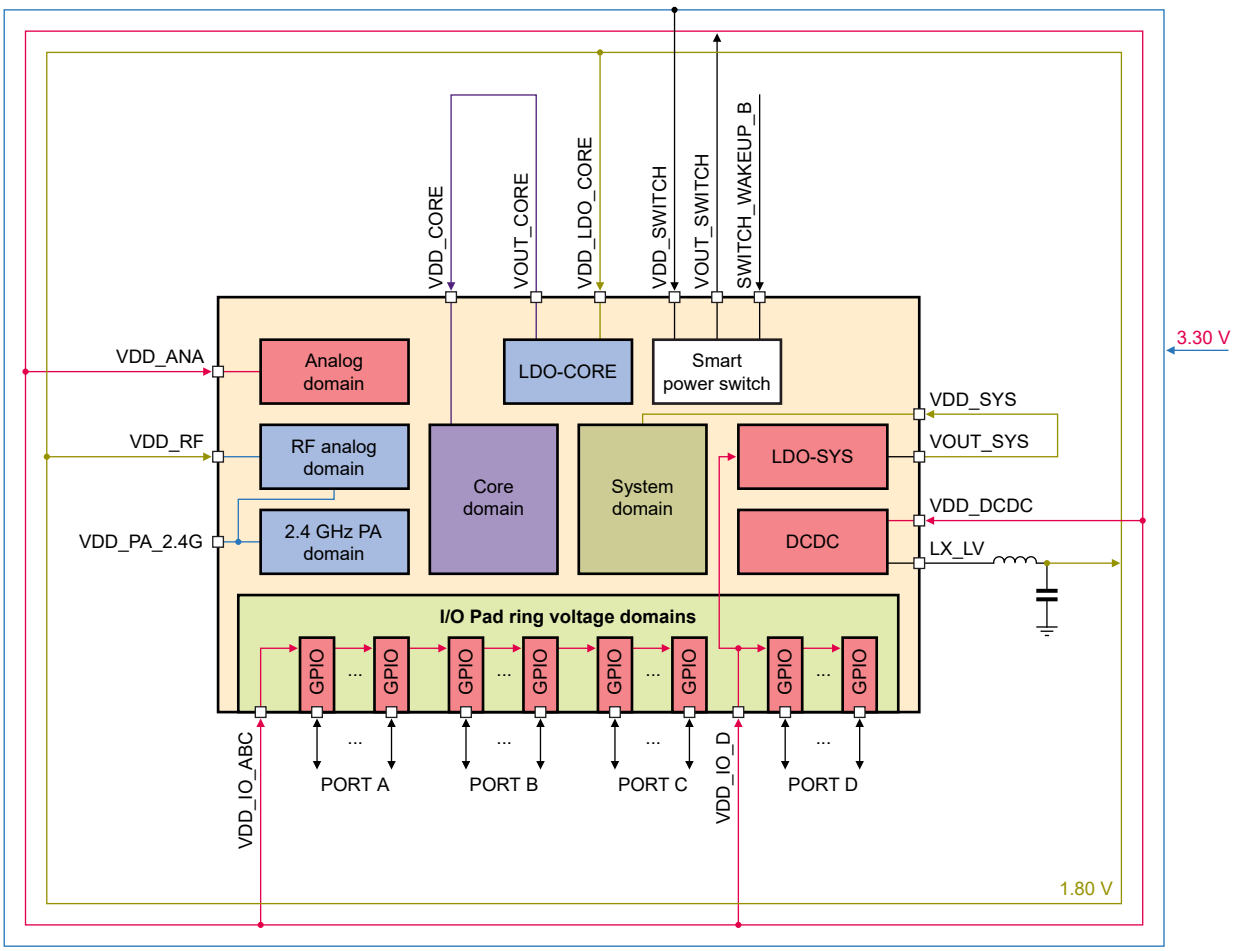


Figure 81. Power all supply

In Figure 82:

- External 3.3 V supply to Smart Power Switch and VDD_DCDC/VDD_IO_D
- Power switch output connected to VDD_ANA and VDD_IO_ABC
- DCDC output connected to LDO-CORE, VDD_RF

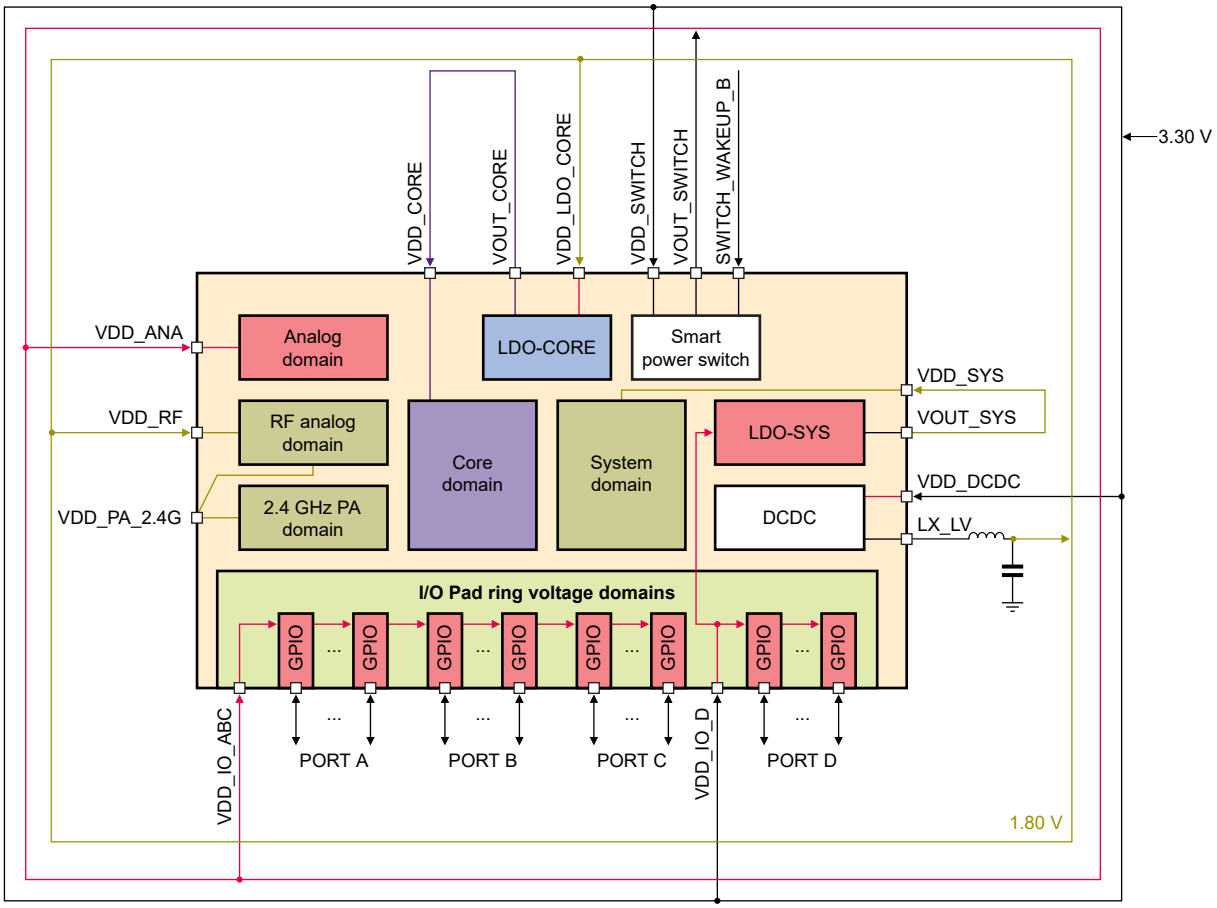


Figure 82. Power all supply except VDD_IO_D/VDD_DCDC

Figure 82 has a higher current drain relative to the scheme in Figure 81 because both VDD_IO_D and VDD_DCDC are on. However, the value of GPIO_D can be retained when the power switch is off.

Chapter 29
Core Mode Controller (CMC)

29.1 Chip-specific CMC information

Table 227. Reference links to related information

Topic	Related module	Reference
Full description	CMC	CMC
System memory map		System memory map
Power Management		Power Management
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

29.1.1 Module instances

This device has one instance of the CMC module, CMC0.

29.1.2 TCM arrays

Table 228. TCM SRAM assignment -264KB

TCM	SRAM instance	AXBS port	Size	Base Address	SRAM Control	ECC
Code TCM	CTCM0[1]	S1	16 KB	0x0400_0000	CMC_SRAM[0]	Yes
	CTCM1[1]	S1	16 KB	0x0400_4000	CMC_SRAM[1]	No
System TCM	STCM0[1]	S2	16 KB	0x2000_0000	CMC_SRAM[2]	Yes
	STCM1[1]	S2	16 KB	0x2000_4000	CMC_SRAM[3]	Yes
	STCM2[1]	S2	32 KB	0x2000_8000	CMC_SRAM[4]	Yes
	STCM3[1]	S2	32 KB	0x2001_0000	CMC_SRAM[5]	No
	STCM4[1]	S2	32 KB	0x2001_8000	CMC_SRAM[6]	No
	STCM5[2]	S3	32 KB	0x2002_0000 (LCE SRAM)	CMC_SRAM[7]	No
	STCM6	S3	32 KB	0x2002_8000 (LCE SRAM)	CMC_SRAM[8]	No
	STCM7	S3	32 KB	0x2003_0000 (LCE SRAM)	CMC_SRAM[9]	No
	STCM8	S4	8 KB	0x2003_8000 (VBAT retention SRAM)	VBAT	Yes

1. If the corresponding SRAMSDR0[SDE] bit is set, any access to the TCM will trig bus fault.
2. If VBAT_LDORAMC[ISO] bit is set and ECC is enabled, any access to the STCM8 will trig ECC fault.

Table 229. TCM SRAM assignment - 200KB Phantom

TCM	SRAM instance	AXBS port	Size	Base Address	SRAM Control	ECC
Code TCM	CTCM0[1]	S1	16 KB	0x0400_0000	CMC_SRAM[0]	Yes
	CTCM1[1]	S1	16 KB	0x0400_4000	CMC_SRAM[1]	No
System TCM	STCM0[1]	S2	16 KB	0x2000_0000	CMC_SRAM[2]	Yes
	STCM1[1]	S2	16 KB	0x2000_4000	CMC_SRAM[3]	Yes
	STCM2[1]	S2	32 KB	0x2000_8000	CMC_SRAM[4]	Yes
	STCM3[1]	S2	32 KB	0x2001_0000	CMC_SRAM[5]	No
	STCM4[1]	S2	32 KB	0x2001_8000	CMC_SRAM[6]	No
	STCM5[2]	S3	32 KB	0x2002_0000 (LCE SRAM)	CMC_SRAM[7]	No
	STCM8	S4	8 KB	0x2003_8000 (VBAT retention SRAM)	VBAT	Yes

1. If the corresponding SRAMSDR0[SDE] bit is set, any access to the TCM will trig bus fault.
2. If VBAT_LDORAMC[ISO] bit is set and ECC is enabled, any access to the STCM8 will trig ECC fault.

Table 230. TCM SRAM assignment - 136 KB Phantom

TCM	SRAM instance	AXBS port	Size	Base Address	SRAM Control	ECC
Code TCM	CTCM0 [1]	S1	16 KB	0x0400_0000	CMC_SRAM[0]	Yes
	CTCM1[1]	S1	16 KB	0x0400_4000	CMC_SRAM[1]	No
System TCM	STCM0 [1]	S2	16 KB	0x2000_0000	CMC_SRAM[2]	Yes
	STCM1 [1]	S2	16 KB	0x2000_4000	CMC_SRAM[3]	Yes
	STCM2 [1]	S2	32 KB	0x2000_8000	CMC_SRAM[4]	Yes
	STCM3 [1]	S2	32 KB	0x2001_0000	CMC_SRAM[5]	No
	STCM8	S4	8 KB	0x2003_8000 (VBAT retention SRAM)	VBAT	Yes

1. If the corresponding SRAMSDR0[SDE] bit is set, any access to the TCM will trig bus fault.

29.1.3 DIER[STAT]

This devices supports the following bit field values.

Table 231. DIER[STAT] Fields

Field	Field name
31-24	Reserved
23	Radio flash TRIM7 error
22	Radio flash TRIM6 error
21	Radio flash TRIM5 error
20	Radio flash TRIM4 error
19	Radio flash TRIM3 error
18	Radio flash TRIM2 error
17	Radio flash TRIM1 error
16	Radio flash TRIM0 error
15	Main flash TRIM7 error
14	Main flash TRIM6 error
13	Main flash TRIM5 error
12	Main flash TRIM4 error
11	Main flash TRIM3 error
10	Main flash TRIM2 error
9	Main flash TRIM1 error
8	Main flash TRIM0 error
7-2	Reserved
1	Radio flash IFR load dsable
0	Main flash IFR load disable

29.2 Overview

CMC provides the sequencing of the CPU and associated logic through the different operating modes.

This chapter describes the available CPU operating modes, including reset, active mode, and low-power modes.

29.2.1 Block diagram

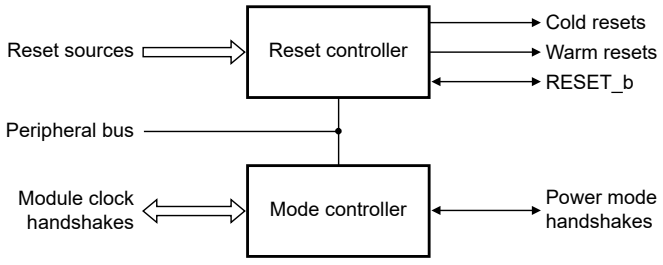


Figure 83. Block diagram

29.2.2 Features

- Configures the low-power mode options
- Provides reset controller including reset status register and warm reset configuration
- Provides boot mode register and status bits

29.3 Functional description

This section provides the functional description of the block.

29.3.1 Modes of operation

The Arm Cortex-M CPU enters a low-power mode with the execution of a WFI or WFE instruction or via the SLEEPONEXIT mechanism. CMC configures the low-power mode that is entered.

The following table describes the low-power modes available to each core.

Table 232. Operating modes

Mode	Entry	Exit	Description
Reset	POR Warm reset WUU via Power-Down	Active	Core and peripherals are reset. SRAM optionally retained on power-down wake-up.
Active	Reset NVIC WUU	WFI WFE SLEEPONEXIT	Core executing instructions, peripherals optionally active.
Sleep	WFI WFE SLEEPONEXIT	NVIC Reset	Core waiting for interrupt or event, peripherals optionally active. Core and peripherals retain state, SRAM optionally retained.
Deep Sleep	WFI WFE SLEEPONEXIT	WUU via Active Reset	Core and peripherals waiting for wake-up. Core and peripherals retain state, SRAM optionally retained.
Power-Down	WFI WFE SLEEPONEXIT	WUU via Reset Reset	Core and peripherals not retained, SRAM optionally retained.
Deep-Power Down	WFI WFE SLEEPONEXIT	WUU via Reset Reset	Core, peripherals, and SRAM not retained.

29.3.2 Active mode

This section describes power options in Active mode.

29.3.2.1 Flash memory

This section describes the Flash Memory Low-Power mode.

You can place the internal flash memory in Low-Power mode under the following conditions:

- Under software control (FLASHCR[FLASHDIS])
- When CPU is sleeping (FLASHCR[FLASHDOZE])
- When the chip enters a low-power mode

When FLASHCR[FLASHDIS] or FLASHCR[FLASHDOZE] becomes 1, you can configure the internal flash memory to automatically exit Low-Power mode during the access on any attempted read access to flash memory space (but not flash peripheral space). FLASHCR[FLASHWAKE] controls this.

When the internal flash memory enters a low-power mode, the wake-up time of the flash memory automatically delays the first access upon exit from Low-Power mode. If there is no access between the internal flash memory exiting Low-Power and subsequent re-entry of Low-Power mode, the wake-up time of the flash memory delays the re-entry.

29.3.2.2 System SRAM

The system SRAM is divided into 11 different power partitions. You can individually power gate these partitions either all the time or only in low-power modes. System SRAM contents in a power gated partition are not retained. You must not access system SRAM partitions when they are power gated.

- Write 1 to SRAMDIS[*i*] to always power gate system SRAM power partition "i".
- Write 1 to SRAMRET[*i*] to power gate system SRAM power partition "i" during a low-power mode only.

29.3.3 Low-power modes

This section describes the low-power modes.

29.3.3.1 Low-power entry

The following steps occur during the Low-Power mode entry sequence.

Table 233. Entry sequence

Step	CKMODE (min)	LPMODE (min)	Description
1	0h	0h	Core enters Low-Power mode by WFI/WFE instruction or via SLEEPONEXIT.
2	1h	0h	• Wake-up interrupt controller is enabled. • Core is clock gated.
3	3h	0h	• Request AHB initiators to enter Low-Power mode. • Wait for acknowledge. • AHB initiators are clock gated.
4	3h	0h	• Request AHB peripherals to enter Low-Power mode. • Wait for acknowledge. • AHB peripherals are clock gated.

Table continues on the next page...

Table 233. Entry sequence (continued)

Step	CKMODE (min)	LPMODE (min)	Description
5	7h	0h	• Request peripherals to enter Low-Power mode. • Wait for acknowledge. • Peripherals are clock gated.
6	Fh	0h	Request power management (regulators, bandgap) to enter Low-Power mode.
7	Fh	1h	• SRAMs enter Low-Power mode. • System clocks are gated.
8	Fh	3h	Power domain is placed in Low-Power retention state (Deep Sleep).
9	Fh	7h	Power domain is switched off (Power-Down).
10	Fh	Fh	Regulators are powered off (Deep Power-Down).

29.3.3.2 DMA wakeup

You can configure the DMA to generate a wake-up when a DMA request for configured channel asserts. This is supported when you request the DMA to enter Low-Power mode and retain the DMA state (not Power Down or Deep Power Down).

The DMA wakeup triggers an exit from Low-Power mode for everything except the core, which remains clock gated. Re-enter Low-Power mode after the DMA request negates, and the normal low-power mode entry sequence is followed.

Because a DMA wake-up results in everything except the core from exiting Low-Power mode, you must ensure that other modules not involved in the wakeup remain in a known state. To accomplish this, disable the modules before the initial entry in Low-Power mode or configure the Doze field in selected modules.

If the flash memory is not required during the DMA wakeup, NXP recommends that FLASHCR[FLASHDOZE] = 1.

NOTE

If the DMA request does not negate due to the DMA transfer, the chip remains in a higher power state until an interrupt or other wake-up sources can wakeup the core.

An interrupt that occurs during a DMA wakeup causes an immediate exit from Low-Power mode without affecting the DMA transfer.

29.3.3.3 Power domains

CMC configures Low-Power mode of 2 different power domains when the core enters a low-power mode with CKMODE = Fh. You can configure the different power domains to enter different low-power modes , but you must not configure the WAKE domain to a lower-power mode than any of the other domains.

NOTE

The WAKE domain LPMODE register setting must always be less than or equal to the LPMODE register setting for all other power domains.

CMC controls the following power domains:

- MAIN
- WAKE

The table below lists allowed combinations for MAIN and WAKE.

Table 234. Power Mode Combinations for MAIN and WAKE

CMC PMCTRLMAIN	CMC PMCTRLWAKE
0x0	0x0
0x1	0x1
0x3	0x3
0x3	0x1
0xF	0xF

Configure all power domains to the same Low-Power mode using Global Power Mode Control (GPMCTRL). Alternatively, configure each PMCTRL register to assign an individual low-power mode to each domain.

29.3.3.4 Debug in low-power modes

When the debugger asserts CDBGPWRUPREQ, it requests the debug logic to power up and enable the functionality depending on DBGCTL[SOD].

- When DBGCTL[SOD] = 0, the core clock remains enabled even when the core is sleeping (CKMODE = 0h). CDBGPWRUPACK remains asserted.
- When DBGCTL[SOD] = 1, ignore the debug request when the core sleeps. CDBPWRUPQACK negates when the core is sleeping.

NOTE

Do not attach a debugger when the JTAG/SWD logic is powered down.

29.3.4 Clocks

- The slow bus clock clocks CMC registers and logic.
- 1 MHz clock clocks the timeout counters.

29.3.5 Reset

This section describes the sources of reset and the different resets that you can generate.

29.3.5.1 Reset sources

This section describes the different reset sources.

Power-on reset (POR)

When you initially apply power to the MCU or the supply voltage is below the POR falling threshold, the POR circuit triggers the POR condition.

The POR condition asserts a cold reset in all power domains. SRS[POR] and SRS[LVD] become 1 on a POR condition.

Low voltage detect (LVD)

The LVD circuit enables by default and keeps the MCU in reset until the supply voltage rises above the LVD rising threshold. When the LVD circuit is enabled, it triggers an LVD reset condition if the supply voltage is below the LVD falling threshold.

SRS[LVD] becomes 1 on an LVD reset condition. The LVD reset condition asserts a cold reset in all power domains. Only the LVD or HVD detection logic is unaffected by LVD or HVD resets.

High voltage detect (HVD)

The HVD circuit disables by default, but when enabled, it triggers an HVD reset condition if the supply voltage exceeds the HVD threshold.

SRS[HVD] becomes 1 on an HVD reset condition. The HVD reset condition asserts a cold reset in all power domains. Only the LVD or HVD detection logic is unaffected by LVD or HVD resets.

Wakeup (WAKEUP)

On a wakeup from Power Down or Deep-Power Down mode, the power management logic triggers a Wake-up reset in the power domains that had powered off.

The wake-up reset condition asserts a cold reset in all power domains that were powered down. The system power domain, including the RESET_b pin, is unaffected by a wake-up from Power Down or Deep-Power Down mode (unless another reset source triggers the wake-up). SRS[WAKEUP] becomes 1 on a wake-up reset condition.

External pin reset (RESET_b)

The RESET_b pin is a bidirectional open-drain pin with an internal pull-up resistor. The RESET_b pin function depends on the mode:

- During reset, the RESET_b drives low until the MCU completes initialization, at which point the RESET_b pin is released. If the RESET_b pin asserts externally, then the MCU remains in reset until the RESET_b input is pulled high.
- During active and low-power modes, the RESET_b pin can assert externally to force the MCU into the PIN reset condition.

The RESET_b pin implements a digital filter that you can configure to filter out glitches on the RESET_b pin that are less than 1–32 CMC clock cycles. The filter bypasses in low-power modes when you disable the CMC clock.

The PIN reset condition asserts a warm reset in all power domains. SRS[PIN] and SRS[WARM] become 1 on a PIN reset condition.

Debug access port reset (DAP)

Any debug access port that can initiate a reset request from a connected debugger triggers the DAP reset condition.

The DAP reset condition asserts a warm reset in all power domains. SRS[DAP] and SRS[WARM] become 1 on a DAP reset condition.

Reset timeout (RSTACK)

The reset state machine includes a timeout counter that is triggered by the reset state machine not progressing within 8192 cycles of the 1 MHz clock. This triggers the RSTACK reset condition.

The RSTACK reset condition asserts a warm reset in all power domains. SRS[RSTACK], SRS[FATAL], and SRS[WARM] become 1 on an RSTACK reset condition.

Low-power timeout (LPACK)

The low-power entry state machine includes a timeout counter that triggers if a module does not acknowledge entry into Low-Power mode after 8192 cycles of the 1 MHz clock. This triggers the LPACK reset condition.

The LPACK reset condition asserts a warm reset in all power domains. SRS[LPACK] and SRS[WARM] become 1 on an LPACK reset condition.

System clock generation (SCG)

The system clock generation includes loss of clock and loss of lock monitors that you can configure to generate a reset, this triggers the SCG reset condition.

The SCG reset condition asserts a warm reset in all power domains. SRS[SCG], SRS[FATAL], and SRS[WARM] become 1 on an SCG reset condition.

Watchdog 0 (WDOG0)

The watchdog timer monitors the software by expecting periodic refreshing of the watchdog counter. When this does not occur, it triggers the WDOG0 reset condition.

The WDOG0 reset condition asserts a warm reset in all power domains. SRS[WDOG0] and SRS[WARM] become 1 on a WDOG0 reset condition.

Software (SW)

The software can request a system reset by configuring the system reset request in the Cortex-M33 core, this triggers the software reset condition.

The software reset condition asserts a warm reset in all power domains. SRS[SW] and SRS[WARM] become 1 on a software reset condition.

Lockup (LOCKUP)

The Cortex-M33 core enters Lockup state as a result of certain illegal operations, this triggers the LOCKUP reset condition.

The LOCKUP reset condition asserts an MCU reset in all power domains. SRS[LOCKUP] and SRS[WARM] become 1 on a LOCKUP reset condition.

Watchdog 1 (WDOG1)

The watchdog timer monitors the software by expecting periodic refreshing of the watchdog counter. When this does not occur, it triggers the WDOG1 reset condition.

The WDOG1 reset condition asserts a warm reset in all power domains. SRS[WDOG1] and SRS[WARM] become 1 on a WDOG1 reset condition.

Security violation (SECVIO)

When a security module detects a security violation, it triggers the SECVIO reset condition.

The SECVIO reset condition asserts a warm reset in all power domains. SRS[SECVIO], SRS[FATAL], and SRS[WARM] become 1 on a SECVIO reset condition.

29.3.5.2 Reset types

This section describes the different resets that you can generate.

Cold reset

Each power domain generates a cold reset to reset the debug logic and mode control logic. The cold reset for each power domain can assert as a result of the following events.

- Initial POR of the chip
- Voltage detect monitor (LVD, for example)
- Power domain wake-up from Power Down or Deep-Power Down (varies per domain)

A cold reset does not guarantee the contents of on-chip SRAM, except for a Power Down wake-up and then only for the SRAM that is configured to retain state.

Warm reset

- Cold Reset or any of the remaining warm reset sources generates a warm reset.
- A warm reset resets most of the logic in each power domain.
- Warm resets are divided into fatal reset sources and non-fatal reset sources.

You can configure the non-fatal reset sources to generate an interrupt instead of the warm reset. The warm reset averts if you can clear the non-fatal reset source (including status flag) within 8192 cycles of the 1 MHz clock. Non-fatal resets retain the contents of on-chip SRAM.

You cannot configure the fatal reset sources to generate an interrupt and do not guarantee the contents of on-chip SRAM.

29.3.5.3 Reset sequence

Power-on reset

Perform the following steps as part of the POR (or voltage detect monitor) sequence:

1. RESET_b pin drives low and internal reset signals asserted.
2. POR or LVD signals negate and clocks are enabled in their default configuration.
3. Internal reset remains asserted for 8 CMC clock cycles.
4. Internal reset to flash memory and fuse controllers negates and their initialization sequences commence.
5. Initialization sequences for flash memory and fuse complete.
6. Internal trim registers are loaded and RESET_b pin is tri-stated.
7. Read the ISP pin status and record it in the Mode (MR0) register.
8. Reset state machine waits for RESET_b pin input to pull high or drive high externally.
9. Internal reset signals negate.
10. Core exits reset and fetches the initial program counter and stack pointer from ROM.

Deep-power down wake-up

Perform the following steps as part of the deep-power down wake-up sequence:

1. Internal reset signals asserted.
2. Wake-up signal negates and clocks are enabled in their default configuration.
3. Internal reset remains asserted for 8 CMC clock cycles.
4. Internal reset to flash memory and fuse controllers negates and commence their initialization sequences.
5. Initialization sequences for flash memory and fuse complete.
6. Internal trim registers are loaded.
7. Internal reset signals negate.
8. Core exits reset and fetches the initial program counter and stack pointer from ROM.

A wake-up from deep-power down via the RESET_b pin follows the warm reset sequence.

Power down wake-up

Perform the following steps as part of the power down wake-up sequence:

1. Internal reset signals asserted.
2. Clocks are enabled in their default configuration.
3. Internal reset remains asserted for 8 CMC clock cycles.
4. Internal trim registers are loaded.
5. Internal reset signals negate.
6. Core exits reset and fetches the initial program counter and stack pointer from ROM.

A wake-up from power down via the RESET_b pin follows the warm reset sequence.

Warm reset

Perform the following steps as part of the warm reset sequence:

1. RESET_b pin drives low and internal reset signals asserted.
2. Clocks are enabled in their default configuration.
3. Internal reset remains asserted for 8 CMC clock cycles.
4. Internal reset to flash memory and fuse controllers negates and commence their initialization sequences.
5. Initialization sequences for flash memory and fuse complete.
6. Internal trim registers are loaded and RESET_b pin is tri-stated.
7. Read the ISP pin status and record it in the Mode (MR0) register.
8. Reset state machine waits for RESET_b pin input to pull high or drive high externally.
9. Internal reset signals negate.
10. Core exits reset and fetches the initial program counter and stack pointer from ROM.

29.3.6 Interrupts

CMC generates a single interrupt, which System Reset Interrupt Enable (SRIE) configures.

29.4 External signals

Table 235. External signals

Signal	Description	Direction
RESET_B	Bidirectional open-drain reset pin with pullup that asserts low during warm reset except when waking up from a low-power mode.	Input or output
BOOT_CONFIGn	The input pin is sampled at the end of the RESET_B assertion and stored in Mode (MR0).	Input

29.5 Initialization

By default, the digital glitch filter is disabled on RESET_b pin. To enable the filter, configure:

- RPC[LPFEN], RPC[FILTEN], or both.
- RPC[FILTCFG].

29.6 Application information

To configure for Deep-Power Down Low-Power mode entry:

1. Write Fh to Clock Control (CKCTRL)
2. Write 8h to Power Mode Protection (PMPROT)
3. Write Fh to Global Power Mode Control (GPMCTRL)
4. Execute WFI instruction

To configure for Power-Down Low-Power mode entry:

1. Write Fh to Clock Control (CKCTRL)
2. Write 4h to Power Mode Protection (PMPROT)
3. Write 7h to Global Power Mode Control (GPMCTRL)
4. Execute WFI instruction

To configure for Deep Sleep Low-Power mode entry:

1. Write Fh to Clock Control (CKCTRL)
2. Write 2h to Power Mode Protection (PMPROT)
3. Write 3h to Global Power Mode Control (GPMCTRL)
4. Execute WFI instruction

To configure for MAIN in power-down and WAKE in Deep Sleep Low-Power mode entry:

1. Write Fh to Clock Control (CKCTRL)
2. Write 3h to Power Mode Protection (PMPROT)
3. Write 3h to PMCTRLMAIN
4. Write 1h to PMCTRLWAKE
5. Execute WFI instruction

29.7 Memory map and register descriptions

This section describes the registers in the CMC module.

29.7.1 CMC register descriptions

NOTE

Different CMC registers reset on different reset types.

NOTE

You must read back the last register written to before executing the WFI instruction. This ensures that before the MCU enters the low power mode, all register writes associated with setting up the low power mode are complete, failure to do this may result in the low power mode not being entered correctly.

29.7.1.1 CMC memory map

CMC0 base address: 4000_1000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	0302_0000h
10h	Clock Control (CKCTRL)	32	RW	0000_0000h
14h	Clock Status (CKSTAT)	32	RW	0000_0000h
18h	Power Mode Protection (PMPROT)	32	RW	0000_0000h
1Ch	Global Power Mode Control (GPMCTRL)	32	RW	0000_0000h
20h	Power Mode Control (PMCTRLMAIN)	32	RW	0000_0000h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
24h	Power Mode Control (PMCTRLWAKE)	32	RW	0000_0000h
80h	System Reset Status (SRS)	32	R	See section
84h	Reset Pin Control (RPC)	32	RW	0000_0000h
88h	Sticky System Reset Status (SSRS)	32	RW	0000_0006h
8Ch	System Reset Interrupt Enable (SRIE)	32	RW	0000_8800h
90h	System Reset Interrupt Flag (SRIF)	32	RW	0000_0000h
9Ch	Reset Count Register (RSTCNT)	32	R	0000_0000h
A0h	Mode (MR0)	32	RW	0000_0000h
B0h	Force Mode (FM0)	32	RW	0000_0000h
C0h	SRAM Disable (SRAMDIS0)	32	RW	0000_0000h
D0h	SRAM Retention (SRAMRET0)	32	RW	0000_0000h
E0h	Flash Control (FLASHCR)	32	RW	0000_0000h
F0h	Device Initialization Error Register (DIER)	32	R	0000_0000h
FCh	BootROM Lock Register (BLR)	32	RW	0000_0492h
100h - 10Ch	BootROM Scratch Register (BSR0 - BSR3)	32	RW	0000_0000h
110h	Core Control (CORECTL)	32	RW	0000_0000h
120h	Debug Control (DBGCTL)	32	RW	0000_0000h

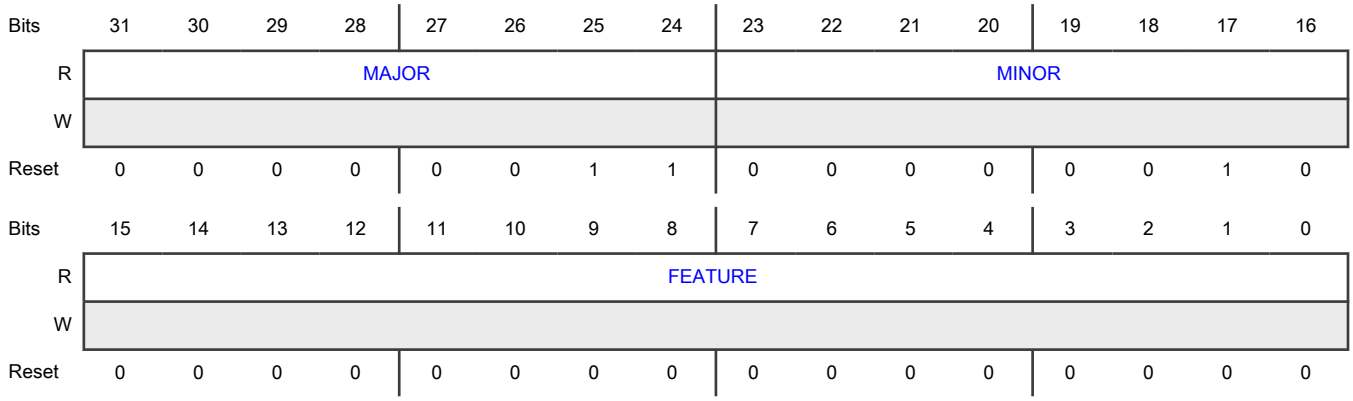
29.7.1.2 Version ID (VERID)

Offset

Register	Offset
VERID	0h

Function
Contains version numbers for module design and feature set.

Diagram



Fields

Field	Function
31-24 MAJOR	Major Version Number Returns the major version number for the module specification.
23-16 MINOR	Minor Version Number Returns the minor version number for the module specification.
15-0 FEATURE	Feature Specification Number Returns the feature set number.

29.7.1.3 Clock Control (CKCTRL)

Offset

Register	Offset
CKCTRL	10h

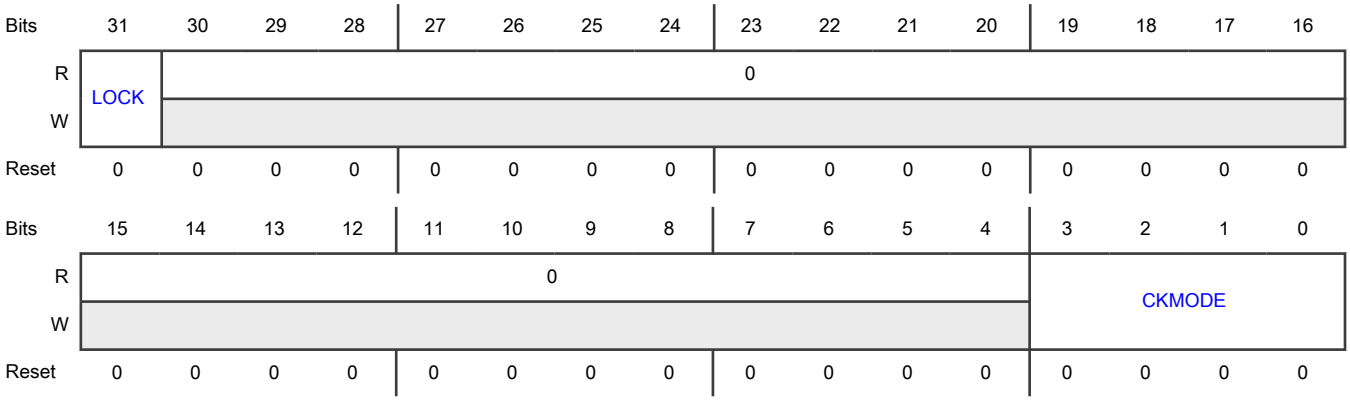
Function

Configures the amount of clock gating when the core asserts sleeping due to WFI, WFE, or SLEEPONEXIT.

NOTE

This register resets on WAKE warm reset.

Diagram



Fields

Field	Function
31 LOCK	Lock Locks the register and blocks writes until the next reset. 0b - Allowed 1b - Blocked
30-4 —	Reserved
3-0 CKMODE	Clocking Mode Configures the amount of clock gating when the core enters a low-power mode because of WFI, WFE or SLEEPONEXIT. Configuring CKMODE > 0 requires the SLEEPDEEP field in the Arm core to become 1. Configuring PMCTRLx[LPMODE] > 0 requires writing Fh to CKMODE. 0000b - Core clock is on 0001b - Core clock is off 0011b - Core and platform clocks are off 0111b - Core, platform, and peripheral clocks are off, but no change in Low-Power mode 1111b - Core, platform, and peripheral clocks are off, and core enters Low-Power mode

29.7.1.4 Clock Status (CKSTAT)

Offset

Register	Offset
CKSTAT	14h

Function

Returns the clock gating status and wake-up source from the previous Low-Power mode entry, provided the core was clock gated. This requires configuring CKCTRL[CKMODE] > 0 and the wake-up event must occur after the core is clock gated. The register contents are only valid when CKSTAT[VALID] = 1.

NOTE

This register resets on WAKE warm reset.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	VALID	0														
W	W1C															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	WAKEUP							0				CKMODE			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 VALID	Clock Status Valid Indicates that the core clock was gated since you last wrote 0 to this field. 0b - Core clock not gated 1b - Core clock was gated due to Low-Power mode entry
30-15 —	Reserved
14-8 WAKEUP	Wake-up Source Returns any wake-up sources from the previous Low-Power mode entry. [0] - Wake-up source is reset interrupt or wakeup from Deep Power-Down [1] - Wake-up source is debug request [2] - Wake-up source is interrupt [3] - Wake-up source is DMA wakeup [4] - Wake-up source is WUU request [5] - Wake-up source is bus master wakeup [6] - Wake-up source is bus master wakeup A wakeup from Power-Down or Deep Power-Down writes 1 to WAKEUP[0]. Depending on Low-Power mode, other wake-up bits may not become 1.

Table continues on the next page...

Table continued from the previous page...

Field	Function
7-4 —	Reserved
3-0 CKMODE	Low Power Status Returns the result of the previous Low-Power mode entry. 0000b - Core clock is on 0001b - Core clock is off 0011b - Core and platform clocks are off 0111b - Core, platform, and peripheral clocks are off, but no change in Low-Power mode 1111b - Core, platform, and peripheral clocks are off, and core enters Low-Power mode All other values are reserved.

29.7.1.5 Power Mode Protection (PMPROT)

Offset

Register	Offset
PMPROT	18h

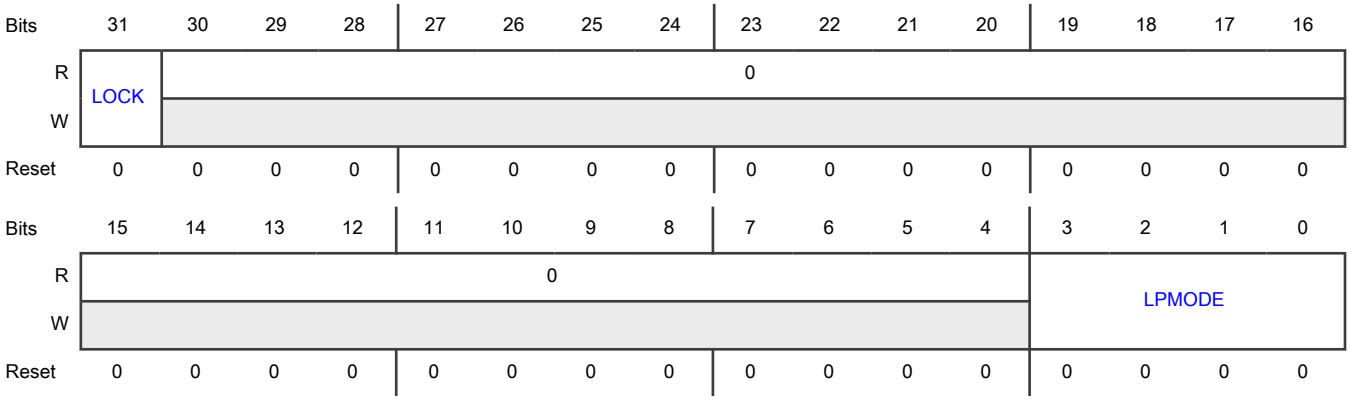
Function

Provides protection for entry in low-power modes, you must allow a low-power mode before configuring any Power Mode Control register (PMCTRLx) to that mode.

NOTE

This register resets on WAKE warm reset.

Diagram



Fields

Field	Function
31 LOCK	Lock Register Locks the register and blocks writes until the next reset. 0b - Allowed 1b - Blocked
30-4 —	Reserved
3-0 LPMODE	Low-Power Mode Bit 0: When set, allows the PMCTRLx[LPM] field to be configured for Sleep. Bit 1: When set, allows the PMCTRLx[LPM] field to be configured for Deep Sleep. Bit 2: When set, allows the PMCTRLx[LPM] field to be configured for Power Down. Bit 3: When set, allows the PMCTRLx[LPM] field to be configured for Deep Power Down. 0000b - Not allowed 0001b - Allowed 0010b - Allowed 0011b - Allowed 0100b - Allowed 0101b - Allowed 0110b - Allowed 0111b - Allowed 1000b - Allowed 1001b - Allowed 1010b - Allowed 1011b - Allowed 1100b - Allowed 1101b - Allowed 1110b - Allowed 1111b - Allowed

29.7.1.6 Global Power Mode Control (GPMCTRL)

Offset

Register	Offset
GPMCTRL	1Ch

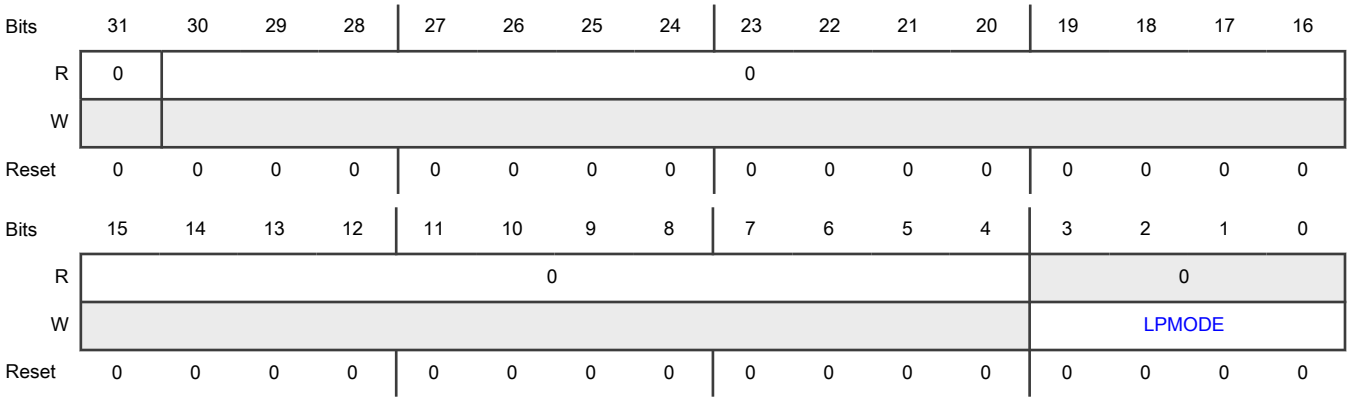
Function

Updates all PMCTRLx registers with the value written.

NOTE

This register resets on WAKE cold reset.

Diagram



Fields

Field	Function
31 —	Reserved
30-4 —	Reserved
3-0 LPMODE	Low-Power Mode Specifies that all PMCTRLx[LPMODE] fields update with the value written.

29.7.1.7 Power Mode Control (PMCTRLMAIN - PMCTRLWAKE)

Offset

Register	Offset
PMCTRLMAIN	20h
PMCTRLWAKE	24h

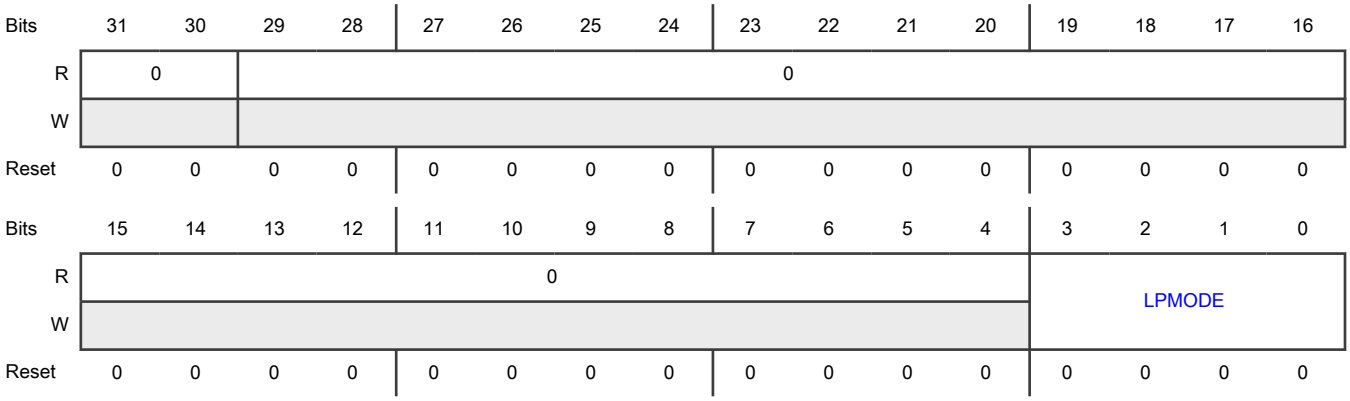
Function

Configures entry into low-power modes for each power domain, provided that the selected power mode is allowed via an appropriate setting of Power Mode Protection (PMPROT), and CKMODE = Fh.

NOTE

This register resets by WAKE cold reset.

Diagram



Fields

Field	Function
31-30 —	Reserved
29-4 —	Reserved
3-0 LPMODE	Low-Power Mode Selects the desired Low-Power mode when a core executes WFI or WFE instruction. Writes to this field are blocked if you have not enabled the protection level using Power Mode Protection (PMPROT). You must not configure this field for the WAKE domain to a lower power mode than any other power domain. **NOTE** See Power domains section for details on allowed combinations. 0000b - Active 0001b - Sleep 0011b - Deep Sleep 0111b - Power Down 1111b - Deep-Power Down

29.7.1.8 System Reset Status (SRS)

Offset

Register	Offset
SRS	80h

Function

Updates on every MAIN warm reset to indicate the type/source of the most recent reset.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	SECVIO	0	0	0	0	WDOG1	0	0	0					0	0
W																
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	LOCKUP	SW	WDOG0	SCG	LPACK	RSTACK	DAP	PIN	0		FATAL	WARM	HVD	LVD	POR	WAKEUP
W																
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Fields

Field	Function
31 —	Reserved
30 SECVIO	Security Violation Reset Indicates a security violation logic that causes a reset. This is a fatal reset source and SRAM contents are not guaranteed. 0b - Reset not generated 1b - Reset generated
29 —	Reserved
28 —	Reserved
27 —	Reserved
26 —	Reserved
25 WDOG1	Watchdog 1 Reset Indicates the WatchDog 1 timeout that generates a reset. 0b - Reset is not generated 1b - Reset is generated
24	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
23 —	Reserved
22-18 —	Reserved
17 —	Reserved
16 —	Reserved
15 LOCKUP	Lockup Reset Indicates the Arm core indication of a LOCKUP event that causes a reset. 0b - Reset not generated 1b - Reset generated
14 SW	Software Reset Indicates a software reset request from the Arm core (SYSRESETREQ) that causes a reset. 0b - Reset not generated 1b - Reset generated
13 WDOG0	Watchdog 0 Reset Indicates the WatchDog 0 timeout that causes a reset. 0b - Reset is not generated 1b - Reset is generated
12 SCG	System Clock Generation Reset Indicates a loss-of-clock or loss-of-lock event in the SCG that causes a reset. This is a fatal reset source and SRAM contents are not guaranteed. 0b - Reset is not generated 1b - Reset is generated
11 LPACK	Low Power Acknowledge Timeout Reset Indicates a timeout in the Low Power Mode entry logic that causes a reset. This timeout is generated if a peripheral does not acknowledge entry into Low-Power mode within 8192 cycles of 1 MHz clock. 0b - Reset not generated 1b - Reset generated

Table continues on the next page...

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Field	Function
10 RSTACK	Reset Timeout Indicates a timeout or other error condition in the system reset generation logic that causes a reset. This is a fatal reset source, and SRAM contents are not guaranteed. 0b - Reset not generated 1b - Reset generated
9 DAP	Debug Access Port Reset Indicates a reset request from a DAP that causes a reset. 0b - Reset was not generated 1b - Reset was generated
8 PIN	Pin Reset Indicates an external assertion of the RESET_b pin that causes a reset. 0b - Reset was not generated 1b - Reset was generated
7-6 —	Reserved
5 FATAL	Fatal Reset Asserts if the last reset source was a fatal reset source. You cannot guarantee SRAM contents following a fatal reset source. 0b - Reset was not generated 1b - Reset was generated
4 WARM	Warm Reset Asserts if the last reset source was a warm reset source. 0b - Reset not generated 1b - Reset generated
3 HVD	High Voltage Detect Reset Indicates an HVD that causes a reset. You cannot guarantee SRAM contents following an HVD reset source. 0b - Reset not generated 1b - Reset generated
2 LVD	Low Voltage Detect Reset Indicates an LVD that causes a reset. You cannot guarantee SRAM contents following an LVD reset source.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Reset not generated 1b - Reset generated
1 POR	Power-on Reset Indicates the POR detection logic that causes a reset. You cannot guarantee SRAM contents following a POR source. 0b - Reset not generated 1b - Reset generated
0 WAKEUP	Wake-up Reset Indicates a wake-up from Power Down or Deep-Power Down mode that causes a reset. 0b - Reset not generated 1b - Reset generated

29.7.1.9 Reset Pin Control (RPC)

Offset

Register	Offset
RPC	84h

Function

NOTE

WAKE cold reset resets this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0						LPFEN	FILTEN	0				FILTCFG			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-10 —	Reserved
9 LPFEN	Low-Power Filter Enable Enables the low-power reset pin filter in both Active and Low-Power modes when this field = 1. The RESET_b pin must assert for more than three 32.768 KHz clock cycles to always propagate through the filter. A glitch less than two 32.768 KHz clock cycles never propagates through the filter. 0b - Disables 1b - Enables
8 FILTEN	Filter Enable Enables the slow clock reset pin filter in Active modes. The RESET_b pin must assert for more than FILTCFG + 1 slow system clock cycles to always propagate through the filter. A glitch less than FILTCFG slow system clock cycles never propagates through the filter. If RPC[LPFEN] also becomes 1, then the filters operate in series. 0b - Disables 1b - Enables
7-5 —	Reserved
4-0 FILTCFG	Reset Filter Configuration Configures the reset pin filter's width from 1 to 32 slow system clock cycles.

29.7.1.10 Sticky System Reset Status (SSRS)

Offset

Register	Offset
SSRS	88h

Function

Stores all sources of system reset that has generated a system reset since the last WAKE cold reset and that you have not cleared. SSRS does not update following a core software reset.

NOTE

This register resets on WAKE cold reset.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	SECVIO	0	0	0	0	WDOG1	0	0	0					0	0
W		W1C					W1C									
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	LOCKUP	SW	WDOG0	SCG	LPACK	RSTACK	DAP	PIN	0		FATAL	WARM	HVD	LVD	POR	WAKEUP
W	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C			W1C	W1C	W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0

Fields

Field	Function
31 —	Reserved
30 SECVIO	Security Violation Reset Indicates a security violation that causes a reset. This is a fatal reset source and SRAM contents are not guaranteed. 0b - Reset not generated 1b - Reset generated
29 —	Reserved
28 —	Reserved
27 —	Reserved
26 —	Reserved
25 WDOG1	Watchdog 1 Reset Indicates the WatchDog 1 timeout that causes a reset. 0b - Reset is not generated 1b - Reset is generated
24	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
23 —	Reserved
22-18 —	Reserved
17 —	Reserved
16 —	Reserved
15 LOCKUP	Lockup Reset Indicates the core lockup that causes a reset. 0b - Reset not generated 1b - Reset generated
14 SW	Software Reset Indicates the software request from the Arm core (SYSRESETREQ) that causes a reset. 0b - Reset not generated 1b - Reset generated
13 WDOG0	Watchdog 0 Reset Indicates the WatchDog 0 timeout that causes a reset. 0b - Reset is not generated 1b - Reset is generated
12 SCG	System Clock Generation Reset Indicates an SCG loss of lock or loss of clock that causes a reset. This is a fatal reset source and SRAM contents are not guaranteed. 0b - Reset is not generated 1b - Reset is generated
11 LPACK	Low Power Acknowledge Timeout Reset Indicates a low power acknowledge timeout that causes a reset. 0b - Reset not generated 1b - Reset generated

Table continues on the next page...

Table continued from the previous page...

Field	Function
10 RSTACK	Reset Timeout Indicates a reset controller timeout that causes a reset. This is a fatal reset source and SRAM contents are not guaranteed. 0b - Reset not generated 1b - Reset generated
9 DAP	DAP Reset Indicates a DAP reset request that causes a reset. 0b - Reset not generated 1b - Reset generated
8 PIN	Pin Reset Indicates a RESET_B pin that causes a reset. 0b - Reset not generated 1b - Reset generated
7-6 —	Reserved
5 FATAL	Fatal Reset Indicates a fatal reset source that causes a reset. 0b - Reset was not generated 1b - Reset was generated
4 WARM	Warm Reset Indicates a warm reset source that causes a reset. 0b - Reset not generated 1b - Reset generated
3 HVD	High Voltage Detect Reset Indicates the HVD that causes a reset. 0b - Reset not generated 1b - Reset generated
2 LVD	Low Voltage Detect Reset Indicates the LVD that causes a reset. 0b - Reset not generated 1b - Reset generated

Table continues on the next page...

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Field	Function
1 POR	Power-on Reset Indicates the POR that causes a reset. 0b - Reset not generated 1b - Reset generated
0 WAKEUP	Wake-up Reset Indicates the wake-up from VLLS mode that causes a reset. 0b - Reset not generated 1b - Reset generated

29.7.1.11 System Reset Interrupt Enable (SRIE)

Offset

Register	Offset
SRIE	8Ch

Function

Delays the assertion of a system reset for 8194 cycles of the 1 MHz clock when an interrupt is generated. This allows you to perform a graceful shutdown or to abort the warm reset provided you can clear the pending reset source by resetting the source and then clearing the pending flag. This feature cannot delay a cold or fatal warm reset source. System Reset Status (SRS) updates after the warm reset occurs.

The reset interrupt is not supported in Power Down or Deep-Power Down mode.

NOTE

This register is reset on WAKE Cold Reset.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				0	0	WDOG	0	0	0					0	0
W							1									
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	LOCK	SW	WDOG	0	LPAC	0	DAP	PIN	0							
W	UP		0		K											
Reset	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 —	Reserved
27 —	Reserved
26 —	Reserved
25 WDOG1	Watchdog 1 Reset 0b - Interrupt disabled 1b - Interrupt enabled
24 —	Reserved
23 —	Reserved
22-18 —	Reserved
17 —	Reserved
16 —	Reserved
15 LOCKUP	Lockup Reset **NOTE** A core in the lockup state cannot service interrupts. 0b - Interrupt disabled 1b - Interrupt enabled
14 SW	Software Reset 0b - Interrupt disabled 1b - Interrupt enabled
13 WDOG0	Watchdog 0 Reset 0b - Interrupt disabled 1b - Interrupt enabled

Table continues on the next page...

Table continued from the previous page...

Field	Function
12 —	Reserved
11 LPACK	Low Power Acknowledge Timeout Reset 0b - Interrupt disabled 1b - Interrupt enabled
10 —	Reserved
9 DAP	DAP Reset 0b - Interrupt disabled 1b - Interrupt enabled
8 PIN	Pin Reset 0b - Interrupt disabled 1b - Interrupt enabled
7-0 —	Reserved

29.7.1.12 System Reset Interrupt Flag (SRIF)

Offset

Register	Offset
SRIF	90h

Function

Returns the source of the reset interrupt. You can clear the pending reset source by resetting the source and then clearing the pending flag.

NOTE

This register resets on WAKE warm reset.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				0	0	WDOG1	0	0	0					0	0
W							W1C									
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	LOCKUP	SW	WDOG0	0	LPACK	0	DAP	PIN	0							
W	W1C	W1C	W1C		W1C		W1C	W1C								
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 —	Reserved
27 —	Reserved
26 —	Reserved
25 WDOG1	Watchdog 1 Reset 0b - Reset source not pending 1b - Reset source pending
24 —	Reserved
23 —	Reserved
22-18 —	Reserved
17 —	Reserved
16 —	Reserved
15	Lockup Reset

Table continues on the next page...

Table continued from the previous page...

Field	Function
LOCKUP	0b - Reset source not pending 1b - Reset source pending
14 SW	Software Reset 0b - Reset source not pending 1b - Reset source pending
13 WDOG0	Watchdog 0 Reset 0b - Reset source not pending 1b - Reset source pending
12 —	Reserved
11 LPACK	Low Power Acknowledge Timeout Reset 0b - Reset source not pending 1b - Reset source pending
10 —	Reserved
9 DAP	DAP Reset 0b - Reset source not pending 1b - Reset source pending
8 PIN	Pin Reset 0b - Reset source not pending 1b - Reset source pending
7-0 —	Reserved

29.7.1.13 Reset Count Register (RSTCNT)

Offset

Register	Offset
RSTCNT	9Ch

Function

The Reset Count Register returns the number of reset sequences completed since the last WAKE Cold Reset.

NOTE

This register is reset on WAKE Cold Reset.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								COUNT							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-8 —	Reserved
7-0 COUNT	Count Number of reset sequences completed since the last WAKE Cold Reset. When the count reaches the maximum value, it will saturate and no longer increment.

29.7.1.14 Mode (MR0)

Offset

Register	Offset
MR0	A0h

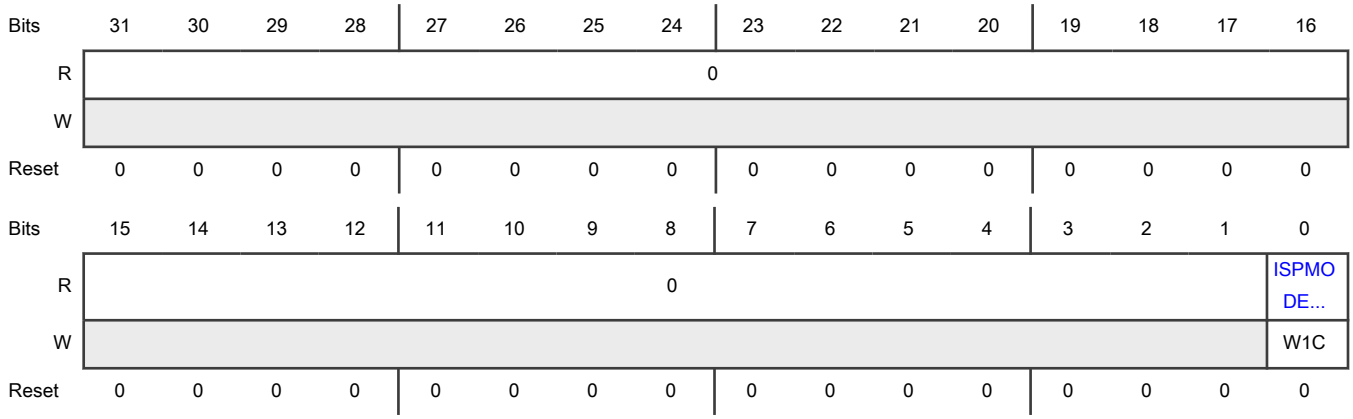
Function

Contains the state of the boot mode pins sampled at the end of the reset.

NOTE

This register resets on WAKE warm reset, and the reset value may vary depending on the pin state.

Diagram



Fields

Field	Function
31-1 —	Reserved
0 ISPMODE_n	Boot Configuration Returns the logic state of the BOOT_CONFIGn pin on the last negation of RESET_b pin.

29.7.1.15 Force Mode (FM0)

Offset

Register	Offset
FM0	B0h

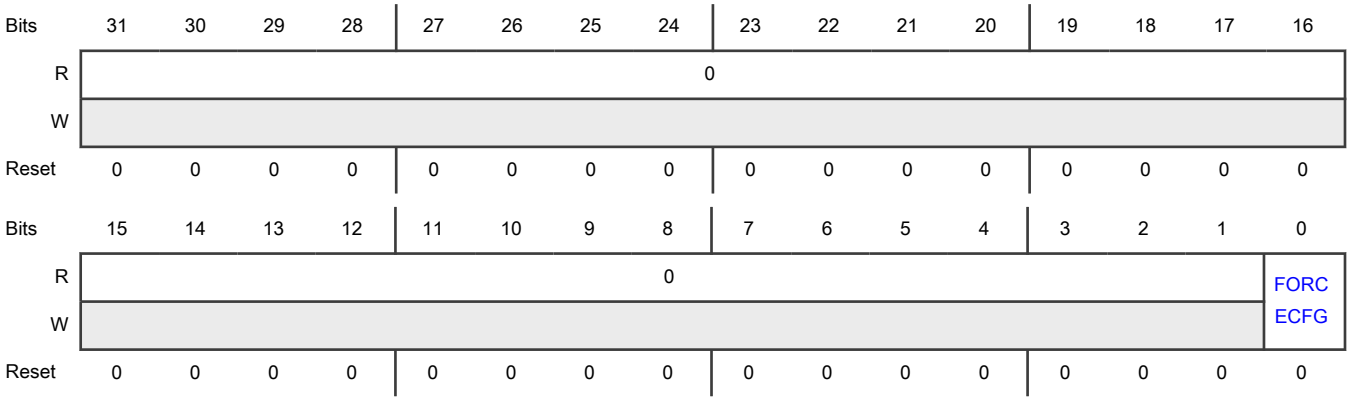
Function

Contains registers that override the state of the boot mode pins.

NOTE

This register resets on WAKE cold reset.

Diagram



Fields

Field	Function
31-1 —	Reserved
0 FORCECFG	Boot Configuration Forces the corresponding field in Mode (MR0) to assert on next system reset. 0b - No effect 1b - Asserts

29.7.1.16 SRAM Disable (SRAMDIS0)

Offset

Register	Offset
SRAMDIS0	C0h

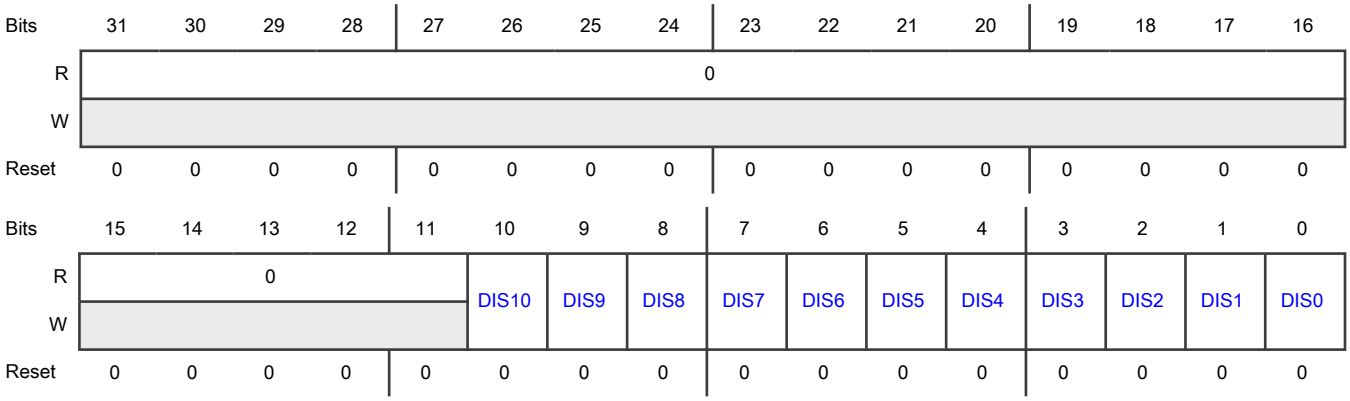
Function

Powers off the specific on-chip System SRAM arrays whenever the corresponding register field becomes 1. You must not access the SRAM array and also do not retain the SRAM array contents.

NOTE

This register resets on MAIN warm reset.

Diagram



Fields

Field	Function
31-11 —	Reserved
10-0 DISn	Shut Down Enable **NOTE** See the chip-specific CMC section for register bit details.

29.7.1.17 SRAM Retention (SRAMRET0)

Offset

Register	Offset
SRAMRET0	D0h

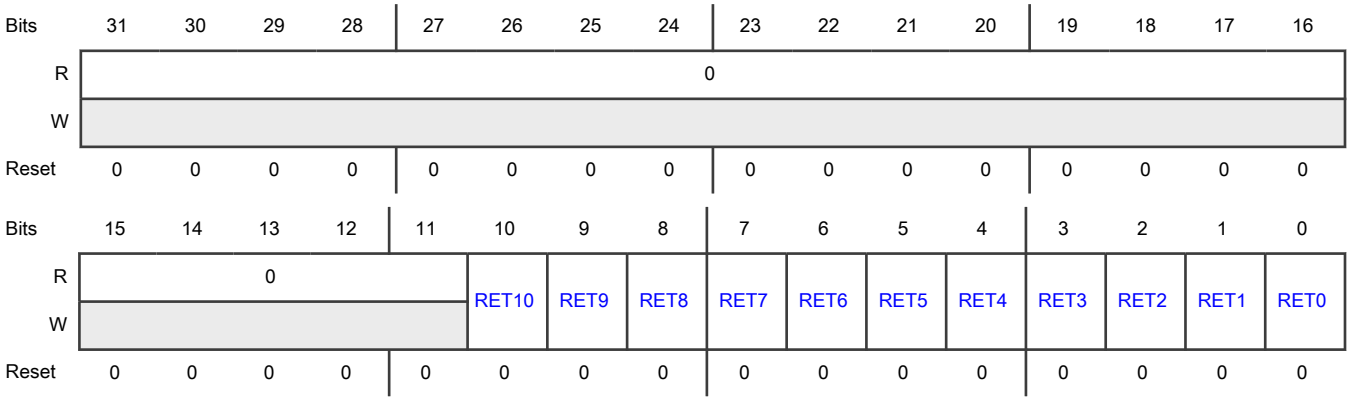
Function

Configures if the on-chip System SRAM arrays are retained or powered off in low-power modes.

NOTE

This register resets on WAKE warm reset.

Diagram



Fields

Field	Function
31-11 —	Reserved
10-0 RETn	Deep Sleep Enable Controls whether the SRAM array is retained or powered off in Low-Power modes. **NOTE** You cannot retain SRAM arrays in Low-Power modes if their power domain is switched off. See the chip-specific CMC section for register bit details.

29.7.1.18 Flash Control (FLASHCR)

Offset

Register	Offset
FLASHCR	E0h

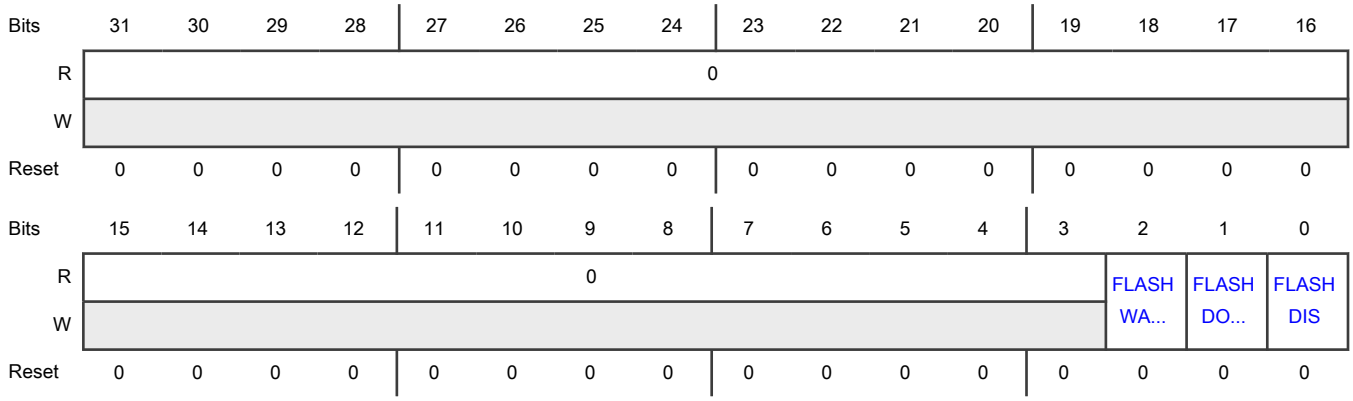
Function

Controls Low-Power mode of the on-chip flash memory.

NOTE

This register resets on WAKE warm reset.

Diagram



Fields

Field	Function
31-3 —	Reserved
2 FLASHWAKE	Flash Wake Specifies that when this field becomes 1, an attempt to read the flash memory when it is in Low-Power state because of FLASHCR[FLASHDIS] or FLASHCR[FLASHDOZE], causes the flash memory to exit Low-Power state for the duration of the flash memory access. 0b - No effect 1b - Flash memory is not disabled during flash memory accesses
1 FLASHDOZE	Flash Doze Disables flash memory accesses and places flash memory in Low-Power state whenever the core clock is gated (CKMODE > 0) because of execution of WFI, WFE, or SLEEPONEXIT. Other bus masters that attempt to access the flash memory stalls until the core is no longer sleeping. 0b - No effect 1b - Flash memory is disabled when core is sleeping (CKMODE > 0)
0 FLASHDIS	Flash Disable Places flash memory in Low-Power state when this field becomes 1. Relocate the interrupts out of flash memory before disabling it. 0b - No effect 1b - Flash memory is disabled

29.7.1.19 Device Initialization Error Register (DIER)

Offset

Register	Offset
DIER	F0h

Function

This registers contains status flags to indicate if any errors occurred during the reset initialization sequence.

NOTE

This register resets on WAKE warm reset.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	STAT															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	STAT															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 STAT	Device initialization status flags **NOTE** See the chip-specific CMC section for register bit details.

29.7.1.20 BootROM Lock Register (BLR)

Offset

Register	Offset
BLR	FCh

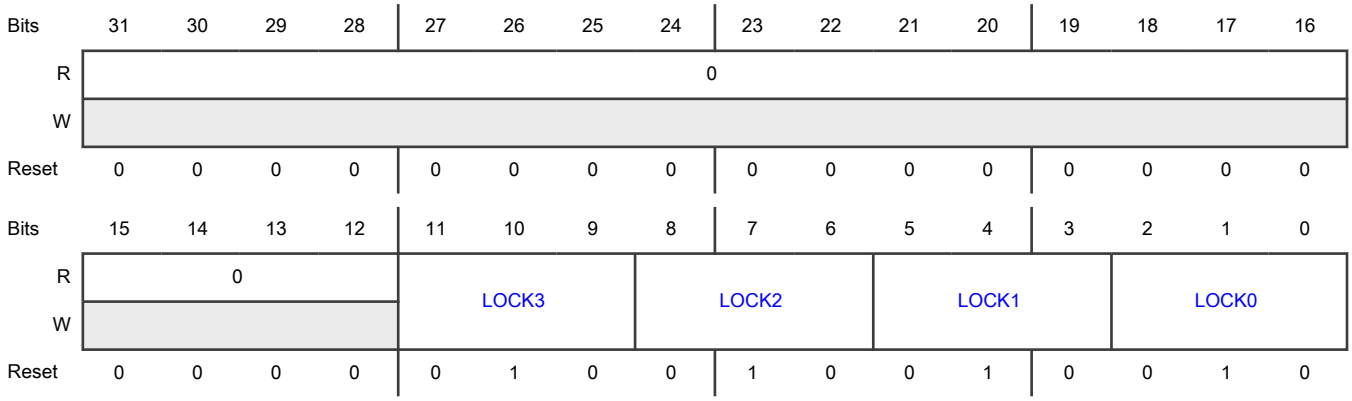
Function

The BootROM Lock Register can only be written using 32-bit writes and provided the BootROM Lock Register equals its reset value.

NOTE

This register is reset on MAIN Warm Reset.

Diagram



Fields

Field	Function
31-12 —	Reserved
11-9 LOCK3	Lock Scratch 3 The corresponding BootROM Scratch Register can only be written when the Lock field equals 010. All other values are reversed and will lock the scratch register. 010b - BootROM Scratch Register can be written 101b - BootROM Scratch Register cannot be written
8-6 LOCK2	Lock Scratch 2 The corresponding BootROM Scratch Register can only be written when the Lock field equals 010. All other values are reversed and will lock the scratch register. 010b - BootROM Scratch Register can be written 101b - BootROM Scratch Register cannot be written
5-3 LOCK1	Lock Scratch 1 The corresponding BootROM Scratch Register can only be written when the Lock field equals 010. All other values are reversed and will lock the scratch register. 010b - BootROM Scratch Register can be written 101b - BootROM Scratch Register cannot be written
2-0 LOCK0	Lock Scratch 0 The corresponding BootROM Scratch Register can only be written when the Lock field equals 010. All other values are reversed and will lock the scratch register. 010b - BootROM Scratch Register can be written 101b - BootROM Scratch Register cannot be written

29.7.1.21 BootROM Scratch Register (BSR0 - BSR3)

Offset

Register	Offset
BSR0	100h
BSR1	104h
BSR2	108h
BSR3	10Ch

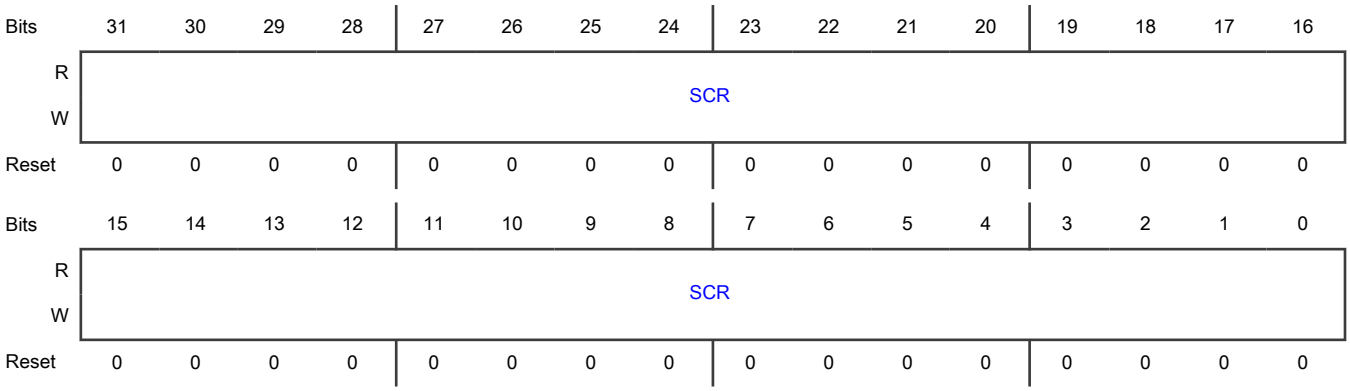
Function

This register can only be written using 32-bit writes and provided the corresponding field in BootROM Lock Register equals 010.

NOTE

This register resets on WAKE cold reset.

Diagram



Fields

Field	Function
31-0 SCR	Register used by the BootROM **NOTE** See the BootROM section of the security reference manual for details.

29.7.1.22 Core Control (CORECTL)

Offset

Register	Offset
CORECTL	110h

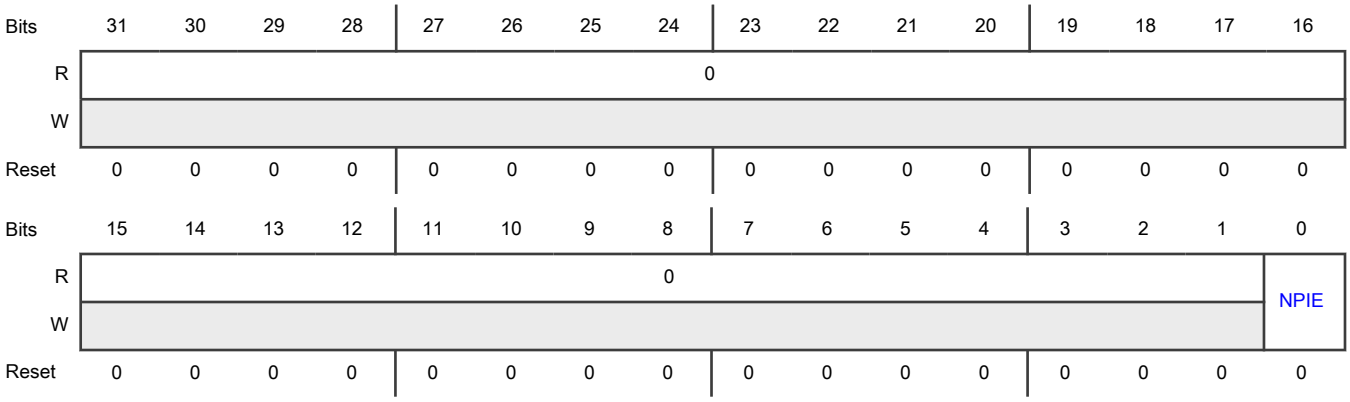
Function

Configures options for the core.

NOTE

This register resets on MAIN warm reset.

Diagram



Fields

Field	Function
31-1 —	Reserved
0 NPIE	Non-maskable Pin Interrupt Enable Enables or disables the pin interrupt. You can write to this field only when NPIE = 0. 0b - Disables 1b - Enables

29.7.1.23 Debug Control (DBGCTL)

Offset

Register	Offset
DBGCTL	120h

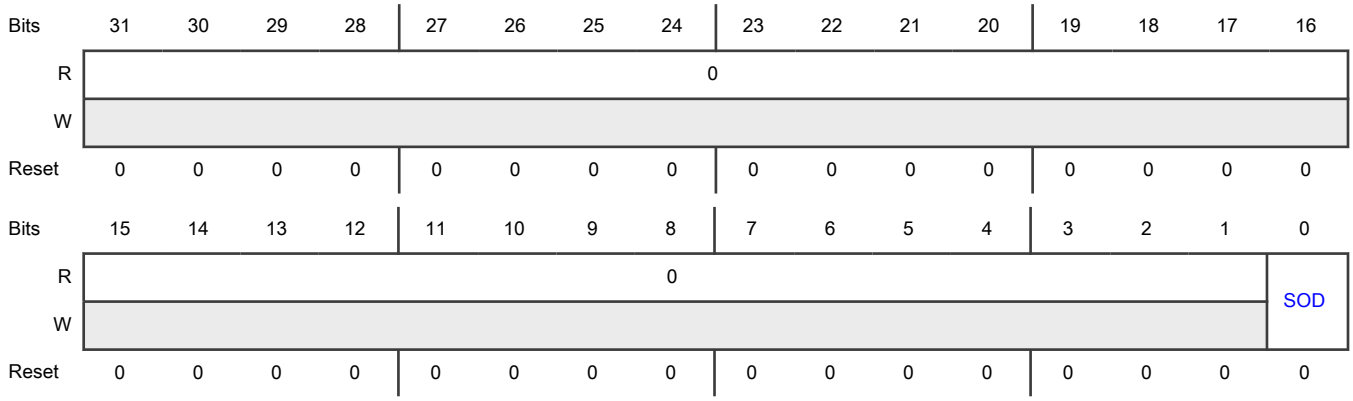
Function

Configures options for debug.

NOTE

This register resets on WAKE cold reset.

Diagram



Fields

Field	Function
31-1 —	Reserved
0 SOD	Sleep Or Debug Configures whether the debug remains enabled when core sleeps. 0b - Remains enabled 1b - Disabled

Chapter 30
System Power Control (SPC)

30.1 Chip-specific SPC information

Table 236. Reference links to related information

Topic	Related module	Reference
Full description	SPC	SPC
System memory map		System memory map
Power Management		Power Management
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing
Reset		Reset

NOTE

The "switch" in this chapter refers to the "smart power switch" in the Power Management.

30.1.1 Module instances

- This device has one instance of the SPC module, SPC0.
- If the LPCMP is being used in DPDOWN then the low power IREF must remain enabled.

30.1.2 Voltage regulators

This section describes the various on-chip regulators.

Table 237. On-chip regulators

Regulator name	Description
DCDC_LV	The DCDC_LV can be used to power VDD_SYS domain. It can power the IO ring, other on-chip modules, and external components as well. However, user should take care that the total load current doesn't exceed the maximum capacity.
LDO_CORE	The LDO_CORE can be used to power VDD_CORE domain.
LDO_SYS	The LDO_SYS can be used to power VDD_SYS domain. It can power the IO ring, other on-chip modules, and external components as well. However, user should take care that the total load current doesn't exceed the maximum capacity.

30.1.3 Voltage monitors

30.1.3.1 VDD_SYS voltage monitors

The following sections describe the voltage monitors inspecting the VDD_SYS supply.

30.1.3.1.1 Power-On-Reset (POR)

During power-on, the POR keeps the device under reset until the VDD_SYS supply voltage reaches the specified threshold. When VDD_SYS is above the VPOR limit, the device POR reset is released. However, the device stays in reset until the LVD on VDD_SYS is released.

30.1.3.1.2 Low Voltage Detect

This device integrates a Low Voltage Detector (LVD) circuit on VDD_SYS input voltage. The LVD monitors the VDD_SYS power supply voltage by comparing it to a programmable threshold. When VDD_SYS drops below the threshold, the user has the option of generating an LVD reset or an LVW interrupt. The VDD_SYS LVD circuit is ON by default. The user can disable the VDD_SYS LVD through software.

30.1.3.1.3 High Voltage Detect

This device integrates a High Voltage Detector (HVD) circuit on VDD_SYS input voltage. The HVD monitors the VDD_SYS power supply voltage by comparing it to a programmable threshold. When VDD_SYS rises above the threshold, the user has the option of generating an HVD reset or an HVW interrupt. The VDD_SYS HVD circuit is OFF by default. The user can enable the VDD_SYS HVD through software.

30.1.3.2 VDD_CORE voltage monitors

The following sections describe the voltage monitors for the VDD_CORE supply.

30.1.3.2.1 Low Voltage Detect

This device integrates a Low Voltage Detector (LVD) circuit on VDD_CORE input voltage. The LVD monitors the VDD_CORE power supply voltage by comparing it to a programmable threshold. When VDD_CORE drops below the threshold, the user has the option of generating an LVD reset or an LVW interrupt. The VDD_CORE LVD circuit is ON by default. The user can disable the VDD_CORE LVD through software.

30.1.3.2.2 High Voltage Detect

This device integrates a High Voltage Detector (HVD) circuit on VDD_CORE input voltage. The HVD monitors the VDD_CORE power supply voltage by comparing it to a programmable threshold. When VDD_CORE rises above the threshold, the user has the option of generating an HVD reset or an HVW interrupt. The VDD_CORE HVD circuit is OFF by default. The user can enable the VDD_CORE HVD through software.

30.1.3.3 VDD_IO_ABC voltage supply monitors

The following sections describe the voltage monitors for the power supply that powers PORTA, PORTB and PORTC.

30.1.3.3.1 Low Voltage Detect

This device integrates a Low Voltage Detector (LVD) circuit on the input voltage that powers PORTA. The LVD monitors that power supply voltage by comparing it to a programmable threshold. When input voltage powering PORTA drops below the threshold, the user has the option of generating an LVD reset or an LVW interrupt. The LVD circuit for this power supply is ON by default. The user can disable the LVD through software.

30.1.3.3.2 High Voltage Detect

This device integrates a High Voltage Detector (HVD) circuit on the input voltage that powers PORTA. The HVD monitors that power supply voltage by comparing it to a programmable threshold. When the input voltage powering PORTA rises above the threshold, the user has the option of generating an HVD reset or an HVW interrupt. The HVD circuit for this power supply is OFF by default. The user can enable the HVD through software.

30.1.4 SC[ISO_CLR] bits

Each bit in the SC[ISO_CLR] field controls the ISO for one of the chip LV power domains:

- Bit 16 - Core Main domain
- Bit 17 - Core Wake domain
- Bit 18 - Core Radio domain

Refer to Power domains for more details.

30.1.5 EVD_CFG[EVDISO], EVD_CFG[EVDLPISO], and EVD_CFG[EVDSTAT] fields

Each bit of the EVDISO, EVDLPISO, and EVSTAT fields corresponds to one of the IO or analog supplies.

- [0] - VDD_IO_ABC
- [1] - VDD_IO_D
- [2] - VDD_ANA

30.1.6 SRAMCTL[VSM] field

For this device, the VSM has only two options.

- [01b] - SRAM configured for 1.0 V operation and the values in SRAM_TMTR1 is loaded for the read/write timing margin
- [10b] - SRAM configured for 1.1 V operation and the values in SRAM_TMTR2 is loaded for the read/write timing margin

Follow the steps below to change the SRAM settings, refer to Active mode voltage updates for more details.

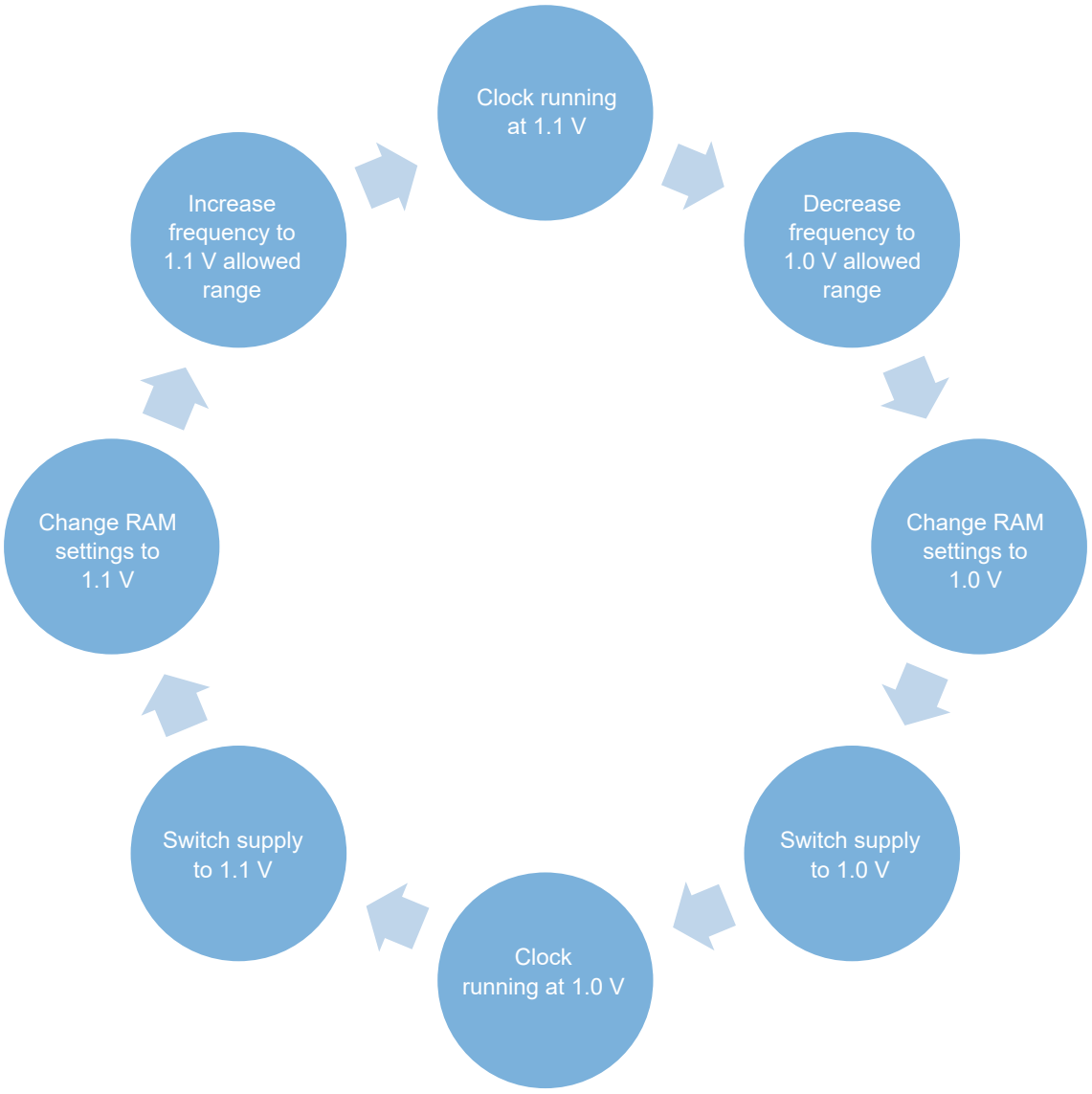


Figure 84. SRAM settings change steps

30.1.7 LP_CFG[IO_HVDE] field

If the LP_CFG[IO_HVDE] is set to 1, it monitors VDD_IO_ABC on PORTA, PORTB and PORTC.

30.1.8 DCDC pulsed mode clocking

DCDC can optionally enter in DCDC pulsed mode. In DCDC pulsed mode, the DCDC refresh period is based on a clock counter which is feed by the 32K_CLK clock in this device.

30.2 Overview

SPC contains and controls the following components:

- Regulator for SRAM domain providing the retention voltage to SRAM array in low power modes.
- Two low-drop-out (LDO) voltage regulators (LDO_CORE and LDO_SYS)

- One DCDC used for regulating system, core, and radio power
- Circuits that monitor and assure correct voltage levels:
  - Power-on reset (POR)
  - Low-voltage detect (LVD)
  - Analog glitch detector
  - High-voltage detect (HVD)

SPC turns these components on and off, and switches them to different power mode levels based on power-mode change requests from each chip power domain.

30.2.1 Block diagram

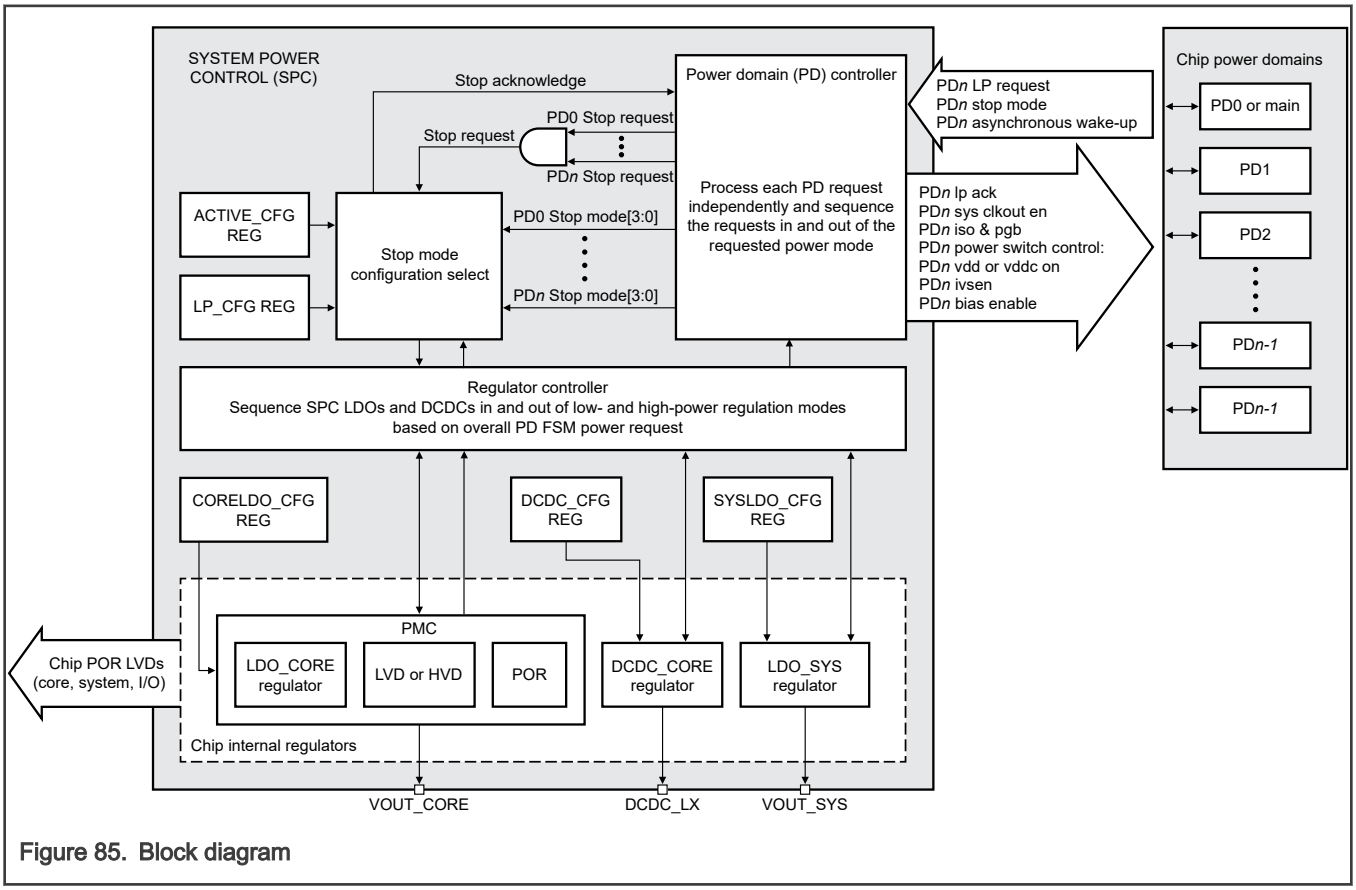


Figure 85. Block diagram

30.2.2 Features

- Selectable core internal voltage regulator (LDO_CORE or DCDC)
- Selectable system internal voltage regulator (1.8 V LDO_SYS)
- Radio voltage regulator (1.8 V LDO_SYS or 1.8 V DCDC)
- Active POR providing brown-out detect
- Low-voltage detect
- High-voltage detect
- Core power gate control
- Analog glitch detector

30.3 Functional description

30.3.1 Power mode transitions

Figure 86 shows the power mode state transitions available for each power-down domain. A POR or LVD reset initially returns the power-down domains to ACTIVE state.

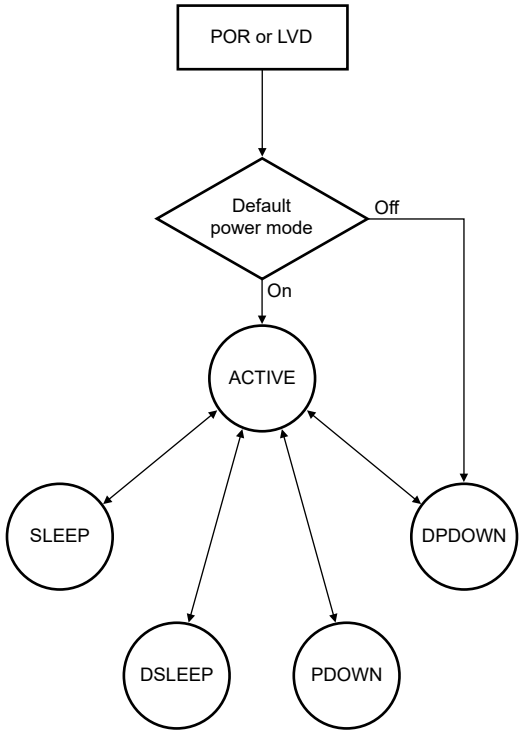


Figure 86. Power mode state diagram

SPC allows each power domain to enter or exit low-power modes independently of the other. You must ensure that any common system resources (for example, clock sources) are always available whenever required for a power-domain current power mode. For example, if a clock source in power domain 0 drives power domain 1, you must ensure that power domain 0 does not enter a low-power mode, because that would disable the clock source.

Figure 87 defines the low-power entry and exit flow for each of the SPC power-down domains.

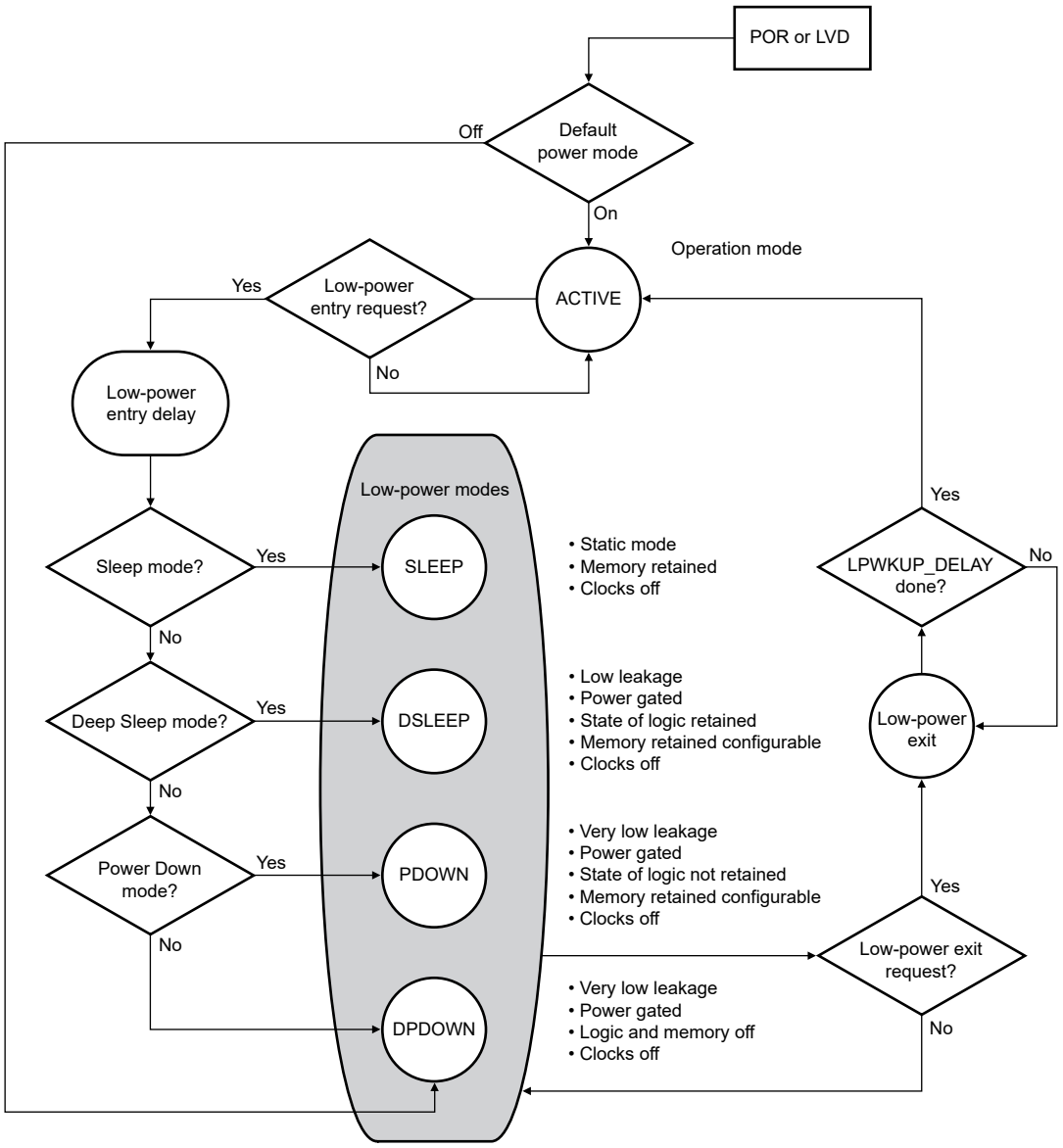


Figure 87. SPC regulator power mode state diagram

NOTE

This section mentions the power modes supported by the module. For the power modes supported on your device, see the chip-specific Power management chapter.

30.3.2 Active mode voltage updates

This section describes voltage and frequency changes in Active mode.

The active mode voltage can also be set by High Power Mode Configuration (HP_CFG). HP_CFG will be selected to set the active mode voltage level when in active mode and if HP_CNFG_CTRL[HP_REQ_EN] is enabled and if any of the following conditions are true:

- HP_CNFG_CTRL[OVERRIDE_EN] = 0 and the external HP request is asserted by the secondary core domain.
- HP_CNFG_CTRL[OVERRIDE_EN] = 1 and HP_CNFG_CTRL[OVERRIDE_SEL] = 1.

You can alter the operating voltage and frequency during Active mode to optimize power consumption depending on the application's performance requirements.

When increasing voltage and frequency in Active mode, you must perform the following steps:

1. Increase voltage to a new level (ACTIVE_CFG[CORELDO_VDD_LVL] and/or ACTIVE_CFG[DCDC_VDD_LVL]).
2. Wait for voltage change to complete (SC[BUSY] = 0).
3. Configure flash memory to support higher voltage level and frequency (FMU_FCTRL[RWSC].
4. Configure SRAM to support higher voltage levels (SRAMCTL[VSM]).
5. Request SRAM voltage update (write 1 to SRAMCTL[REQ]).
6. Wait for SRAM voltage change to complete (SRAMCTL[ACK] = 1).
7. Clear request for SRAM voltage change (write 0 to SRAMCTL[REQ]).
8. Increase frequency to a new level (for example, SCG_RCCR).
9. You can continue execution.

When decreasing voltage and frequency in Active mode perform the following steps:

1. Decrease frequency to a new level (for example, SCG_RCCR).
2. Configure flash memory to support lower voltage level and frequency (FMU_FCTRL[RWSC].
3. Configure SRAM to support lower voltage levels (SRAMCTL[VSM]).
4. Request SRAM voltage update (write 1 to SRAMCTL[REQ]).
5. Wait for SRAM voltage change to complete (SRAMCTL[ACK] = 1).
6. Clear request for SRAM voltage change (write 0 to SRAMCTL[REQ]).
7. Decrease voltage to a new level (ACTIVE_CFG[CORELDO_VDD_LVL] and/or ACTIVE_CFG[DCDC_VDD_LVL]).
8. Wait for voltage change to complete (SC[BUSY] = 0).
9. You can continue execution.

30.3.3 Low-Power Request (LPREQ) pin

The LPREQ pin asserts after low-power entry and negates after low-power wakeup.

The pin is intended to control external switches (for example, if certain power supply rails are switched off in the low-power mode).

SPC controls the state of the LPREQ pin based on how you configure Low-Power Request Configuration (LPREQ_CFG). You control the LPREQ pin in Active mode. SPC controls the pin when the chip transitions from Active to a low-power mode, and after wake-up from these power modes.

NOTE

If the power supply rails are switched off externally, software must configure the internal isolation of these power domains using External Voltage Domain Configuration (EVD_CFG).

To use the LPREQ pin:

1. Specify the pin polarity (LPREQ_CFG[LPREQPOL]).
2. Enable the pin output (LPREQ_CFG[LPREQOE]).
3. Configure the pin mux for the desired pin using the PORT PCR registers.
4. If switch needs additional time after wake-up, use Low Power Wake-Up Delay (LPWKUP_DELAY) to extend the wake-up time.

30.3.4 DCDC

DCDC is a hysteretic converter. It is active during a burst period, when it switches the output to charge to a specific voltage. Then DCDC stops switching for a quiet period until the output voltage drops to a lower level, and it does another active burst.

30.3.4.1 DCDC drive strength

DCDC supports multiple drive strength options that you can choose:

- Normal
- Low
- Pulse refresh

The normal and low drive strengths differ in these DCDC characteristics:

- Maximum load current
- Quiescent current
- Transient response

With low drive strength, you can benefit from the lower quiescent current if:

- The load current is below the I_{LOAD} specification in the data sheet.
- Your application can tolerate the slower transient response.

Be careful when choosing low drive strength. If you exceed I_{LOAD} or require faster transient response, you must use normal drive strength. Furthermore, most other DCDC features are only available with normal drive strength.

Pulse-refresh drive strength offers even lower quiescent current in low-power modes, by deactivating DCDC when not active. This strength has an active pulsing period where DCDC charges the output voltage. Then DCDC deactivates for a configurable amount of time. No analog comparator is powered to monitor the DCDC output voltage. Instead, this drive strength is time-based using an SPC timer where DCDC_BURST_CFG[PULSE_REFRESH_CNT] specifies the timer period. Every period, SPC enables DCDC to charge the voltage again. When DCDC is off, no voltage regulation occurs. You must specify DCDC_BURST_CFG[PULSE_REFRESH_CNT] to manage the voltage drop on the DCDC capacitor and avoid a brownout condition.

30.3.4.2 DCDC burst

You can control and monitor the DCDC burst. Synchronizing with the quiet period between bursts can be valuable for noise-sensitive applications—for example, during a high-resolution ADC measurement or a radio transmission.

Before requesting a burst to start, clear the DCDC_BURST_CFG[BURST_ACK] flag. Then, your firmware can request a burst by writing 1 to DCDC_BURST_CFG[BURST_REQ]. SPC sets the DCDC_BURST_CFG[BURST_ACK] flag when the burst has completed and DCDC enters a quiet period.

SPC also provides signals to synchronize the burst activity with other peripherals in the chip. If DCDC_BURST_CFG[EXT_BURST_EN] = 1 before a burst starts, the output DCDC_BURST_TRIG_PULSE signal asserts when a burst completes, and can trigger other actions such as an ADC conversion. Another SPC output signal is DCDC_BURST_ACTIVE, which EXT_BURST_EN does not gate. DCDC_BURST_ACTIVE can also trigger other peripherals such as a timer. You can use this signal to estimate the power that DCDC delivers.

When bursting, you can control the DCDC switching center frequency with the frequency-stabilization feature. DCDC_CFG[FREQ_CNTRL_ON] enables this feature, and when the feature is enabled, DCDC_CFG[FREQ_CNTRL] controls it. The main parameters that control the period between active bursts and quiet period are:

- Load current
- External capacitor
- DCDC hysteresis

NOTE

Writing 1 to DCDC_CFG[FREQ_CNTRL_ON] stabilizes the frequency by limiting DCDC current. See the DCDC I_{LOAD} maximum limit in the data sheet for this mode.

30.3.4.3 DCDC voltage changes

To support power optimization of applications, DCDC can provide multiple output voltages.

Two separate registers, which specify Active mode output and Low-Power mode output, independently control the DCDC output voltage. Whenever an SoC mode change occurs, by using two independent registers, there is no need to reconfigure the output voltage. ACTIVE_CFG[DCDC_VDD_LVL] controls the DCDC output voltage when the SoC mode is Active or in Sleep mode. The DCDC drive strength is normal (ACTIVE_CFG[DCDC_VDD_DS] = 10b). LP_CFG[DCDC_VDD_LVL] controls the DCDC output voltage when the SoC mode is in a Low-Power mode (i.e., not Active or Sleep mode) or the DCDC drive strength is low (ACTIVE_CFG[DCDC_VDD_DS] = 01b) and the SoC is in an Active or Sleep mode.

When Active Power Mode Configuration (ACTIVE_CFG) controls the output, DCDC output options present:

- 1.25 V
- 1.35 V
- 1.5 V
- 1.8 V
- 2.5 V

When the device is in active mode, DCDC Configuration (DCDC_CFG) can support an additional DCDC output voltage option used for radio transmission up to 10 dBm when it supplies VDD_RF.

See Active mode voltage updates to change the DCDC output level in Active mode.

When Low-Power Mode Configuration (LP_CFG) controls the output, DCDC output options present:

- 1.25 V
- 1.35 V
- 1.5 V
- 1.8 V

When entering SoC power-down mode with IVS disabled, SPC supports only the 0.7 V option. You have to configure LPWKUP_DELAY to the correct value. In Deep Sleep mode, you must also align the output voltage with the clock frequencies of any clocks kept alive in the Low-Power mode. If you keep some clock sources active, ensure to leave the bandgap enabled.

To change the DCDC output level in Low-Power mode, follow this procedure:

1. Configure LP_CFG[DCDC_VDD_LVL] to desired level.
2. Configure LP_CFG[DCDC_VDD_DS] = 0x1.
3. Configure ACTIVE_CFG[DCDC_VDD_LVL] to same level as in configure LP_CFG[DCDC_VDD_LVL].

30.3.4.4 DCDC voltage ramping up control

DCDC integrates a voltage ramp control feature that inserts a delay in the DCDC voltage update when DCDC is transitioning to a higher voltage. This helps to control the DCDC max transient current during the transition, decreasing the current peak due to DCDC capacitor recharge. This feature is only available when switching DCDC voltage to a higher voltage level in active modes, when the DCDC Drive Strength is set to Normal.

DCDC ramp control feature can be enabled and adjusted depending on the application requirements. DCDC_CFG[RAMP_CNTRL_EN] provides an enable control of the feature, and DCDC_CFG[RAMP_CNTRL] can adjust the ramp rate during the voltage transition.

30.3.5 Clocking

Table 238. Clocks

SPC component:	Clock source
Registers and logic	Slow bus clock
Delay counters	10 MHz internal clock

SPC uses the internal clock that PMC analog block generates to sequence the system regulator and chip power domains in and out of different power modes. This clock has a frequency of 10 MHz. SPC automatically enables the clock when it detects a power mode change, including entry into low-power modes and exit from low-power modes of any of the system power domains, or configuration changes to either Active Power Mode Configuration (ACTIVE_CFG) , or High Power Mode Configuration (HP_CFG), or Low-Power Mode Configuration (LP_CFG). This clock cannot run unless the PMC bandgap is up and enabled. Once SPC completes all transactions and is not busy, that is, SC[BUSY] = 0, this clock will turn off synchronously.

30.3.6 Reset

30.3.6.1 Reset sources

30.3.6.1.1 Power-on reset (POR)

When you initially apply power to the chip, or the supply voltage is below the POR falling threshold, the POR circuit triggers the POR condition. The POR condition asserts a cold reset in all power domains.

30.3.6.1.2 Low-voltage detect (LVD)

SPC supports the following LVD circuits:

- Core VDD
- System VDD
- I/O VDD

Each of these circuits is enabled by default and keeps the chip in reset until each of these supply voltages rises above the LVD rising threshold. Enabling any of the LVD circuits triggers an LVD reset condition if the corresponding supply voltage is below the LVD falling threshold.

The LVD reset condition asserts a cold reset in all power domains. The LVD- and HVD-detection logic is the only logic that HVD and LVD resets do not affect. The corresponding status fields in Voltage Detect Status (VD_STAT) become 1 after the corresponding LVD reset condition occurs.

30.3.6.1.3 High-voltage detect (HVD)

SPC supports the following HVD circuits:

- Core VDD
- System VDD
- I/O VDD

Each of these circuits is enabled by default and triggers an HVD reset condition if the corresponding supply voltage is above the HVD threshold.

Any of these reset condition asserts a cold reset in all power domains. The LVD- and HVD-detection logic is the only logic that HVD and LVD resets do not affect. The corresponding status fields in Voltage Detect Status (VD_STAT) become 1 after the corresponding HVD reset condition occurs.

30.3.6.1.4 Glitch detect

This chip guards against short pulses on the core VDD and VSS. This security feature can detect glitches due to a hacking attack and alerts the core to reset the chip or generate an interruptn operation.

After power-on reset, the core VDD glitch-detect system is enabled. When the system is in Active mode, use ACTIVE_CFG[GLITCH_DETECT_DISABLE] to enable or disable the glitch-detect system. When the system is in Low-Power mode, use LP_CFG[GLITCH_DETECT_DISABLE] to enable or disable the glitch-detect system.

The glitch-detect system uses a 4-bit ripple counter to monitor the quantity of detected glitches. The VDD_CORE_GLITCH_DETECT_SC[GLITCH_DETECT_FLAG] status flags capture the state of each of these counters.

NOTE

The chip has analog voltage glitch detector (aGDET) that enhances protection against voltage manipulation. After the chip is out of reset, the NXP FMU logic configures aGDET to reset the chip when voltage manipulation is detected. The aGDET is validated on silicon across multiple process, voltage, and temperature corners by activating a large number of possible data paths. To avoid false detections due to unforeseen environment or application behavior, NXP recommends disabling aGDET in the early start-up code. You can also configure hardware interrupt for aGDET and handle action in the interrupt handler by disabling default reset actions. aGDET can be used by the application when security-critical operations, for example, cryptographic operation using private or symmetric keys (digital signature, encryption, decryption, and so on) or sensitive decision-making process. However, you must ensure that the system remains free from false detections in those circumstances. See the SDK example in this document for details on sensor usage.

30.3.6.2 Reset sequence

The following steps occur as part of the POR, LVD, or HVD sequence:

1. The RESET_b pin deasserts.
2. The internal reset signals assert.
3. The POR or LVD signals negate.
4. System clocks are enabled.

30.3.7 Interrupts

SPC generates a single interrupt. The trigger for this interrupt comes from:

- Any of the LVD, HVD, or glitch-detect circuits when they are not configured for reset and their corresponding HVDIE or LVDIE register.
- The Interrupt Enable (IE) register (for the glitch-detect case).

30.4 External signals

Signal	Description	Direction
LPREQ	Low-power request pin used to signal external power-management circuits for a change in supply voltage	Output
VOUT_CORE	Output of the LDO_CORE regulator	Output
VOUT_SYS	Output of the LDO_SYS regulator	Output
DCDC_LX	Output of the DCDC_CORE regulator	Output

30.5 Initialization

To initialize SPC with LDO_CORE off, write 0 to CNTRL[CORELDO_EN].

To initialize SPC with LDO_SYS off, write 0 to CNTRL[SYSLDO_EN].

To initialize SPC with DCDC_CORE off, write 0 to CNTRL[DCDC_EN].

Except for the above, SPC does not require any special initialization.

30.6 Application information

To change DCDC level in Low-Power mode:

1. Configure LP_CFG[DCDC_VDD_LVL] to desired level.
2. Configure LP_CFG[DCDC_VDD_DS] = 0x1
3. Configure ACTIVE_CFG[DCDC_VDD_LVL] to same level programmed in Configure LP_CFG[DCDC_VDD_LVL]

To disable Bandgap in Active mode:

1. Disable all LVD's and HVD's in ACTIVE_CFG[29:24]= 0x00
2. Disable Glitch Detect, ACTIVE_CFG[GLITCH_DETECT_DISABLE] = 1
3. Configure LDO's and DCDC to Low Drive Strength in ACTIVE_CFG register
4. Configure ACTIVE_CFG[BGMODE] = 0x0

To disable Bandgap in Low-Power mode:

1. Disable all LVD's and HVD's in LP_CFG[29:24]= 0x00
2. Disable Glitch Detect, LP_CFG[GLITCH_DETECT_DISABLE] = 1
3. Configure LDO's and DCDC to Low Drive Strength in LP_CFG register
4. Configure LP_CFG[BGMODE] = 0x0

30.7 SPC register descriptions

Different chip reset types affect the reset of different SPC registers. Each register description provides details. See the Reset chapter for more information about the types of reset on this chip.

You may use only 32-bit writes for any writable SPC registers. 8-bit or 16-bit writes cause a transfer error.

30.7.1 SPC memory map

SPC0 base address: 4001_6000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	0000_0000h
10h	Status Control (SC)	32	RW	8000_0000h
14h	SPC Regulator Control (CNTRL)	32	RW	0000_0007h
1Ch	Low-Power Request Configuration (LPREQ_CFG)	32	RW	0000_0000h
20h	SPC Configuration (CFG)	32	RW	0000_0000h
30h - 38h	SPC Power Domain Mode Status (PD_STATUS0 - PD_STATUS2)	32	RW	0000_0000h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
40h	SRAM Control (SRAMCTL)	32	RW	0000_0001h
60h	High Power Config Control (HP_CNFG_CTRL)	32	RW	0000_0000h
E0h	General Purpose Wake-up (WAKEUP)	32	RW	0000_0000h
100h	Active Power Mode Configuration (ACTIVE_CFG)	32	RW	3F10_0E15h
108h	Low-Power Mode Configuration (LP_CFG)	32	RW	0002_1104h
110h	High Power Mode Configuration (HP_CFG)	32	RW	3F10_0215h
120h	Low Power Wake-Up Delay (LPWKUP_DELAY)	32	RW	0000_0000h
124h	Active Voltage Trim Delay (ACTIVE_VDELAY)	32	RW	0000_00C8h
130h	Voltage Detect Status (VD_STAT)	32	RW	0000_0000h
134h	Core Voltage Detect Configuration (VD_CORE_CFG)	32	RW	0000_0001h
138h	System Voltage Detect Configuration (VD_SYS_CFG)	32	RW	0000_0001h
13Ch	IO Voltage Detect Configuration (VD_IO_CFG)	32	RW	0000_0101h
140h	External Voltage Domain Configuration (EVD_CFG)	32	RW	0007_0000h
144h	Glitch Detect Status Control (GLITCH_DETECT_SC)	32	RW	0000_013Fh
300h	LDO_CORE Configuration (CORELDO_CFG)	32	RW	0000_0046h
400h	LDO_SYS Configuration (SYSLDO_CFG)	32	RW	0008_0111h
500h	DCDC Configuration (DCDC_CFG)	32	RW	0000_0000h
504h	DCDC Burst Configuration (DCDC_BURST_CFG)	32	RW	0140_0000h

30.7.2 Version ID (VERID)

Offset

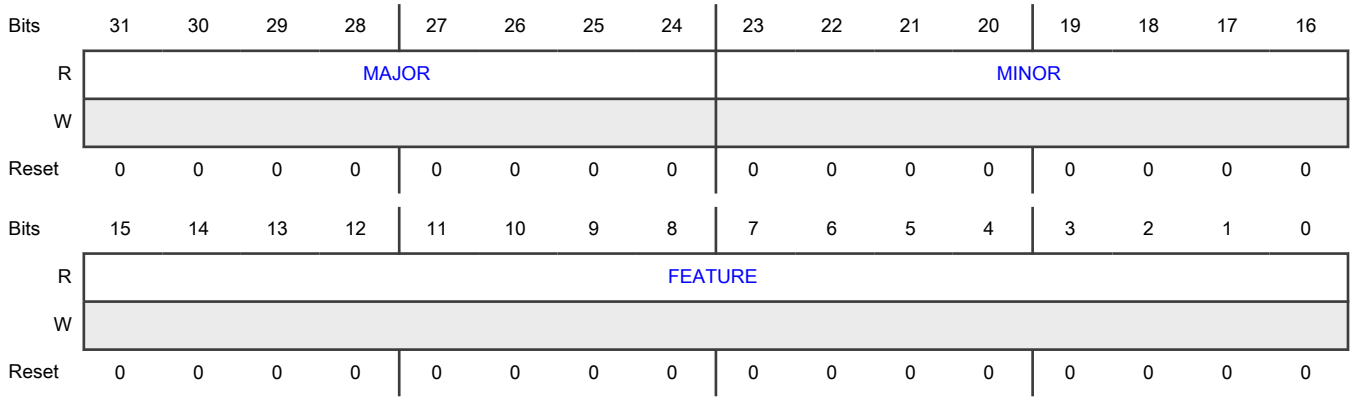
Register	Offset
VERID	0h

Function

Indicates:

- The version integrated for this instance on the chip.
- Inclusion or exclusion of several optional features.

Diagram



Fields

Field	Function
31-24 MAJOR	Major Version Number
23-16 MINOR	Minor Version Number
15-0 FEATURE	Feature Specification Number Indicates the feature set number. 0000_0000_0000_0000b - Standard features All other values are reserved.

30.7.3 Status Control (SC)

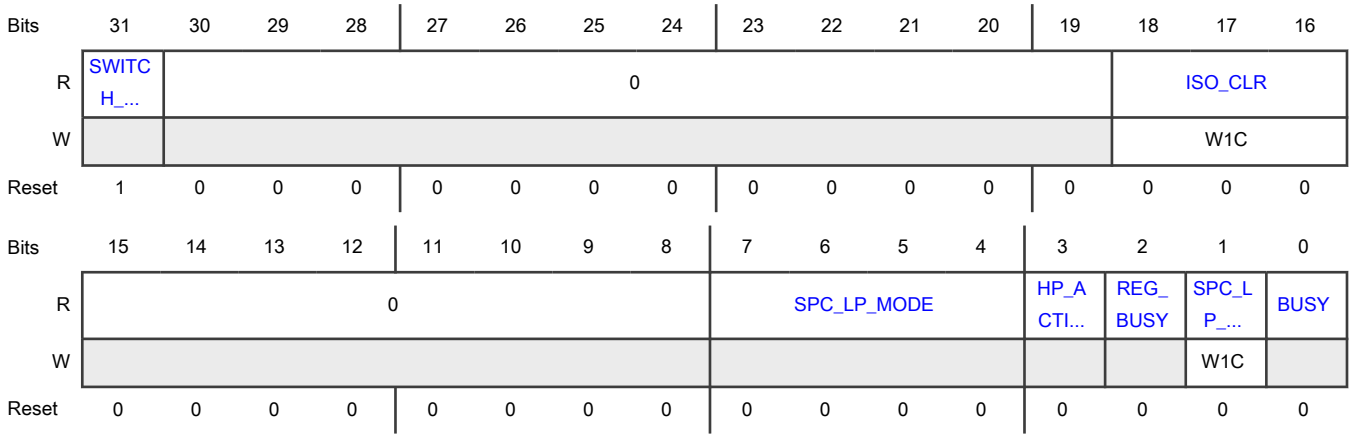
Offset

Register	Offset
SC	10h

Function

Indicates the current SPC status.

Diagram



Fields

Field	Function
31 SWITCH_STATE	Power Switch State Indicates the power switch state. 0b - Off 1b - On
30-19 —	Reserved
18-16 ISO_CLR	Isolation Clear Flags Indicates whether certain peripherals and I/O pads are in a latched state as a result of having been in DPDOWN mode. Each bit of this field is a flag associated with a module on this chip. See the chip-specific SPC information for the module-bit association. For each flag: • A value of 0 means that peripherals and I/O pads are in the normal run state. • A value of 1 means that peripherals and I/O pads can retain their state in their power domain. If a flag in this field is 1, writing 1 to that flag clears the flag and releases the I/O pads and peripherals to their normal run-mode state. After recovering from a power-down mode, you must restore the chip configuration before clearing a flag in this field. In particular, you must restore the pin configuration for enabled WUU wake-up to avoid any WUU flag from being falsely set when the associated ISO_CLR flag is cleared. This field resets after a system reset(not Deep Power Down wakeup reset).
15-8 —	Reserved
7-4	Power Domain Low-Power Mode Request Indicates the last low-power mode that the power domain requested.

Table continues on the next page...

Table continued from the previous page...

Field	Function
SPC_LP_MODE	0000b - Sleep mode with system clock running 0001b - SLEEP with system clock off 0010b - DSLEEP with system clock off 0100b - PDOWN with system clock off 1000b - DPDOWN with system clock off
3 HP_ACTIVE	HP_CFG Select Status Flag Indicates which active CFG register (HP_CFG or ACTIVE_CFG) is selected as the active configuration register. 0b - ACTIVE_CFG selected 1b - HP_CFG selected
2 REG_BUSY	SPC REG Busy Status Flag Indicates whether SPC is busy updating regulator settings. SPC sets this flag: • When SPC executes any type of regulator settings in Active mode or any of the chip low-power modes. • Due to LP_CFG[CORELDO_VDD_LVL] and LP_CFG[DCDC_VDD_LVL] changes while in Active mode. **NOTE** Wait until this flag is clear before changing power-mode configuration registers. 0b - Not busy 1b - Busy
1 SPC_LP_REQ	SPC Power Mode Configuration Status Flag Indicates when all power-down domains requested low-power mode and SPC entered a low-power state. **NOTE** This field behaves differently for register reads and writes. When reading 0b - SPC is in Active mode; the ACTIVE_CFG register has control 1b - All power domains requested low-power mode; SPC entered a low-power state; power-mode configuration based on the LP_CFG register When writing 0b - No effect 1b - Clear the flag
0	SPC Busy Status Flag

Table continues on the next page...

Table continued from the previous page...

Field	Function
BUSY	Indicates whether SPC is busy. SPC sets this flag: • When SPC executes any type of power mode transition in Active mode or any of the chip low-power modes. • Due to LP_CFG[CORELDO_VDD_LVL] and LP_CFG[DCDC_VDD_LVL] changes while in Active mode. **NOTE** Wait until this flag is clear before changing power-mode configuration registers. 0b - Not busy 1b - Busy

30.7.4 SPC Regulator Control (CNTRL)

Offset

Register	Offset
CNTRL	14h

Function

Enables the SPC regulators.

You can write to the fields in this register only one time.

The register resets only after a POR, LVD, or HVD event.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												0	DCDC_EN	SYSLDO_...	CORELDO...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1

Fields

Field	Function
31-4 —	Reserved
3 —	Reserved
2 DCDC_EN	DCDC_CORE Regulator Enable 0b - Disable 1b - Enable
1 SYSLDO_EN	LDO_SYS Regulator Enable 0b - Disable 1b - Enable
0 CORELDO_EN	LDO_CORE Regulator Enable 0b - Disable 1b - Enable

30.7.5 Low-Power Request Configuration (LPREQ_CFG)

Offset

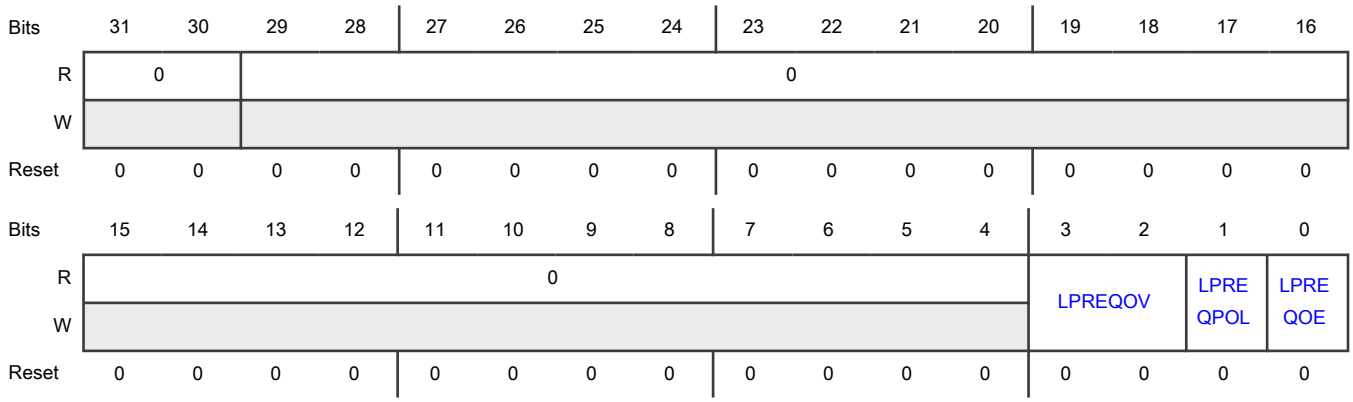
Register	Offset
LPREQ_CFG	1Ch

Function

Configures the low-power output request pin.

The register resets only after a POR, LVD, or HVD event.

Diagram



Fields

Field	Function
31-30 —	Reserved
29-4 —	Reserved
3-2 LPREQOV	Low-Power Request Output Override Forces the low-power request pin high. 00b - Not forced 01b - Reserved 10b - Forced low (ignore LPREQPOL settings) 11b - Forced high (ignore LPREQPOL settings)
1 LPREQPOL	Low-Power Request Output Pin Polarity Control Controls the true polarity of the low-power request output pin. 0b - High 1b - Low
0 LPREQOE	Low-Power Request Output Enable Enables the low-power request output pin. 0b - Disable 1b - Enable

30.7.6 SPC Configuration (CFG)

Offset

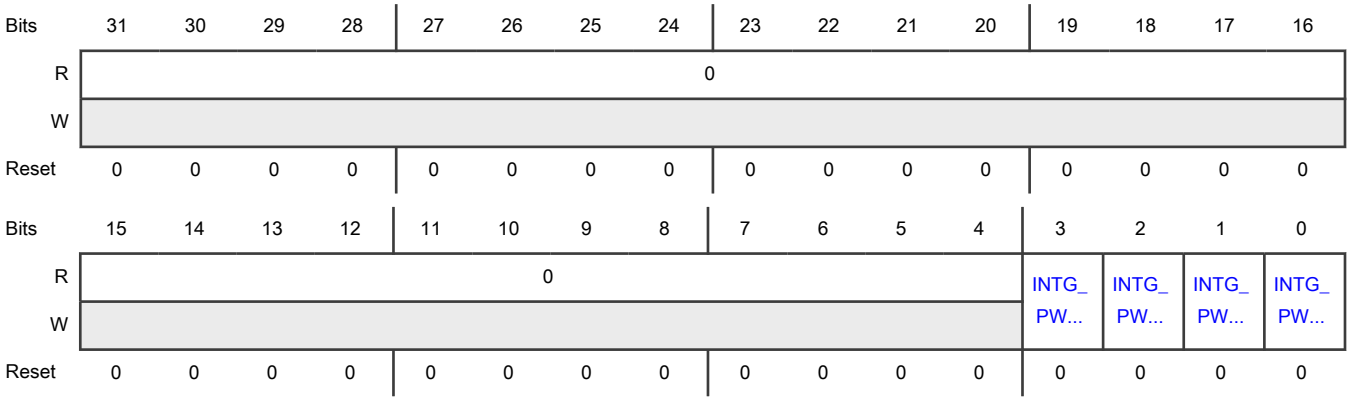
Register	Offset
CFG	20h

Function

Controls the features of the integrated power switch that you can use to gate board-level supplies.

The register resets only after a POR, LVD, or HVD event.

Diagram



Fields

Field	Function
31-4 —	Reserved
3 INTG_PWSWTCH_WKUP_ACTIVE_EN	Integrated Power Switch Wake-up Enable Enables the switch in active mode. When this field is 1, SPC drives a pin in active mode to close the switch. 0b - Disable 1b - Enable
2 INTG_PWSWTCH_SLEEP_ACTIVE_EN	Integrated Power Switch Active Enable Disables the switch in active mode. When this field is 1, SPC drives a pin in active mode to open the switch. 0b - Disable 1b - Enable
1 INTG_PWSWTCH_WKUP_EN	Integrated Power Switch Wake-up Enable Enables the switch after waking up from any low-power mode. When this field is 1, SPC drives a pin during low-power wake-up sequence to close the switch. 0b - Disable 1b - Enable
0 INTG_PWSWTCH_SLEEP_EN	Integrated Power Switch Sleep Enable Disables the switch entering in any low-power mode. When this field is 1, SPC drives a pin during low-power entry sequence to open the switch. 0b - Disable 1b - Enable

30.7.7 SPC Power Domain Mode Status (PD_STATUS0 - PD_STATUS2)

Offset

Register	Offset
PD_STATUS0	30h
PD_STATUS1	34h
PD_STATUS2	38h

Function

Indicates power mode status for each of the SPC power domains. See the chip-specific SPC information to determine which power domains are associated with this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				LP_MODE				0			PD_LP_R...	0			PWR_REQ...
W												W1C				
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-12 —	Reserved
11-8 LP_MODE	Power Domain Low Power Mode Request Indicates the last low-power mode that the power domain requested. 0000b - SLEEP with system clock running 0001b - SLEEP with system clock off 0010b - DSLEEP with system clock off 0100b - PDOWN with system clock off 1000b - DPDOWN with system clock off
7-5	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
4 PD_LP_REQ	Power Domain Low Power Request Flag Set when low power mode was requested by Power Domain since last cleared by software. 0b - Did not request 1b - Requested
3-1 —	Reserved
0 PWR_REQ_STATUS	Power Request Status Flag Indicates whether the power domain requested low-power mode. 0b - Did not request 1b - Requested

30.7.8 SRAM Control (SRAMCTL)

Offset

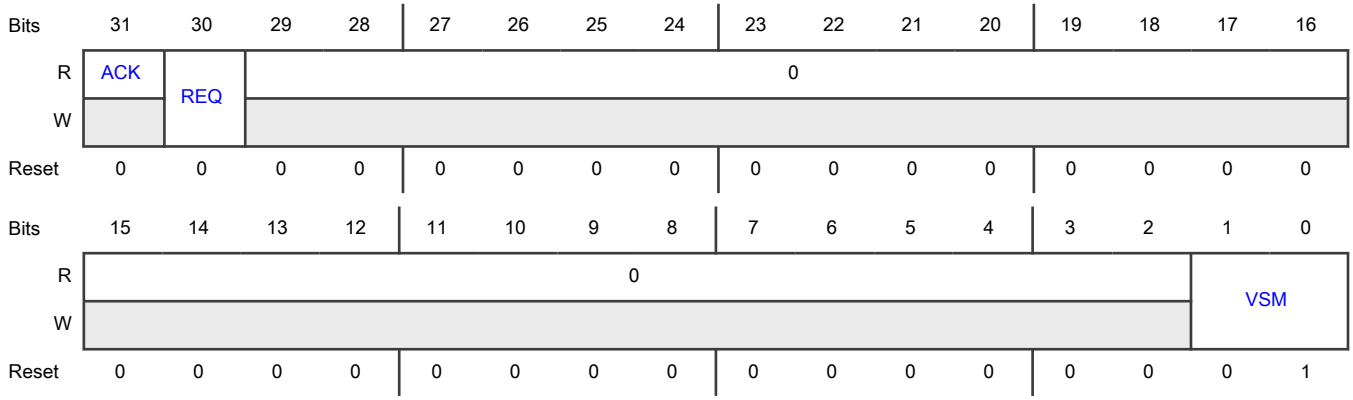
Register	Offset
SRAMCTL	40h

Function

Configures the SRAM timing for different voltage levels.

When transitioning between two voltage levels, you must keep the SRAM timing at the lowest voltage level until the voltage change is complete.

Diagram



Fields

Field	Function
31 ACK	SRAM Voltage Update Request Acknowledge Indicates whether SPC acknowledged the request for an SRAM trim-value change. 0b - Not acknowledged 1b - Acknowledged
30 REQ	SRAM Voltage Update Request Allows you to request an SRAM trim value change. After requesting the change, you must wait for the ACK field to become 1, then write 0 to REQ. 0b - Do not request 1b - Request
29-2 —	Reserved
1-0 VSM	Voltage Select Margin Specifies the operating voltage for the SRAM's read/write timing margin. 00b - Reserved 01b - 1.0 V 10b - 1.1 V 11b - SRAM configured for "1.2" V operation

30.7.9 High Power Config Control (HP_CNFG_CTRL)

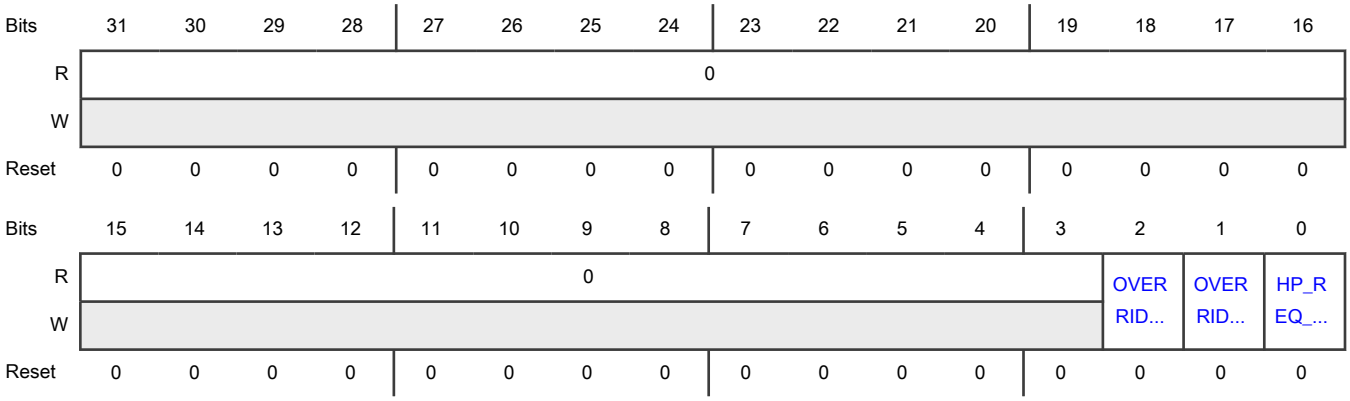
Offset

Register	Offset
HP_CNFG_CTRL	60h

Function

Control the HP_CNFG operation.

Diagram



Fields

Field	Function
31-3 —	Reserved
2 OVERRIDE_SEL	Override Select Overrides the external HP request and forces the HP request to the OVERRIDE_SEL value. **NOTE** OVERRIDE_SEL is ignored if OVERRIDE_EN is set to 0. 0b - Force the HP request to 0 1b - Force the HP request to 1
1 OVERRIDE_EN	Override Enable Overrides the high power request to a value set by the OVERRIDE_SEL 0b - Override Disabled 1b - Override Enabled
0 HP_REQ_EN	High Power Request Enable Enables the high power request and forces SPC to switch the active power configuration from ACTIVE_CFG to HP_CFG when a high power request is detected. **NOTE** 0b - High Power request Disable 1b - High power reqeust Enable

30.7.10 General Purpose Wake-up (WAKEUP)

Offset

Register	Offset
WAKEUP	E0h

Function

Specifies the wake-up value that the boot ROM uses.

This register resets after POR, LVD ,or any system reset except wake-up from Power Down or Deep Power Down modes.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	WAKEUP															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	WAKEUP															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 WAKEUP	Wake-up Specifies the value that the boot ROM uses to quickly restore Cortex-M33 core context or to switch execution to a defined address in the flash memory or SRAM after wake-up.

30.7.11 Active Power Mode Configuration (ACTIVE_CFG)

Offset

Register	Offset
ACTIVE_CFG	100h

Function

Controls the SPC regulators settings in the Active power mode.

Changes to the drive strength or voltage level for any of the LDOs or DCDC sets the SC[BUSY] flag until SPC changes its state to the new value.

NOTE

The LVDE and HVDE fields reset only with a POR. All other fields reset only with a system reset.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		IO_HVDE	SYS_HVDE	CORE_HV...	IO_LVDE	SYS_LVDE	CORE_LV...	Reserved	0	BGMODE		0	LPBUFF_...	0	
W																
Reset	0	0	1	1	1	1	1	1	0	0	0	1	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0		GLITCH_...	DCDC_VDD_LVL		DCDC_VDD_DS		0	SYSLDO_...	0	SYSLDO_...	CORELDO_VDD_LVL		0	CORELDO...
W																
Reset	0	0	0	0	1	1	1	0	0	0	0	1	0	1	0	1

Fields

Field	Function
31-30 —	Reserved
29 IO_HVDE	IO High-Voltage Detection Enable Enables the IO high-voltage detection. When IO_HVDE = 1, you must write a value to BGMODE that enables the bandgap. Only a POR resets this field. This field monitors VDD IO on PORT. See the chip-specific SPC information for port details. 0b - Disable 1b - Enable
28 SYS_HVDE	System High-Voltage Detection Enable Enables the system high-voltage detection. When SYS_HVDE = 1, you must write a value to BGMODE that enables the bandgap. Only a POR resets this field. 0b - Disable 1b - Enable
27 CORE_HVDE	Core High-Voltage Detection Enable Enables the core high-voltage detection. When CORE_HVDE = 1, you must write a value to BGMODE that enables the bandgap. Only a POR resets this field.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Disable 1b - Enable
26 IO_LVDE	IO Low-Voltage Detection Enable Enables the IO low-voltage detection. When IO_LVDE = 1, you must write a value to BGMODE that enables the bandgap. Only a POR resets this field. This field monitors VDD IO on PORT. See the chip-specific SPC information for port details. 0b - Disable 1b - Enable
25 SYS_LVDE	System Low-Voltage Detection Enable Enables the system low-voltage detection. When SYS_LVDE = 1, you must write a value to BGMODE that enables the bandgap. Only a POR resets this field. 0b - Disable 1b - Enable
24 CORE_LVDE	Core Low-Voltage Detection Enable Enables the core low-voltage detection. When CORE_LVDE = 1, you must write a value to BGMODE that enables the bandgap. Only a POR resets this field. 0b - Disable 1b - Enable
23 —	Reserved
22 —	Reserved
21-20 BGMODE	Bandgap Mode Specifies the bandgap mode configuration. SPC forces BGMODE to 01b to enable the bandgap, if: • A write to disable the bandgap is detected while any regulator is in normal drive strength. • Any of the LVD or HVDs are enabled. • VDD CORE glitch detection is enabled.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	00b - Bandgap disabled 01b - Bandgap enabled, buffer disabled 10b - Bandgap enabled, buffer enabled 11b - Reserved
19 —	Reserved
18 LPBUFF_EN	CMP Bandgap Buffer Enable Enables the buffer-stored reference voltage to CMP. 0b - Disable 1b - Enable
17-16 —	Reserved
15 —	Reserved
14-13 —	Reserved
12 GLITCH_DETECT_DISABLE	Glitch Detect Disable Reset on POR only. State of GLITCH_DETECT_DISABLE will be ignored if Bandgap is disabled and Glitch Detect hardware will be forced to OFF state. 0b - Low Voltage Glitch Detect enabled 1b - Low Voltage Glitch Detect disabled
11-10 DCDC_VDD_LVL	DCDC VDD Regulator Voltage Level Specifies the DCDC VDD regulator level. When switching the DCDC drive strength from low to normal, ensure that the DCDC high VDD LVL setting is set to the same level that was set prior to switching the DCDC to low drive strength. Otherwise, if the LVDs are enabled, an unexpected LVD can occur. 00b - Low undervoltage voltage (1.25 V) 01b - Mid voltage (1.35 V) 10b - Normal voltage (1.5 V) 11b - Overdrive voltage (1.8 V)
9-8	DCDC VDD Drive Strength

Table continues on the next page...

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Field	Function
DCDC_VDD_DS	Specifies the DCDC VDD regulator drive strength. If you specify normal drive strength, you must write a value to ACTIVE_CFG[BGMODE] that enables the bandgap. 01b - Low 10b - Normal All other values are reserved.
7 —	Reserved
6 SYSLDO_VDD_LVL	LDO_SYS VDD Regulator Voltage Level Specifies the LDO_SYS VDD regulator level. You must write 0 to SYS_HVDE before writing 1 to SYSLDO_VDD_LVL. The VDD_SYS voltage can only operate at the overdrive voltage for a limited amount of time for the life of the chip. See the chip data sheet for the maximum voltage and time specifications. This is intended only for programming eFuses. 0b - Normal voltage (1.8 V) 1b - Overdrive voltage (2.5 V)
5 —	Reserved
4 SYSLDO_VDD_DS	LDO_SYS VDD Drive Strength Specifies the LDO_SYS VDD regulator drive strength If you specify normal drive strength, you must write a value to ACTIVE_CFG[BGMODE] that enables the bandgap. If you have enabled LVDs or HVDs, and attempt to specify low drive strength, SPC ignores the attempt. SPC forces a normal drive strength when SYSLDO_VDD_LVL = 1. 0b - Low 1b - Normal
3-2 CORELDO_VDD_LVL	LDO_CORE VDD Regulator Voltage Level Selects the LDO_CORE VDD regulator level. If the CORELDO_VDD_DS fields are set to the same value in both the ACTIVE_CFG and LP_CFG registers, the CORELDO_VDD_LVL's in the ACTIVE_CFG and LP_CFG register must be set to the same voltage level settings. You can change the core VDD levels for the LDO_CORE low power regulator only when CORELDO_VDD_DS=1.

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Field	Function
	When switching CORELDO_VDD_DS from low to normal drive strength, ensure the LDO_CORE high VDD LVL setting is set to the same level that was set prior to switching to the LDO_CORE drive strength (CORELDO_VDD_DS). Otherwise, if the LVDs are enabled, an unexpected LVD can occur. 00b - Reserved 01b - Regulate to mid voltage (1.05 V) 10b - Regulate to normal voltage (1.1 V) 11b - Reserved
1 —	Reserved
0 CORELDO_VDD_DS	LDO_CORE VDD Drive Strength Selects the LDO_CORE VDD regulator drive strength **NOTE** When setting CORELDO_VDD_DS to Normal, BGMODE must be programmed to a value that enables the Bandgap. Writes to set drive strength to Low will be ignored if LVD/HVDs are kept enabled. 0b - Low 1b - Normal

30.7.12 Low-Power Mode Configuration (LP_CFG)

Offset

Register	Offset
LP_CFG	108h

Function

Controls the SPC regulator settings in low-power stop modes.

This register resets only after a POR or LVD event.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		IO_HVDE	SYS_HVDE	CORE_HV...	IO_LVDE	SYS_LVDE	CORE_LV...	LP_IREF...	0	BGMODE		0	LPBUFF_...	CORE VDD...	0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0		GLITCH_...	DCDC_VDD_LVL		DCDC_VDD_DS		0	0		SYSLDO_...	CORELDO_VDD_LVL		0	CORE LDO...
W																
Reset	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0

Fields

Field	Function
31-30 —	Reserved
29 IO_HVDE	IO High Voltage Detect Enable This field monitors VDD IO on PORT. For port details, see the chip-specific SPC information. This field resets only after a POR, LVD, or HVD event. When IO_HVDE = 1, you must use LP_CFG[BGMODE] to enable the bandgap. If you enable the bandgap to support voltage detection, the low-power mode Idd increases. 0b - Disable 1b - Enable
28 SYS_HVDE	System High Voltage Detect Enable This field resets only after a POR, LVD, or HVD event. When SYS_HVDE = 1, you must use LP_CFG[BGMODE] to enable the bandgap. If you enable the bandgap to support voltage detection, the low-power mode Idd increases. 0b - Disable 1b - Enable
27 CORE_HVDE	Core High Voltage Detect Enable This field resets only after a POR, LVD, or HVD event. When CORE_HVDE = 1, you must use LP_CFG[BGMODE] to enable the bandgap. If you enable the bandgap to support voltage detection, the low-power mode Idd increases. 0b - Disable 1b - Enable
26 IO_LVDE	IO Low Voltage Detect Enable This field monitors VDD IO on PORT. For port details, see the chip-specific SPC information.

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Field	Function
	This field resets only after a POR, LVD, or HVD event. When IO_LVDE = 1, you must use LP_CFG[BGMODE] to enable the bandgap. If you enable the bandgap to support voltage detection, the low-power mode Idd increases. 0b - Disable 1b - Enable
25 SYS_LVDE	System Low Voltage Detect Enable This field resets only after a POR, LVD, or HVD event. When SYS_LVDE = 1, you must use LP_CFG[BGMODE] to enable the bandgap. If you enable the bandgap to support voltage detection, the low-power mode Idd increases. 0b - Disable 1b - Enable
24 CORE_LVDE	Core Low Voltage Detect Enable This field resets only after a POR, LVD, or HVD event. When CORE_LVDE = 1, you must use LP_CFG[BGMODE] to enable the bandgap. If you enable the bandgap to support voltage detection, the low-power mode Idd increases. 0b - Disable 1b - Enable
23 LP_IREFEN	Low-Power IREF Enable You can disable the low-power IREF only when all power domains are in DPDOWN mode. In all other low-power modes, writing to this field has no effect and the low-power IREF is always enabled. See the chip-specific SPC information for the modules that require the low-power IREF to be enabled in DPDOWN mode when you use the module in DPDOWN mode. 0b - Disable for power saving in Deep Power Down mode 1b - Enable
22 —	Reserved
21-20 BGMODE	Bandgap Mode Specifies the bandgap mode configuration. BGMODE will be set to 01b to keep the Bandgap enabled if a write to disable Bandgap is detected while keeping any of the regulators in normal drive strength or if any of the LVD/HVDs are kept enabled or if VDD CORE glitch detect are kept enabled. 00b - Bandgap disabled 01b - Bandgap enabled, buffer disabled 10b - Bandgap enabled, buffer enabled

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Field	Function
	11b - Reserved
19 —	Reserved
18 LPBUFF_EN	CMP Bandgap Buffer Enable Enables the buffer-stored reference voltage to CMP. The CMP bandgap buffer is automatically disabled and turned off in DPDOWN mode. 0b - Disable 1b - Enable
17 COREVDD_IVS_EN	CORE VDD Internal Voltage Scaling (IVS) Enable Enables the IVS regulator. When enabled, the IVS regulator scales the external input CORE VDD to a lower voltage level to reduce internal leakage during Deep Sleep and Power Down modes. COREVDD_IVS_EN is automatically 0 in SLEEP or DPDOWN modes. CORE VDD can only get IVS in DSLEEP and PDOWN modes. 0b - Disable 1b - Enable
16 —	Reserved
15 —	Reserved
14-13 —	Reserved
12 GLITCH_DETECT_DISABLE	Glitch Detect Disable This field resets only after a POR, LVD, or HVD event. If you have disabled the bandgap, SPC ignores the value of GLITCH_DETECT_DISABLE and deactivates the glitch-detect hardware. 0b - Enable 1b - Disable
11-10 DCDC_VDD_LVL	DCDC VDD Regulator Voltage Level Specifies the DCDC VDD regulator level. 00b - Low undervoltage (1.25 V)

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Field	Function
	01b - Mid voltage (1.35 V) 10b - Normal voltage (1.5 V) 11b - Overdrive voltage (1.8 V)
9-8 DCDC_VDD_DS	DCDC VDD Drive Strength Specifies the drive strength of the DCDC VDD regulator. If you specify normal drive strength, you must write a value to LP_CFG[BGMODE] that enables the bandgap. The DCDC regulator is always turned off and disabled in DPDOWN mode. Pulse Refresh mode is invalid in SLEEP mode. If you have enabled LVDs or HVDs, and attempt to specify low or pulse drive strength, SPC ignores the attempt and forces the normal drive strength. SPC ignores writes to reserved values. 00b - Pulse refresh 01b - Low 10b - Normal 11b - Reserved
7 —	Reserved
6-5 —	Reserved
4 SYSLDO_VDD_DS	LDO_SYS VDD Drive Strength Specifies the drive strength of the LDO_SYS VDD regulator. If you specify normal drive strength, you must write a value to LP_CFG[BGMODE] that enables the bandgap. If you have enabled LVDs or HVDs, and attempt to specify low drive strength, SPC ignores the attempt. 0b - Low 1b - Normal
3-2 CORELDO_VDD_LVL	LDO_CORE VDD Regulator Voltage Level Specifies the LDO_CORE VDD regulator level for low-power sleep modes. If the CORELDO_VDD_DS fields are set to the same value in both the ACTIVE_CFG and LP_CFG registers, the CORELDO_VDD_LVL's in the ACTIVE_CFG and LP_CFG register must be set to the same voltage level settings. You can change the core VDD levels for the LDO_CORE low power regulator only when ACTIVE_CFG[CORELDO_VDD_DS] = 1. So, before entering any of the low-power states (DSLEEP,

Table continues on the next page...

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Field	Function
	PDOWN, DPDOWN) with LDO_CORE low power regulator selected (LP_CFG[CORELDO_VDD_DS] = 0), you must use CORELDO_VDD_LVL to select the correct regulation level during ACTIVE run mode. Updating CORELDO_VDD_LVL sets the SC[BUSY] flag. That flag remains set for at least the total time delay that Active Voltage Trim Delay (ACTIVE_VDELAY) specifies. Before changing CORELDO_VDD_LVL, you must wait until the SC[BUSY] flag clears before entering the selected low-power sleep mode. This ensures the correct core VDD voltage levels are set after the chip is in the chosen mode. When LP_CFG[DCDC_VDD_LVL] is not 00b, you must program LP_CFG[CORELDO_VDD_LVL] to have same value as LP_CFG[DCDC_VDD_LVL], even if LDO_CORE is off. When LP_CFG[DCDC_VDD_LVL] is 00b, you must disable VDD_CORE LVD in Low-Power mode, and LP_CFG[CORELDO_VDD_LVL] can be different with LP_CFG[DCDC_VDD_LVL]. 00b - Reserved 01b - Mid voltage (1.05 V) 10b - Normal voltage (1.1 V) 11b - Reserved
1 ——	Reserved
0 CORELDO_VDD_DS	LDO_CORE VDD Drive Strength Specifies the drive strength of the LDO_CORE VDD regulator. The LDO_CORE regulator is forced to disabled in DPDOWN Sleep mode. If you specify normal drive strength, you must write a value to LP[BGMODE] that enables the bandgap. If you have enabled LVDs or HVDs, and attempt to specify low drive strength, SPC ignores the attempt. 0b - Low 1b - Normal

30.7.13 High Power Mode Configuration (HP_CFG)

Offset

Register	Offset
HP_CFG	110h

Function

Controls the SPC regulators settings in the High Power active mode.

High Power configuration mode is selected as the active configuration register when HP_REQ_EN=1, a high power(HP) request is detected and HP_CNFG_CTRL[OVERRIDE_EN] is not set or when HP_CNFG_CTRL[OVERRIDE_EN] is set and HP_CNFG_CTRL[OVERRIDE_SEL] is set 1.

Changes to the drive strength or voltage level for any of the LDOs or DCDC set SC[BUSY] and SC[REG_BUSY] until SPC changes its state to the new value.

NOTE

The LVDE and HVDE fields reset only with a POR. All other fields reset only with a system reset.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		IO_HVDE	SYS_HVDE	CORE_HV...	IO_LVDE	SYS_LVDE	CORE_LV...	0	0	BGMODE		0	LPBUFF_...	0	
W																
Reset	0	0	1	1	1	1	1	1	0	0	0	1	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0		GLITCH_...	DCDC_VDD_LVL		DCDC_VDD_DS		0	SYSLDO_...	0	SYSLDO_...	CORELDO_VDD_LVL		0	CORELDO...
W																
Reset	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	1

Fields

Field	Function
31-30 —	Reserved
29 IO_HVDE	IO High-Voltage Detection Enable Enables the IO high-voltage detection. When IO_HVDE = 1, you must write a value to BGMODE that enables the bandgap. Only a POR resets this field. Monitors VDD IO on PORT. For port details, see the chip-specific information. 0b - Disable 1b - Enable
28 SYS_HVDE	System High-Voltage Detection Enable Enables the system high-voltage detection. When SYS_HVDE = 1, you must write a value to BGMODE that enables the bandgap. Only a POR resets this field. 0b - Disable 1b - Enable
27 CORE_HVDE	Core High-Voltage Detection Enable Enables the core high-voltage detection. When CORE_HVDE = 1, you must write a value to BGMODE that enables the bandgap.

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Field	Function
	Only a POR resets this field. 0b - Disable 1b - Enable
26 IO_LVDE	IO Low-Voltage Detection Enable Enables the IO low-voltage detection. When IO_LVDE = 1, you must write a value to BGMODE that enables the bandgap. Only a POR resets this field. Monitors VDD IO on PORT. For port details, see the chip-specific information. 0b - Disable 1b - Enable
25 SYS_LVDE	System Low-Voltage Detection Enable Enables the system low-voltage detection. When SYS_LVDE = 1, you must write a value to BGMODE that enables the bandgap. Only a POR resets this field. 0b - Disable 1b - Enable
24 CORE_LVDE	Core Low-Voltage Detection Enable Enables the core low-voltage detection. When CORE_LVDE = 1, you must write a value to BGMODE that enables the bandgap. Only a POR resets this field. 0b - Disable 1b - Enable
23 —	Reserved
22 —	Reserved
21-20 BGMODE	Bandgap Mode Specifies the bandgap mode configuration. BGMODE will be set to 01b to keep the Bandgap enabled if a write to disable Bandgap is detected while keeping any of the regulators in normal drive strength or if any of the LVD/HVDs are kept enabled or if VDD CORE glitch detect are kept enabled. 00b - Bandgap disabled

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Field	Function
	01b - Bandgap enabled, buffer disabled 10b - Bandgap enabled, buffer enabled 11b - Reserved
19 —	Reserved
18 LPBUFF_EN	CMP Bandgap Buffer Enable Enables the buffer-stored reference voltage to CMP. 0b - Disable 1b - Enable
17-16 —	Reserved
15 —	Reserved
14-13 —	Reserved
12 GLITCH_DETECT_DISABLE	VDD Core Glitch Detect Disable Reset on POR only. State of GLITCH_DETECT_DISABLE will be ignored if Bandgap is disabled and Glitch Detect hardware will be forced to OFF state. 0b - VDD Core Low Voltage Glitch Detect enabled 1b - VDD Core Low Voltage Glitch Detect disabled
11-10 DCDC_VDD_LVL	DCDC VDD Regulator Voltage Level Specifies the DCDC VDD regulator level. When switching the DCDC drive strength from low to normal, ensure that the DCDC high VDD LVL setting is set to the same level that was set prior to switching the DCDC to low drive strength. Otherwise, if the LVDs are enabled, an unexpected LVD can occur. 00b - Low undervoltage (1.25 V) 01b - Mid voltage (1.35 V) 10b - Normal voltage (1.5 V) 11b - Overdrive voltage (1.8 V)
9-8	DCDC VDD Drive Strength Specifies the DCDC VDD regulator drive strength.

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Field	Function
DCDC_VDD_DS	If you specify normal drive strength, you must write a value to HP_CFG[BGMODE] that enables the bandgap. If you have enabled LVDs or HVDs, and attempt to specify low drive strength, SPC ignores the attempt. 01b - Low 10b - Normal All other values are reserved.
7 ——	Reserved
6 SYSLDO_VDD_LVL	LDO_SYS VDD Regulator Voltage Level Specifies the LDO_SYS VDD regulator level. You must write 0 to SYS_HVDE before writing 1 to SYSLDO_VDD_LVL. The VDD_SYS voltage can only operate at the overdrive voltage for a limited amount of time for the life of the chip. See the chip data sheet for the maximum voltage and time specifications. This is intended only for programming eFuses. 0b - Normal voltage (1.8 V) 1b - Overdrive voltage (2.5 V)
5 ——	Reserved
4 SYSLDO_VDD_DS	LDO_SYS VDD Drive Strength Specifies the LDO_SYS VDD regulator drive strength If you specify normal drive strength, you must write a value to HP_CFG[BGMODE] that enables the bandgap. If you have enabled LVDs or HVDs, and attempt to specify low drive strength, SPC ignores the attempt. SPC forces a normal drive strength when SYSLDO_VDD_LVL = 1. 0b - Low 1b - Normal
3-2 CORELDO_VDD_LVL	LDO_CORE VDD Regulator Voltage Level Selects the LDO_CORE VDD regulator level. When switching CORELDO_VDD_DS from low to normal drive strength, ensure the LDO_CORE high VDD LVL setting is set to the same level that was set prior to switching to the LDO_CORE drive strength (CORELDO_VDD_DS). Otherwise, if the LVDs are enabled, an unexpected LVD can occur. 00b - Reserved 01b - Regulate to mid voltage (1.05 V)

Table continues on the next page...

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Field	Function
	10b - Regulate to normal voltage (1.1 V) 11b - Reserved
1 —	Reserved
0 CORELDO_VDD_DS	LDO_CORE VDD Drive Strength Selects the LDO_CORE VDD regulator drive strength **NOTE** When setting CORELDO_VDD_DS to Normal, BGMODE must be programmed to a value that enables the Bandgap. Writes to set drive strength to Low will be ignored if LVD/HVDs are kept enabled. 0b - Low 1b - Normal

30.7.14 Low Power Wake-Up Delay (LPWKUP_DELAY)

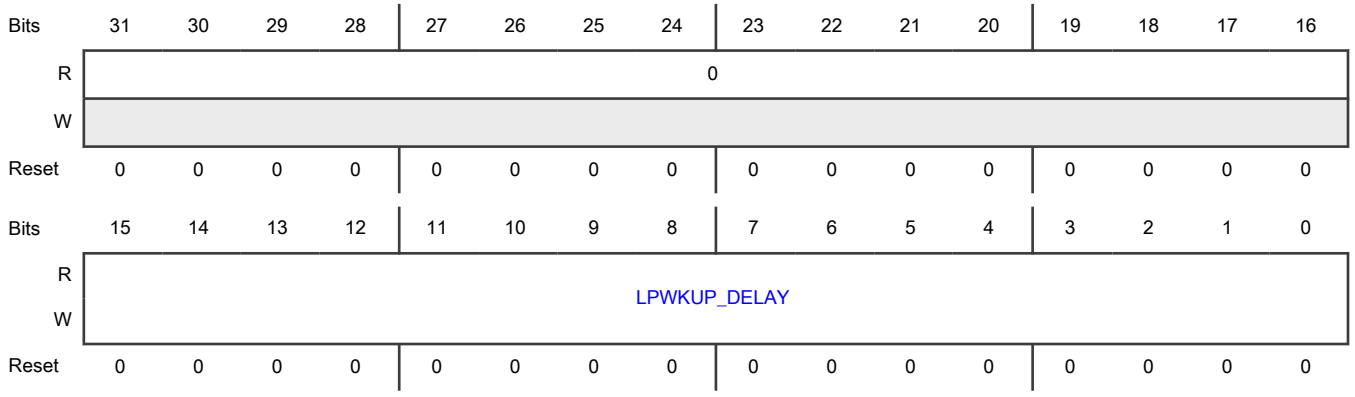
Offset

Register	Offset
LPWKUP_DELAY	120h

Function

Works with the LPREQ pin to extend the wake-up time if the switch needs additional time after wake-up.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 LPWKUP_DELAY	Low-Power Wake-Up Delay Specifies the number of SPC timer clock cycles that SPC waits after exiting low-power modes. This field resets only after a POR, LVD, or HVD event. When voltage levels are not the same between ACTIVE mode and Low Power mode, you must write a nonzero value to this field.

30.7.15 Active Voltage Trim Delay (ACTIVE_VDELAY)

Offset

Register	Offset
ACTIVE_VDELAY	124h

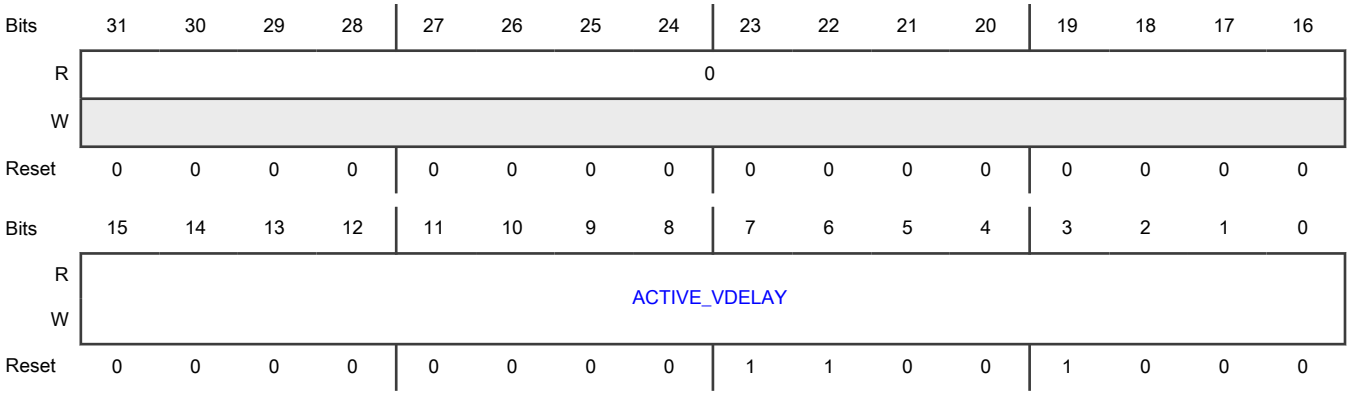
Function

Specifies the delay due to voltage level changes to the regulators in Active mode.

This register resets only after a POR event.

SPC loads the ACTIVE_VDELAY values are loaded from IFR or FUSE after any reset. NXP trims this reset value for the recommended wait time.

Diagram



Fields

Field	Function
31-16	Reserved

Table continues on the next page...

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Field	Function
—	
15-0 ACTIVE_VDELAY	Active Voltage Delay Specifies the number of SPC timer clock cycles that SPC waits when changing the core-regulator voltage level in Active mode.

30.7.16 Voltage Detect Status (VD_STAT)

Offset

Register	Offset
VD_STAT	130h

Function

Displays the LVD or HVD captured for:

- Core VDD.
- System VDD.
- IO VDD.

This register resets only after a POR event.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0									0	0	0	0	0	0	0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0									IOVDD_H...	SYSVDD_...	COREVDD...	0	IOVDD_L...	SYSVDD_...	COREVDD...
W										W1C	W1C	W1C		W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-23 —	Reserved

Table continues on the next page...

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Field	Function
22 —	Reserved
21 —	Reserved
20 —	Reserved
19 —	Reserved
18 —	Reserved
17 —	Reserved
16 —	Reserved
15-7 —	Reserved
6 IOVDD_HVDF	IO VDD HVD Flag Indicates an IO VDD HVD event. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Event not detected 1b - Event detected When writing 0b - No effect 1b - Clear the flag
5 SYSVDD_HVDF	System HVD Flag Indicates a system HVD event. **NOTE** This field behaves differently for register reads and writes.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	When reading 0b - Event not detected 1b - Event detected When writing 0b - No effect 1b - Clear the flag
4 COREVDD_HVDF	Core VDD HVD Flag Indicates a core VDD HVD event. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Event not detected 1b - Event detected When writing 0b - No effect 1b - Clear the flag
3 —	Reserved
2 IOVDD_LVDF	IO VDD LVD Flag Indicates an IO VDD LVD event. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Event not detected 1b - Event detected When writing 0b - No effect 1b - Clear the flag
1 SYSVDD_LVDF	System Low-Voltage Detect Flag Indicates a system LVD event. **NOTE** This field behaves differently for register reads and writes.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	When reading 0b - Event not detected 1b - Event detected When writing 0b - No effect 1b - Clear the flag
0 COREVDD_LVDF	Core Low-Voltage Detect Flag Indicates a core LVD event. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Event not detected 1b - Event detected When writing 0b - No effect 1b - Clear the flag

30.7.17 Core Voltage Detect Configuration (VD_CORE_CFG)

Offset

Register	Offset
VD_CORE_CFG	134h

Function

Provides these functions:

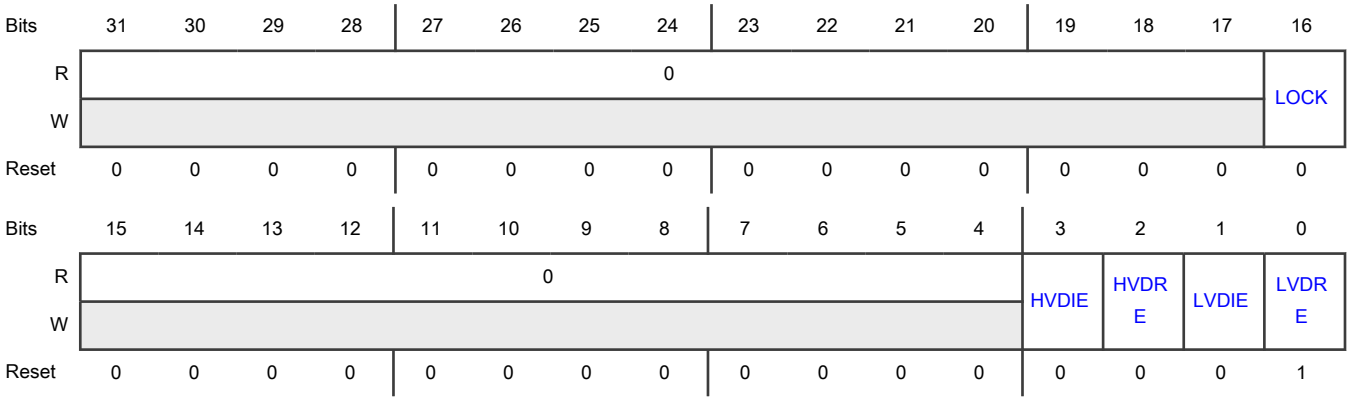
- Configures the low-voltage trip point.
- Enables the core LVD reset and interrupts.

This register resets only after a POR event.

NOTE

If you write 1 to both LVDRE and LVDIE, SPC generates an interrupt after exiting from LVDRE reset. If you don't want this to occur, configure the LVD or HVD so only one is enabled.

Diagram



Fields

Field	Function
31-17 —	Reserved
16 LOCK	Core Voltage Detect Reset Enable Lock Allows writing to the LVDRE and HVDRE fields. 0b - Allow 1b - Deny
15-4 —	Reserved
3 HVDIE	Core VDD HVD Interrupt Enable Enables the Core VDD HVD (COREVDD_HVDF) event to generate a hardware interrupt. If you write 1 to HVDIE with HVD set, SPC automatically generates an HVD interrupt. 0b - Disable 1b - Enable
2 HVDRE	Core VDD HVD Reset Enable Enables the core VDD HVD (COREVDD_HVDF) event to generate a hardware reset. Before writing to this field, you must write 0 to LOCK. 0b - Disable 1b - Enable
1 LVDIE	Core LVD Interrupt Enable Enables the Core LVD (COREVDD_LVDF) event to generate a hardware interrupt. If you write 1 to LVDIE with LVDF set, SPC automatically generates an LVD interrupt.

Table continues on the next page...

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Field	Function
	0b - Disable 1b - Enable
0 LVDRE	Core LVD Reset Enable Enables the core LVD (COREVDD_LVDF) event to generate a hardware reset. Before writing to this field, you must write 0 to LOCK. 0b - Disable 1b - Enable

30.7.18 System Voltage Detect Configuration (VD_SYS_CFG)

Offset

Register	Offset
VD_SYS_CFG	138h

Function

Provides these functions:

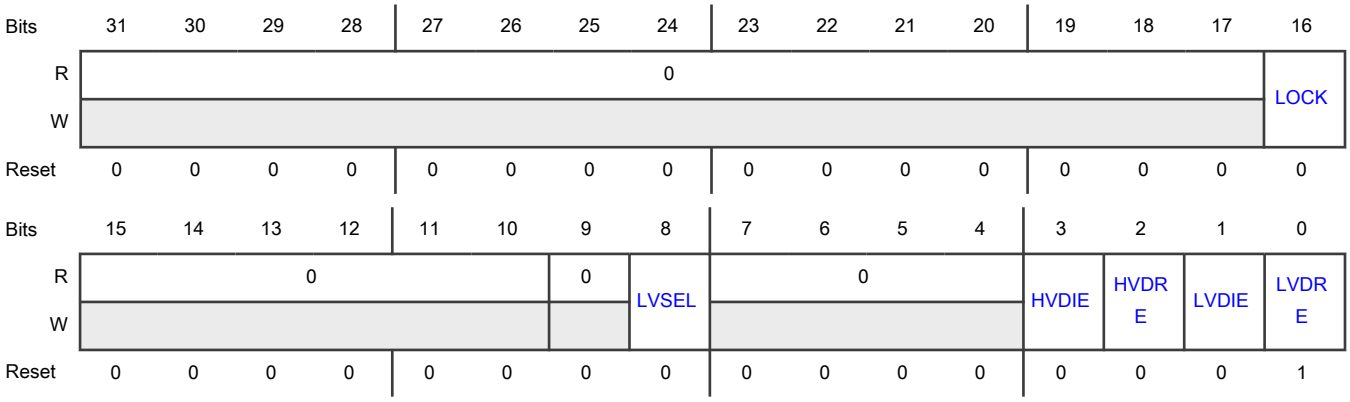
- Configures the low-voltage trip point.
- Enables the system LVD reset and interrupts.

This register resets only after a POR event.

NOTE

If you write 1 to both LVDRE and LVDIE, SPC generates an interrupt after exiting from LVDRE reset. If you don't want this to occur, configure the LVD or HVD so only one is enabled.

Diagram



Fields

Field	Function
31-17 —	Reserved
16 LOCK	System Voltage Detect Reset Enable Lock Allows writing to the LVDRE, HVDRE, and LVSEL fields. 0b - Allow 1b - Deny
15-10 —	Reserved
9 —	Reserved
8 LVSEL	System Low-Voltage Level Select Specifies the LVD trip-point level for the system monitor. See the chip data sheet for the normal- and safe-level values. Before writing to this field, you must write 0 to LOCK. If you want to change LVSEL, you must do this after disabling the LVD reset and interrupt. Otherwise, SPC could generate an LVD due to the LVSEL change. 0b - Normal 1b - Safe
7-4 —	Reserved
3 HVDIE	System HVD Interrupt Enable Enables the system HVD (SYSVDD_HVDF) event to generate a hardware interrupt. If you write 1 to HVDIE with HVDF set, SPC automatically generates an HVD interrupt. 0b - Disable 1b - Enable
2 HVDRE	System HVD Reset Enable Enables the system HVD (SYSVDD_HVDF) event to generate a hardware reset. Before writing to this field, you must write 0 to LOCK. 0b - Disable 1b - Enable
1	System LVD Interrupt Enable Enables the system LVD (SYSVDD_LVDF) event to generate a hardware interrupt.

Table continues on the next page...

Table continued from the previous page...

Field	Function
LVDIE	If you write 1 to LVDIE with LVDF set, SPC automatically generates an LVD interrupt. 0b - Disable 1b - Enable
0 LVDRE	System LVD Reset Enable Enables the system LVD (SYSVDD_LVDF) event to generate a hardware reset. Before writing to this field, you must write 0 to LOCK. 0b - Disable 1b - Enable

30.7.19 IO Voltage Detect Configuration (VD_IO_CFG)

Offset

Register	Offset
VD_IO_CFG	13Ch

Function

Enables the IO VDD LVD and HVD reset and interrupts.

This register resets only after a POR event.

NOTE

If you write 1 to both LVDRE and LVDIE, SPC generates an interrupt after exiting from LVDRE reset. If you don't want this to occur, configure the LVD or HVD so only one is enabled.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															LOCK
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0						0	LVSEL	0				HVDIE	HVDRE	LVDIE	LVDRE
W																
Reset	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1

Fields

Field	Function
31-17 —	Reserved
16 LOCK	IO Voltage Detect Reset Enable Lock Allows writing to the LVDRE, HVDRE, and LVSEL fields. 0b - Allow 1b - Deny
15-10 —	Reserved
9 —	Reserved
8 LVSEL	IO VDD Low-Voltage Level Select Specifies the LVD trip point for the IO VDD monitor. See the chip data sheet for the high-range and low-range values. Before writing to this field, you must write 0 to LOCK. If you want to change LVSEL, you must do this after disabling the LVD reset and interrupt. Otherwise, SPC could generate an LVD due to the LVSEL change. 0b - High range 1b - Low range
7-4 —	Reserved
3 HVDIE	IO VDD HVD Interrupt Enable Enables the IO VDD HVD (IOVDD_HVDF) event to generate a hardware interrupt. If you write 1 to HVDIE with HVDF set, SPC automatically generates an HVD interrupt. 0b - Disable 1b - Enable
2 HVDRE	IO VDD HVD Reset Enable Enables the IO VDD HVD (IOVDD_HVDF) event to generate a hardware reset. Before writing to this field, you must write 0 to LOCK. 0b - Disable 1b - Enable
1	IO VDD LVD Interrupt Enable Enables the IO VDD LVD (IOVDD_LVDF) event to generate a hardware interrupt.

Table continues on the next page...

Table continued from the previous page...

Field	Function
LVDIE	If you write 1 to LVDIE with LVDF set, SPC automatically generates an LVD interrupt. 0b - Disable 1b - Enable
0 LVDRE	IO VDD LVD Reset Enable Enables the IO VDD LVD (IOVDD_LVDF) event to generate a hardware reset. Before writing to this field, you must write 0 to LOCK. 0b - Disable 1b - Enable

30.7.20 External Voltage Domain Configuration (EVD_CFG)

Offset

Register	Offset
EVD_CFG	140h

Function

Isolates signals from external voltage domains under certain conditions.

Chip pins supply the external voltage domains. These domains are controlled at the board level. This register allows you to control internal isolations for signals from these domains if either of the following conditions is true:

- They are not powered on the board.
- They are powered off externally in low-power modes (using the SPC_LPREQ pin).

Any logic in the isolated voltage domain also resets, because the voltage domain is assumed to be powered off. This reset does not impact any VDD_CORE internal power domains or registers—only I/O pads, analog components, or both.

This register resets only after a POR event.

Each bit of the EVDISO, EVDLPISO, and EVDSTAT fields corresponds to one of the I/O or analog supplies according to Table 239.

Table 239. Mapping of bits to supplies

Bit position in field	Description
0	VDD_IO_ABE
1	VDD_IO_C
2	VDD_IO_D

NOTE

Bit 0 VDD_IO_ABE should not be set in EVD_CFG[EVDISO] and it should only be set in EVD_CFG[EVDLPISO] when moving to Deep Power Down mode.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0													EVDSTAT		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	1[1]	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				EVDLPISO				0				EVDISO			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

1. The reset value of this field can change based on external voltage conditions.

Fields

Field	Function
31-19 —	Reserved
18-16 EVDSTAT	External Voltage Domain Status Indicates the status of the external voltage domains. See Table 239 for the mapping of each bit of this field. Each bit's value has the following meaning: 0b - Isolated or not powered 1b - Not isolated
15-11 —	Reserved
10-8 EVDLPISO	External Voltage Domain Low-Power Isolation Isolates the external voltage domain in low-power modes. Use this field if you use the SPC_LPREQ pin to power off any voltage domain in low-power modes. See Table 239 for the mapping of each bit of this field. Each bit's value has the following meaning: 0b - Not isolated 1b - Isolated
7-3 —	Reserved
2-0 EVDISO	External Voltage Domain Isolation Isolates the external voltage domain. Use this field if any voltage domain is always powered off on the board, or whenever a voltage domain is powered off under software control.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	See Table 239 for the mapping of each bit of this field. Each bit's value has the following meaning: 0b - Not isolated 1b - Isolated

30.7.21 Glitch Detect Status Control (GLITCH_DETECT_SC)

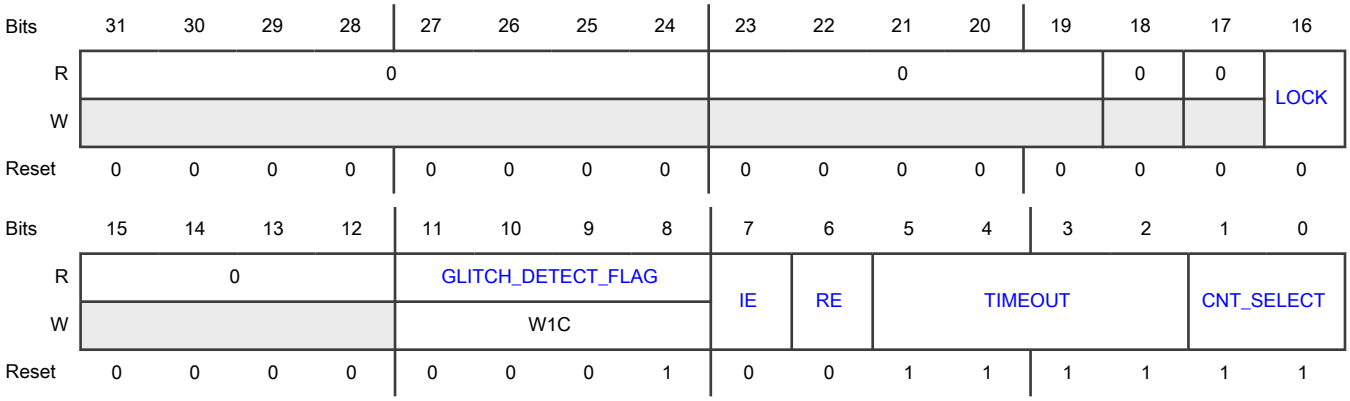
Offset

Register	Offset
GLITCH_DETECT_SC	144h

Function

Controls the GLITCH_DETECT operation.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-19 —	Reserved
18 —	Reserved
17	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
16 LOCK	Glitch Detect Reset Enable Lock Bit Used to prevent writes to the GLITCH_RE register bit. 0b - Writes to RE are allowed. 1b - Writes to RE are ignored.
15-12 —	Reserved
11-8 GLITCH_DETECT_FLAG	GLITCH_DETECT_FLAG State of 4-bit Glitch Ripple Counter output. Based on CNT_SELECT program value, the correct 4-bit output state is monitored to generate interrupt or reset based on the settings of IE and RE.
7 IE	Glitch Detect Interrupt Enable Enables GLITCH_DETECT_FLAG[CNT_SELECT] to generate a hardware interrupt. **NOTE** Setting IE with GLITCH_DETECT_FLAG[CNT_SELECT] set will cause an automatic glitch detect interrupt to get generated. 0b - GLITCH_DETECT_FLAG[CNT_SELECT] does not generate hardware interrupt (user polling) 1b - GLITCH_DETECT_FLAG[CNT_SELECT] does generate hardware interrupt
6 RE	Glitch Detect Reset Enable Enables GLITCH_DETECT_FLAG[CNT_SELECT] to generate a POR/LVD reset. **NOTE** Writes to this bit require the VDD_CORE_GLITCH_DETECT_SC[LOCK] bit to be cleared. 0b - GLITCH_DETECT_FLAG[CNT_SELECT] does not generate POR/LVD reset 1b - GLITCH_DETECT_FLAG[CNT_SELECT] does generate POR/LVD reset
5-2 TIMEOUT	Timeout Specifies the timeout value used to reset glitch detect and compare logic after an initial glitch is detected. The timeout is based on the internal 10 MHz reference clock. After initial glitch is detected, the total timeout used to reset the glitch-detect logic is (TIMEOUT + initialization of internal timer clock). **NOTE** A TIMEOUT value of 0 is not valid and user my ensure that a value greater than 0 is programmed.
1-0	Counter Select

Table continues on the next page...

Table continued from the previous page...

Field	Function
CNT_SELECT	Specifies the ripple-counter bit to use for detecting a glitch in the VDD core. 00b - 0 01b - 1 10b - 2 11b - 3

30.7.22 LDO_CORE Configuration (CORELDO_CFG)

Offset

Register	Offset
CORELDO_CFG	300h

Function

Configures LDO_CORE.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				0				0	0		CORELDO_SPARE				DPDOWN_...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0[1]	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0							PASSTHR...	0				0	0	0	0
W																
Reset	0	0	0	0	0	0	0	0[1]	0	1	0	0	0	1	1	0

1. The bits reset solely on a POR/LVD/HVD event.

Fields

Field	Function
31-29 —	Reserved
28-24 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
23 —	Reserved
22-21 —	Reserved
20-17 CORELDO_SPARE	CORELDO_SPARE DAC/ATS Bandgap Buffer Enable register. 0000b - TBD. 0001b - TBD.
16 DPDOWN_PULLDOWN_DISABLE	LDO_CORE Deep Power Down Pulldown Disable Forces the LDO_CORE to discharge in Deep Power Down modes if CNTRL[CORELDO_EN] = 1. 0b - LDO_CORE pulldown in Deep Power Down not disabled 1b - LDO_CORE pulldown in Deep Power Down disabled
15-9 —	Reserved
8 PASSTHROUGH	LDO_CORE Pass Through Enable Sets the core ldo in bypass mode. **NOTE** Prior to enabling core ldo pass through, user must sequence in series the CORELDO followed by DCDC to correct regulated voltages by programming the CORELDO_VDD_LVL and DCDC VDD_LVL to correct values.
7-4 —	Reserved
3 —	Reserved
2 —	Reserved
1 —	Reserved
0 —	Reserved

30.7.23 LDO_SYS Configuration (SYSLDO_CFG)

Offset

Register	Offset
SYSLDO_CFG	400h

Function

Configures LDO_SYS.

This register resets only after a POR or LVD event.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0						0		0				0		0	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0							0	0		0	0	0			ISINK EN
W																
Reset	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1[1]

1. This value gets loaded with IFR or FUSE values during reset.

Fields

Field	Function
31-26 —	Reserved
25-24 —	Reserved
23-20 —	Reserved
19 —	Reserved
18-16 —	Reserved
15-9	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
8 —	Reserved
7-6 —	Reserved
5 —	Reserved
4 —	Reserved
3-1 —	Reserved
0 ISINKEN	Current Sink Enable Enables the current-sink feature of the system's low-power regulator. Discharges the output voltage when LDO_SYS is disabled. 0b - Disable 1b - Enable

30.7.24 DCDC Configuration (DCDC_CFG)

Offset

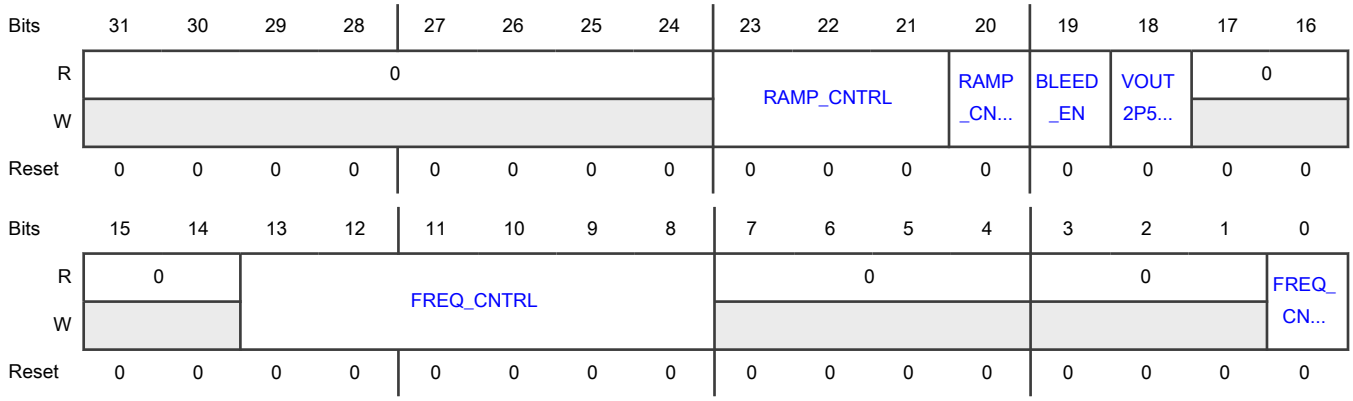
Register	Offset
DCDC_CFG	500h

Function

Configures DCDC.

This register resets only after a POR, LVD, or HVD event.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-21 RAMP_CNTRL	DCDC Ramp Control Select Controls and selects the DCDC Voltage ramp rate when switching DCDC trim for a higher voltage level. **NOTE** DCDC Ramp Rate = [567-(DCDC Ramp Trim*2 - DCDC Ramp Trim/2)]/2^RAMP_CNTRL **NOTE** DCDC Ramp Trim is the internal trim value changing by one lsb after every DCDC RAMP Rate delay
20 RAMP_CNTRL_EN	DCDC Trim Step Enable Enables DCDC trim voltage stepping.
19 BLEED_EN	DCDC Bleed Enable Adds a bleed resistor to discharge DCDC output when DCDC is disabled. 0b - Do not add 1b - Add
18 VOUT2P5_SEL	2.5 V Output Select Specifies the value of DCDC Vout. This field is only meaningful in Active Mode when DCDC drive strength is set to Normal. When VOUT2P5_SEL = 1, the DCDC_2P5_TRIM[VTRIM_2P5] trim values adjust the DCDC 2.5 V output. 0b - From DCDC_VDD_LVL register 1b - 2.5 V

Table continues on the next page...

Table continued from the previous page...

Field	Function
17-16 —	Reserved
15-14 —	Reserved
13-8 FREQ_CNTRL	DCDC Burst Frequency Control Specifies the frequency of the current burst.
7-4 —	Reserved
3-1 —	Reserved
0 FREQ_CNTRL_ON	DCDC Burst Frequency Control Enable Enables DCDC frequency stabilization. 0b - Disable 1b - Enable

30.7.25 DCDC Burst Configuration (DCDC_BURST_CFG)

Offset

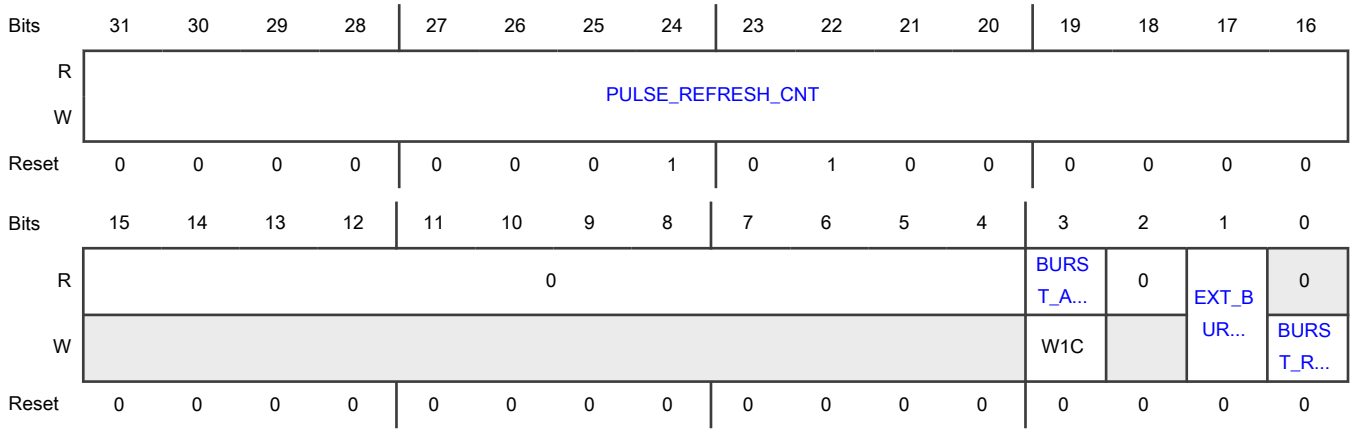
Register	Offset
DCDC_BURST_CFG	504h

Function

Controls the DCDC burst operation.

This register resets only after a POR, LVD, or HVD event.

Diagram



Fields

Field	Function
31-16 PULSE_REFRESH_CNT	Refresh Count Value Controls the DCDC refresh frequency when DCDC is in Pulse Refresh mode. When DCDC is enabled and running in Pulse Refresh mode, PULSE_REFRESH_CNT controls how often the DCDC is pulsed on and off based on a low-power reference clock. You must specify a count value that is long enough to allow a DCDC burst to occur. The pulse duration (time between on and off) is: (reference clock period) × (PULSE_REFRESH_CNT + 2) **NOTE** See the chip-specific information for more on DCDC pulsed mode clocking.
15-4 —	Reserved
3 BURST_ACK	Burst Acknowledge Flag Indicates that the DCDC burst completed, and therefore DCDC entered Quiet mode. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Did not complete 1b - Completed When writing 0b - No effect 1b - Clear the flag
2 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
1 EXT_BURST_EN	External Burst Request Enable Enables external burst requests. When this field is 1, SPC asserts the output burst trigger DCDC_BURST_TRIG_PULSE after the DCDC burst request has been acknowledged. **NOTE** Enable external bursts before writing 1 to BURST_REQ and after BURST_ACK is 0. 0b - Disable 1b - Enable
0 BURST_REQ	Software Burst Request Generates a software burst request to DCDC. **NOTE** Do not generate a new burst request until the previous burst request has completed and you acknowledged this by clearing the BURST_ACK flag. 0b - Do not generate 1b - Generate

Chapter 31
Smart Power Switch (VBAT)

31.1 Chip-specific VBAT information

Table 240. Reference links to related information

Topic	Related module	Reference
Full description	VBAT	VBAT
System memory map		System memory map
Power management		Power management map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

31.1.1 Signal naming

The table below lists the VBAT signal in this device.

Table 241. Device signal name - VBAT signal name

Device signal name	VBAT signal name
SWITCH_WAKEUP_B	WAKEUP_b

31.1.2 VBAT supply

VBAT is supplied from the chip power supply VDD_SWITCH.

31.1.3 VBAT backup SRAM LDO for memory retention

VBAT module in the device can optionally retain the contents of the 8KB SRAM STCM8 array that supports ECC.

31.2 Overview

VBAT works with the power management system to implement power-saving mechanisms. It provides bandgap timers and a voltage regulator to supply retention SRAM in low-power modes.

VBAT implements the 16 kHz internal clock source via FRO16K.

31.2.1 Block diagram

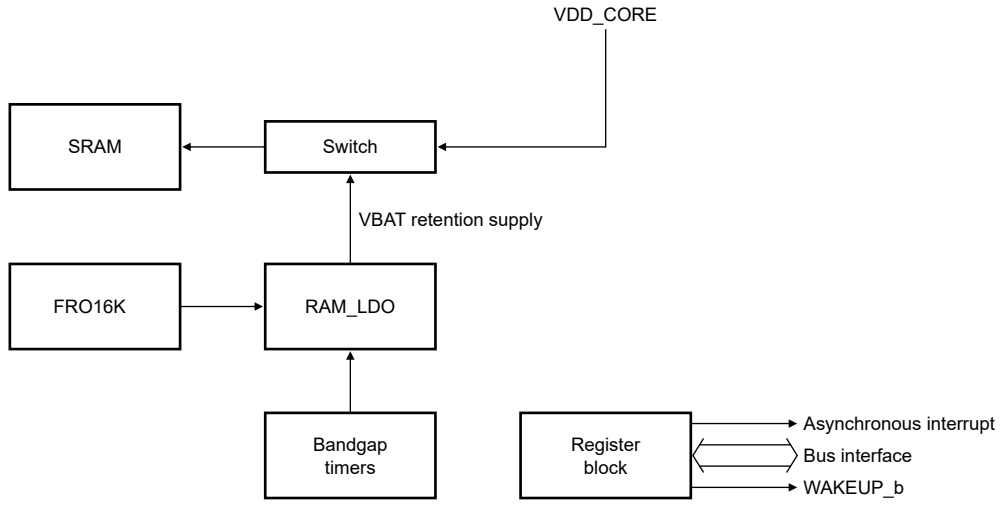


Figure 88. Block diagram

31.2.2 Features

- Supports internal 16 kHz free-running oscillator (FRO16K)
- Supports backup retention SRAM regulator

31.3 Functional description

The following sections describe the functional details of VBAT.

31.3.1 Operations

This section describes the operations of VBAT.

31.3.1.1 FRO 16.384 kHz clock

FRO16K is enabled by default on POR. You can disable it or lock it to prevent any change to the enable field. FRO 16k should be enabled prior to enabling the backup SRAM LDO regulator or VBAT bandgap timers.

31.3.1.2 SRAM LDO

SRAM LDO is a retention regulator that retains VBAT retention SRAM in low-power modes, including when VBAT is the only available supply. When STATUSA[LDO_RDY] becomes 1, the chip can enter into a low-power mode where the VBAT supply retains SRAM. Enable the bandgap and LDO before entering a low-power mode where the VBAT supply powers the retention SRAM. Enable Refresh mode for the lowest power consumption.

It takes approximately 8ms for the LDO_RDY flag to set after software enables the bandgap and LDO. When using the SRAM LDO it is recommended to leave it enabled in active modes to avoid this delay before entering a low power mode.

Although SRAM is automatically retained in all low-power modes, you can manually switch SRAM to the VBAT retention supply anytime. Do not access the SRAM when it receives power from the VBAT retention supply. You must manually reverse these steps before accessing the SRAM again.

To manually switch VBAT to power the SRAM:

1. Isolate the SRAM array (write 1 to LDORAMC[ISO]).
2. Switch the supply from VDD_CORE to the VBAT retention LDO (write 1 to LDORAMC[SWI]).

When SRAM LDO is disabled, LDORAMC[RETn] controls whether the retention of VBAT SRAM happens using VDD_CORE in low-power modes.

In general, using the SRAM LDO to retain the VBAT retention SRAM is a lower power option than using VDD_CORE directly.

NOTE

Enable FRO16K before enabling SRAM LDO or the bandgap.

31.3.1.3 Bandgap timer

Two software-configurable bandgap timers are available when the SRAM LDO bandgap is enabled. These timers share logic with the bandgap timer refresh logic to minimize power, so they use the FRO16K clock source and are only available when the bandgap is enabled. When you change the configured timeout, NXP recommends that you:

1. Disable the timer.
2. Clear the flag.
3. Write the new timeout value.
4. Enable the timeout again.

31.3.2 Low-power modes

VBAT remains functional in all low-power modes.

31.3.3 Debug mode

Debug modes do not affect VBAT.

31.3.4 Clocks

VBAT implements the following clock domains:

- Bus interface clock - access the registers
- FRO16K internal clock

31.3.5 Reset

Only the POR resets VBAT.

31.3.6 Interrupts

VBAT generates one interrupt combining the following sources:

- VBAT POR
- Wake-up pin assertion
- Bandgap timer 0
- Bandgap timer 1
- LDO ready

31.4 External signals

Table 242. External signals

Signal	Description	Direction
WAKEUP_b	Active low wake-up pin, falling edge sets the WAKEUP_FLAG. When WAKEUP_b pin is configured for open drain operation, an external wakeup source can drive this pin low, and the falling edge will assert the WAKEUP_FLAG	Input/Output

31.5 Initialization

To enable and lock the FRO16K:

1. Write 1h to FROCTLA[FRO_EN].
2. Write 1h to FROLCKA[LOCK].
3. Alter FROCLKE[CLKE] to clock gate different FRO16K outputs to different peripherals to reduce power consumption.

To enable and lock the LDO and bandgap:

1. Enable the FRO16K.
2. Write 7h to LDO_RAM Control A (LDOCTLA).
3. Wait for STATUSA[LDO_RDY] to become 1.
4. Write 1h to LDOLCKA[LOCK].

31.6 Application information

Configure the VBAT LDO to retain the state of any required SRAM to guard against an unexpected loss of power to the system:

1. Enable the LDO and bandgap.
2. Configure LDORAMC[RETn] to retain the appropriate arrays.

For a software-controlled power down, follow these steps to ensure robust retention of memory before switching off external power:

1. Write 1b to LDORAMC[ISO].
2. Write 1b to LDORAMC[SWI].

You must reverse the above steps to access the SRAM arrays, which the VBAT LDO retains. That is, follow these steps after external power is again switched on:

1. Write 0b to LDORAMC[SWI].
2. Write 0b to LDORAMC[ISO].

31.7 Memory map and register definition

This section includes VBAT memory map and detailed descriptions of all registers.

NOTE

The VBAT registers are reset on VBAT Cold Reset only (VBAT POR).

31.7.1 VBAT register descriptions

31.7.1.1 VBAT memory map

VBAT0 base address: 4002_B000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	0100_0003h
10h	Status A (STATUSA)	32	RW	0000_0001h
18h	Interrupt Enable A (IRQENA)	32	RW	0000_0001h
20h	Wake-up Enable A (WAKENA)	32	RW	0000_0001h
30h	Lock A (LOCKA)	32	RW	0000_0000h
200h	FRO16K Control A (FROCTLA)	32	RW	0000_0001h
218h	FRO16K Lock A (FROLCKA)	32	RW	0000_0000h
220h	FRO16K Clock Enable (FROCLKE)	32	RW	0000_0000h
300h	LDO_RAM Control A (LDOCTLA)	32	RW	0000_0000h
318h	LDO_RAM Lock A (LDOLCKA)	32	RW	0000_0000h
320h	RAM Control (LDORAMC)	32	RW	0000_0000h
330h	Bandgap Timer 0 (LDOTIMER0)	32	RW	0000_0000h
338h	Bandgap Timer 1 (LDOTIMER1)	32	RW	0000_0000h

31.7.1.2 Version ID (VERID)

Offset

Register	Offset
VERID	0h

Function

Records the specific version of VBAT in the chip.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	MAJOR								MINOR							
W																
Reset	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	FEATURE															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

Fields

Field	Function
31-24 MAJOR	Major Version Number Returns the major version number for the specification.
23-16 MINOR	Minor Version Number Returns the minor version number for the specification.
15-0 FEATURE	Feature Specification Number Returns the feature set number, indicating the feature set present in this instance of VBAT.

31.7.1.3 Status A (STATUSA)

Offset

Register	Offset
STATUSA	10h

Function
Contains all status flags for VBAT.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0												0	0	0	0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	0	0	0	0	0	0	0	0	0	LDO_RDY	TIMER1_...	TIMER0_...	WAKEUP_...	POR_DET
W													W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Fields

Field	Function
31-20 —	Reserved
19	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
18 —	Reserved
17 —	Reserved
16 —	Reserved
15 —	Reserved
14 —	Reserved
13 —	Reserved
12 —	Reserved
11 —	Reserved
10 —	Reserved
9 —	Reserved
8 —	Reserved
7 —	Reserved
6 —	Reserved
5 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
4 LDO_RDY	LDO Ready Indicates whether LDO or bandgap is enabled and ready to enter Low-Power mode. 0b - Disabled (not ready) 1b - Enabled (ready)
3 TIMER1_FLAG	Bandgap Timer 1 Flag Asserts periodically according to the bandgap timer 1 period. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not reached 1b - Reached When writing 0b - No effect 1b - Clear the flag
2 TIMER0_FLAG	Bandgap Timer 0 Flag Asserts periodically according to the bandgap timer 0 period. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not reached 1b - Reached When writing 0b - No effect 1b - Clear the flag
1 WAKEUP_FLAG	Wakeup Pin Flag Asserts whenever VBAT detects a falling edge on the wake-up pin. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not asserted 1b - Asserted When writing

Table continues on the next page...

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Field	Function
	0b - No effect 1b - Clear the flag
0 POR_DET	POR Detect Flag Indicates if the VBAT POR has asserted. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not reset 1b - Reset When writing 0b - No effect 1b - Clear the flag

31.7.1.4 Interrupt Enable A (IRQENA)

Offset

Register	Offset
IRQENA	18h

Function

Contains all interrupt enables for VBAT.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0												0	0	0	0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	0	0	0	0	0	0	0	0	0	LDO_RDY	TIMER1_...	TIMER0_...	WAKEUP_...	POR_DET
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Fields

Field	Function
31-20 —	Reserved
19 —	Reserved
18 —	Reserved
17 —	Reserved
16 —	Reserved
15 —	Reserved
14 —	Reserved
13 —	Reserved
12 —	Reserved
11 —	Reserved
10 —	Reserved
9 —	Reserved
8 —	Reserved
7 —	Reserved
6	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
5 —	Reserved
4 LDO_RDY	LDO Ready Enables the corresponding interrupt in Status A (STATUSA). 0b - Disable 1b - Enable
3 TIMER1_FLAG	Bandgap Timer 2 Enables the corresponding interrupt in Status A (STATUSA). 0b - Disable 1b - Enable
2 TIMER0_FLAG	Bandgap Timer 0 Enables the corresponding interrupt in Status A (STATUSA). 0b - Disable 1b - Enable
1 WAKEUP_FLAG	Wakeup Pin Flag Enables the corresponding interrupt in Status A (STATUSA). 0b - Disable 1b - Enable
0 POR_DET	POR Detect Enables the corresponding interrupt in Status A (STATUSA). 0b - Disable 1b - Enable

31.7.1.5 Wake-up Enable A (WAKENA)

Offset

Register	Offset
WAKENA	20h

Function
Contains all wake-up enables for VBAT.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0												0	0	0	0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	0	0	0	0	0	0	0	0	0	LDO_RDY	TIMER1_...	TIMER0_...	WAKEUP_...	POR_DET
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Fields

Field	Function
31-20 —	Reserved
19 —	Reserved
18 —	Reserved
17 —	Reserved
16 —	Reserved
15 —	Reserved
14 —	Reserved
13 —	Reserved
12 —	Reserved
11 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
10 —	Reserved
9 —	Reserved
8 —	Reserved
7 —	Reserved
6 —	Reserved
5 —	Reserved
4 LDO_RDY	LDO Ready Enables the corresponding wake-up in Status A (STATUSA). 0b - Disable 1b - Enable
3 TIMER1_FLAG	Bandgap Timer 2 Enables the corresponding wake-up in Status A (STATUSA). 0b - Disable 1b - Enable
2 TIMER0_FLAG	Bandgap Timer 0 Enables the corresponding wake-up in Status A (STATUSA). 0b - Disable 1b - Enable
1 WAKEUP_FLAG	Wake-up Pin Flag Enables the corresponding wake-up in Status A (STATUSA). 0b - Disable 1b - Enable
0 POR_DET	POR Detect Enables the corresponding wake-up in Status A (STATUSA).

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Disable 1b - Enable

31.7.1.6 Lock A (LOCKA)

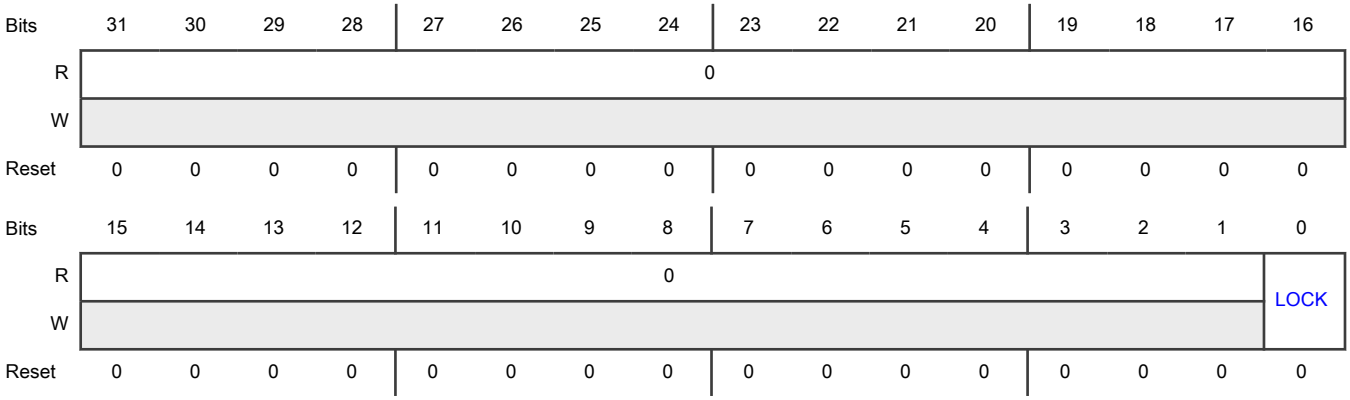
Offset

Register	Offset
LOCKA	30h

Function

Contains the lock bits. Writes to this register are blocked when lock register is set.

Diagram



Fields

Field	Function
31-1 —	Reserved
0 LOCK	Lock When set, blocks writes to the interrupt and wakeup enable registers. 0b - Disables lock 1b - Enables lock. Cleared by VBAT POR.

31.7.1.7 FRO16K Control A (FROCTLA)

Offset

Register	Offset
FROCTLA	200h

Function
Controls FRO16K. Writes to this register are blocked when FROLCKA[LOCK] is 1.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															FRO_EN
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Fields

Field	Function
31-1 —	Reserved
0 FRO_EN	FRO16K Enable 0b - Disable 1b - Enable

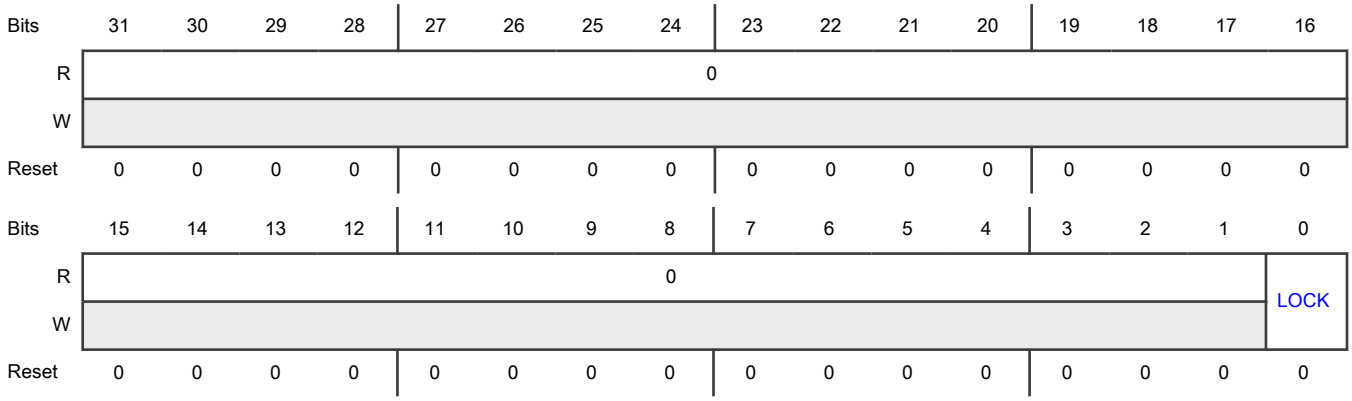
31.7.1.8 FRO16K Lock A (FROLCKA)

Offset

Register	Offset
FROLCKA	218h

Function
Contains the lock field. Writes to this register are blocked when FROLCKA[LOCK] is 1.

Diagram



Fields

Field	Function
31-1 —	Reserved
0 LOCK	Lock Blocks any write to the FRO16K registers when you write 1 to this field. VBAT POR writes 0 to this field. 0b - Do not block 1b - Block

31.7.1.9 FRO16K Clock Enable (FROCLKE)

Offset

Register	Offset
FROCLKE	220h

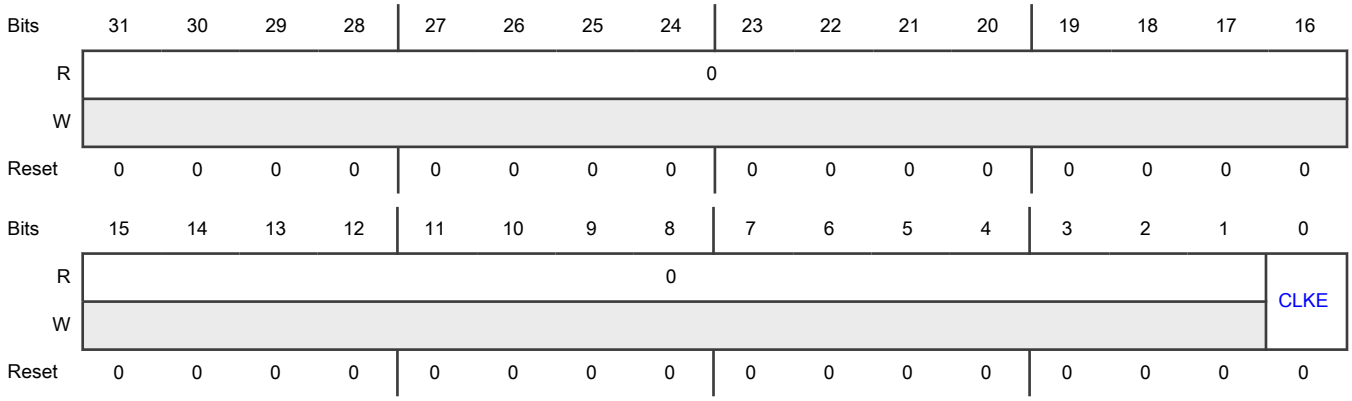
Function

Contains clock gating register field to gate the FRO16K clock to other modules.

NOTE

FROCLKE cannot be locked (not affected by FRO16K Lock A (FROLCKA)).

Diagram



Fields

Field	Function
31-1 —	Reserved
0 CLKE	Clock Enable Enables the corresponding FRO16 kHz output clock to other modules when you write 1 to the corresponding bit in this field. See the chip-specific VBAT information section for more information.

31.7.1.10 LDO_RAM Control A (LDOCTLA)

Offset

Register	Offset
LDOCTLA	300h

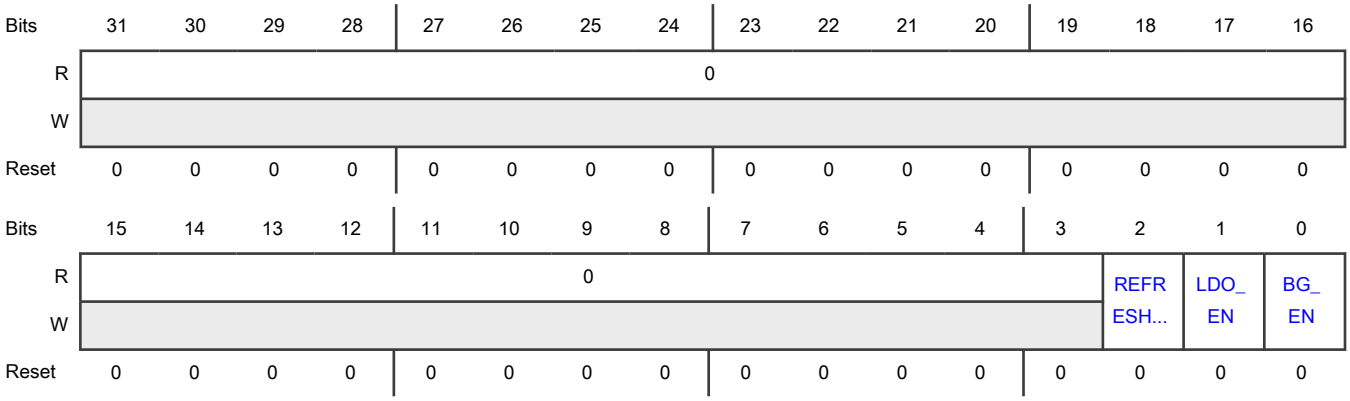
Function

Contains the LDO_RAM control field. When configuring the LDO_RAM, both control A and control B registers need to be programmed to the appropriate values. Writes to this register are blocked when LDOLCKA[LOCK] is 1.

NOTE

The FRO16K must be enabled before enabling the SRAM LDO or the bandgap

Diagram



Fields

Field	Function
31-3 —	Reserved
2 REFRESH_EN	Refresh Enable Enables the Bandgap Low-Power Refresh mode. The refresh mode must also be enabled for lowest power consumption. 0b - Refresh mode is disabled 1b - Refresh mode is enabled for low power operation
1 LDO_EN	LDO Enable Enables the backup SRAM regulator. LDOCTLA[BG_EN] must enable the bandgap when the backup SRAM regulator is enabled. After you enable the bandgap and backup SRAM regulator, you must wait until STATUSA[LDO_RDY] becomes 1 before the SRAM can enter a low-power state where the regulator supplies the array contents. 0b - Disable 1b - Enable
0 BG_EN	Bandgap Enable Enables the LDO_RAM bandgap. 0b - Disable 1b - Enable

31.7.1.11 LDO_RAM Lock A (LDOLCKA)

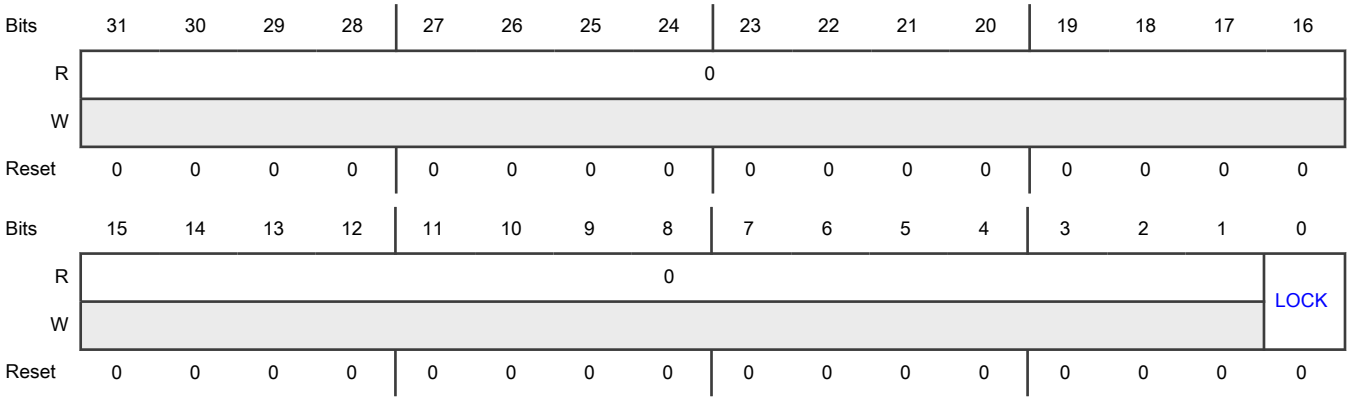
Offset

Register	Offset
LDOLCKA	318h

Function

Contains the lock field. Writes to this register are blocked when the LDO_RAM lock register is 1.

Diagram



Fields

Field	Function
31-1 —	Reserved
0 LOCK	Lock Blocks any write to the LDO_RAM registers. VBAT POR writes 0 to this field. 0b - Do not block 1b - Block

31.7.1.12 RAM Control (LDORAMC)

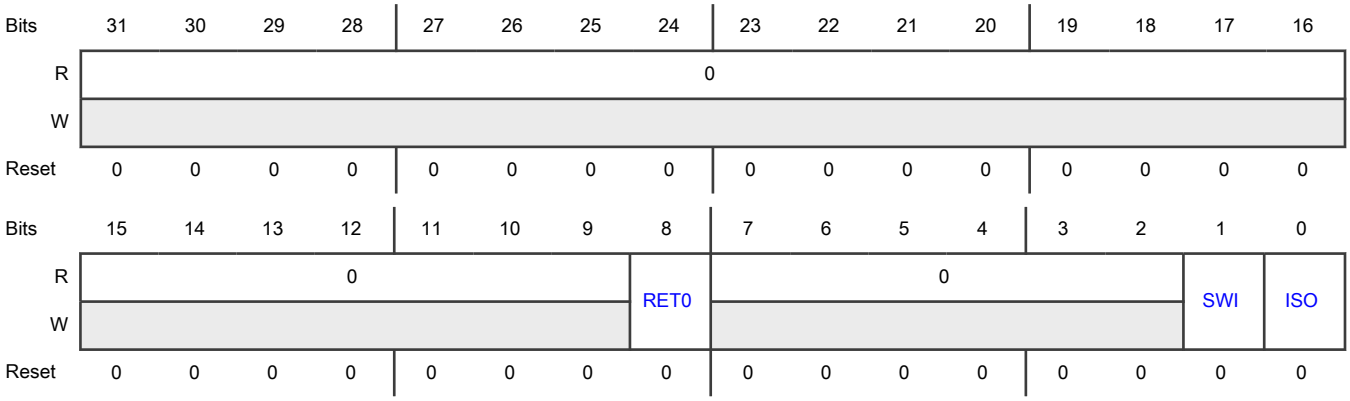
Offset

Register	Offset
LDORAMC	320h

Function

Contains software overrides for the SRAM isolation and backup switch. Always isolate the SRAM array before asserting or negating the switch control.

Diagram



Fields

Field	Function
31-9 —	Reserved
8 RETn	Retention Configures retention of each SRAM array in low power modes. See the VBAT chip-specific section for more details on these SRAM arrays. When LDO_RAM is enabled, at least one SRAM array must be retained. When LDO_RAM is disabled, this field specifies whether VDD_CORE continues to provide power to the SRAM array. 0b - Corresponding SRAM array is retained in low-power modes 1b - Corresponding SRAM array is not retained in low-power modes
7-2 —	Reserved
1 SWI	Switch SRAM Specifies how the SRAM array is powered. Change this field when LDORAMC[ISO] = 1. 0b - Supply follows the chip power modes 1b - LDO_RAM powers the array
0 ISO	Isolate SRAM Specifies how the SRAM array is isolated. 0b - State follows the chip power modes 1b - Isolates SRAM and places it in Low-Power Retention mode

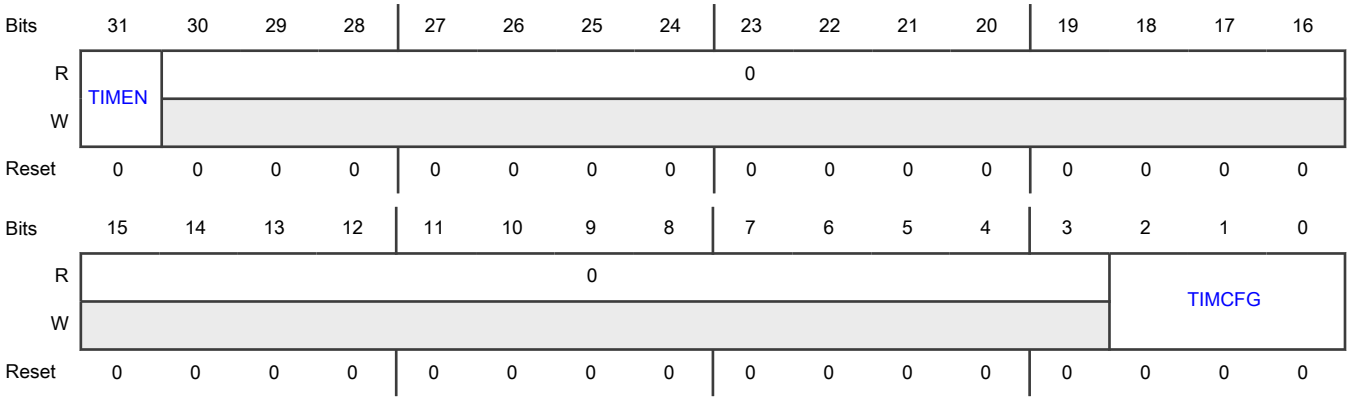
31.7.1.13 Bandgap Timer 0 (LDOTIMER0)

Offset

Register	Offset
LDOTIMER0	330h

Function
Controls one software-configurable timer when the bandgap is enabled and are clocked by FRO16K.

Diagram



Fields

Field	Function
31 TIMEN	Bandgap Timeout Period Enable 0b - Disable 1b - Enable
30-3 —	Reserved
2-0 TIMCFG	Timeout Configuration Configures the bandgap timeout 0 period. Changed when the timer is disabled. 000b - 1 s 001b - 500 ms 010b - 250 ms 011b - 125 ms 100b - 62.5 ms 101b - 31.25 ms 110b - 15.625 ms 111b - 7.8125 ms

31.7.1.14 Bandgap Timer 1 (LDOTIMER1)

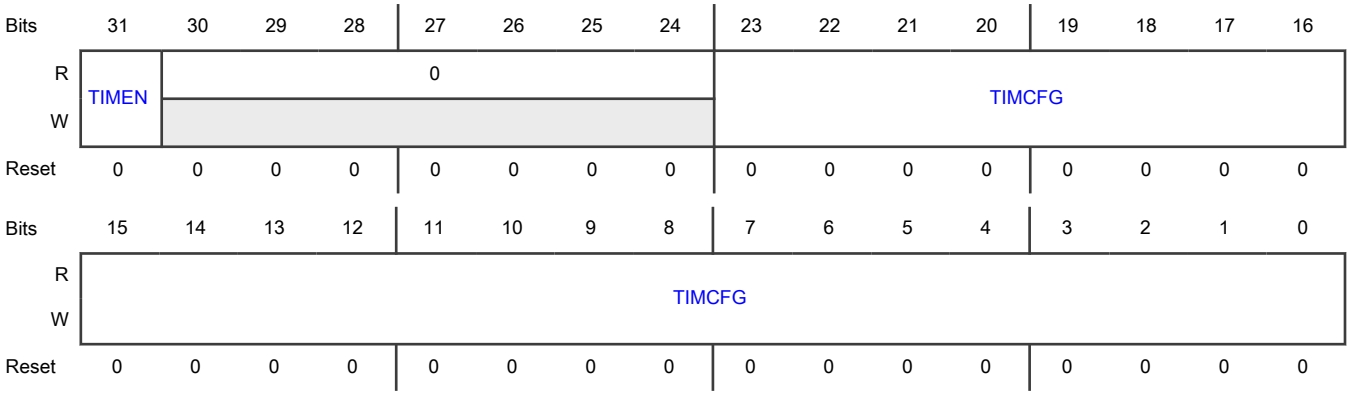
Offset

Register	Offset
LDOTIMER1	338h

Function

Controls the other software-configurable timer when the bandgap is enabled and are clocked by the FRO16K.

Diagram



Fields

Field	Function
31 TIMEN	Bandgap Timeout Period Enable 0b - Disable 1b - Enable
30-24 —	Reserved
23-0 TIMCFG	Timeout Configuration Configures the bandgap timeout 1 period. Configures timeout in number of seconds, ranging from 1 to 16,777,216 s. You can change this field when the timer is disabled.

Chapter 32
External Watchdog Monitor (EWM)

32.1 Chip-specific EWM information

Table 243. Reference links to related information

Topic	Related module	Reference
Full description	EWM	EWM
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

32.1.1 Module instances

This device has one instance of the EWM module, EWM0.

32.2 Overview

For safety purposes, a redundant watchdog system, EWM, is designed to monitor external circuits and the MCU software flow. EWM provides a backup mechanism to the internal watchdog.

The internal watchdog resets the MCU's CPU and peripherals and is used to monitor the flow and execution of the embedded software within the MCU. It consists of a counter that, if allowed to overflow, forces an internal, asynchronous reset to all on-chip peripherals. The counter also optionally asserts the RESET_B pin to reset external devices and circuits. The watchdog counter must not overflow if the software code works well and services the watchdog to restart the actual counter.

The EWM does not reset the MCU's CPU and peripherals, making it different from internal watchdog. The EWM module provides an independent ewm_out_b signal that, when asserted, resets or places an external circuit into a safe mode. The ewm_out_b signal asserts upon EWM counter timeout. An optional external input, ewm_in, allows additional control when asserting the ewm_out_b signal.

32.2.1 Block diagram

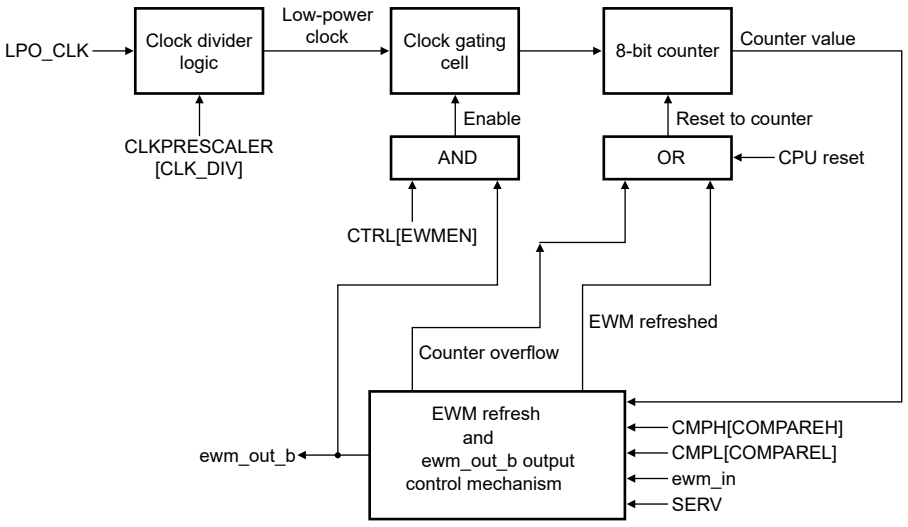


Figure 89. Block diagram

32.2.2 Features

- Independent LPO_CLK source
- Programmable timeout period, specified in terms of the number of EWM LPO_CLK cycles
- Windowed refresh option that provides:
  - A robust check to confirm that the program flow is faster than expected.
  - A programmable window.
  - Refresh outside the window, leading to assertion of the ewm_out_b signal.
- Robust refresh mechanism:
  - Write values of B4h and 2Ch to Service (SERV) within 15 peripheral bus clock cycles.
- One output port, ewm_out_b, which when asserted is used to reset or place the external circuit into Safe mode
- One input port, ewm_in, which allows an external circuit to control the assertion of the ewm_out_b signal

32.3 Functional description

The following sections discuss these aspects of EWM:

- Functional details
- Operating modes

NOTE

If the BUS_CLK is lost, EWM does not generate the ewm_out_b signal and no refresh operation is possible.

32.3.1 Modes of operation

32.3.1.1 Stop mode

When EWM is in Stop mode, the CPU cannot refresh EWM. After entering Stop mode, the EWM counter freezes.

Following are the possible ways to exit Stop mode:

- Through a reset: EWM remains disabled in this case.
- Through an interrupt: EWM is re-enabled and the counter continues to be clocked from the same value as prior to Stop mode entry.

NOTE

Consider the following if EWM enters Stop mode during the CPU refresh mechanism:

- While exiting Stop mode through an interrupt, the refresh mechanism starts from the previous state. That is, if you write the refresh command correctly and EWM enters Stop mode immediately, you must write the next command in 15 peripheral bus clocks after exiting Stop mode.
- You must mask all interrupts before executing the EWM refresh instructions.

32.3.1.2 Debug mode

EWM remains unimpacted when entering Debug mode:

- If EWM is enabled before entering Debug mode, it remains enabled.
- If EWM is disabled before entering Debug mode, it remains disabled.

32.3.2 Using the EWM counter

EWM uses an 8-bit ripple counter that is fed by a clock source independent of the peripheral bus clock source. As the preferred timeout is between 1 ms and 100 ms, the actual clock source must be in the kHz range.

The counter is reset to 0 in these conditions:

- After CPU reset
- After the EWM refresh action completes
- At counter overflow

The CPU cannot access the counter value.

32.3.3 Using compare registers

You can write to Compare Low (CMPL) and Compare High (CMPH) only once after a CPU reset and you cannot modify them until another CPU reset occurs. These registers are used to create a refresh window for the EWM module.

You cannot program Compare Low (CMPL) and Compare High (CMPH) with the same value. In case of any attempt, the ewm_out_b signal asserts as soon as the counter reaches the value of Compare Low (CMPL) + 1.

NOTE

- You must update Compare Low (CMPL) and Compare High (CMPH) before enabling EWM. Therefore, you must provide a reasonable time after POR for the external monitoring circuit to stabilize. You must also ensure that the ewm_in pin is deasserted.
- Updating Compare Low (CMPL) requires one clock cycle to propagate a new value. It is recommended to write Service (SERV) after one clock period of the slowest clock frequency. See the chip-specific information section for more information.

32.3.4 Using the refresh mechanism

Other than the initial configuration of EWM, the CPU can access EWM only through Service (SERV). The CPU must access this register by correctly writing unique data within the windowed time frame, as determined by Compare Low (CMPL) and Compare High (CMPH) for the correct EWM refresh operation. The following table describes conditions that exist and the refresh mechanisms that apply to those conditions.

Table 244. Refresh mechanisms

Condition	Mechanism
The EWM refresh action completes when the value of Compare Low (CMPL) ≤ the counter value ≤ the value of Compare High (CMPH).	The software behaves as expected and the EWM counter resets to 0. The ewm_out_b output signal remains in Deasserted state if, during the EWM refresh action, the ewm_in input is in Deasserted state.
The EWM refresh action completes when the counter value < the value of Compare Low (CMPL).	The software refreshes EWM before the windowed time frame, the counter resets to 0, and the ewm_out_b output signal asserts no matter what the value of the ewm_in input signal is.
The counter value becomes greater than the value of Compare High (CMPH) prior to completion of the EWM refresh action.	The software does not refresh EWM. The EWM counter resets to 0 and the ewm_out_b output signal asserts no matter what the value of the ewm_in input signal is.

See Service (SERV) for more on the refresh mechanism.

32.3.5 Interrupt

When the ewm_out_b signal asserts, an interrupt request can be generated to indicate the assertion of the EWM reset out signal. The interrupt is enabled when CTRL[INTEN] = 1. Writing 0 to this field clears the interrupt request but does not affect the ewm_out_b signal, which can be deasserted only by writing to Control (CTRL) after a system reset.

32.3.6 Clocking

The following table shows EWM clocks.

Table 245. EWM Clocks

Clock	Description
IPG_CLK	This is the system clock and should be turned on for EWM to be able to work properly. During low power modes in which the core is powered down, this clock is disabled,
IPG_CLK_S	This is the IPS clock and is synchronous with IPG_CLK. It is disabled except during IPS write accesses. it is enabled with EWM's IPS_MODULE_EN
LPO_CLOCK	This is a low power clock used for running EWM counter. This clock is gated when EWM is disabled or when ewm_out_b is asserted.

32.3.7 Using the counter clock prescaler

You can program CLKPRESCALER[CLK_DIV] to divide the EWM counter clock source. This divided clock is used to run the EWM counter.

NOTE

The divided clock used to run the EWM counter must not exceed half the frequency of the bus clock.

32.4 External signals

EWM includes external signals, as shown in the following table.

NOTE

All active-low signals are represented with the suffix "_b" throughout the chapter.

Table 246. Signal descriptions

Signal	Description	I/O
ewm_in	EWM's input for the safety status of external safety circuits. You can program the polarity of ewm_in by using CTRL[ASSIN]. The default polarity is active-low.	I
ewm_out_b	EWM's reset out signal	O

32.4.1 Using the ewm_out_b signal

The ewm_out_b is a digital output signal having active-low behaviour; it is considered as "active" or asserted when its value is logic 0 or ground, and conversely, "inactive" or deasserted when its value is logic 1. It is used to gate an external circuit (application-specific) that controls critical safety functions.

The ewm_out_b signal remains deasserted when the CPU regularly refreshes EWM within the programmable refresh window, indicating that the application code is executing as expected.

The ewm_out_b signal asserts in any of the following conditions:

- An EWM refresh action occurs when the counter value is less than the value of Compare Low (CMPL).
- The EWM counter value becomes greater than the value of Compare High (CMPH) and no EWM refresh occurs.
- The functionality of the ewm_in pin is enabled and the ewm_in pin asserts when refreshing EWM.

32.4.2 Using the ewm_out_b pin state in low-power modes

During Wait, Stop, and Power-Down modes, the ewm_out_b pin enters a high-impedance state. You have the option to control the logic state of the pin by using an external pull device or by configuring the internal pull device. When the CPU enters Run mode from Wait or Stop mode recovery, the pin resumes its previous state before entering Wait or Stop mode. When the CPU enters Run mode after exiting Power-Down mode, the pin returns to its reset state.

32.4.3 Using the ewm_in signal

The ewm_in signal is a digital input signal for the safety status of external safety circuits. This signal allows an external circuit to control the assertion of the ewm_out_b signal. For example, in the application, an external circuit monitors a critical safety function, and if there is a fault with the safety function, the external circuit can actively initiate the ewm_out_b signal, which controls the gating circuit.

The ewm_in signal is ignored if EWM is disabled, or if CTRL[INEN] = 0 after any reset.

After you enable EWM (by writing 1 to CTRL[EWMEN]) and the ewm_in functionality (by writing 1 to CTRL[INEN]), the ewm_in signal must be in Deasserted state before the CPU starts refreshing EWM. This ensures that the ewm_out_b signal stays in Deasserted state; otherwise, the ewm_out_b output signal asserts.

32.5 Memory map and register definitions

This section contains the module memory map and registers.

NOTE

EWM supports only 8-bit register accesses; 16-bit and 32-bit accesses are not supported.

32.5.1 EWM register descriptions

32.5.1.1 EWM memory map

EWM0 base address: 4001_3000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Control (CTRL)	8	RW	00h
1h	Service (SERV)	8	RW	00h
2h	Compare Low (CMPL)	8	RW	00h
3h	Compare High (CMPH)	8	RW	FFh
5h	Clock Prescaler (CLKPRESCALER)	8	RW	00h

32.5.1.2 Control (CTRL)

Offset

Register	Offset
CTRL	0h

Function

Controls the functionality of EWM.

NOTE

You can write to CTRL[INEN], CTRL[ASSIN], and CTRL[EWMEN] only once after a CPU reset. Modifying these fields more than once generates a bus transfer error.

Diagram

Bits	7	6	5	4	3	2	1	0
R	0				INTEN	INEN	ASSIN	EWMEN
W								
Reset	0	0	0	0	0	0	0	0

Fields

Field	Function
7-4 —	Reserved
3 INTEN	Interrupt Enable Enables interrupt request generation.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	If this field = 1 and the ewm_out_b signal is asserted, an interrupt request is generated. To deassert interrupt requests, write 0 to this field. 0b - Deasserts interrupt requests 1b - Generates interrupt requests
2 INEN	Input Enable Enables the ewm_in port. When this field = 1, it enables the ewm_in port. 0b - Disables 1b - Enables
1 ASSIN	Assertion State Select Specifies the asserted state of the ewm_in signal. By default, the asserted state of the ewm_in signal is logic 0 (active-low), which is when this field = 0. When this field = 1, the ewm_in asserted state is logic 1 (active-high). You can use this field to change the expected polarity of the ewm_in signal. 0b - Logic 0 1b - Logic 1
0 EWMEN	EWM Enable Enables the EWM module. If this field = 1, it enables the EWM module, and if the field = 0, it disables the EWM module. You cannot re-enable this field until the next reset because of its write-once nature. 0b - Disables 1b - Enables

32.5.1.3 Service (SERV)

Offset

Register	Offset
SERV	1h

Function

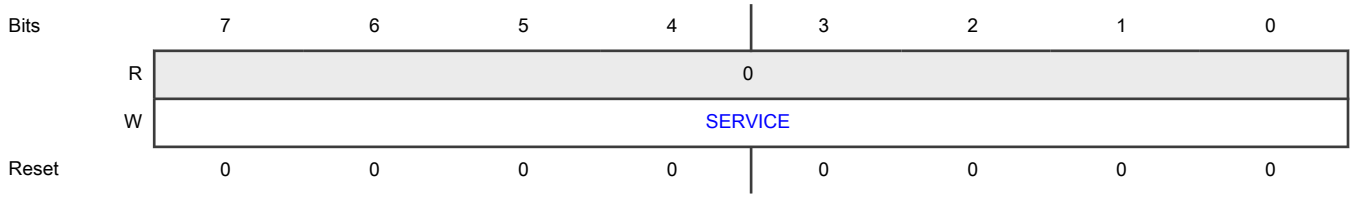
Provides an interface from the CPU to the EWM module.

Attempted reads of this register return 0.

NOTE

If CPU requests service, when EWM counter is in Stop mode, or in reset state, it will be served only when the EWM counter starts.

Diagram



Fields

Field	Function
7-0 SERVICE	Service Provides an interface from the CPU to the EWM module. The EWM refresh mechanism requires the CPU to write these values to this field: a first data byte of B4h, followed by a second data byte of 2Ch. The EWM refresh action is invalid if either of the following conditions is true: • The first or second data byte is not written correctly. • The second data byte is not written within a fixed number of peripheral bus cycles of the first data byte, known as EWM_refresh_time. The number of peripheral bus clock cycles required for EWM_refresh_time is 15.

32.5.1.4 Compare Low (CMPL)

Offset

Register	Offset
CMPL	2h

Function

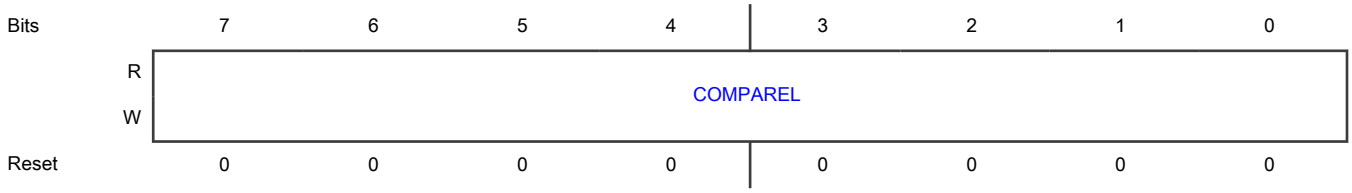
Determines the lower value of the windowed time frame for the correct EWM refresh operation.

This register is reset to 0 after a CPU reset. This provides no minimum time for the CPU to refresh the EWM counter.

NOTE

You can write to this register only once after a CPU reset. Writing to the register more than once generates a bus transfer error.

Diagram



Fields

Field	Function
7-0 COMPAREL	Compare Low Configures the minimum counter value when refreshes are allowed. If a refresh is attempted while the counter value is lower than COMPAREL, then the ewm_out_b signal is asserted. To prevent runaway code from changing the value of this field, you must write to this field after a CPU reset even if the (default) minimum refresh time is required.

32.5.1.5 Compare High (CMPH)

Offset

Register	Offset
CMPH	3h

Function

Determines the higher value of the windowed time frame for the correct EWM refresh operation.

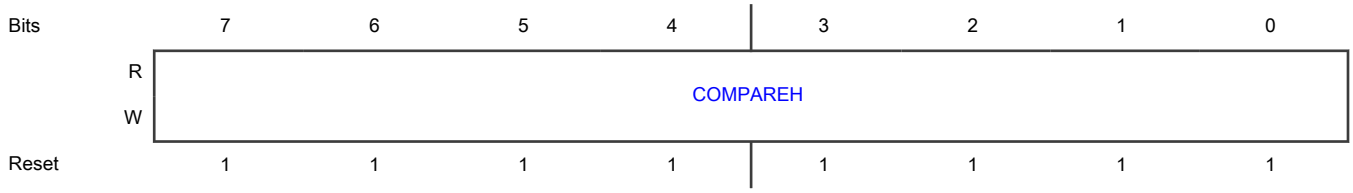
This register is reset to FFh after a CPU reset. This provides a maximum time of up to 256 clocks for the CPU to refresh the EWM counter.

NOTE

You can write to this register only once after a CPU reset. Writing to the register more than once generates a bus transfer error.

The valid values for this register are up to FEh because the EWM counter never expires when the value of COMPAREH = FFh. The expiration happens only if the EWM counter is greater than the value of COMPAREH.

Diagram



Fields

Field	Function
7-0 COMPAREH	Compare High Configures the maximum counter value till when refreshes are allowed. If a refresh is not attempted while the counter value is greater than COMPAREH, then the ewm_out_b signal is asserted. To prevent runaway code from changing the value of this field, you must write to this field after a CPU reset.

32.5.1.6 Clock Prescaler (CLKPRESCALER)

Offset

Register	Offset
CLKPRESCALER	5h

Function

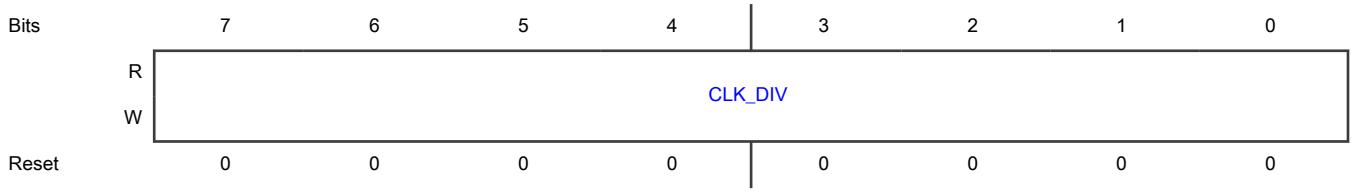
Prescales the EWM counter clock source by a clock divider.

This register is reset to 00h after a CPU reset.

NOTE

You can write to this register only once after a CPU reset. Writing to the register more than once generates a bus transfer error. You must write the required prescaler value before enabling EWM.

Diagram



Fields

Field	Function
7-0	Clock Divider Prescales the selected low-power clock source for running the EWM counter:

Table continues on the next page...

Field	Function
CLK_DIV	Prescaled clock frequency = low-power clock source frequency ÷ (1 + the value of CLK_DIV) See chip-specific information for low-power clock source frequency used in your device.

Chapter 33
Trigger Multiplexer (TRGMUX)

33.1 Chip-specific TRGMUX information

Table 247. Reference links to related information

Topic	Related module	Reference
Full description	TRGMUX	TRGMUX
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

33.1.1 Module instances

This device has one instance of the TRGMUX module, TRGMUX0.

33.1.2 TRGMUX0 inputs

Mux Select	Source Module	Source Function
0	-	Disabled
1	-	Always High
2	TRGMUX0	TRGMUX0_IN0
3	TRGMUX0	TRGMUX0_IN1
4	TRGMUX0	TRGMUX0_IN2
5	TRGMUX0	TRGMUX0_IN3
6	WUU0	Trigger Event
TIMER Modules (TMR)		
7	RTC0	Alarm Event
8	RTC0	Seconds Match
9	LPTMR0	Counter Match
10	LPTMR1	Counter Match
11	LPIT0	Channel 0
12	LPIT0	Channel 1
13	LPIT0	Channel 2
14	LPIT0	Channel 3
15	TPM0	Channel 0
16	TPM0	Channel 1

Table continues on the next page...

Table continued from the previous page...

Mux Select	Source Module	Source Function
17	TPM0	Channel 2
18	TPM0	Channel 3
19	TPM0	Channel 4
20	TPM0	Channel 5
21	TPM0	Overflow
22	TPM1	Channel 0
23	TPM1	Channel 1
24	TPM1	Channel 2
25	TPM1	Channel 3
26	TPM1	Channel 4
27	TPM1	Channel 5
28	TPM1	Overflow
COMMUNICATION Modules (COM)		
29	LPI2C0	Master End of Packet
30	LPI2C0	Slave End of Packet
31	LPI2C1	Master End of Packet
32	LPI2C1	Slave End of Packet
33	LPSPI0	End of Frame
34	LPSPI0	Received Data Word
35	LPSPI1	End of Frame
36	LPSPI1	Received Data Word
37	LPUART0	Received Data Word
38	LPUART0	Transmitted Data Word
39	LPUART0	Receive Line Idle
40	LPUART1	Received Data Word
41	LPUART1	Transmitted Data Word
42	LPUART1	Receive Line Idle
43	FLEXIO0	Channel 0
44	FLEXIO0	Channel 1
45	FLEXIO0	Channel 2
46	FLEXIO0	Channel 3
47	FLEXIO0	Channel 4

Table continues on the next page...

Table continued from the previous page...

Mux Select	Source Module	Source Function
48	FLEXIO0	Channel 5
49	FLEXIO0	Channel 6
50	FLEXIO0	Channel 7
HUMAN MACHINE INTERFACE Modules (HMI)		
51	GPIOA	Pin event Trigger 0
52	GPIOA	Pin event Trigger 1
53	GPIOB	Pin event Trigger 0
54	GPIOB	Pin event Trigger 1
55	GPIOC	Pin event Trigger 0
56	GPIOC	Pin event Trigger 1
57	GPIOD	Pin event Trigger 0
58	GPIOD	Pin event Trigger 1
ANALOG Modules (ANA)		
59	ADC-GP0	ADC-GP0 Trigger Output 0 input is selected
60	ADC-GP0	ADC-GP0 Trigger Output 1 input is selected
61	ADC-GP0	ADC-GP0 Trigger Output 2 input is selected
62	ADC-GP0	ADC-GP0 Trigger Output 3 input is selected
63	CMP-GP0	Comparator Output
64	CMP-GP1	Comparator Output
SYSTEM Modules (SYS)		
65	SPC0	DCDC Burst Trig
RADIO FREQUENCY Modules (RF)		
66	RF-2.4G	TOF TIMESTAMP TRIG
67	RF-2.4G	LANT_SW
SYSTEM Modules (SYS)		
68 - 75	Reserved	Reserved
76	CPU0_TXEV	CM33 (Main)
77	CPU1_TXEV	CM33 (Radio)
78 - 255	Reserved	Reserved

33.1.3 TRGMUX0 outputs

Destination Module	Trigger Output 3	Trigger Output 2	Trigger Output 1	Trigger Output 0
TRGMUX0	TRGMUX_OUT3	TRGMUX_OUT2	TRGMUX_OUT1	TRGMUX_OUT0
LPIT0	Trigger	Trigger	Trigger	Trigger
TPM0	Reserved	Input Capture, Trigger, Output Modulation	Input Capture, Trigger, Output Modulation	Input Capture, Trigger, Output Modulation
TPM1	Reserved	Input Capture, Trigger, Output Modulation	Input Capture, Trigger, Output Modulation	Input Capture, Trigger, Output Modulation
COMMUNICATION Modules (COM)				
LPI2C0	Reserved	Reserved	Reserved	Input Trigger
LPI2C1	Reserved	Reserved	Reserved	Input Trigger
LPSPI0	Reserved	Reserved	Reserved	Host Request
LPSPI1	Reserved	Reserved	Reserved	Host Request
LPUART0	Reserved	Reserved	Reserved	RX Input, CTS Input, TXD Modulation
LPUART1	Reserved	Reserved	Reserved	RX Input, CTS Input, TXD Modulation
FlexIO0	Trigger	Trigger	Trigger	Trigger
ANALOG Modules (ANA)				
ADC-GP0	Trigger	Trigger	Trigger	Trigger
CMP-GP0	Reserved	Reserved	Reserved	Window, Trigger
CMP-GP1	Reserved	Reserved	Reserved	Window, Trigger
COMMUNICATION Modules (COM)				
CAN0	Reserved	Reserved	Reserved	External timer Tick
CAN1	Reserved	Reserved	Reserved	External timer Tick
DSP0	Boolean Logic Combiner 3	Boolean Logic Combiner 2	Boolean Logic Combiner 1	Boolean Logic Combiner 0
DSP0	Boolean Logic Combiner 7	Boolean Logic Combiner 6	Boolean Logic Combiner 5	Boolean Logic Combiner 4

33.2 Overview

TRGMUX allows you to configure the trigger inputs for various peripherals.

33.2.1 Block diagram

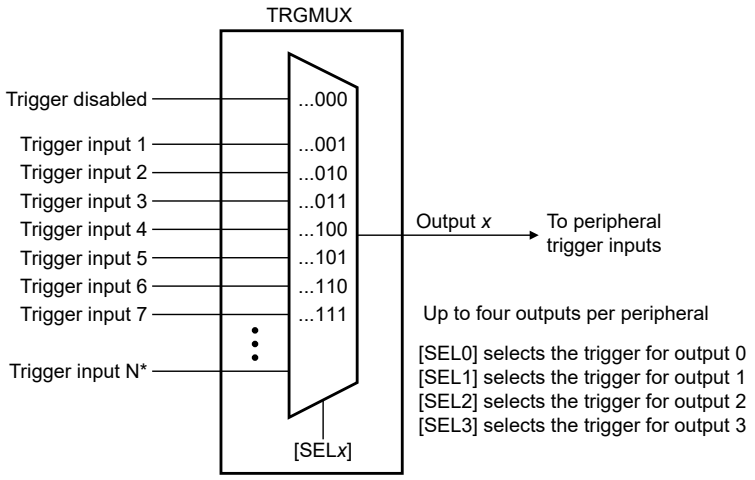


Figure 90. Block diagram

NOTE

Up to 255 trigger inputs may be available for SEL0, SEL1, and SEL2. For SEL3, up to 127 trigger inputs may be available. When the number of trigger inputs is 255, SEL3 is not available and becomes reserved. See the chip-specific TRGMUX information for details about trigger input and output configuration on this chip.

33.2.2 Features

- Configurable trigger sources for peripherals
- Dedicated TRGMUX register for each peripheral

33.3 Functional description

33.3.1 Clocking

This module has no clocking considerations.

33.3.2 Interrupts

This module has no interrupts.

33.4 External signals

This module has no external signals.

33.5 Initialization

This module does not require initialization.

33.6 TRGMUX register descriptions

33.6.1 TRGMUX memory map

You can only write to TRGMUX registers in Supervisor mode.

Table 248. Select bit fields

Field	Description
SEL*x*	Specifies the MUX select for the peripheral trigger inputs. Use this field to select the trigger sources for peripheral modules. 0h - Trigger function is disabled 1h - Trigger function is always high 2h - TRGMUX0 TRGMUX0_IN0 input is selected 3h - TRGMUX0 TRGMUX0_IN1 input is selected 4h - TRGMUX0 TRGMUX0_IN2 input is selected 5h - TRGMUX0 TRGMUX0_IN3 input is selected 6h - WUU0 Trigger Event input is selected 7h - RTC0 Alarm Event input is selected 8h - RTC0 Seconds Match input is selected 9h - LPTMR0 Counter Match input is selected Ah - LPTMR1 Counter Match input is selected Bh - LPIT0 Channel 0 input is selected Ch - LPIT0 Channel 1 input is selected Dh - LPIT0 Channel 2 input is selected Eh - LPIT0 Channel 3 input is selected Fh - TPM0 Channel 0 input is selected 10h - TPM0 Channel 1 input is selected 11h - TPM0 Channel 2 input is selected 12h - TPM0 Channel 3 input is selected 13h - TPM0 Channel 4 input is selected 14h - TPM0 Channel 5 input is selected 15h - TPM0 Overflow input is selected 16h - TPM1 Channel 0 input is selected 17h - TPM1 Channel 1 input is selected 18h - TPM1 Channel 2 input is selected 19h - TPM1 Channel 3 input is selected 1Ah - TPM1 Channel 4 input is selected 1Bh - TPM1 Channel 5 input is selected 1Ch - TPM1 Overflow input is selected 1Dh - LPI2C0 Master End of Packet input is selected 1Eh - LPI2C0 Slave End of Packet input is selected 1Fh - LPI2C1 Master End of Packet input is selected 20h - LPI2C1 Slave End of Packet input is selected

Table continues on the next page...

Table 248. Select bit fields

Field	Description
	21h - LPSPI0 End of Frame input is selected 22h - LPSPI0 Received Data Word input is selected 23h - LPSPI1 End of Frame input is selected 24h - LPSPI1 Received Data Word input is selected 25h - LPUART0 Received Data Word input is selected 26h - LPUART0 Transmitted Data Word input is selected 27h - LPUART0 Receive Line Idle input is selected 28h - LPUART1 Received Data Word input is selected 29h - LPUART1 Transmitted Data Word input is selected 2Ah - LPUART1 Receive Line Idle input is selected 2Bh - FLEXIO0 Channel 0 input is selected 2Ch - FLEXIO0 Channel 1 input is selected 2Dh - FLEXIO0 Channel 2 input is selected 2Eh - FLEXIO0 Channel 3 input is selected 2Fh - FLEXIO0 Channel 4 input is selected 30h - FLEXIO0 Channel 5 input is selected 31h - FLEXIO0 Channel 6 input is selected 32h - FLEXIO0 Channel 7 input is selected 33h - GPIOA Pin event Trigger 0 input is selected 34h - GPIOA Pin event Trigger 1 input is selected 35h - GPIOB Pin event Trigger 0 input is selected 36h - GPIOB Pin event Trigger 1 input is selected 37h - GPIOC Pin event Trigger 0 input is selected 38h - GPIOC Pin event Trigger 1 input is selected 39h - GPIOD Pin event Trigger 0 input is selected 3Ah - GPIOD Pin event Trigger 1 input is selected 3Bh - ADC-GP0 Trigger Output 0 input is selected 3Ch - ADC-GP0 Trigger Output 1 input is selected 3Dh - ADC-GP0 Trigger Output 2 input is selected 3Eh - ADC-GP0 Trigger Output 3 input is selected 3Fh - CMP-GP0 Comparator Output input is selected 40h - CMP-GP1 Comparator Output input is selected 41h - SPC0 DCDC Burst Trig input is selected 42h - RF-2.4G TOF TIMESTAMP TRIG input is selected

Table continues on the next page...

Table 248. Select bit fields

Field	Description
	43h - RF-2.4G LANT_SW input is selected 44h - EZH INT Channel 8 45h - EZH INT Channel 9 46h - EZH INT Channel 10 47h - EZH INT Channel 11 48h - EZH INT Channel 12 49h - EZH INT Channel 13 4Ah - EZH INT Channel 14 4Bh - EZH INT Channel 15 4Ch - CPU0_TXEV CM33(Main) input is selected 4Dh - CPU1_TXEV CM33(Radio) input is selected 4Eh - Unused 4Fh - Unused 50h - Unused 51h - Unused 52h - Unused 53h - Unused 54h - Unused 55h - Unused 56h - Unused 57h - Unused 58h - Unused 59h - Unused 5Ah - Unused 5Bh - Unused 5Ch - Unused 5Dh - Unused 5Eh - Unused 5Fh - Unused 60h - Unused 61h - Unused 62h - Unused 63h - Unused 64h - Unused

Table continues on the next page...

Table 248. Select bit fields

Field	Description
	65h - Unused 66h - Unused 67h - Unused 68h - Unused 69h - Unused 6Ah - Unused 6Bh - Unused 6Ch - Unused 6Dh - Unused 6Eh - Unused 6Fh - Unused 70h - Unused 71h - Unused 72h - Unused 73h - Unused 74h - Unused 75h - Unused 76h - Unused 77h - Unused 78h - Unused 79h - Unused 7Ah - Unused 7Bh - Unused 7Ch - Unused 7Dh - Unused 7Eh - Unused 7Fh - Unused

TRGMUX0 base address: 4001_8000h

Offset	Register	Width (In bits)	Access	Reset value
0h	TRGMUX TRGMUX_OUT0 (TRGMUX_OUT0)	32	RW	0000_0000h
4h	TRGMUX LPIT0 (LPIT0)	32	RW	0000_0000h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
8h	TRGMUX TPM0 (TPM0)	32	RW	0000_0000h
Ch	TRGMUX TPM1 (TPM1)	32	RW	0000_0000h
10h	TRGMUX LPI2C0 (LPI2C0)	32	RW	0000_0000h
14h	TRGMUX LPI2C1 (LPI2C1)	32	RW	0000_0000h
18h	TRGMUX LPSPI0 (LPSPI0)	32	RW	0000_0000h
1Ch	TRGMUX LPSPI1 (LPSPI1)	32	RW	0000_0000h
20h	TRGMUX LPUART0 (LPUART0)	32	RW	0000_0000h
24h	TRGMUX LPUART1 (LPUART1)	32	RW	0000_0000h
28h	TRGMUX FLEXIO0 (FLEXIO0)	32	RW	0000_0000h
2Ch	TRGMUX ADC_GP0 (ADC_GP0)	32	RW	0000_0000h
30h	TRGMUX CMP_GP0 (CMP_GP0)	32	RW	0000_0000h
34h	TRGMUX CMP_GP1 (CMP_GP1)	32	RW	0000_0000h
38h	TRGMUX CAN0 (CAN0)	32	RW	0000_0000h
3Ch	TRGMUX CAN1 (CAN1)	32	RW	0000_0000h
40h	TRGMUX EZH_BLCIN_3_0 (EZH_BLCIN_3_0)	32	RW	0000_0000h
44h	TRGMUX EZH_BLCIN_7_4 (EZH_BLCIN_7_4)	32	RW	0000_0000h

33.6.2 TRGMUX TRGMUX_OUT0 (TRGMUX_OUT0)

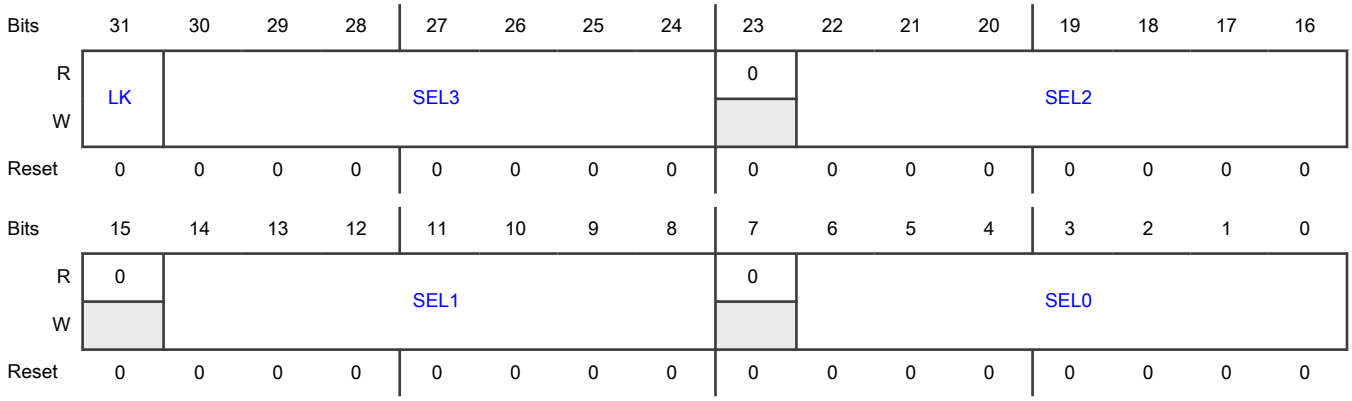
Offset

Register	Offset
TRGMUX_OUT0	0h

Function

Configures the TRGMUX_OUT0 module.

Diagram



Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable 1b - Register is not writable until the next system reset
30-24 SEL3	TRGMUX Source Select 3 Specifies the source select for output 3. See Table 248 for field values.
23 —	Reserved
22-16 SEL2	TRGMUX Source Select 2 Specifies the source select for output 2. See Table 248 for field values.
15 —	Reserved
14-8 SEL1	TRGMUX Source Select 1 Specifies the source select for output 1. See Table 248 for field values.
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

33.6.3 TRGMUX LPIT0 (LPIT0)

Offset

Register	Offset
LPIT0	4h

Function

Configures the LPIT0 module.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	SEL3							0	SEL2						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	SEL1							0	SEL0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable 1b - Register is not writable until the next system reset
30-24 SEL3	TRGMUX Source Select 3 Specifies the source select for output 3. See Table 248 for field values.
23 —	Reserved
22-16 SEL2	TRGMUX Source Select 2 Specifies the source select for output 2. See Table 248 for field values.
15 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
14-8 SEL1	TRGMUX Source Select 1 Specifies the source select for output 1. See Table 248 for field values.
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

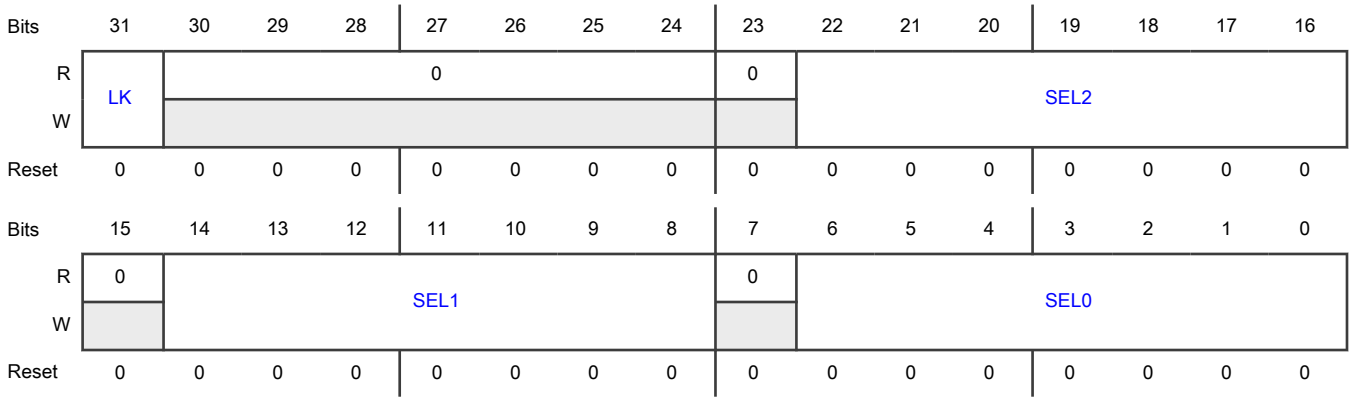
33.6.4 TRGMUX TPM0 (TPM0)

Offset

Register	Offset
TPM0	8h

Function
Configures the TPM0 module.

Diagram



Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Register is not writable until the next system reset
30-24 —	Reserved
23 —	Reserved
22-16 SEL2	TRGMUX Source Select 2 Specifies the source select for output 2. See Table 248 for field values.
15 —	Reserved
14-8 SEL1	TRGMUX Source Select 1 Specifies the source select for output 1. See Table 248 for field values.
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

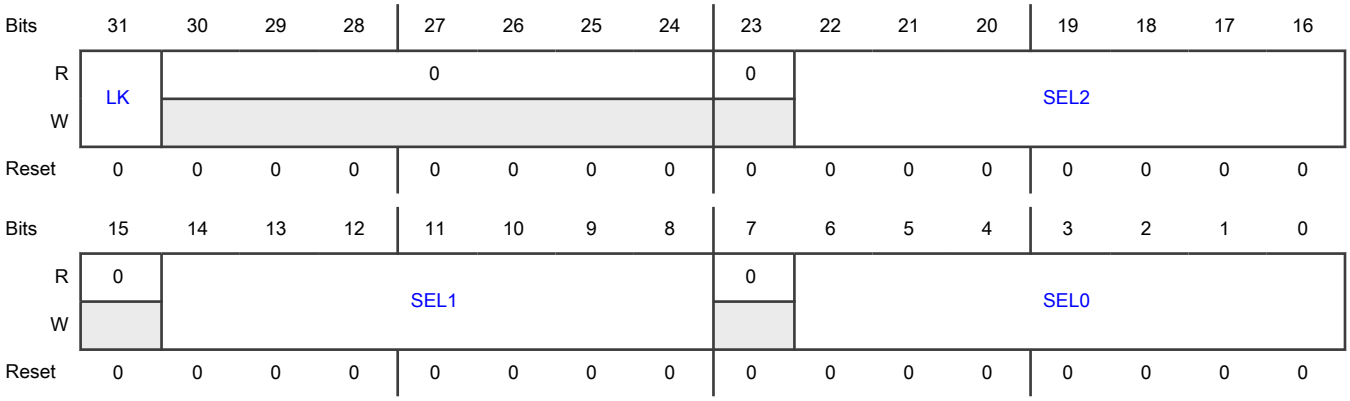
33.6.5 TRGMUX TPM1 (TPM1)

Offset

Register	Offset
TPM1	Ch

Function
Configures the TPM1 module.

Diagram



Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable 1b - Register is not writable until the next system reset
30-24 —	Reserved
23 —	Reserved
22-16 SEL2	TRGMUX Source Select 2 Specifies the source select for output 2. See Table 248 for field values.
15 —	Reserved
14-8 SEL1	TRGMUX Source Select 1 Specifies the source select for output 1. See Table 248 for field values.
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

33.6.6 TRGMUX LPI2C0 (LPI2C0)

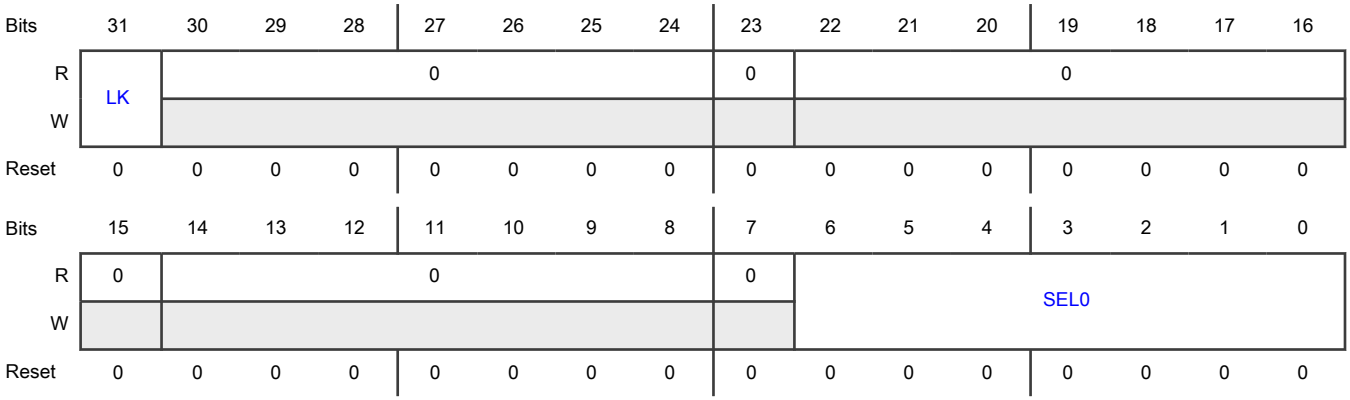
Offset

Register	Offset
LPI2C0	10h

Function

Configures the LPI2C0 module.

Diagram



Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable 1b - Register is not writable until the next system reset
30-24 —	Reserved
23 —	Reserved
22-16 —	Reserved
15 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
14-8 —	Reserved
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

33.6.7 TRGMUX LPI2C1 (LPI2C1)

Offset

Register	Offset
LPI2C1	14h

Function

Configures the LPI2C1 module.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0							0	SEL0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Register is not writable until the next system reset
30-24 —	Reserved
23 —	Reserved
22-16 —	Reserved
15 —	Reserved
14-8 —	Reserved
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

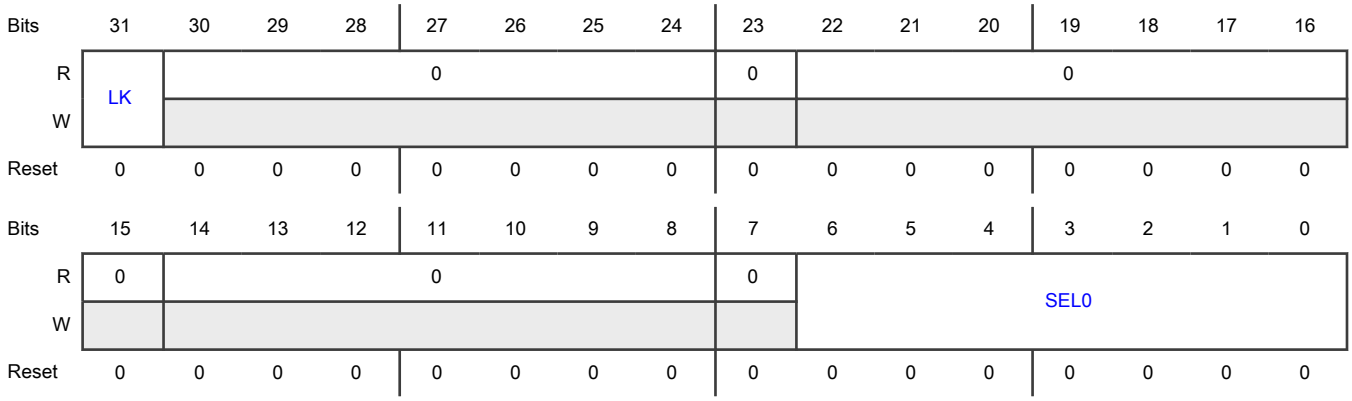
33.6.8 TRGMUX LPSPI0 (LPSPI0)

Offset

Register	Offset
LPSPI0	18h

Function
Configures the LPSPI0 module.

Diagram



Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable 1b - Register is not writable until the next system reset
30-24 —	Reserved
23 —	Reserved
22-16 —	Reserved
15 —	Reserved
14-8 —	Reserved
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

33.6.9 TRGMUX LPSPI1 (LPSPI1)

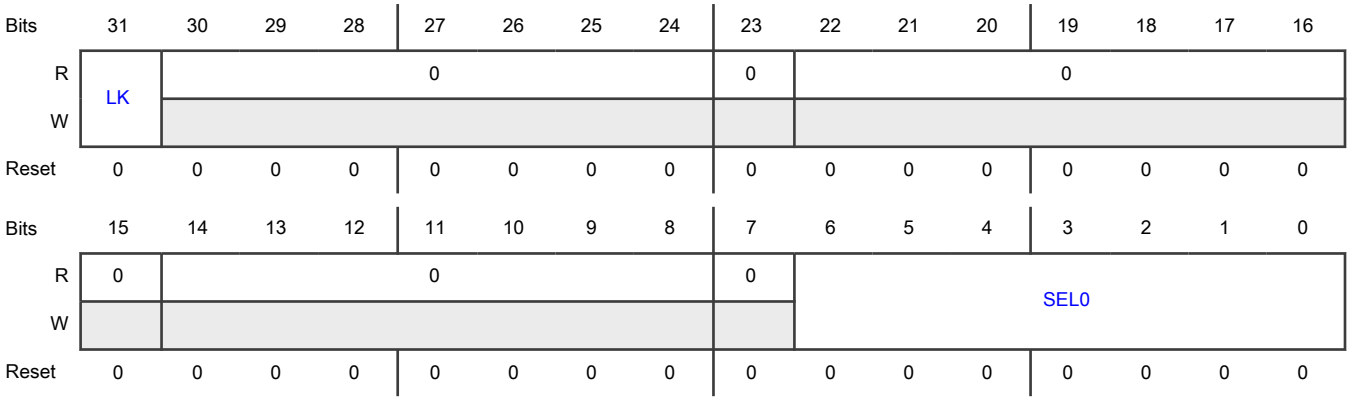
Offset

Register	Offset
LPSPI1	1Ch

Function

Configures the LPSPI1 module.

Diagram



Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable 1b - Register is not writable until the next system reset
30-24 —	Reserved
23 —	Reserved
22-16 —	Reserved
15 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
14-8 —	Reserved
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

33.6.10 TRGMUX LPUART0 (LPUART0)

Offset

Register	Offset
LPUART0	20h

Function
Configures the LPUART0 module.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0							0	SEL0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Register is not writable until the next system reset
30-24 —	Reserved
23 —	Reserved
22-16 —	Reserved
15 —	Reserved
14-8 —	Reserved
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

33.6.11 TRGMUX LPUART1 (LPUART1)

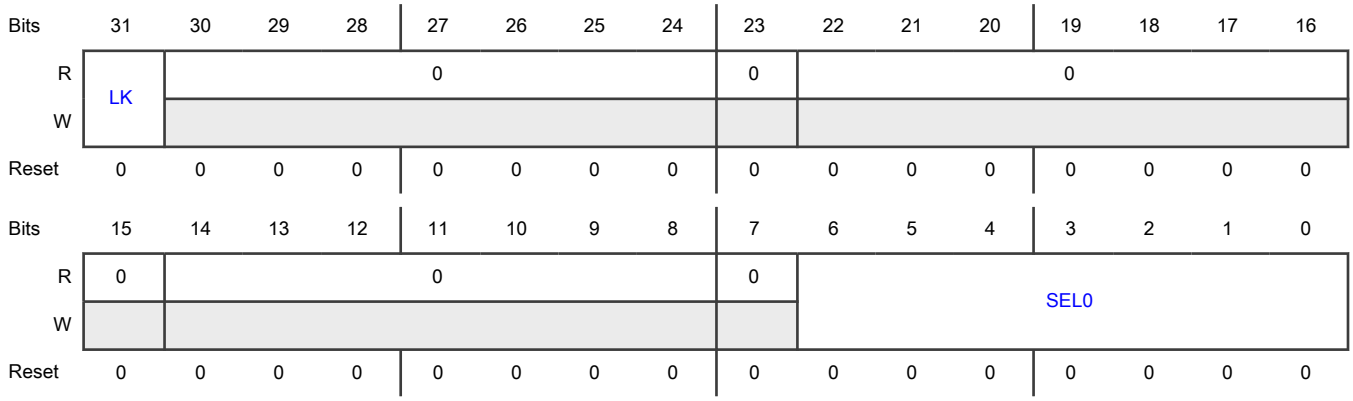
Offset

Register	Offset
LPUART1	24h

Function

Configures the LPUART1 module.

Diagram



Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable 1b - Register is not writable until the next system reset
30-24 —	Reserved
23 —	Reserved
22-16 —	Reserved
15 —	Reserved
14-8 —	Reserved
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

33.6.12 TRGMUX FLEXIO0 (FLEXIO0)

Offset

Register	Offset
FLEXIO0	28h

Function

Configures the FLEXIO0 module.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	SEL3							0	SEL2						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	SEL1							0	SEL0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable 1b - Register is not writable until the next system reset
30-24 SEL3	TRGMUX Source Select 3 Specifies the source select for output 3. See Table 248 for field values.
23 —	Reserved
22-16 SEL2	TRGMUX Source Select 2 Specifies the source select for output 2. See Table 248 for field values.
15 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
14-8 SEL1	TRGMUX Source Select 1 Specifies the source select for output 1. See Table 248 for field values.
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

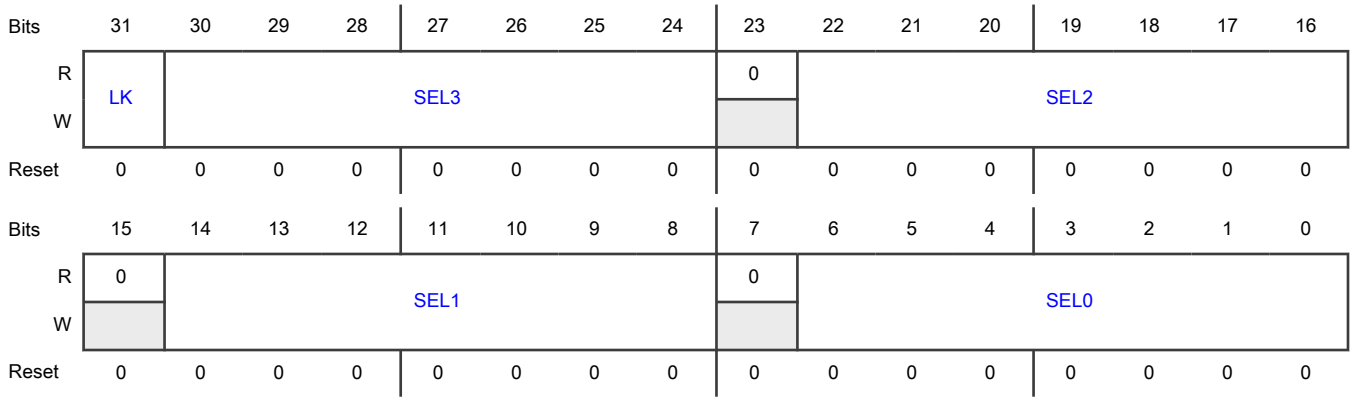
33.6.13 TRGMUX ADC_GP0 (ADC_GP0)

Offset

Register	Offset
ADC_GP0	2Ch

Function
Configures the ADC_GP0 module.

Diagram



Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Register is not writable until the next system reset
30-24 SEL3	TRGMUX Source Select 3 Specifies the source select for output 3. See Table 248 for field values.
23 —	Reserved
22-16 SEL2	TRGMUX Source Select 2 Specifies the source select for output 2. See Table 248 for field values.
15 —	Reserved
14-8 SEL1	TRGMUX Source Select 1 Specifies the source select for output 1. See Table 248 for field values.
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

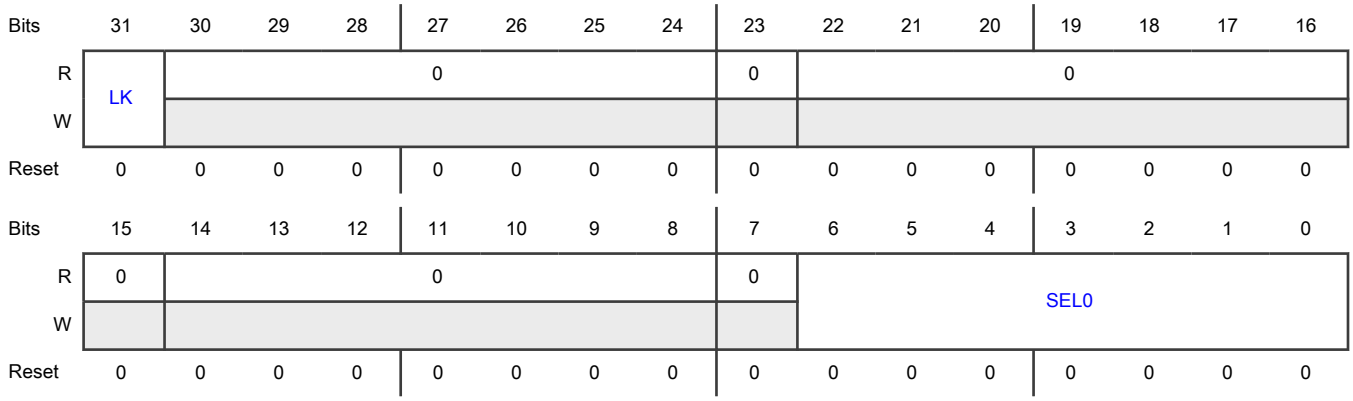
33.6.14 TRGMUX CMP_GP0 (CMP_GP0)

Offset

Register	Offset
CMP_GP0	30h

Function
Configures the CMP_GP0 module.

Diagram



Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable 1b - Register is not writable until the next system reset
30-24 —	Reserved
23 —	Reserved
22-16 —	Reserved
15 —	Reserved
14-8 —	Reserved
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

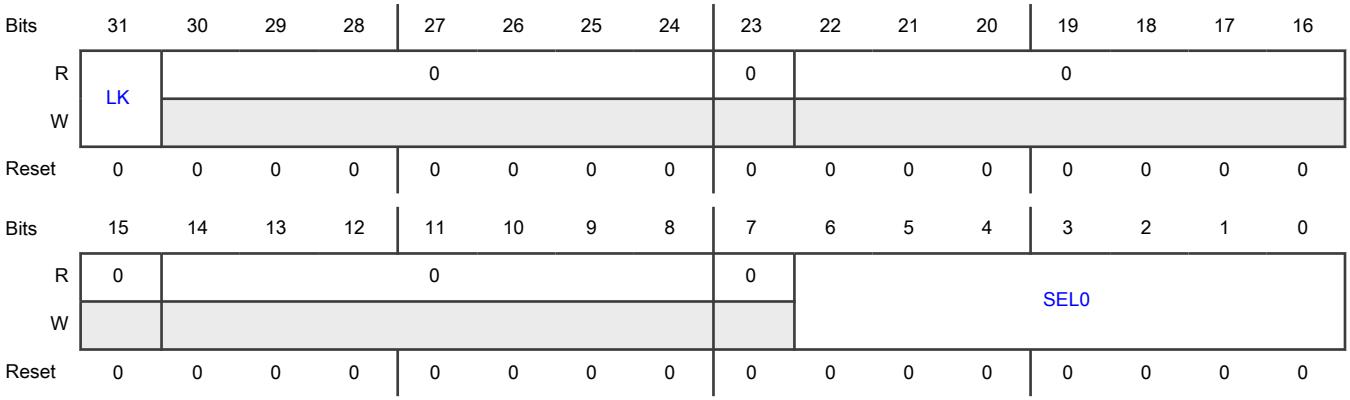
33.6.15 TRGMUX CMP_GP1 (CMP_GP1)

Offset

Register	Offset
CMP_GP1	34h

Function
Configures the CMP_GP1 module.

Diagram



Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable 1b - Register is not writable until the next system reset
30-24 —	Reserved
23 —	Reserved
22-16 —	Reserved
15 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
14-8 —	Reserved
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

33.6.16 TRGMUX CAN0 (CAN0)

Offset

Register	Offset
CAN0	38h

Function
Configures the CAN0 module.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0							0	SEL0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Register is not writable until the next system reset
30-24 —	Reserved
23 —	Reserved
22-16 —	Reserved
15 —	Reserved
14-8 —	Reserved
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

33.6.17 TRGMUX CAN1 (CAN1)

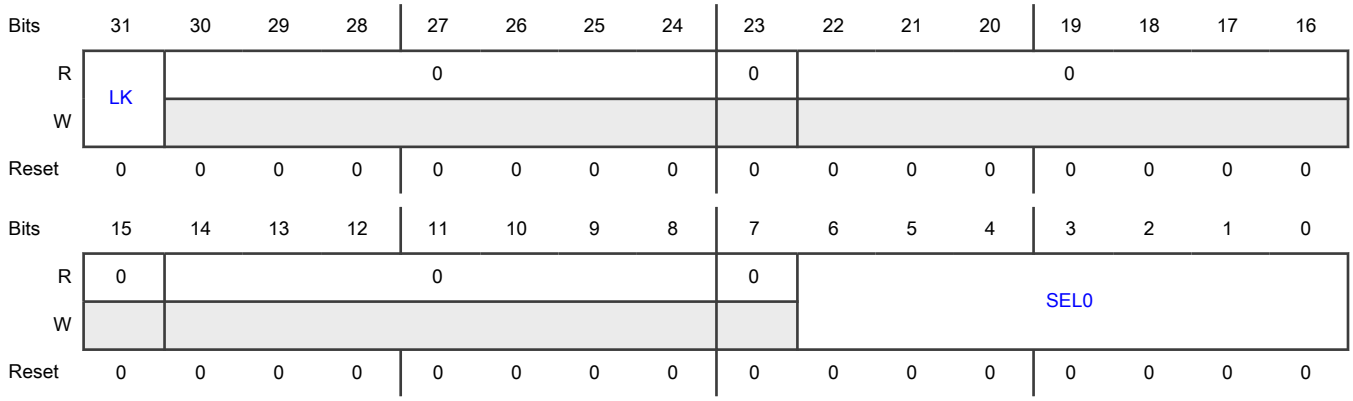
Offset

Register	Offset
CAN1	3Ch

Function

Configures the CAN1 module.

Diagram



Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable 1b - Register is not writable until the next system reset
30-24 —	Reserved
23 —	Reserved
22-16 —	Reserved
15 —	Reserved
14-8 —	Reserved
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

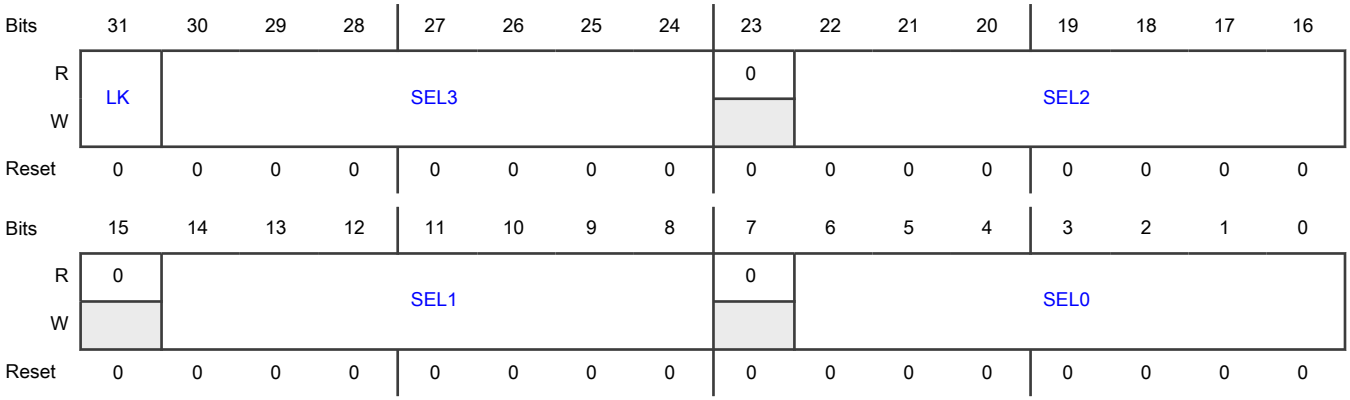
33.6.18 TRGMUX EZH_BLCIN_3_0 (EZH_BLCIN_3_0)

Offset

Register	Offset
EZH_BLCIN_3_0	40h

Function
Configures the EZH_BLCIN_3_0 module.

Diagram



Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable 1b - Register is not writable until the next system reset
30-24 SEL3	TRGMUX Source Select 3 Specifies the source select for output 3. See Table 248 for field values.
23 —	Reserved
22-16 SEL2	TRGMUX Source Select 2 Specifies the source select for output 2. See Table 248 for field values.
15 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
14-8 SEL1	TRGMUX Source Select 1 Specifies the source select for output 1. See Table 248 for field values.
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

33.6.19 TRGMUX EZH_BLCIN_7_4 (EZH_BLCIN_7_4)

Offset

Register	Offset
EZH_BLCIN_7_4	44h

Function
Configures the EZH_BLCIN_7_4 module.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	SEL3							0	SEL2						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	SEL1							0	SEL0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 LK	TRGMUX Register Lock Disables writing to the register. You can write to this field once after system reset. When this field is 1, you cannot write to SEL*x* until the next system reset. This field becomes 0 after system reset. 0b - Register is writable

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Register is not writable until the next system reset
30-24 SEL3	TRGMUX Source Select 3 Specifies the source select for output 3. See Table 248 for field values.
23 —	Reserved
22-16 SEL2	TRGMUX Source Select 2 Specifies the source select for output 2. See Table 248 for field values.
15 —	Reserved
14-8 SEL1	TRGMUX Source Select 1 Specifies the source select for output 1. See Table 248 for field values.
7 —	Reserved
6-0 SEL0	TRGMUX Source Select 0 Specifies the source select for output 0. See Table 248 for field values.

Chapter 34
Wakeup Unit (WUU)

34.1 Chip-specific WUU information

Table 249. Reference links to related information

Topic	Related module	Reference
Full description	WUU	WUU
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

34.1.1 Module instances

This device contains one instance of the WUU module, WUU0.

34.1.2 WUU0 sources

The device uses the following inputs as wakeup sources to the WUU0 module. The WUU0_Px inputs are connections to external physical pins. The WUU0_MxIF inputs are connections to the internal peripheral interrupt flags from different modules that can operate in low-power modes. The WUU0_MxDR inputs are connections to the internal peripheral Asynchronous DMA or module Triggers from different modules that can operate in low-power modes.

NOTE

In addition to the WUU0 wakeup sources, the device also wakes from low power modes when NMI_b or RESET_b pins are enabled and the respective pin is asserted.

Table 250. Wakeup sources for WUU0 inputs

WUU0 input	Source description
WUU0_P0	PTA0
WUU0_P1	PTA2
WUU0_P2	PTA4
WUU0_P3	PTA17
WUU0_P4	PTA19
WUU0_P5	PTA21
WUU0_P6	PTA22
WUU0_P7	PTC0
WUU0_P8	PTC1
WUU0_P9	PTC2
WUU0_P10	PTC4
WUU0_P11	PTC6

Table continues on the next page...

Table 250. Wakeup sources for WUU0 inputs (continued)

WUU0 input	Source description
WUU0_P12	PTC7
WUU0_P13	PTB0
WUU0_P14	PTB3
WUU0_P15	PTB4
WUU0_P16	PTB6
WUU0_P17	PTB8
WUU0_P18	PTA6
WUU0_P19	PTA16
WUU0_P20	PTA18
WUU0_P21	PTA26
WUU0_P22	PTC5
WUU0_P23	PTC9
WUU0_P24	PTC12
WUU0_P25	PTC14
WUU0_P26	PTC16
WUU0_P27	CMP0 Output
WUU0_P28	CMP1 Output
WUU0_P29	—
WUU0_P30	—
WUU0_P31	—
WUU0_M0IF	LPTMR0, LPTMR1
WUU0_M1IF	GPIOD Interrupt 0
WUU0_M2IF	GPIOD Interrupt 1
WUU0_M3IF	Wake-From-Radio (WFR)
WUU0_M4IF	Wake From Smart Power Switch Domain
WUU0_M5IF	Digital Tamper Detect
WUU0_M6IF	Real Time Clock 0 Alarm
WUU0_M7IF	Real Time Clock 0 Seconds
WUU0_M0DR	LPTMR0 Asynchronous DMA
WUU0_M1DR	LPTMR1 Asynchronous DMA
WUU0_M2DR	Radio Asynchronous wakeup request
WUU0_M3DR	Reserved

Table continues on the next page...

Table 250. Wakeup sources for WUU0 inputs (continued)

WUU0 input	Source description
WUU0_M4DR	GPIOD Asynchronous DMA request 0
WUU0_M5DR	GPIOD Asynchronous DMA request 1
WUU0_M6DR	Reserved
WUU0_M7DR	Reserved
WUU0_M8DR	LPTMR0 Asynchronous Trigger
WUU0_M9DR	LPTMR1 Asynchronous Trigger
WUU0_M8IF	Radio IMU wakeup request

34.1.3 LPO clock

The LPO mentioned in this chapter is the 32 kHz clock from CCM32K, see 32 kHz Clock Control Module (CCM32K) for details.

34.2 Overview

WUU facilitates in selecting external pins and on-chip modules as interrupt wake-up sources from Deep Sleep/Power Down power modes. You can also configure the external pins to act as interrupt wake-up sources in all power modes. WUU helps pins and modules generate a temporary wake-up from Deep Sleep mode for servicing DMA or trigger events. Digital filtering is also available for the external wake-up pins.

See the chip-specific WUU information section for input sources to WUU.

34.2.1 Block diagram

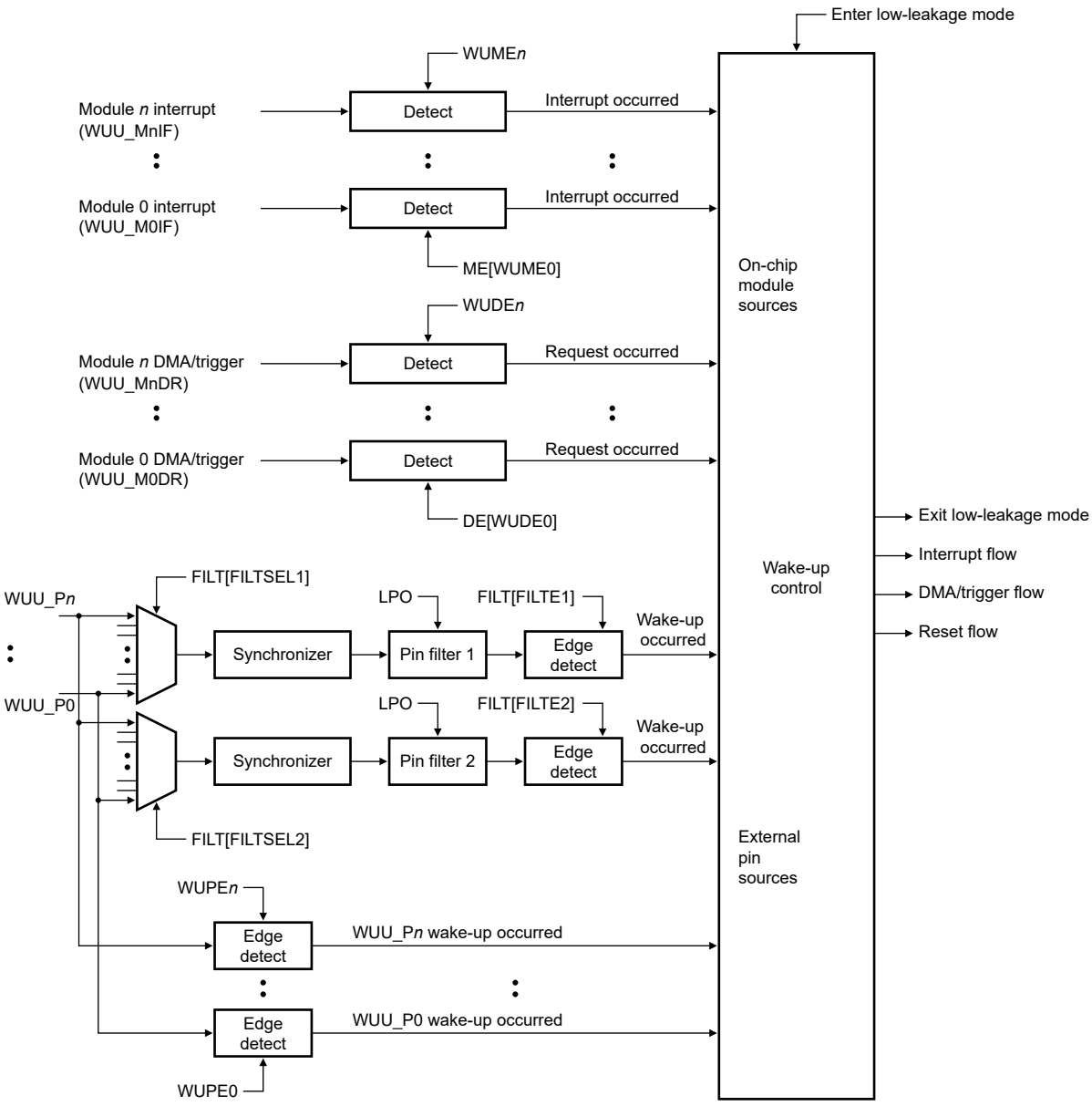


Figure 91. WUU block diagram

34.2.2 Features

- Supports external input pins and on-chip modules with individual enable bits to wake the chip from low-leakage modes.
- Contains input sources that may be external pins or from on-chip modules capable of running in Deep Sleep or Power Down power modes. See the chip-specific WUU information for the wake-up input sources for this chip.
- Supports configuring on-chip modules as DMA or trigger sources for temporary wake-up from Deep Sleep mode.
- Supports configuring external pins as DMA request or trigger sources for temporary wake-up from Deep Sleep mode.
- Provides external input pins programmable for falling-edge, rising-edge, or any edge detection.
- Provides optional digital filters to qualify an external pin detect. Disabling the LPO clock bypasses and disables filters.

- Filters all external input pins; but only 2 filters are available at a given time.
- Enables external input pin and filter detection in all power modes (not limited to Deep Sleep/Power Down power modes).

34.3 Functional description

34.3.1 Operation

WUU allows on-chip modules and external input pins as a source of wake-up from low-leakage modes.

WUU contains pin enables for each external pin and on-chip module. For each external pin, you can disable or select the edge type for the wake-up with the following options:

- Falling edge
- Rising edge
- Either edge

Exit due to a pin event triggers a WUU interrupt after wake-up is complete. When enabling an external pin as a wake-up source, configure the pin as an input pin. You can also configure a pin to generate an interrupt from a Deep Sleep/Power Down mode or a DMA/trigger event for temporary wake-up from Deep Sleep mode. Detection logic for a pin can optionally remain enabled during all power modes using Pin Mode Configuration (PMC).

On the basis of the LPO clock, WUU implements optional 3-cycle glitch filters. Detected external pin must remain asserted until the enabled glitch filter times out. Additional latency of up to two cycles is due to synchronization, which results in a total of up to five cycles of delay before the detect circuit alerts the system to the wake-up event when the filter function is enabled. Two wake-up detect filters are available for selected external pins. Glitch filtering is not provided for the on-chip modules. You can configure a filter to generate an interrupt from Deep Sleep/Power Down mode or a DMA/trigger event for temporary wake-up from Deep Sleep mode. Detection logic for a filter can optionally remain enabled during all power modes using Pin Filter Mode Configuration (FMC).

For on-chip module interrupts, ME[WUME*n*] enables the associated module interrupt as a wake-up source. Exit due to a module interrupt will not trigger a WUU interrupt.

For on-chip module DMA/trigger events, DE[WUDE*n*] enables the associated module DMA/trigger event as a wake-up source. Exit due to a module DMA/trigger event does not trigger a WUU interrupt.

34.3.2 Modes of operation

WUU becomes functional on entry into a low-leakage power mode. After recovery from Deep Sleep mode, WUU is immediately disabled. After recovery from Power Down mode, WUU continues to detect wake-up events until you have reinitialized the system and deasserted isolation. Detection of external pin/filter events can also optionally remain enabled in all power modes using Pin Mode Configuration (PMC)/Pin Filter Mode Configuration (FMC).

34.3.2.1 Deep Sleep mode

Wake-up events due to either an external pin input (WUU_Px) or an on-chip module interrupt (WUU_MxIF) result in a CPU interrupt flow to begin user code execution. The source of the wake-up determines the subsequent path of code execution:

- Pin events trigger the WUU interrupt service routine.
- Module interrupts trigger that same module's interrupt service routine.

NOTE

The interrupt controller must not mask the WUU interrupt to avoid a scenario where the system does not fully recover from Deep Sleep mode after an external pin event.

Wake-up events due to an on-chip module request (WUU_MxDR) DMA/trigger event result in a temporary exit from Deep Sleep mode to allow the request to be serviced when the CPU clock remains gated. The system reenters Deep Sleep mode after servicing the request.

Wake-up events due to an external pin (WUU_Px) DMA/trigger event result in a temporary exit from Deep Sleep mode to allow the request to be serviced when the CPU clock remains gated. The system reenters Deep Sleep mode after servicing the request.

34.3.2.2 Non–low-leakage modes

WUU is inactive in all non–low-leakage modes, with the exception of external pin/filter detection which can explicitly be kept enabled during all power modes using Pin Mode Configuration (PMC)/Pin Filter Mode Configuration (FMC). WUU chips are accessible in non–low-leakage modes and are available for configuring and reading status when bus transactions are possible.

34.3.3 Clocking

During chip low-power operation, in order to provide the wake-up function for the chip, ensure that clocking is available for WUU by the LPO clock. See the chip-specific WUU information for the chip clock connection details.

34.3.4 Reset

WUU resets after VSYS warm reset. This is the global chip reset, but it does not include the reset that asserts due to wake-up from low-power mode.

34.3.5 Interrupts

You can enable on-chip module interrupts as wake-up sources in Module Interrupt Enable (ME).

34.3.6 DMA

You can enable on-chip DMA requests as wake-up sources in Module DMA/Trigger Enable (DE).

With external pin inputs, you can generate a DMA request using either rising edge, falling edge, or both edge detection in Pin DMA/Trigger Configuration 1 (PDC1) and Pin DMA/Trigger Configuration 2 (PDC2).

34.4 External signals

Table 251. External signals

Signal	Description	I/O
WUU_Pn	External pin wake-up inputs; can be enabled to detect a rising edge, a falling edge, or any change.	I
WUU_MnIF	On-chip module interrupt flags	I
WUU_MnDR	On-chip module DMA/trigger events	I

34.5 Initialization

For an enabled module wake-up input, clear the module's flag before entering Deep Sleep or Power Down mode to avoid an immediate exit from the mode.

Clear the flags associated with external input pins, filtered and unfiltered, prior to entry to Deep Sleep or Power Down mode.

When an external wake-up pin filter is first enabled in Pin Filter (FILT), filter operation begins immediately. After enabling an external pin filter or changing its source pin, wait for at least five LPO clock cycles to allow the filter to initialize before entering Deep Sleep or Power Down mode or before enabling filter detection for all power modes in Pin Filter Mode Configuration (FMC).

NOTE

After recovering from a Power Down mode, you must restore the chip configuration before relaxing any power domain isolation controls. In particular, to avoid any WUU flag from being falsely set, restore the pin configuration for the enabled WUU wake-up pins before removing any voltage isolation between power domains.

34.6 Application information

To enable an external pin as a wake-up source in low-power modes, follow these steps:

1. If the flag is not 0, write 1 to PF[WUF*n*].
2. Configure the PDC*m*[WUPDC*n*] as either an interrupt or DMA request.
3. Configure the PE*m*[WUPE*n*] for rising edge, falling edge, or both edge detection.

When you have configured an external pin to be an active wake-up source in all power modes (PMC[WUPMC*n*] = 1), you must not change the corresponding wake-up pin enable (PE*m*[WUPE*n*]) and wake-up pin configuration (PDC*m*[WUPDC*n*]) settings for that pin. To modify the PE*m*[WUPE*n*] or PDC*m*[WUPDC*n*] settings, follow these steps:

1. Write 0 to PMC[WUPMC*n*] for that pin.
2. Update the corresponding PE*m*[WUPE*n*] or PDC*m*[WUPDC*n*] settings as needed.
3. Write 1 to PMC[WUPMC*n*] for that pin.

34.7 Memory map and register definition

This section includes the WUU module memory map and detailed descriptions of all registers.

34.7.1 WUU register descriptions

NOTE

You can write to WUU registers only in Supervisor mode. A bus error results from write accesses in User mode.

VSYS warm reset resets all WUU registers.

34.7.1.1 WUU memory map

WUU0 base address: 4001_9000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	0100_0001h
4h	Parameter (PARAM)	32	R	2020_2002h
8h	Pin Enable 1 (PE1)	32	RW	0000_0000h
Ch	Pin Enable 2 (PE2)	32	RW	0000_0000h
18h	Module Interrupt Enable (ME)	32	RW	0000_0000h
1Ch	Module DMA/Trigger Enable (DE)	32	RW	0000_0000h
20h	Pin Flag (PF)	32	RW	0000_0000h
30h	Pin Filter (FILT)	32	RW	0000_0000h
38h	Pin DMA/Trigger Configuration 1 (PDC1)	32	RW	0000_0000h
3Ch	Pin DMA/Trigger Configuration 2 (PDC2)	32	RW	0000_0000h
48h	Pin Filter DMA/Trigger Configuration (FDC)	32	RW	0000_0000h
50h	Pin Mode Configuration (PMC)	32	RW	0000_0000h
58h	Pin Filter Mode Configuration (FMC)	32	RW	0000_0000h

34.7.1.2 Version ID (VERID)

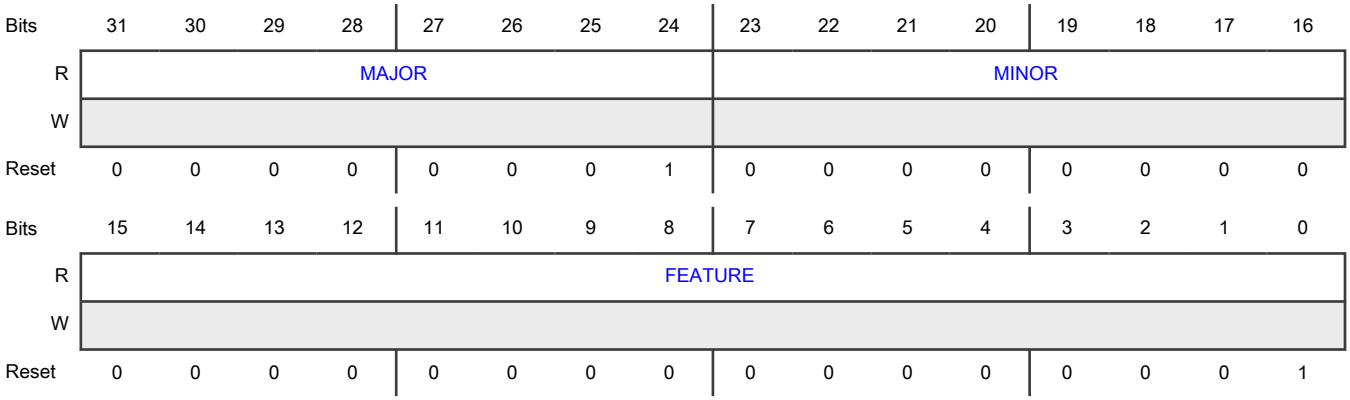
Offset

Register	Offset
VERID	0h

Function

Contains version numbers for the module design and feature set.

Diagram



Fields

Field	Function
31-24 MAJOR	Major Version Number Specifies the major version number for the module specification.
23-16 MINOR	Minor Version Number Specifies the minor version number for the module specification.
15-0 FEATURE	Feature Specification Number Specifies the feature set number. 0000_0000_0000_0000b - Standard features implemented 0000_0000_0000_0001b - Support for DMA/Trigger generation from wake-up pins and filters enabled. Support for external pin/filter detection during all power modes enabled. All other values are reserved.

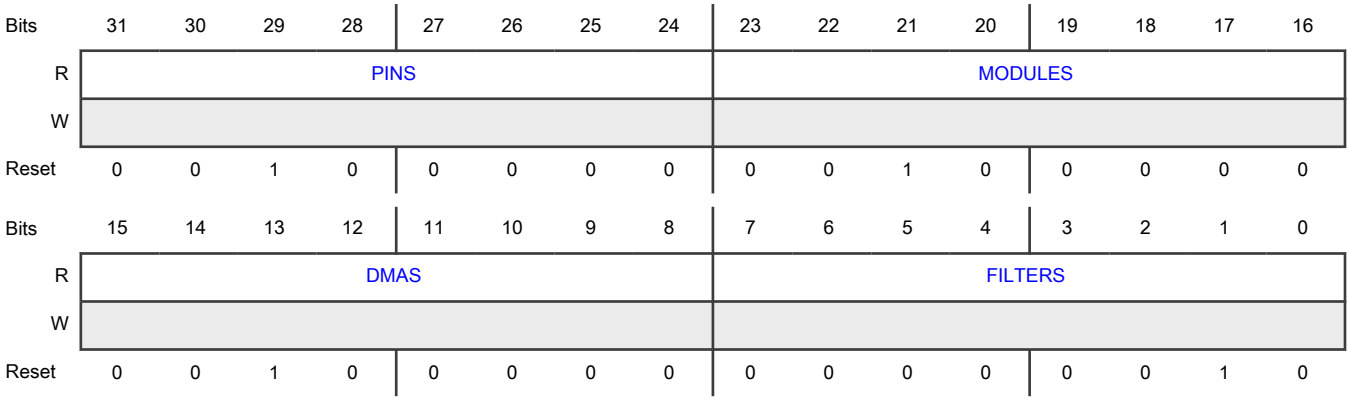
34.7.1.3 Parameter (PARAM)

Offset

Register	Offset
PARAM	4h

Function
Contains parameter values implemented in the module.

Diagram



Fields

Field	Function
31-24 PINS	Pin Number Indicates the number of pin wake-up sources supported.
23-16 MODULES	Module Number Indicates the number of module wake-up sources.
15-8 DMAS	DMA Number Indicates the number of DMA wake-up sources.
7-0 FILTERS	Filter Number Indicates the number of pin filters.

34.7.1.4 Pin Enable 1 (PE1)

Offset

Register	Offset
PE1	8h

Function

Enables and selects the edge detect type for the available external wake-up input pins in the range from WUU_P0 to WUU_P15.

NOTE

- Do not modify the value of PE1[WUPE*n*] when its corresponding PMC[WUPMC*n*] = 1.
- VSYS warm reset resets this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	WUPE15		WUPE14		WUPE13		WUPE12		WUPE11		WUPE10		WUPE9		WUPE8	
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	WUPE7		WUPE6		WUPE5		WUPE4		WUPE3		WUPE2		WUPE1		WUPE0	
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 WUPE15	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
29-28 WUPE14	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge.

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Field	Function
	00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
27-26 WUPE13	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
25-24 WUPE12	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
23-22 WUPE11	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable

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Field	Function
	01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
21-20 WUPE10	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
19-18 WUPE9	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
17-16 WUPE8	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level)

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Field	Function
	10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
15-14 WUPE7	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
13-12 WUPE6	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
11-10 WUPE5	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level)

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Field	Function
	11b - Enable (detect on any edge)
9-8 WUPE4	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
7-6 WUPE3	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
5-4 WUPE2	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)

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Field	Function
3-2 WUPE1	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
1-0 WUPE0	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)

34.7.1.5 Pin Enable 2 (PE2)

Offset

Register	Offset
PE2	Ch

Function

Contains the field to enable and select the edge detect type for the available external wake-up input pins in the range from WUU_P16 to WUU_P31.

NOTE

- Do not modify the value of PE2[WUPE*n*] when its corresponding PMC[WUPMC*n*] = 1.
- VSYS warm reset resets this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		0		0		WUPE28		WUPE27		WUPE26		WUPE25		WUPE24	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	WUPE23		WUPE22		WUPE21		WUPE20		WUPE19		WUPE18		WUPE17		WUPE16	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 Reserved31	Reserved • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Not supported 01b - Not supported 10b - Not supported 11b - Not supported
29-28 Reserved30	Reserved • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Not supported 01b - Not supported 10b - Not supported 11b - Not supported
27-26 Reserved29	Reserved • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level.

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Field	Function
	• For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Not supported 01b - Not supported 10b - Not supported 11b - Not supported
25-24 WUPE28	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up and configures the edge detection. • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
23-22 WUPE27	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up and configures the edge detection. • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
21-20 WUPE26	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up and configures the edge detection. • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level.

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Field	Function
	• For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
19-18 WUPE25	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up and configures the edge detection. • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
17-16 WUPE24	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up and configures the edge detection. • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
15-14 WUPE23	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up and configures the edge detection. • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level.

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Field	Function
	• For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
13-12 WUPE22	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up and configures the edge detection. • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
11-10 WUPE21	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up and configures the edge detection. • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
9-8 WUPE20	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up and configures the edge detection. • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level.

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Field	Function
	• For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
7-6 WUPE19	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up and configures the edge detection. • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
5-4 WUPE18	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up and configures the edge detection. • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
3-2 WUPE17	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up and configures the edge detection. • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level.

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Field	Function
	• For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)
1-0 WUPE16	Wake-up Pin Enable for WUU_Pn Enables the external input pin for wake-up and configures the edge detection. • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level. • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level. • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge. 00b - Disable 01b - Enable (detect on rising edge or high level) 10b - Enable (detect on falling edge or low level) 11b - Enable (detect on any edge)

34.7.1.6 Module Interrupt Enable (ME)

Offset

Register	Offset
ME	18h

Function

Contains the bits to enable an on-chip module interrupt as a wake-up source.

NOTE

VSYS warm reset resets this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	0	0	0	0	0	WUME8	WUME7	WUME6	WUME5	WUME4	WUME3	WUME2	WUME1	WUME0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 —	Reserved
30 —	Reserved
29 —	Reserved
28 —	Reserved
27 —	Reserved
26 —	Reserved
25 —	Reserved
24 —	Reserved
23 —	Reserved
22 —	Reserved

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Field	Function
21 —	Reserved
20 —	Reserved
19 —	Reserved
18 —	Reserved
17 —	Reserved
16 —	Reserved
15 —	Reserved
14 —	Reserved
13 —	Reserved
12 —	Reserved
11 —	Reserved
10 —	Reserved
9 —	Reserved
8 WUME8	Module Interrupt Wake-up Enable for Module 8 Enables an on-chip module interrupt as a wake-up source input. 0b - Disable

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Field	Function
	1b - Enable
7 WUME7	Module Interrupt Wake-up Enable for Module 7 Enables an on-chip module interrupt as a wake-up source input. 0b - Disable 1b - Enable
6 WUME6	Module Interrupt Wake-up Enable for Module 6 Enables an on-chip module interrupt as a wake-up source input. 0b - Disable 1b - Enable
5 WUME5	Module Interrupt Wake-up Enable for Module 5 Enables an on-chip module interrupt as a wake-up source input. 0b - Disable 1b - Enable
4 WUME4	Module Interrupt Wake-up Enable for Module 4 Enables an on-chip module interrupt as a wake-up source input. 0b - Disable 1b - Enable
3 WUME3	Module Interrupt Wake-up Enable for Module 3 Enables an on-chip module interrupt as a wake-up source input. 0b - Disable 1b - Enable
2 WUME2	Module Interrupt Wake-up Enable for Module 2 Enables an on-chip module interrupt as a wake-up source input. 0b - Disable 1b - Enable
1 WUME1	Module Interrupt Wake-up Enable for Module 1 Enables an on-chip module interrupt as a wake-up source input. 0b - Disable 1b - Enable
0 WUME0	Module Interrupt Wake-up Enable for Module 0 Enables an on-chip module interrupt as a wake-up source input.

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Field	Function
	0b - Disable 1b - Enable

34.7.1.7 Module DMA/Trigger Enable (DE)

Offset

Register	Offset
DE	1Ch

Function

Contains the bits to enable an on-chip module DMA/trigger event as a wake-up source.

NOTE

VSYS warm reset resets this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	0	0	0	0	WUDE9	WUDE8	0	0	WUDE5	WUDE4	0	WUDE2	WUDE1	WUDE0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 —	Reserved
30 —	Reserved
29 —	Reserved

Table continues on the next page...

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Field	Function
28 —	Reserved
27 —	Reserved
26 —	Reserved
25 —	Reserved
24 —	Reserved
23 —	Reserved
22 —	Reserved
21 —	Reserved
20 —	Reserved
19 —	Reserved
18 —	Reserved
17 —	Reserved
16 —	Reserved
15 —	Reserved
14	Reserved

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Field	Function
—	
13 —	Reserved
12 —	Reserved
11 —	Reserved
10 —	Reserved
9 WUDE9	DMA/Trigger Wake-up Enable for Module 9 Enables an on-chip module DMA/trigger event as a wake-up source. 0b - Disable 1b - Enable
8 WUDE8	DMA/Trigger Wake-up Enable for Module 8 Enables an on-chip module DMA/trigger event as a wake-up source. 0b - Disable 1b - Enable
7 —	Reserved
6 —	Reserved
5 WUDE5	DMA/Trigger Wake-up Enable for Module 5 Enables an on-chip module DMA/trigger event as a wake-up source. 0b - Disable 1b - Enable
4 WUDE4	DMA/Trigger Wake-up Enable for Module 4 Enables an on-chip module DMA/trigger event as a wake-up source. 0b - Disable 1b - Enable
3	Reserved

Table continues on the next page...

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Field	Function
—	
2 WUDE2	DMA/Trigger Wake-up Enable for Module 2 Enables an on-chip module DMA/trigger event as a wake-up source. 0b - Disable 1b - Enable
1 WUDE1	DMA/Trigger Wake-up Enable for Module 1 Enables an on-chip module DMA/trigger event as a wake-up source. 0b - Disable 1b - Enable
0 WUDE0	DMA/Trigger Wake-up Enable for Module 0 Enables an on-chip module DMA/trigger event as a wake-up source. 0b - Disable 1b - Enable

34.7.1.8 Pin Flag (PF)

Offset

Register	Offset
PF	20h

Function

Contains the wake-up flags indicating which wake-up source caused the chip to exit Deep Sleep (if the corresponding PMC[WUPMC*n*] = 1) or Power Down mode. For Deep Sleep mode, this is the source causing the CPU interrupt flow. For Power Down mode, this is the source causing the chip reset flow.

To clear a flag, write a 1 to the corresponding PF[WUF*n*]. If set, the wake-up flag (WUF*n*) remains set even if the associated pin wake-up is disabled in its PE*m*[WUPE*n*] field.

NOTE

VSYS warm reset resets this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	0	0	WUF28	WUF27	WUF26	WUF25	WUF24	WUF23	WUF22	WUF21	WUF20	WUF19	WUF18	WUF17	WUF16
W				W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	WUF15	WUF14	WUF13	WUF12	WUF11	WUF10	WUF9	WUF8	WUF7	WUF6	WUF5	WUF4	WUF3	WUF2	WUF1	WUF0
W	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 Reserved31	Reserved 0b - Not supported 1b - Not supported
30 Reserved30	Reserved 0b - Not supported 1b - Not supported
29 Reserved29	Reserved 0b - Not supported 1b - Not supported
28 WUF28	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
27 WUF27	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
26 WUF26	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes

Table continues on the next page...

Table continued from the previous page...

Field	Function
25 WUF25	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
24 WUF24	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
23 WUF23	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
22 WUF22	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
21 WUF21	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
20 WUF20	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
19 WUF19	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
18 WUF18	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Yes
17 WUF17	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
16 WUF16	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
15 WUF15	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
14 WUF14	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
13 WUF13	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
12 WUF12	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
11 WUF11	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
10 WUF10	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode.

Table continues on the next page...

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Field	Function
	0b - No 1b - Yes
9 WUF9	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
8 WUF8	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
7 WUF7	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
6 WUF6	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
5 WUF5	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
4 WUF4	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
3 WUF3	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
2	Wake-up Flag for WUU_Pn

Table continues on the next page...

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Field	Function
WUF2	Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
1 WUF1	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
0 WUF0	Wake-up Flag for WUU_Pn Indicates that an enabled external wake-up pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes

34.7.1.9 Pin Filter (FILT)

Offset

Register	Offset
FILT	30h

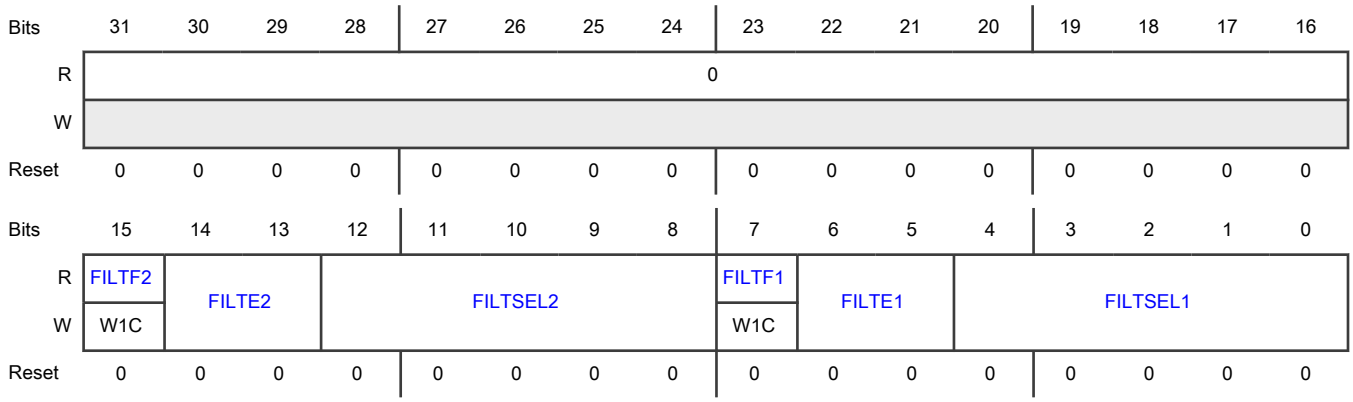
Function

Contains control and status fields to enable and configure the digital filter features for an external wake-up pin.

NOTE

VSYS warm reset resets this register.

Diagram



Fields

Field	Function
31-16 —	Reserved
15 FILTF2	Filter 2 Flag Indicates that the filtered external pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
14-13 FILTE2	Filter 2 Enable Enables the filter for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge 00b - Disable 01b - Enable (Detect on rising edge or high level) 10b - Enable (Detect on falling edge or low level) 11b - Enable (Detect on any edge)
12-8 FILTSEL2	Filter 2 Pin Select Selects and filters the external pin WUU_Pn, where *n* equals the value programmed into FILTSEL2.
7 FILTF1	Filter 1 Flag Indicates that the filtered external pin was a source of exiting a low-leakage power mode. 0b - No 1b - Yes
6-5 FILTE1	Filter 1 Enable Enables the filter for wake-up. This field configures the edge detection as follows: • For field value = 01b, when configured as an interrupt/DMA request: Detect on rising edge. When configured as a trigger event: Detect on high level • For field value = 10b, when configured as an interrupt/DMA request: Detect on falling edge. When configured as a trigger event: Detect on low level • For field value = 11b, when configured as an interrupt/DMA request: Detect on any edge 00b - Disable 01b - Enable (Detect on rising edge or high level) 10b - Enable (Detect on falling edge or low level)

Table continues on the next page...

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Field	Function
	11b - Enable (Detect on any edge)
4-0 FILTSEL1	Filter 1 Pin Select Selects and filters the external pin WUU_Pn, where *n* equals the value programmed into FILTSEL1.

34.7.1.10 Pin DMA/Trigger Configuration 1 (PDC1)

Offset

Register	Offset
PDC1	38h

Function

Configures the available external wake-up input pins in the range from WUU_P0 to WUU_P15 to generate an interrupt, DMA, or a trigger event when detected.

- When configured as an interrupt, the interrupt is asserted when the edge programmed in Pin Enable 1 (PE1) is detected and remains asserted until the corresponding flag is cleared in Pin Flag (PF).
- When configured as a DMA request, the request is asserted when the edge programmed in Pin Enable 1 (PE1) is detected and remains asserted until either the corresponding flag is cleared in Pin Flag (PF) or until the requested DMA transfer is complete.
- When configured as a trigger event, the trigger is asserted when the level programmed in Pin Enable 1 (PE1) is detected and remains asserted when the input pin is asserted. The corresponding flag in Pin Flag (PF) will not be set.

NOTE

- Do not modify the value of PDC*m*[WUPDC*n*] field when its corresponding PMC[WUPMC*n*] = 1.
- VSYS warm reset resets this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	WUPDC15		WUPDC14		WUPDC13		WUPDC12		WUPDC11		WUPDC10		WUPDC9		WUPDC8	
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	WUPDC7		WUPDC6		WUPDC5		WUPDC4		WUPDC3		WUPDC2		WUPDC1		WUPDC0	
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 WUPDC15	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
29-28 WUPDC14	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
27-26 WUPDC13	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
25-24 WUPDC12	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
23-22 WUPDC11	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
21-20 WUPDC10	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event.

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Field	Function
	00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
19-18 WUPDC9	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
17-16 WUPDC8	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
15-14 WUPDC7	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
13-12 WUPDC6	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
11-10 WUPDC5	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt

Table continues on the next page...

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Field	Function
	01b - DMA request 10b - Trigger event 11b - Reserved
9-8 WUPDC4	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
7-6 WUPDC3	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
5-4 WUPDC2	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
3-2 WUPDC1	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
1-0 WUPDC0	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request

Table continues on the next page...

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Field	Function
	10b - Trigger event 11b - Reserved

34.7.1.11 Pin DMA/Trigger Configuration 2 (PDC2)

Offset

Register	Offset
PDC2	3Ch

Function

Configures the available external wake-up input pins in the range from WUU_P16 to WUU_P31 to generate an interrupt, DMA, or a trigger event when detected.

- When configured as an interrupt, the interrupt is asserted when the edge programmed in Pin Enable 2 (PE2) is detected and remains asserted until the corresponding flag is cleared in Pin Flag (PF).
- When configured as a DMA request, the request is asserted when the edge programmed in Pin Enable 2 (PE2) is detected and remains asserted until either the corresponding flag is cleared in Pin Flag (PF) or until the requested DMA transfer is complete.
- When configured as a trigger event, the trigger is asserted when the level programmed in Pin Enable 2 (PE2) is detected and remains asserted when the input pin is asserted. The corresponding flag in Pin Flag (PF) will not be set.

NOTE

- Do not modify the value of PDC*m*[WUPDC*n*] field when its corresponding PMC[WUPMC*n*] = 1.
- VSYS warm reset resets this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		0		0		WUPDC28		WUPDC27		WUPDC26		WUPDC25		WUPDC24	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	WUPDC23		WUPDC22		WUPDC21		WUPDC20		WUPDC19		WUPDC18		WUPDC17		WUPDC16	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 Reserved31	Reserved 00b - Not supported 01b - Not supported 10b - Not supported 11b - Not supported
29-28 Reserved30	Reserved 00b - Not supported 01b - Not supported 10b - Not supported 11b - Not supported
27-26 Reserved29	Reserved 00b - Not supported 01b - Not supported 10b - Not supported 11b - Not supported
25-24 WUPDC28	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
23-22 WUPDC27	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
21-20 WUPDC26	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request

Table continues on the next page...

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Field	Function
	10b - Trigger event 11b - Reserved
19-18 WUPDC25	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
17-16 WUPDC24	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
15-14 WUPDC23	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
13-12 WUPDC22	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
11-10 WUPDC21	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved

Table continues on the next page...

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Field	Function
9-8 WUPDC20	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
7-6 WUPDC19	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
5-4 WUPDC18	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
3-2 WUPDC17	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved
1-0 WUPDC16	Wake-up Pin Configuration for WUU_Pn Configures an external pin as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request 10b - Trigger event 11b - Reserved

34.7.1.12 Pin Filter DMA/Trigger Configuration (FDC)

Offset

Register	Offset
FDC	48h

Function

Configures the external pin filters to generate an interrupt, DMA, or a trigger event when detected.

- When configured as an interrupt, the interrupt is asserted when the edge programmed in FILT*m*[FILTE*n*] is detected and remains asserted until the corresponding FILTF*n* flag is cleared.
- When configured as a DMA request, the request is asserted when the edge programmed in FILT*m*[FILTE*n*] is detected and remains asserted until either the corresponding FILTF*n* flag is cleared or until the requested DMA transfer is complete.
- When configured as a trigger event, the trigger is asserted when the level programmed in Pin Filter (FILT) is detected and remains asserted when the input pin is asserted. The corresponding FILTF*n* flag will not be set.

NOTE

VSYS warm reset resets this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												FILTC2		FILTC1	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-4 —	Reserved
3-2: FILTC2 1-0: FILTC1	Filter Configuration for FILTn Configures a filter as an interrupt, DMA, or Trigger event. 00b - Interrupt 01b - DMA request

Table continues on the next page...

Table continued from the previous page...

Field	Function
	10b - Trigger event 11b - Reserved

34.7.1.13 Pin Mode Configuration (PMC)

Offset

Register	Offset
PMC	50h

Function

Configures the detection logic for the available external wake-up input pins to remain enabled during all power modes, not just during Deep Sleep or Power Down mode.

NOTE

VSYS warm reset resets this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	0	0	WUPMC28	WUPMC27	WUPMC26	WUPMC25	WUPMC24	WUPMC23	WUPMC22	WUPMC21	WUPMC20	WUPMC19	WUPMC18	WUPMC17	WUPMC16
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	WUPMC15	WUPMC14	WUPMC13	WUPMC12	WUPMC11	WUPMC10	WUPMC9	WUPMC8	WUPMC7	WUPMC6	WUPMC5	WUPMC4	WUPMC3	WUPMC2	WUPMC1	WUPMC0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 Reserved31	Reserved 0b - Not supported 1b - Not supported
30 Reserved30	Reserved 0b - Not supported

Table continues on the next page...

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Field	Function
	1b - Not supported
29 Reserved29	Reserved 0b - Not supported 1b - Not supported
28 WUPMC28	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
27 WUPMC27	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
26 WUPMC26	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
25 WUPMC25	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
24 WUPMC24	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).

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Field	Function
23 WUPMC23	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
22 WUPMC22	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
21 WUPMC21	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
20 WUPMC20	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
19 WUPMC19	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
18 WUPMC18	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).

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Field	Function
17 WUPMC17	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
16 WUPMC16	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
15 WUPMC15	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
14 WUPMC14	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
13 WUPMC13	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
12 WUPMC12	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).

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Field	Function
11 WUPMC11	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
10 WUPMC10	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
9 WUPMC9	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
8 WUPMC8	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
7 WUPMC7	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
6 WUPMC6	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).

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Field	Function
5 WUPMC5	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
4 WUPMC4	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
3 WUPMC3	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
2 WUPMC2	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
1 WUPMC1	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).
0 WUPMC0	Wake-up Pin Mode Configuration for WUU_Pn Configures an external wake-up pin to provide active detection during all power modes. 0b - Active only during a low-leakage mode. You can modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn). 1b - Active during all power modes. Do not modify the corresponding fields within Pin Enable (PEn) or Pin DMA/Trigger Configuration (PDCn).

34.7.1.14 Pin Filter Mode Configuration (FMC)

Offset

Register	Offset
FMC	58h

Function

Configures the detection logic for external pin filters to remain enabled during all power modes, not just during Deep Sleep/Power Down mode.

NOTE

VSYS warm reset resets this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0														FILTM2	FILTM1
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-2 —	Reserved
1-0 FILTMn	Filter Mode for FILTn Configures an external wake-up pin filter to provide active detection during all power modes. 0b - Active only during Deep Sleep/Power Down mode 1b - Active during all power modes

Chapter 35
Watchdog Timer (WDOG)

35.1 Chip-specific WDOG information

Table 252. Reference links to related information

Topic	Related module	Reference
Full description	WDOG	WDOG
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

35.1.1 Module instances

This device has two instances of the WDOG module, WDOG0 and WDOG1.

NOTE

On reset, the WDOG0 is enabled and the WDOG1 is disable by default.

35.1.2 CS[CLK] fields

The CS[CLK] configures the clock source that feeds the watchdog counter as below.

- 00b - SLOW_CLK
- 01b - 32K_CLK
- 11b - OSC-RF

35.1.3 CS[PRES] fields

NOTE

If the watchdog (WDOG) is using the 32 kHz clock source, don't enable the prescale bit before entering PD/DPD low power modes.

35.1.4 WDOG0 and ROM Bootloader

During a normal boot of ROM bootloader, The WDDOG0 is disabled during execution and re-enabled before the bootloader transfers control to the boot image. A normal boot occurs after each warm reset or when system wakes up from low power mode, if the low power wakeup path fails.

At each normal boot:

- The CS[TST] bit in the WDOG0 register is cleared and CS[UPDATE] bit is set.
- The typical value of WDOG0 CS register after a normal boot is 0000_32A0h.

Carefully configure the WDOG0 CS register, if normal boot is the boot path after waking up from a special Power Down mode. If the system enters a Power Down mode with the MAIN domain is Powered Down and the WAKE domain is in Deep Sleep. Take the following precautions before entering Power Down mode:

- Do not clear the CS[UPDATE] bit of WDOG0 (i.e., must not be set to 0b).
- Do not set the CS[CLK] field to 01b or select any clock source slower than 6 MHz.

If these conditions are not followed, it may result in boot failure upon wakeup.

If the system wakes up successfully from Power Down mode using the low power wakeup path, the ROM bootloader does not change the WDOG0 configuration.

35.2 Overview

WDOG is an independent timer that is available for system use. It provides a safety feature to ensure that the software is executing as planned and that the CPU is not stuck in an infinite loop or executing unintended code. If WDOG is not serviced (refreshed) within a certain period, it resets the chip.

35.2.1 Block diagram

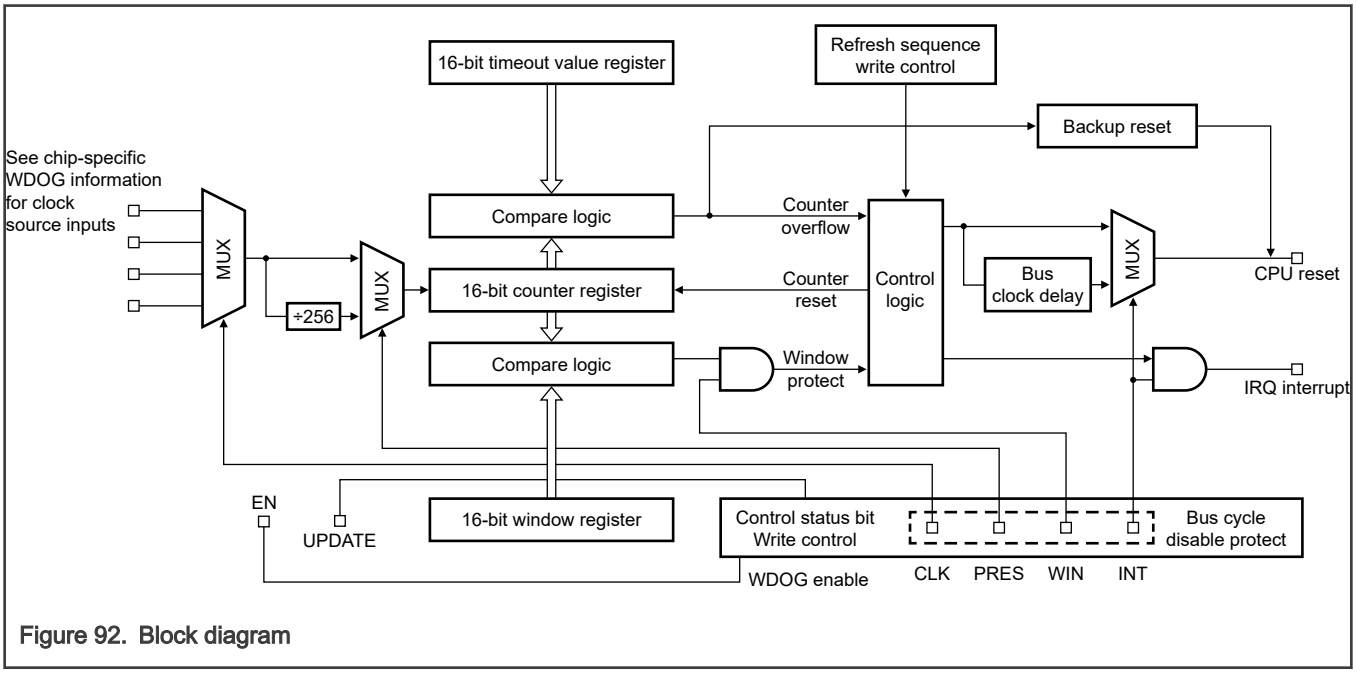


Figure 92. Block diagram

35.2.2 Features

- Configurable clock source inputs independent of the bus clock
- Programmable timeout period
  - Programmable 16-bit timeout value
  - Optional, fixed 256 clock prescaler when longer timeout periods are needed
- Robust write sequences for counter refresh: provision to refresh the sequence of writing to WDOG Counter (CNT)
- Window mode option for the refresh mechanism
  - Programmable 16-bit window value
  - Robust check to ensure that program flow is faster than expected
  - Early refresh attempts that trigger a reset
- Optional timeout interrupt to allow post-processing diagnostics
  - Interrupt request to CPU with an interrupt vector for an interrupt service routine (ISR)
  - Forced reset that occurs 128 bus clocks after the interrupt vector fetch
- Write-once-after-reset configuration fields to ensure that WDOG configuration is not altered mistakenly
- Robust write sequence for unlocking write-once configuration fields

— Unlock sequence of writing to WDOG Counter (CNT), for allowing updates to write-once configuration fields

— You must make updates within 1024 bus clocks after unlocking and before WDOG closing unlock window

35.3 Functional description

WDOG provides a fail-safe mechanism to ensure that you can reset the system to a known state of operation in case of system failure, such as the CPU clock stopping or there being a runaway condition in the software code. The WDOG counter runs continuously off a selectable clock source and expects to be serviced (refreshed) periodically. If it is not refreshed, it generates a reset triggering event.

35.3.1 Refresh mechanism

WDOG resets the chip if the WDOG counter is not refreshed. A robust refresh mechanism makes it very unlikely for a runaway code to refresh WDOG.

To refresh the WDOG counter, you must execute a refresh write sequence before the timeout period expires. In addition, in case of Window mode, you must not start the refresh sequence until you set the time value in Watchdog Window (WIN). See the following figure for more information.

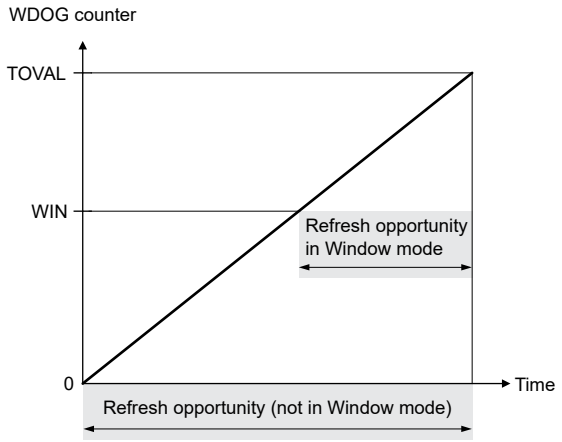


Figure 93. Refresh opportunity for the WDOG counter

35.3.1.1 Using Window mode

Software finishing its main control loop faster than expected could be an indication of a problem. Depending on the requirements of the application, you can program WDOG to force a reset when refresh attempts are early.

When Window mode is enabled, you must refresh WDOG after the counter has reached a minimum expected time value; otherwise, WDOG resets the chip. The minimum expected time value is specified in Watchdog Window (WIN). Setting CS[WIN] enables Window mode.

35.3.1.2 Refreshing WDOG

The refresh write sequence is based on the following methods:

- Either two 16-bit writes (A602h, B480h) or four 8-bit writes (A6h, 02h, B4h, 80h) to WDOG Counter (CNT) if CS[CMD32EN] = 0 [1]
- One 32-bit write (B480_A602h) to WDOG Counter (CNT) if CS[CMD32EN] = 1

[1] The example sequence of four 8-bit writes is as below:

— write A6h to WDOG_CNT[CNTHIGH], write 02h to WDOG_CNT[CNTLOW];

— write B4h to WDOG_CNT[CNTHIGH], write 80h to WDOG_CNT[CNTLOW].

You must apply these methods before WDOG times out; otherwise, it resets the chip.

Before starting the refresh sequence, disable the global interrupts. Otherwise, an interrupt could effectively invalidate the refresh sequence, if the interrupt occurs before the refresh writes finish. After the sequence finishes, restore the global interrupt control state.

See Application information for example code.

35.3.2 Configuring WDOG

35.3.2.1 Configuring WDOG once

All WDOG control bitfields, timeout value, and window value are write-once after reset. This means that after a write has occurred, they cannot be changed unless a reset occurs. You can ensure this by configuring the window and timeout values first, followed by the other control bitfields, when CS[UPDATE] = 0.

This provides a robust mechanism to configure WDOG and ensure that a runaway condition cannot mistakenly disable or modify the WDOG configuration, after the module is configured.

The new configuration takes effect only after you write to all registers except WDOG Counter (CNT) after reset. Otherwise, WDOG uses the reset values by default. If the Window mode is disabled (CS[WIN] is 0), you do not need to write to Watchdog Window (WIN) to bring the new configuration into effect.

35.3.2.2 Reconfiguring WDOG

In some cases (for example, when supporting a bootloader function), you may want to reconfigure or disable WDOG, without forcing a reset first:

- By writing 1 to CS[UPDATE] on the initial configuration of WDOG after a reset, you can reconfigure WDOG at any time by executing an unlock sequence.
- Conversely, if CS[UPDATE] remains 0, the only way to reconfigure WDOG is by initiating a reset.

The unlock sequence is similar to the refresh sequence but uses different values.

35.3.2.3 Unlocking WDOG

The unlock sequence is based on the following two methods:

- Either two 16-bit writes (C520h, D928h) or four 8-bit writes (C5h, 20h, D9h, 28h) to WDOG Counter (CNT), after WDOG is configured, if CS[CMD32EN] is 0 [2]
- One 32-bit write (D928_C520h) to WDOG Counter (CNT), after WDOG is configured, if CS[CMD32EN] is 1

An improper unlock sequence causes WDOG to reset. On completing the unlock sequence, you must reconfigure WDOG within 1024 bus clocks; otherwise, WDOG closes the unlock window.

NOTE

Because it requires 1024 bus clocks to reconfigure WDOG, you must insert some delays before executing STOP or WAIT instructions after reconfiguring WDOG. This ensures that WDOG's new configuration takes effect before the chip enters Low-Power mode. Otherwise, the chip may not wake up from Low-Power mode.

35.3.3 Functionality in Debug and Low-Power modes

By default, WDOG is not functional in Debug, Wait, or Stop modes. However, it can remain functional in these modes as follows:

- For Debug mode, write 1 to CS[DBG] (WDOG is functional in Debug mode even when Debug mode holds the CPU).

[2] The example sequence of four 8-bit writes is as below:

— write C5h to WDOG_CNT[CNTHIGH], write 20h to WDOG_CNT[CNTLOW];

— write D9h to WDOG_CNT[CNTHIGH], write 28h to WDOG_CNT[CNTLOW].

- For Wait mode, write 1 to CS[WAIT].
- For Stop mode, write 1 to CS[STOP] and CS[WAIT], and ensure that the clock source is active in Stop mode.

NOTE

WDOG can generate an interrupt in Stop mode.

Do not write 1 to CS[INT] in Stop mode. Otherwise, WDOG reset after a delay of 128 bus clocks (lose bus clock) will not occur, but backup reset will take effect.

For Debug and Stop modes, in addition to the aforementioned configuration, you must use a clock source other than the bus clock as the reference clock for the counter; otherwise, WDOG cannot function.

35.3.4 Fast testing of WDOG

Before executing the application code in safety-critical applications, you must test that WDOG works as expected and resets the chip. Testing every bit of a 16-bit counter by letting it run to the overflow value takes a relatively long time (64 k clocks).

To help minimize the startup delay for application code after reset, WDOG implements a feature that tests its functioning more quickly by splitting the counter into its constituent byte-wide stages. The low and high bytes are run independently and tested for a timeout against the corresponding byte of WDOG Timeout Value (TOVAL). For a complete coverage when testing the high byte of the counter, the test feature feeds the input clock via the 8th bit of the low byte, thus ensuring that the overflow connection from the low byte to the high byte is tested.

Using this test feature reduces the test time to 512 clocks (not including overhead, such as, user configuration and reset vector fetches). To further speed testing, use a faster clock (such as the bus clock) for the counter reference.

In case POR bitfield in the system reset register is set, indicating a power-on reset occurs, you must perform the WDOG fast test.

35.3.4.1 Testing each byte of the counter

For procedure of test, follow these steps:

1. Program the preferred WDOG timeout value in WDOG Timeout Value (TOVAL) during the WDOG configuration period.
2. Select a byte of the counter to test by using the configuration CS[TST] = 10b for the low byte, and CS[TST] = 11b for the high byte.
3. Wait for WDOG to timeout. Optionally, in the idle loop, increment RAM locations as a parallel software counter for later comparison. Because RAM is not affected by a WDOG reset, the timeout period of the WDOG counter can be compared with the software counter to verify whether the timeout period occurred as expected.

   The WDOG counter then times out and forces a reset.
4. Confirm that the WDOG flag in the system reset register is set, indicating that WDOG caused the reset (the POR flag remains clear).
5. Confirm that CS[TST] showing a test (10b or 11b) was performed.

If confirmed, the count and compare functions work for the selected byte. Repeat the procedure, and then select the next byte in step 2.

NOTE

Only a POR writes 0 to TST, which is not affected by other resets.

35.3.4.2 Entering User mode

After successfully testing the low and high bytes of the WDOG counter, you can configure TST to 01b to indicate that WDOG is ready for use in application User mode. Therefore, if a reset occurs again, you can recognize the reset trigger as a real WDOG reset caused by runaway or faulty application code.

As an ongoing test when using the default clock source, you can periodically read WDOG Counter (CNT) to ensure that the counter is being incremented.

35.3.5 Clocking

You can program CLK to select clock source options in the WDOG counter. See the chip-specific WDOG information for available clock inputs and the default option for this chip.

The option allows you to select a clock source that is independent of the bus clock for applications that need to meet more robust safety requirements. Using a clock source other than the bus clock ensures that the WDOG counter continues to run if the bus clock is somehow halted (see Backup reset).

For WDOG to function properly, you must enable the default WDOG clock source after its functional reset is deasserted.

An optional fixed prescaler for all clock sources allows longer timeout periods. When CS[PRES] is set to 1, the clock source is prescaled by 256 before clocking the WDOG counter.

The following table summarizes examples of the different available WDOG timeout periods. In the table, RCP means "reference clock period".

Table 253. WDOG timeout availability

Reference clock	Prescaler	WDOG timeout availability
REF_CLK	Pass through	1 × RCP to 65535 × RCP
	Enable	256 × RCP to 16776960 × RCP

NOTE

When you switch clock sources during reconfiguration, WDOG holds the counter at zero for 2.5 periods of the previous clock source and 2.5 periods of the new clock source after the configuration period (1024 bus clocks) ends. This delay ensures a smooth transition before restarting the counter with the new configuration.

35.3.6 Backup reset

The backup reset function is a safeguard feature that independently generates a reset in case the main WDOG logic loses its clock (the bus clock) and can no longer monitor the counter. If the WDOG counter overflows twice in succession (without an intervening reset), the backup reset function takes effect and generates a reset.

The backup reset becomes valid when an interrupt is enabled and the WDOG clock is not from a bus clock. If an interrupt is enabled, once the bus clock is cut off before exiting the interrupt routine, the normal watchdog reset is blocked. In this case, the second overflow causes a backup reset directly.

NOTE

You must use a clock source other than the bus clock as a reference clock for the counter; otherwise, the backup reset function becomes unavailable.

35.3.7 Interrupts

WDOG can generate an interrupt request to delay resets.

When interrupts are enabled (CS[INT] = 1), and after a reset-triggering event (such as a counter timeout or invalid refresh attempt), WDOG:

1. Generates an interrupt request.
2. Waits 128 bus clocks (from the interrupt vector fetch, not the reset-triggering event).
3. Forces a reset.

This process allows the ISR to perform tasks such as analyzing the stack to debug code.

When interrupts are disabled (CS[INT] = 0), WDOG does not wait before forcing a reset.

35.4 External signals

This module has no external signals.

35.5 Initialization

See Configuring WDOG once.

35.6 Application information

To disable or reconfigure WDOG, it should be completed before WDOG timeout. Disabling or reconfiguring WDOG should occur at the very beginning of the software code, for example, at the beginning of the startup or main function.

NOTE

- After you configure WDOG, it needs at least 2.5 periods of WDOG clock to take effect. This means a gap must have at least 2.5 clocks between two configurations.
- When the chip starts from boot ROM and then jumps to flash memory, you must disable WDOG at the beginning of the bootloader and enable it after the bootloader exits. To reconfigure WDOG using the flash memory program, it also needs the interval of at least 2.5 WDOG clocks after the bootloader exits.

To disable or reconfigure WDOG without forcing a reset, you must write 1 to CS[UPDATE] during the initial WDOG configuration. You can use the unlock sequence at any time, within the timeout limit, to reconfigure WDOG.

35.6.1 Disabling WDOG

To disable WDOG, you must first perform the unlock sequence. Then, write 0 to clear CS[EN]. The following code snippet shows an example of a 32-bit write.

```
DisableInterrupts; // disable global interrupt
WDOG_CNT = 0xD928C520; //unlock watchdog
WDOG_CS &= ~WDOG_CS_EN_MASK | WDOG_CS_UPDATE(1); //disable watchdog
EnableInterrupts; //enable global interrupt
```

35.6.2 Disabling WDOG after reset

All WDOG registers are unlocked by reset. Therefore, an unlock sequence is unnecessary but it needs to be written to all WDOG registers to make the new configuration take effect. The following code snippet shows an example of disabling WDOG after reset.

```
DisableInterrupts; // disable global interrupt
WDOG_CS &= ~WDOG_CS_EN_MASK; // disable watchdog
WDOG_TOVAL= 0xFFFF;
while(WDOG_CS[ULK]);  // waiting for lock
while(~WDOG_CS[RCS]); // waiting for new configuration to take effect
EnableInterrupts; // enable global interrupt
```

35.6.3 Configuring WDOG

WDOG can be configured once by clearing CS[UPDATE] = 0. After that, yWDOG cannot be reconfigured until a reset. To reconfigure without forcing a reset, write 1 to set CS[UPDATE] when configuring WDOG. The following example code shows how to configure WDOG without Window mode, clock source as LPO, interrupt enabled, and timeout value to 256 clocks. The following code snippet shows an example of a 32-bit write.

35.6.3.1 Configuring once

```
DisableInterrupts; // disable global interrupt
WDOG_CNT = 0xD928C520; //unlock watchdog
while(WDOG_CS[ULK]==0);  //wait until registers are unlocked
```

```
WDOG_TOVAL = 256; //set timeout value
WDOG_CS = WDOG_CS_EN(1) | WDOG_CS_CLK(1) | WDOG_CS_INT(1) |
          WDOG_CS_WIN(0) | WDOG_CS_UPDATE(0);
while(WDOG_CS[RCS]==0); //wait until new configuration takes effect
EnableInterrupts; //enable global interrupt
```

35.6.3.2 Configuring for Reconfigurable mode

```
DisableInterrupts; //disable global interrupt
WDOG_CNT = 0xD928C520; //unlock watchdog
while(WDOG_CS[ULK]==0);  //wait until registers are unlocked
WDOG_TOVAL = 256; //set timeout value
WDOG_CS = WDOG_CS_EN(1) | WDOG_CS_CLK(1) | WDOG_CS_INT(1) |
          WDOG_CS_WIN(0) | WDOG_CS_UPDATE(1);
while(WDOG_CS[RCS]==0); //wait until new configuration takes effect
EnableInterrupts; //enable global interrupt
```

35.6.4 Refreshing WDOG

To refresh WDOG and reset the WDOG counter to zero, a refresh sequence is required. The following code snippet shows an example of a 32-bit write.

```
DisableInterrupts; // disable global interrupt
WDOG_CNT = 0xB480A602; // refresh watchdog
EnableInterrupts; // enable global interrupt
```

35.7 Memory map and register definition

35.7.1 WDOG register descriptions

35.7.1.1 WDOG memory map

WDOG0 base address: 4001_A000h

WDOG1 base address: 4001_B000h

Offset	Register	Width (In bits)	Access	Reset value
0h	WDOG Control and Status (CS)	32	RW	See section
4h	WDOG Counter (CNT)	32	RW	0000_0000h
8h	WDOG Timeout Value (TOVAL)	32	RW	0000_FFFFh
Ch	Watchdog Window (WIN)	32	RW	0000_0000h

35.7.1.2 WDOG Control and Status (CS)

Offset

Register	Offset
CS	0h

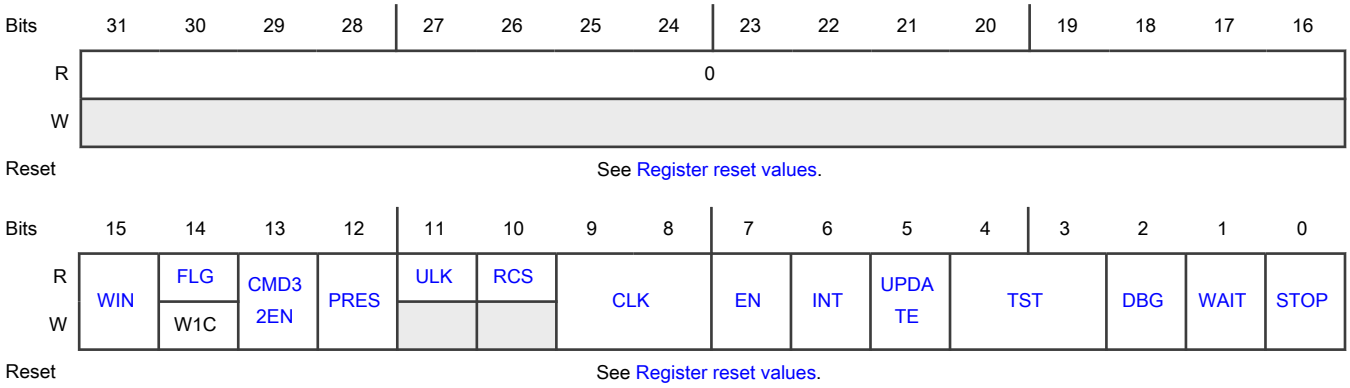
Function

Describes watchdog control and status.

NOTE

TST is cleared (0:0) on POR only. Any other reset does not affect the value of this field.

Diagram



Register reset values

Register	Reset value
CS	WDOG0: 0000_3A80h WDOG1: 0000_3A00h

Fields

Field	Function
31-16 —	Reserved
15 WIN	WDOG Window This write-once bitfield enables Window mode. 0b - Disable 1b - Enable
14 FLG	WDOG Interrupt Flag Acts as an interrupt indicator when CS[INT] = 1. 0b - No interrupt occurred 1b - An interrupt occurred
13 CMD32EN	Command 32 Enable

Table continues on the next page...

Table continued from the previous page...

Field	Function
	This write-once bitfield enables or disables WDOG support for 32-bit (otherwise 16-bit or 8-bit) refresh or unlock command write words. If this field = 0, it disables support for 32-bit refresh or unlock command write words. Only a 16-bit or 8-bit write is supported. If this field = 1, it enables support for 32-bit refresh or unlock command write words. A 16-bit or 8-bit write is not supported. You must unlock WDOG after writing to this field for reconfiguration. 0b - Disable 1b - Enable
12 PRES	WDOG Prescaler This write-once bitfield enables a fixed 256 prescaling of the WDOG counter reference clock. See Block diagram that shows the clock divider option. 0b - Disable 1b - Enable
11 ULK	Unlock Status Indicates whether WDOG is unlocked. 0b - Locked 1b - Unlocked
10 RCS	Reconfiguration Success Indicates whether the reconfiguration is successful. This field becomes 1 when new configuration takes effect, and becomes 0 with a successful unlock command. 0b - Unsuccessful 1b - Successful
9-8 CLK	WDOG Clock Selects the clock source that feeds the WDOG counter. You can write to this field only once. **NOTE** See chip-specific WDOG information for details of bitfield settings.
7 EN	WDOG Enable Enables the WDOG counter to start counting. You can write to this field only once. 0b - Disable 1b - Enable
6	WDOG Interrupt

Table continues on the next page...

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Field	Function
INT	Configures WDOG to immediately generate an interrupt request upon a reset-triggering event (timeout or illegal write to WDOG), before forcing a reset. After the interrupt vector fetch (that takes place after the reset-triggering event), the reset occurs after a delay of 128 bus clocks. If this field = 0, it disables WDOG interrupts (WDOG resets are not delayed). If this field = 1, it enables WDOG interrupts (WDOG interrupts are delayed by 128 bus clocks from the interrupt vector fetch). You can write to this field only once. 0b - Disable 1b - Enable
5 UPDATE	Updates Allowed Allows you to reconfigure WDOG without a reset. If this field = 0, you cannot update WDOG after the initial configuration, without forcing a reset. If this field = 1, you can modify the WDOG configuration registers within 1024 bus clocks after performing the unlock write sequence. You can write to this field only once. 0b - Updates not allowed 1b - Updates allowed
4-3 TST	WDOG Test Enables Fast Test mode, which allows you to exercise all bits of the counter to demonstrate that WDOG is functioning properly. See Fast testing of WDOG for more information. If this field = 0, it disables WDOG Test mode. If this field = 1, it enables WDOG User mode and disables WDOG Test mode. After testing WDOG, you must use this setting to indicate that WDOG is functioning normally in User mode. If this field = 10, it enables WDOG Test mode; only the low byte is used. CNTLOW is compared with TOVALLOW. If this field = 11, it enables WDOG Test mode; only the high byte is used. CNTHIGH is compared with TOVALHIGH. This write-once field is cleared (0:0) on POR only. Any other reset does not affect the value of this field. 00b - Disable WDOG Test mode 01b - Enable WDOG User mode 10b-11b - Enable WDOG Test mode
2 DBG	Debug Enable Enables WDOG to operate when the chip is in Debug mode. You can write to this field only once. 0b - Disable 1b - Enable
1 WAIT	Wait Enable Enables WDOG to operate when the chip is in Wait mode. You can write to this field only once.

Table continues on the next page...

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Field	Function
	0b - Disable 1b - Enable
0 STOP	Stop Enable Enables WDOG to operate when the chip is in Stop mode. You can write to this field only once. 0b - Disable 1b - Enable

35.7.1.3 WDOG Counter (CNT)

Offset

Register	Offset
CNT	4h

Function

Provides access to the value of the free-running WDOG counter. You can read the counter register at any time but cannot write directly to it. However, the following write sequences to this register have special functions:

1. The refresh sequence resets WDOG counter to 0000h. See Refreshing WDOG for more information.
2. The unlock sequence allows WDOG to be reconfigured without forcing a reset (when CS[UPDATE] = 1). See Configuring for Reconfigurable mode for more information.

NOTE

All other writes to this register are illegal and force a reset.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	CNTHIGH								CNTLOW							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-16 —	Reserved
15-8 CNTHIGH	Counter High Byte Contains the WDOG high byte.
7-0 CNTLOW	Counter Low Byte Contains the WDOG low byte.

35.7.1.4 WDOG Timeout Value (TOVAL)

Offset

Register	Offset
TOVAL	8h

Function

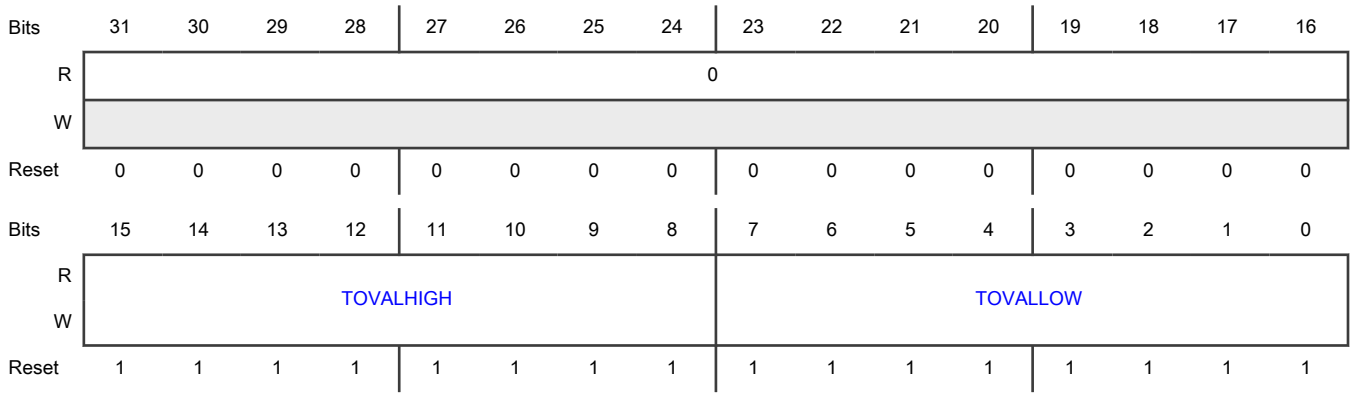
Contains the 16-bit value used to set the timeout period of WDOG.

The WDOG counter (CNT) is continuously compared with the timeout value (TOVAL). If the counter reaches the timeout value, WDOG forces a reset triggering event.

NOTE

Do not write 0 to this register (if CS[TST] = 11b, then TOVALHIGH cannot be written as 0; if CS[TST] = 10b, then TOVALLOW cannot be 0); otherwise, WDOG always generates a reset.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-8 TOVALHIGH	Timeout Value High Contains the high byte of the timeout value.
7-0 TOVALLOW	Timeout Value Low Contains the low byte of the timeout value.

35.7.1.5 Watchdog Window (WIN)

Offset

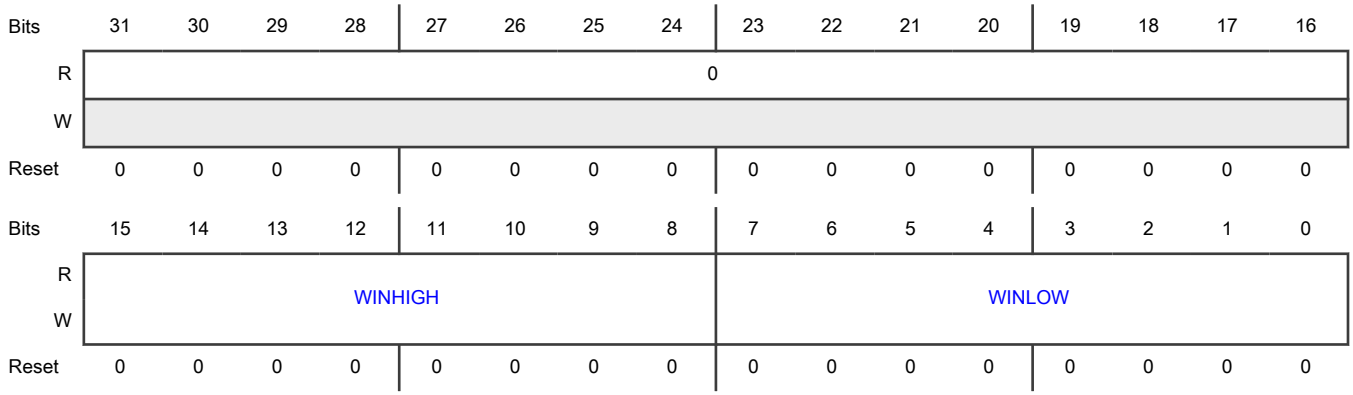
Register	Offset
WIN	Ch

Function

Determines the earliest time that a refresh sequence is considered valid, if CS[WIN] = 1. See Refresh mechanism for more information.

The WIN register value must be less than the TOVAL register value.

Diagram



Fields

Field	Function
31-16 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
15-8 WINHIGH	High Byte Contains the high byte of the WDOG window.
7-0 WINLOW	Low Byte Contains the low byte of the WDOG window.

Chapter 36
Cyclic Redundancy Check (CRC)

36.1 Chip-specific CRC information

Table 254. Reference links to related information

Topic	Related module	Reference
Full description	CRC	CRC
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

36.1.1 Module instances

This device has one instance of the CRC module, CRC0.

36.2 Overview

CRC generates 16-bit or 32-bit CRC codes output for error detection. You can calculate these codes for up to 32 bits input data at a time.

CRC provides a programmable polynomial and other parameters to meet 16-bit or 32-bit CRC standards.

36.2.1 Block diagram

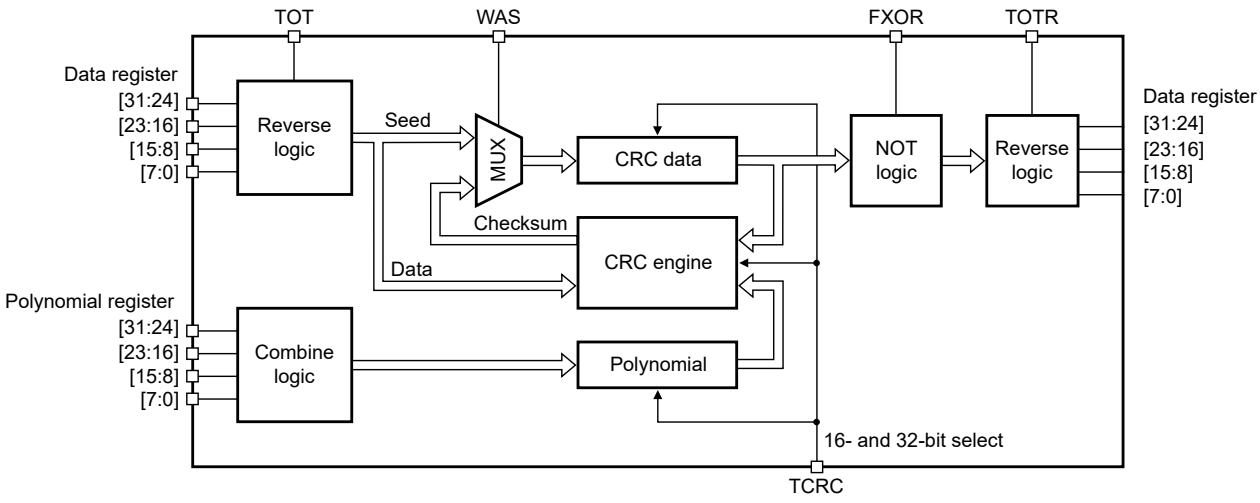


Figure 94. Block diagram

36.2.2 Features

CRC has the following features:

- Hardware CRC generator circuit using 16-bit or 32-bit programmable shift registers
- Programmable initial seed value and polynomial

- Transpose of input or output data (CRC result) in bitwise or bytewise (this option is required for certain CRC standards. You cannot perform a bytewise transpose operation when accessing DATA via 8-bit access.)
- Invert final CRC result
- 32-bit CPU register programming interface

36.3 Functional description

36.3.1 Modes of operation

The following section describes mode of operation that affects the functionality of CRC: Run mode.

36.3.1.1 Run mode

Run mode is the basic mode of operation.

36.3.2 CRC calculations

In 16-bit and 32-bit CRC modes, you can program data values as 8 bits, 16 bits, or 32 bits at a time, provided all bytes are contiguous. Noncontiguous bytes lead to an incorrect CRC calculation.

36.3.2.1 Calculating a 16-bit CRC

Perform these steps to calculate a 16-bit CRC:

1. Write 0 to CTRL[TCRC] to enable 16-bit CRC mode.
2. Program the transpose and complement options in Control (CTRL) as required for the CRC calculation.
3. Write a 16-bit polynomial to GPOLY[LOW].

   GPOLY[HIGH] is not usable in 16-bit CRC mode.
4. Write 1 to CTRL[WAS] to program the seed value.
5. Write a 16-bit seed to DATA[LU] and DATA[LL].

   DATA[HU] and DATA[HL] are not used.
6. Write 0 to CTRL[WAS] to start writing data values.
7. Write data values into DATA[LU], and DATA[LL]

   CRC is calculated on every data value write and the intermediate CRC result is stored back into DATA[LU] and DATA[LL]
8. After writing all the data values, read the final CRC result from DATA[LU] and DATA[LL].

CRC is calculated bytewise and two clocks are required to complete one CRC calculation.

The transpose and complement operations are performed on-the-fly when reading or writing values. See Transpose feature and Result complement for details.

36.3.2.2 Calculating a 32-bit CRC

Perform these steps to calculate a 32-bit CRC:

1. Write 1 to CTRL[TCRC] to enable 32-bit CRC mode.
2. Program the transpose and complement options in Control (CTRL) as required for CRC calculation. See Transpose feature and Result complement for details.
3. Write a 32-bit polynomial to GPOLY[HIGH] and GPOLY[LOW] .
4. Write 1 to CTRL[WAS] to program the seed value.
5. Write a 32-bit seed to DATA[HU], DATA[HL], DATA[LU], and DATA[LL].

6. Write 0 to CTRL[WAS] to start writing data values.
7. Write data values into DATA[HU], DATA[HL], DATA[LU], and DATA[LL]

   CRC is computed on every data value write and the intermediate CRC result is stored back into DATA .
8. After writing all the values, read the final CRC result from DATA[HU], DATA[HL], DATA[LU], and DATA[LL].

   CRC is calculated bytewise and two clocks are required to complete one CRC calculation.

The transpose and complement operations are performed on-the-fly when reading or writing values. See Transpose feature and Result complement for details.

36.3.3 Transpose feature

Transpose is not enabled by default. However, CRC requires input data and/or final checksum to be transposed. You have an option to configure each transpose operation separately to meet CRC standards. The data is transposed on-the-fly while being read or written.

Some protocols use the little-endian format for data stream to calculateCRC. In this case, transpose flips bits.

36.3.3.1 Types of transpose

CRC provides several types of transpose to flip bits and/or bytes for both writing input data and reading result separately using the CTRL[TOT] and CTRL[TOTR] according to the CRC calculation being used.

The following types of transpose are available for writing to and reading from DATA.

1. CTRL[TOT] or CTRL[TOTR] is 0.

   No transposition occurs.
2. CTRL[TOT] or CTRL[TOTR] is 1.

   Bits in a byte are transposed when bytes are not transposed.

   reg[31:0] becomes {reg[24:31], reg[16:23], reg[8:15], reg[0:7]}.

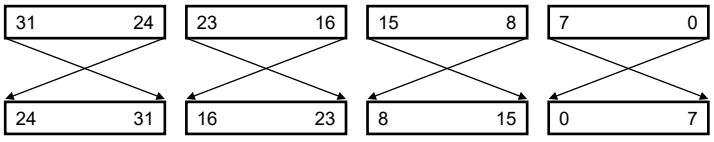


Figure 95. Transpose type 1b

3. CTRL[TOT] or CTRL[TOTR] is 10b.

   Both bits in bytes and bytes are transposed.

   reg[31:0] becomes {reg[0:7], reg[8:15], reg[16:23], reg[24:31]}.

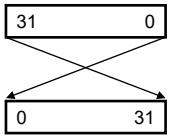


Figure 96. Transpose type 10b

4. CTRL[TOT] or CTRL[TOTR] is 11b.

   Bytes are transposed but bits are not transposed.

   reg[31:0] becomes {reg[7:0], reg[15:8], reg[23:16], reg[31:24]}.

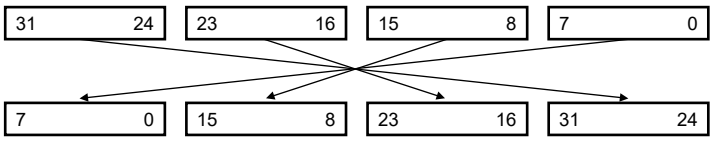


Figure 97. Transpose type 11b

NOTE

For 8-bit and 16-bit write accesses to Data (DATA), the data is transposed with 0s on the unused byte or bytes (taking 32 bits as a whole), but CRC is calculated on the valid byte(s) only. When reading the Data (DATA) for a 16-bit CRC result and using transpose options 10 and 11, the resulting value after transposition resides in DATA[HU] and DATA[HL]. You must account for this situation when reading the 16-bit CRC result, so reading 32 bits is preferred.

36.3.4 Result complement

When CTRL[FXOR] = 1, the checksum is complemented. The CRC result complement function outputs the complement of the checksum value stored in Data (DATA) every time Data (DATA) is read. When CTRL[FXOR] = 0,, reading Data (DATA) accesses the raw checksum value.

36.3.5 Clocking

Table 255. CRC clocks

Type of clock	Description
Bus clock	Used to control the access to the CRC registers and function the CRC module
Function clock	Used to function the CRC module

NOTE

See the chip-specific clocking chapter, to know the specific CRC clocks supported on your device.

36.3.6 Interrupts

This module has no interrupts.

36.4 External signals

There is no CRC signal that connects off chip.

36.5 Initialization

To enable CRC calculation, you must program:

- CTRL[WAS] .
- Polynomial (GPOLY).
- Parameters for transposition and CRC result inversion in the applicable registers.

Writing 1 to CTRL[WAS] enables you to program the seed value into CRC Data registers.

After writing all the data, you must wait for at least two clock cycles to read the data from CRC Data (DATA) register.

After a CRC calculation completes, you can reinitialize the module for a new CRC computation by again writing 1 to CTRL[WAS] and programming a new, or previously used, seed value. You must set all other parameters before programming the seed value and subsequent data values.

36.6 Use cases

The following tables use the little-endian format.

36.6.1 CTRL programming

The following table shows Control (CTRL) programming for 16-bit CRC.

Table 256. CTRL programming for 16-bit CRC

Algorithm	Polynomial	Seed	Ref in	Ref out	XOR out	CTRL[TOT]	CTRL[TOTR]	CTRL[FXOR]
CRC-16_CCITT_FALSE	1021h	FFFFh	0	0	0000h	0h	0h	0h
CRC-16_ARC	8005h	0000h	1	1	0000h	1h	2h	0h
CRC-16_AUG_CCITT	1021h	1D0Fh	0	0	0000h	0h	0h	0h
CRC-16_BUYPASS	8005h	0000h	0	0	0000h	0h	0h	0h
CRC-16_CCITT_ZERO	1021h	0000h	0	0	0000h	0h	0h	0h
CRC-16_CDMA2000	C867h	FFFFh	0	0	0000h	0h	0h	0h
CRC-16_DDS_110	8005h	800Dh	0	0	0000h	0h	0h	0h
CRC-16_DECT_X	589h	0000h	0	0	0000h	0h	0h	0h
CRC-16_DNP	3D65h	0000h	1	1	FFFFh	1h	2h	1h
CRC-16_EN_13757	3D65h	0000h	0	0	FFFFh	0h	0h	1h
CRC-16_GENIBUS	1021h	FFFFh	0	0	FFFFh	0h	0h	1h
CRC-16_MAXIM	8005h	0000h	1	1	FFFFh	1h	2h	1h
CRC-16_MCRF4XX	1021h	FFFFh	1	1	0000h	1h	2h	0h
CRC-16_RIELLO	1021h	B2AAh	1	1	0000h	1h	2h	0h
CRC-16_T10_DIF	8BB7h	0000h	0	0	0000h	0h	0h	0h
CRC-16_TELEDISK	A097h	0000h	0	0	0000h	0h	0h	0h
CRC-16_TMS37157	1021h	89ECh	1	1	0000h	1h	2h	0h
CRC-16_USB	8005h	FFFFh	1	1	FFFFh	1h	2h	1h
CRC-16_A	1021h	C6C6h	1	1	0000h	1h	2h	0h
CRC-16_KERMIT	1021h	0000h	1	1	0000h	1h	2h	0h
CRC-16_MODBUS	8005h	FFFFh	1	1	0000h	1h	2h	0h
CRC-16_X_25	1021h	FFFFh	1	1	FFFFh	1h	2h	1h
CRC-16_XMODEM	1021h	0000h	0	0	0000h	0h	0h	0h

The following table shows Control (CTRL) programming for 32-bit CRC.

Table 257. CTRL programming for 32-bit CRC

Algorithm	Polynomial	Seed	Ref in	Ref out	XOR out	CTRL[TOT]	CTRL[TOTR]	CTRL[FXOR]
CRC-32	04C11DB7h	FFFFFFFFh	1	1	FFFF_FFFFh	1h	2h	1h
CRC-32_BZIP2	04C11DB7h	FFFFFFFFh	0	0	FFFF_FFFFh	0h	0h	1h
CRC-32C	1EDC6F41h	FFFFFFFFh	1	1	FFFF_FFFFh	1h	2h	1h
CRC-32D	A833982Bh	FFFFFFFFh	1	1	FFFF_FFFFh	1h	2h	1h
CRC-32_MPEG-2	04C11DB7h	FFFFFFFFh	0	0	0000_0000h	0h	0h	0h
CRC-32_POSIX	04C11DB7h	00000000h	0	0	FFFF_FFFFh	0h	0h	1h
CRC-32Q	814141ABh	00000000h	0	0	0000_0000h	0h	0h	0h
CRC-32_JAMCRC	04C11DB7h	FFFFFFFFh	1	1	0000_0000h	1h	2h	0h
CRC-32_XFER	000000AFh	00000000h	0	0	0000_0000h	0h	0h	0h

36.6.2 Expected read data fields

The following table shows the expected read data fields for 16-bit CRC.

Table 258. Expected read data fields for 16-bit CRC

Algorithm	Data (DATA)
CRC16_CCITT_FALSE	[31:16] = Unknown[15:0] = Valid data
CRC16_ARC	[31:16] = Valid data [15:0] = Unknown
CRC16_AUG_CCITT	[31:16] = Unknown [15:0] = Valid data
CRC16_BUYPASS	[31:16] = Unknown [15:0] = Valid data
CRC16_CCITT_ZERO	[31:16] = Unknown [15:0] = Valid data
CRC16_CDMA2000	[31:16] = Unknown [15:0] = Valid data
CRC16_DDS_110	[31:16] = Unknown [15:0] = Valid data
CRC16_DECT_X	[31:16] = Unknown [15:0] = Valid data
CRC16_DNP	[31:16] = Valid data [15:0] = Unknown
CRC-16_EN_13757	[31:16] = Unknown [15:0] = Valid data
CRC-16_GENIBUS	[31:16] = Unknown [15:0] = Valid data
CRC-16_MAXIM	[31:16] = Valid data [15:0] = Unknown
CRC-16_MCRF4XX	[31:16] = Valid data [15:0] = Unknown
CRC-16_RIELLO	[31:16] = Valid data [15:0] = Unknown
CRC-16_T10_DIF	[31:16] = Unknown [15:0] = Valid data
CRC-16_TELEDISK	[31:16] = Unknown [15:0] = Valid data
CRC-16_TMS37157	[31:16] = Valid data [15:0] = Unknown
CRC-16_USB	[31:16] = Valid data [15:0] = Unknown

Table continues on the next page...

Table 258. Expected read data fields for 16-bit CRC (continued)

Algorithm	Data (DATA)
CRC-16_A	[31:16] = Valid data [15:0] = Unknown
CRC-16_KERMIT	[31:16] = Valid data [15:0] = Unknown
CRC-16_MODBUS	[31:16] = Valid data [15:0] = Unknown
CRC-16_X_25	[31:16] = Valid data [15:0] = Unknown
CRC-16_XMODEM	[31:16] = Unknown [15:0] = Valid data

The following table shows the expected read data fields for 32-bit CRC.

Table 259. Expected read data fields for 32-bit CRC

Algorithm	Data (DATA)
CRC-32	[31:0] = Valid data
CRC-32_BZIP2	[31:0] = Valid data
CRC-32C	[31:0] = Valid data
CRC-32D	[31:0] = Valid data
CRC-32_MPEG-2	[31:0] = Valid data
CRC-32_POSIX	[31:0] = Valid data
CRC-32Q	[31:0] = Valid data
CRC-32_JAMCRC	[31:0] = Valid data
CRC-32_XFER	[31:0] = Valid data

36.7 Memory map and register descriptions

NOTE

You must reconfigure CRC engine in case an IPS transfer error occurs (ips_xfr_err).

The CRC module generates a transfer error in the following cases:

- Write accesses to the register addresses that are not mapped to the peripherals but included in the address spaces of the peripherals.

36.7.1 CRC register descriptions

36.7.1.1 CRC memory map

CRC0 base address: 4002_3000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Data (DATA)	32	RW	FFFF_FFFFh
4h	Polynomial (GPOLY)	32	RW	0000_1021h
8h	Control (CTRL)	32	RW	0000_0000h

36.7.1.2 Data (DATA)

Offset

Register	Offset
DATA	0h

Function

Configures the value of seed, data, and checksum. When CTRL[WAS] = 1, any write to this register is regarded as the seed value. When CTRL[WAS] becomes 0, any write to this register is regarded as data for general CRC calculation.

In 16-bit CRC mode, DATA[HU] and DATA[HL] are not used for programming the seed value, and reads of these fields return an indeterminate value. In 32-bit CRC mode, all fields are used for programming the seed value.

When programming data values, you can program to write 8 bits, 16 bits, or 32 bits in big endian order, provided all bytes are contiguous, with the MSB of data value written first.

After writing all data values, you can read the CRC result from DATA register. In 16-bit CRC mode, the CRC result is available in DATA[LU] and DATA[LL]. In 32-bit CRC mode, all fields contain the result. After writing all data, you must wait for at least two clock cycles to read the data from CRC data (DATA) register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	HU								HL							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	LU								LL							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 HU	Upper Part of High Byte Generates CRC checksum in both 16-bit and 32-bit CRC modes if CTRL[WAS] = 0. • In 16-bit CRC mode (CTRL[TCRC] = 0), this field is not used for programming a seed value. • In 32-bit CRC mode (CTRL[TCRC] = 1), the values written to this field are part of the seed value when CTRL[WAS] = 1.
23-16 HL	Lower Part of High Byte Generates CRC checksum in both 16-bit and 32-bit CRC modes if CTRL[WAS] = 0. • In 16-bit CRC mode (CTRL[TCRC] = 0), this field is not used for programming a seed value.

Table continues on the next page...

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Field	Function
	• In 32-bit CRC mode (CTRL[TCRC] = 1), the values written to this field are part of the seed value when CTRL[WAS] = 1.
15-8 LU	Upper Part of Low Byte Generates CRC checksum when CTRL[WAS] = 0. When CTRL[WAS] = 1,the values written to this field are part of the seed value.
7-0 LL	Lower Part of Low Byte Generates CRC checksum when CTRL[WAS] = 0. When CTRL[WAS] = 1, the values written to this field are part of the seed value.

36.7.1.3 Polynomial (GPOLY)

Offset

Register	Offset
GPOLY	4h

Function

Configures polynomial value for CRC calculation.

- Sets the upper 16 bits of polynomial that are used only in 32-bit CRC mode. Writes to this field are ignored in 16-bit CRC mode.
- Sets the lower 16 bits of polynomial that are used in both 16-bit and 32-bit CRC modes.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	HIGH															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	LOW															
Reset	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1

Fields

Field	Function
31-16 HIGH	High Half-Word Writable and readable in 32-bit CRC mode (CTRL[TCRC] = 1). You cannot write to this field in 16-bit CRC mode (CTRL[TCRC] = 0).
15-0 LOW	Low Half-Word Writable and readable in both 16-bit and 32-bit CRC modes.

36.7.1.4 Control (CTRL)

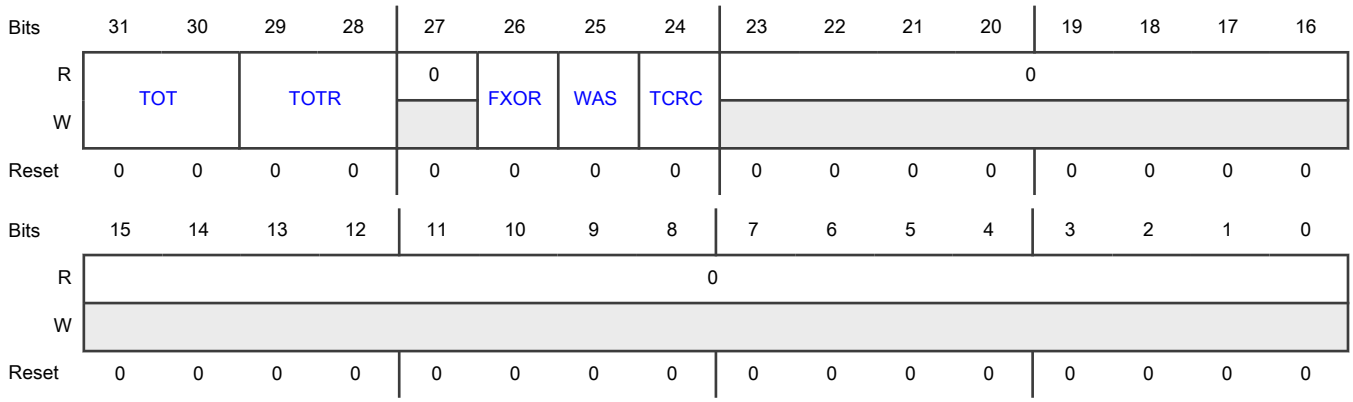
Offset

Register	Offset
CTRL	8h

Function

Sets control for CRC. You must write 1 to the appropriate fields of this register before starting a new CRC calculation, which you can initialize by writing 1 to CTRL[WAS] and then writing the seed into DATA.

Diagram



Fields

Field	Function
31-30 TOT	Transpose Type for Write Sets transpose type for the values written to DATA. See Transpose feature for the available transpose options. 00b - No transposition 01b - Bits in bytes are transposed, but bytes are not transposed.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	10b - Both bits in bytes and bytes are transposed. 11b - Only bytes are transposed, no bits in a byte are transposed.
29-28 TOTR	Transpose Type for Read Sets transpose type for the values read from DATA . See Transpose feature for the available transpose options. 00b - No transposition 01b - Bits in bytes are transposed, but bytes are not transposed. 10b - Both bits in bytes and bytes are transposed. 11b - Only bytes are transposed, no bits in a byte are transposed.
27 —	Reserved
26 FXOR	Complement Read of CRC Data Register Enables on-the-fly complementing of read data. Some CRC protocols require the final checksum to be XORed with FFFFFFFFh or FFFFh. 0b - Disables XOR on reading data. 1b - Inverts or complements the read value of the CRC Data.
25 WAS	Write as Seed Specifies whether writes to DATA are data values or seed values. When this field = 1, the value that you write to is considered as seed value. When this field = 0, the value that you write to is considered as data for CRC calculation. 0b - Data values 1b - Seed values
24 TCRC	TCRC Defines the width of CRC. 0b - 16 bits 1b - 32 bits
23-0 —	Reserved

Chapter 37
16-bit Analog-to-Digital Converter (ADC)

37.1 Chip-specific ADC information

Table 260. Reference links to related information

Topic	Related module	Reference
Full description	ADC	ADC
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

37.1.1 Module instances

This device has one instance of the ADC module, ADC0.

37.1.2 ADC input connections

ADC Channel (CMDLn[ADCH])	A Connection	B Connection	Input Type
0	-	-	Reserved
1	ADC0_A5	ADC0_B5	PTD GPIO domain, muxed
2	ADC0_A6	ADC0_B6	PTD GPIO domain, muxed
3	-	-	Reserved
4	-	-	Reserved
5	ADC0_A8	-	GPIO domain, muxed
6	-	-	Reserved
7	ADC0_A10	ADC0_B10	PTA, PTB GPIO domain, muxed
8	-	ADC0_B11	PTA, PTB GPIO domain, muxed
9	ADC0_A12	ADC0_B12	PTA, PTB GPIO domain, muxed
10	ADC0_A13	ADC0_B13	PTB GPIO domain, muxed
11	ADC0_A14	ADC0_B14	PTA, Channel B PTC Larger Packages only GPIO domain, muxed
12	ADC0_A15	ADC0_B15	PTA, Channel B PTC Larger Packages only GPIO domain, muxed

Table continues on the next page...

Table continued from the previous page...

ADC Channel (CMDLn[ADCH])	A Connection	B Connection	Input Type
13	ADC0_A16	ADC0_B16	Larger Packages only: GPIO domain, muxed
14	ADC0_A17	ADC0_B17	Larger Packages only: GPIO domain, muxed
15	ADC0_A18	ADC0_B18	Larger Packages only: GPIO domain, muxed
16	ADC0_A19	ADC0_B19	Larger Packages only: GPIO domain, muxed
17	-	-	Reserved
18	-	-	Reserved
19	-	-	Reserved
20	-	-	Reserved
21	-	-	Reserved
22	-	-	Reserved
23	VREFO	VREFL	Dedicated VREF connection
24	-	-	Reserved
25	VREF BG+	VREF BG-	VREF bandgap (connect to vref_test_mux_out_pos_ana_3v,vref_test_mux_out_neg_ana_3v)
26	Temperature+	Temperature-	Temperature Sensor (inside ADC, no top level connection)
27	PMC BG+	PMC BG-	PMC Bandgap (spc0_pmc_1vbuf_ana_1p8v)
28	VDD_LDO_CORE / 4	VDD_CORE / 4	PMC Resistive dividers
29	VDD_LDO_SYS / 4	VDD_SYS / 4	PMC Resistive dividers

37.1.3 ADC voltage reference options

The ADC voltage references are:

- CFG[REFSEL]=00, VDD_ANA supply pin
- CFG[REFSEL]=01, VREFO voltage reference driven from the VREF block
- CFG[REFSEL]=10, VREFH reference pin has dedicated connection

37.1.4 ADC trigger inputs

ADC Trigger sources get routed through the Trigger Multiplexer (TRGMUX). See the TRGMUX chapter for available trigger sources.

37.2 Overview

The 16-bit analog-to-digital converter (ADC) is a dual successive approximation ADC designed for operation within an integrated microcontroller system-on-a-chip.

NOTE

For chip-specific modes of operation, see the power management information for the device.

37.2.1 Block diagram

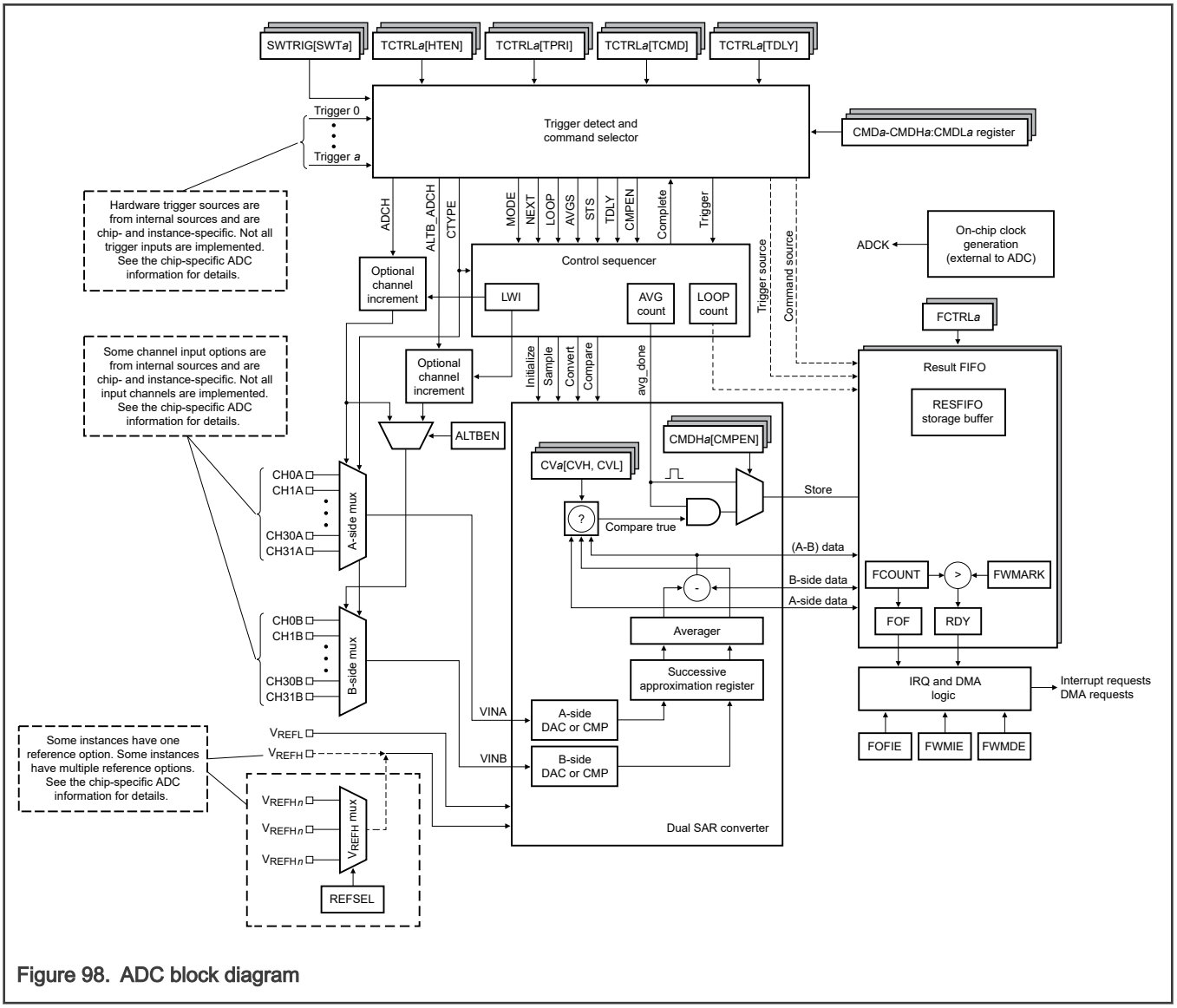


Figure 98. ADC block diagram

37.2.2 Features

ADC has these features:

- Linear successive approximation algorithm
  - Differential operation with 16-bit or 13-bit resolution
  - Single-ended operation with 16-bit or 12-bit resolution
  - Support for two simultaneous single-ended conversions
- Configurable analog input sample time
- Configurable speed options to accommodate operation in low-power modes of SoC
- Trigger detection with up to 4 trigger sources with priority level configuration. Software or hardware trigger option for each.
- 15 command buffers, to allow independent options selection and channel sequence scanning
- Automatic comparisons for less-than, greater-than, within range, or out-of-range with "store on true" and "repeat until true" options
- 2 independent result FIFOs, each containing 16 entries. Each FIFO has configurable watermark and overflow detection.
- Interrupt, DMA, or polled operation
- Linearity and gain adjustment calibration logic

37.3 Functional description

ADC performs analog-to-digital conversions on any of the software-selectable analog input channels via a successive approximation algorithm.

The ADC module can average the result of multiple conversions on a channel before storing the calculated result. The hardware average function is enabled by setting CMDHn[AVGS] to a non-zero value. The function operates in any conversion mode or configuration.

ADC can compare the result of a conversion with the contents of two value registers for less-than, greater-than, inside-range, or outside-range detection. The compare function operates in any conversion mode or configuration.

When the conversion and averaging loops finish, the resulting data is placed in one of 2 available FIFO data buffers . The data includes tag information associated with the result. When the number of stored data words exceeds the setting, a configurable watermark level supports interrupts or DMA requests. Interrupts can also be enabled to indicate when FIFO overflow errors occur.

The module initializes to its lowest power state during reset.

The ADC analog circuits can be pre-enabled to begin conversions sooner at the expense of higher idle currents. Conversions are initiated by selectable trigger events from software or hardware sources.

The trigger-detection logic includes a configurable enable and priority scheme for available trigger sources.

ADC includes multiple command buffers to provide flexibility for channel scanning and independent channel selections for different trigger sources. These command buffers can be configured for:

- Differential or single-ended conversion
- Sample time
- Averaging on a per-channel basis

ADC includes offset and linearity calibration logic. A request for calibration should be made upon reset or power up. Each successive approximation register (SAR) conversion uses calibration data calculated during the calibration routine.

The sequencing of an ADC command is summarized in the flow diagram below.

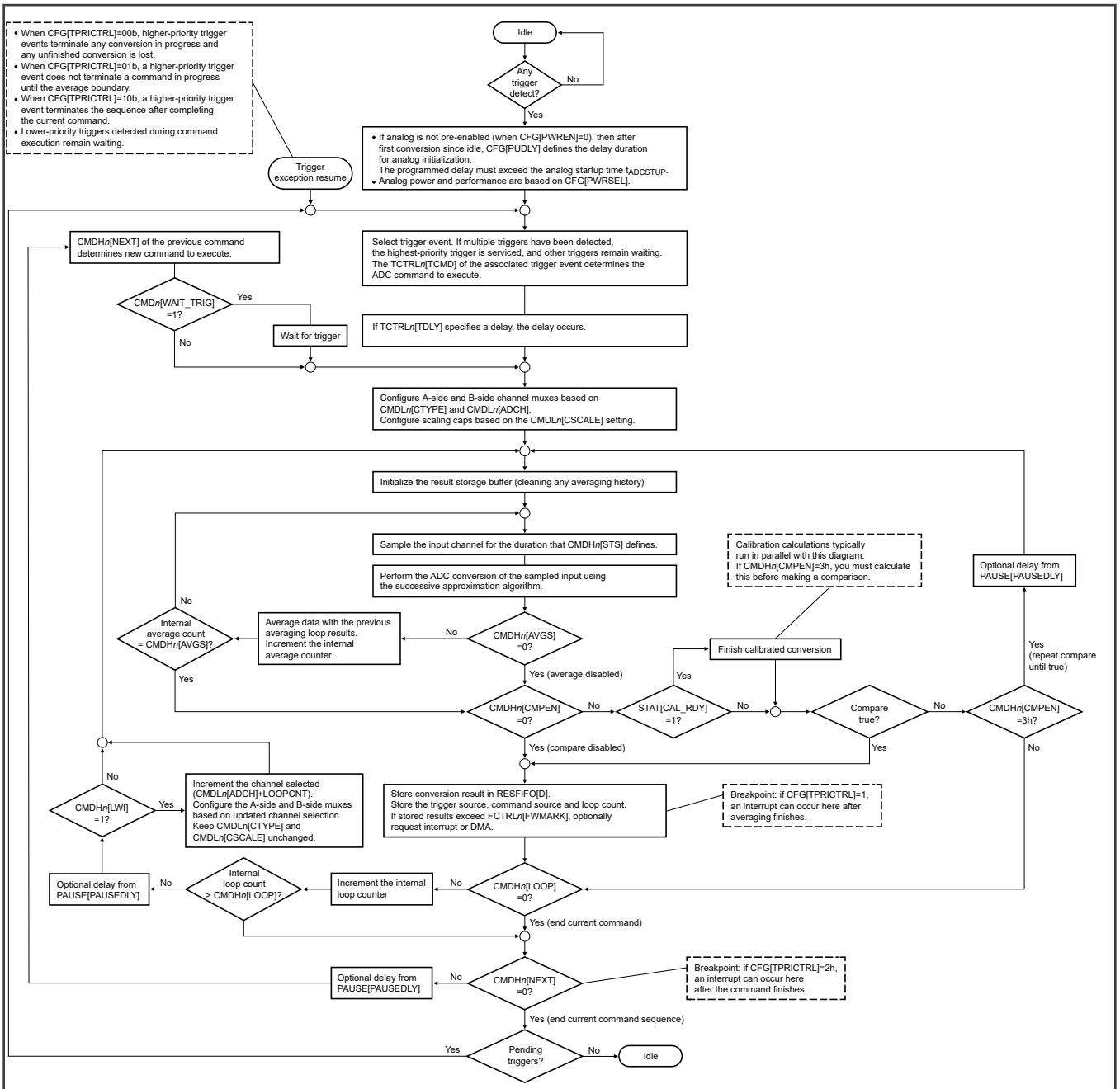


Figure 99. ADC command execution flow diagram

37.3.1 Power control mode

By default, the ADC analog circuits are disabled while ADC is in its idle state. When a trigger is detected and ADC command processing is initiated, the analog circuits are enabled. These circuits require a period of initialization before the first conversion cycle.

The value of CFG[PUDLY] should be set to incur a delay longer than $t_{ADCSTUP}$. The accuracy of initial conversions after activation is degraded if the value of CFG[PUDLY] is too low.

You can achieve faster conversion startup times by setting CFG[PWREN] to pre-enable the analog circuits of ADC. This faster conversion consumes extra power, even while ADC is in an idle state. When CFG[PWREN] is 1, the Power Enable timer is

activated. The timer enforces the minimum time required (configured by CFG[PUDLY]) before detected triggers can initiate ADC conversions.

ADC also has options for controlling power and performance summarized in the table below. See the device data sheet for specification of the available power modes.

Table 261. Power option settings

CFG[PWRSEL]	Description
00b (Default)	Slowest speed and lowest power
01b	Faster speed and higher power
10b	Even faster speed and even higher power
11b	Fastest speed and highest power

37.3.2 ADC behavior in low-power mode

ADC supports system-level low-power modes. In low-power modes where ADC can remain functional, CTRL[DOZEN] controls ADC behavior.

When CTRL[DOZEN] = 0, if ADC was configured and enabled before entering low-power mode, ADC can continue operating while the system transitions to the low-power state. Any conversion in progress is not disrupted. External hardware trigger detection and active conversions are operational.

When CTRL[DOZEN] = 1, ADC waits for the current averaging iteration or FIFO storage to complete before acknowledging the low-power entry request.

When entering a low-power mode where ADC cannot remain functional, the module:

- Ignores CTRL[DOZEN].
- Waits for the current averaging iteration or FIFO storage to complete before acknowledging the low-power entry request.

After entering the low-power state, the ADC is kept inactive until the system exits the low-power state. The setting of CFG[PWREN] is ignored and the ADC analog circuits are forced to their lowest-power state. Upon waking from the low-power state, the analog circuits are automatically re-enabled and the power-up delay timer begins, if:

- The analog circuits were pre-enabled before entering Stop mode (CFG[PWREN] = 1), and
- The control registers retained their states in low-power mode.

Any triggered conversion is stalled until the power-up delay associated with CFG[PUDLY] has finished.

37.3.3 Voltage reference

The voltage reference high (V_{REFH}) used by ADC is supplied from either an on-chip voltage reference source or from an off-chip source via external pins. V_{REFL} is always from an external pin and must be at the same voltage as the Analog Power Domain Ground.

This block supports a programmable selection of the Voltage Reference High used for ADC conversions (via CFG[REFSEL]).

See the chip configuration information on the voltage reference options specific to this packaged device.

37.3.4 Trigger detect and command execution

See Figure 99 for a flow diagram of command execution sequencing.

ADC command execution is initiated from up to 4 trigger sources. Each trigger can be software-generated by writing 1b to the corresponding SWTRIG[SWTn] field. Alternatively, asynchronous input sources at the periphery of the module can generate hardware triggers. The number and sources of hardware triggers implemented is device-specific. See the chip-specific ADC information for descriptions of available hardware trigger sources for this device.

Each hardware trigger source is enabled by setting the associated enable field (TCTRLn[HTEN]). Each trigger source is assigned a priority via the associated priority control field (TCTRLn[TPRI]). Each of the trigger sources is associated with a command buffer via the associated command select field (TCTRLn[TCMD]).

When a hardware trigger input is enabled, hardware trigger events are detected on the rising edge of the associated hardware trigger source.

Each trigger source has an associated priority field TCTRLn[TPRI] which allows arbitration between trigger sources. Arbitration selects two things: which trigger sequence to execute next, and how to handle a trigger exception. Trigger exceptions are defined as allowing a higher-priority trigger sequence to interrupt operation of a lower-priority sequence. When a trigger exception occurs, programmable arbitration allows the configurable stop and resume points for low-priority sequences. The fields affecting arbitration are CFG[HPT_EXDI], CFG[TCMDRES], CFG[TRES], and CFG[TPRICTRL].

1. When CFG[HPT_EXDI] = 1b, trigger exceptions are disabled and any higher priority triggers are left pending until the current sequence completes. New triggers are accepted based on priority.
2. When CFG[HPT_EXDI] = 0b (default), exceptions are enabled and the higher-priority sequence begins executing at a user-specified breakpoint.

Breakpoint locations are determined by CFG[TPRICTRL], which affects latency for accepting trigger exceptions.

1. When CFG[TPRICTRL] = 0h, a higher-priority trigger causes an immediate command abort and the new command specified by the trigger is immediately started.
2. When CFG[TPRICTRL] = 1h, the current conversion is allowed to complete (including averaging) before the higher-priority exception starts. In this mode, if the command is running through a series of averages, this series completes. However, there is no requirement to finish the entire command before being interrupted. For example, if the command consists of four loop iterations, there is no requirement to complete all four iterations before the interrupt occurs.
3. When CFG[TPRICTRL] = 2h, a higher-priority trigger begins once the current command is completed. If a command consists of five loop iterations each containing eight averages, then all 40 conversions must be completed before accepting the trigger exception.

CFG[TCMDRES] and CFG[TRES] determine what ADC does after accepting a trigger exception. The module can be programmed to resume commands after returning from a trigger exception.

1. When CFG[TRES] = 0h, commands are not automatically resumed after being stopped by an exception. However, an interrupt is set to indicate that this case has occurred. The flag TSTAT[TEXC_NUM] can be used to resolve which trigger was stopped by the exception.
2. When CFG[TRES] = 1h, ADC automatically resumes commands after they were stopped by an exception.

Using CFG[TRES] with CFG[TCMDRES], the module can be programmed to resume commands at one of two possible locations.

1. When CFG[TCMDRES] = 0h, the trigger which was stopped by an exception is resumed from the beginning of its associated command sequence. Triggers that are waiting to be resumed take the same priority programmed to TCTRLn[TPRI].
2. When CFG[TCMDRES] = 1h, the trigger is resumed from the command that it was executing before being interrupted by an exception.

If a trigger occurs with priority lower than the priority of the currently executing command, trigger detection is left pending until the current command sequence finishes. Lower-priority trigger events cannot be serviced until a higher-priority triggered command (or command sequence) completes.

When a conversion is completed (including hardware averaging when CMDHn[AVGS] is non-zero), the result is placed in a RESFIFO buffer. When an ADC command selects looping (when CMDHn[LOOP] is non-zero) a command stores multiple conversion results to the FIFO during execution of that command.

At the end of command execution, CMDHn[NEXT] selects the next command to be executed. Multiple commands can be executed sequentially by configuring the CMDHn[NEXT] field of each command. Setting the next command to 0h causes conversions to terminate at the completion of the current command. Unending circular command execution is allowed by setting the CMDHn[NEXT] field of the last command in a sequence to the first command in the sequence.

By default, command sequences execute automatically in the order in which CMDHn[NEXT] fields are programmed. However, by using CMDHn[WAIT_TRIG], command execution can be stalled and launched based on trigger inputs. For example, if TRIGGER2 is programmed to start the command sequence CMD1, CMD2, CMD3, then this sequence is run once unconditionally to completion upon receiving TRIGGER2. If CMDH2[WAIT_TRIG] = 1h, however, the sequence pauses after CMD1 until TRIGGER2 is received again. In this way, sequences can be stalled until a trigger assertion is received.

Disabling ADC by writing 0b to CTRL[ADCEN] terminates any active ADC command processing. Writing 0b to CTRL[ADCEN] causes the current command (or command sequence) to terminate, clears any pending triggers, and sends the ADC module to an idle state.

37.3.5 Pause option

When an application does not require the maximum conversion rate, the effective conversion rate can be reduced:

- By implementing periodic trigger events to initiate ADC conversions, or
- By selecting a reduced-frequency clock as the ADCK source.

Both options are chip-specific and are dependent on ADC triggering and clocking options external to the ADC module. The latency associated with ADC analog power-up delays limits the maximum conversion rate when using periodic triggering.

Conversion rates can also be reduced by inserting a pause of a programmable duration:

- Between loop iterations
- Between commands in a sequence
- Between conversions, when a command is executing in the Compare Until True configuration

When PAUSE[PAUSEEN] = 1, PAUSE[PAUSEDLY] controls the duration of pausing during command execution sequencing. The pause delay is a count of (PAUSE[PAUSEDLY] * 4) ADCK cycles.

NOTE

Do not change the PAUSE register while CTRL[ADCEN] = 1. Writes to the PAUSE register while CTRL[ADCEN] is 1 can lead to metastable operation.

See Figure 99 for the places during command execution sequencing where the pause can be inserted.

37.3.6 Temperature sensor

ADC has a dedicated input channel for an on-chip temperature sensor. See the chip-specific channel definition to determine which channel is connected to the on-chip temperature sensor.

To calculate the temperature, you must first execute a conversion of the temperature sensor channel with configuration requirements. The sequence to convert the temperature sensor channel is:

1. Configure a command buffer register to convert the temperature sensor channel (CMDLn[ADCH]).
2. Program the command buffer with the following parameters:
   - Resolution set to 16b mode: CMDLn[MODE] = 1h
   - Differential: CMDLn[CTYPE] = 2h
   - Max averaging: CMDHn[AVGS] = Ah
   - Max sample time: CMDHn[STS] = 7h
   - LOOP set to 1: CMDHn[LOOP] = 1h
   - Loop with increment disabled: CMDHn[LWI] = 0h
   - Compare function disabled: CMDHn[CMPEN] = 0h
3. Configure a trigger control register TCTRLn with the following parameters:
   - TCTRLn[TCMD] = command buffer used in steps 2 and 3.

- TCTRLn[FIFO_SEL_A] directs conversion results to FIFO0 orFIFO1

4. Trigger a conversion of the temperature sensor channel. You trigger the conversion by writing 1 to the associated bit in Software Trigger Register (SWTRIG) (that is, the trigger configured in the previous step).

After completing the conversion of the temperature sensor channel, two results are stored in the FIFO selected by TCTRLn[FIFO_SEL_A]. Each result corresponds to a component of the overall temperature value. Read these values from the FIFO and use the following equation to calculate the ambient temperature.

$$\text{Temp} = A\left[\frac{\alpha(\text{Vbe8}-\text{Vbe1})}{\text{Vbe8} + (\alpha(\text{Vbe8}-\text{Vbe1}))}\right] - B$$

Equation 1. Temperature sensor function

In the preceding equation:

- Vbe1 is the first value stored to the FIFO as a result of the temperature sensor channel conversion.
- Vbe8 is the second value stored to the FIFO as a result of the temperature sensor channel conversion.
- A is the slope factor.
- B is the offset factor.
- α is the bandgap coefficient.

A, B, and α are specified constant values from the ADC electrical information in the chip data sheet.

37.3.7 Result FIFO operation

ADC includes 2 16-entry FIFOs in which the result of ADC conversions are stored. In addition, a valid indicator bit, the trigger source, the source command, and the loop count are also stored with the data. FCTRLn[FCOUNT] indicates how many valid data words are stored in each RESFIFO.

A programmable watermark threshold supports configurable notification of data availability. When FCTRLn[FCOUNT] is greater than FCTRLn[FWMARK], the associated RDY flag is asserted. When IE[FWMIEn] = 1, a watermark interrupt request is issued. When DE[FWMDEn] = 1, a DMA request is issued. Reading RESFIFO provides the oldest unread data word entry in the FIFO and decrements FCTRLn[FCOUNT]. When FCTRLn[FCOUNT] falls equal to or below FCTRLn[FWMARK], the RDY flag is cleared.

Each FIFO can be emptied by successive reads of RESFIFOn. When RESFIFOn[VALID] is 1, the associated FIFO entry is valid. Reading RESFIFOn when the FIFO is empty (when RESFIFOn[VALID] = 0 and FCTRLn[FCOUNT] = 0h) provides an undefined data word. All FIFOs are reset by writing 1b to CTRL[RSTFIFOn].

If ADC attempts to store a data word to the FIFO when the FIFO is full, the FIFO overflow flag (FCTRLn[FOF]) is set. When IE[FOFIEn] = 1, an overflow interrupt request is issued. The FOF flag is cleared by writing 1 to STAT[FOFn]. When overflow events occur, no new data is stored and the data associated with the storage event that triggered the overflow is lost.

Conversion results can be steered to any FIFO in the design. TCTRLn[FIFO_SEL_A] and TCTRLn[FIFO_SEL_B] determine into which FIFO the final result is written. Depending on which trigger is executing, the results can be steered to different locations. Depending on the type of conversion selected, the FIFO destination register fields are interpreted differently. During either differential or single-ended mode (CMDLn[CTYPE] != 3h) only one result is produced. The destination during these modes is determined from TCTRLn[FIFO_SEL_A]. In dual-single-ended mode, both TCTRLn[FIFO_SEL_A] and TCTRLn[FIFO_SEL_B] determine the Channel A and Channel B destinations respectively.

37.3.8 Sampling Modes

The ADC module supports three different sampling modes: dual single-ended, single-ended, and differential. The sampling mode is determined by the currently executing command using CMDLn[CTYPE].

When executing a command in dual single-ended mode, two independent conversion results are calculated and stored in selectable FIFO destinations. Command processing, however, is not individually controlled for each independent channel being sampled. When operating in dual single-ended mode both channels are sampled and processed simultaneously.

The selection of Channel B is controlled by CMDLn[ALTBEN].

- When CMDLn[ALTBEN] = 1, the channel for the B-side is selected independently (via the value of CMDLn[ALTB_ADCH]).
- When CMDLn[ALTBEN] = 0, the Channel B selection is controlled by CMDLn[ADCH] and Channel A and Channel B are paired (CH0A/CH0B, CH1A/CH1B, and so on).

If comparisons are enabled in dual single-ended mode, only the A-side channels (CH0A, CH1A, and so on) are used for the comparison. The A-side comparison determines whether both the A-side and B-side results are written to the FIFOs.

- If the A-side comparison passes, both the A-side and B-side results are stored.
- If the A-side comparison fails, A-side and B-side results are not written to the FIFOs.

Single-ended mode is configurable to allow either A-side or B-side channels to be sampled. In single-ended mode, the results from each conversion can be written to a selectable FIFO using TCTRLn[FIFO_SEL_A].

In differential mode, the final SAR calculation is equivalent to V(CHA) - V(CHB). If the result is negative, then the value is stored in sign-extended two's complement format. TCTRLn[FIFO_SEL_A] also determines where differential conversion results are stored.

In dual single-ended mode, however, two independent results are produced. Individual control is provided by using TCTRLn[FIFO_SEL_A] and TCTRLn[FIFO_SEL_B] to select a FIFO destination for both results during this mode. Both single-ended results may be written to the same destination by programming TCTRLn[FIFO_SEL_A] = TCTRLn[FIFO_SEL_B]. In this case, the CH_A result is always stored before the CH_B result.

37.3.9 Compare Function

After the input is sampled and converted and any averaging iterations are performed, CMDHn[CMPEN] determines:

- Whether to use the automatic compare function, storing the conversion result when true.
- Whether to repeat the channel acquisition until the automatic compare function returns a true result.

The command-sequencing options related to the compare function are summarized in the table below.

NOTE

Latency is added to the end of a compare-until-true conversion to resolve the next command or loop in a sequence. This latency is necessary to calibrate the SAR data before resolving the result of a comparison. Delay for this feature is only added when resolving the result of a conversion. Intermediate samples during averaging do not include extra latency; only loop and command boundaries experience this delay. The latency is always less than or equal to five ADC clock cycles.

Table 262. Compare modes

CMDHn[CMPEN]	Compare function	Description
00b	Compare disabled	Do not perform compare operation. Always store the conversion result to the FIFO.
01b	Reserved	
10b	Store on true	Perform compare operation. Store conversion result to FIFO after averaging only when the result of the comparison is true. Regardless of the comparison result, the LOOP setting is considered. The LOOP counter is incremented before deciding whether the current command has completed or additional LOOP iterations are required.
11b	Repeat compare until true	Perform compare operation. Store conversion result to FIFO after averaging only when the result of the comparison is true. Once a comparison is true, the LOOP setting is considered. The LOOP counter is incremented before deciding whether the current command has completed or additional LOOP iterations are required. When a comparison is false, the conversion is repeated without considering the LOOP setting, and the LOOP counter is not incremented.

The compare operation checks the result based on the values of CVn[CVH] and CVn[CVL], as shown in the following table.

Table 263. Compare operations

CVn[CVL] vs. CVn[CVH]	Operation	Description
set CVn[CVL] < CVn[CVH]	Outside range (General form)	True if the result is less than CVn[CVL] **or** greater than CVn[CVH].
set CVn[CVH] to maximum value set CVn[CVL] to compare point	Less than	True if the result is less than CVn[CVL].
set CVn[CVL] to minimum value set CVn[CVH] to compare point	Greater than	True if the result is greater than CVn[CVH].
set CVn[CVL] > CVn[CVH]	Inside range	True if the result is less than CVn[CVL] **and** greater than CVn[CVH].

NOTE

When ADC continues operating in a low-power mode, the compare function can monitor the voltage and wake the device only when the compare condition is met.

37.3.10 Cycles per conversion

The number of ADCK cycles needed to complete a conversion, varies based on the selected resolution (CMDLa[MODE]), the sample time configured, and several other configuration options discussed below.

To calculate the cycle count, first, determine the Base Cycles Count from Table 264. Next, add the Sample Time Adder based on CMDHa[STS] setting as summarized in Table 265. If averaging is enabled (CMDHa[AVGS] does not equal to 0), then the total cycle (Base Cycles Count + Sample Time Adder) should be multiplied by the number of averages configured as summarized in Table 266.

$$CycleCount\ /\ Conversion = [(BaseCycleCount + SampleTimeAdder) * AverageMultiplier]$$

Equation 2. Cycle Count/Conversion

Note that there is latency associated with trigger detection and starting an initial conversion. There is additional latency associated with offset and gain error adjustment of a raw conversion result and storage of a final result to the FIFO. Due to the pipe-lining of conversions when looping or command chaining is configured, the next conversion is immediately started while a raw conversion result is being adjusted and stored and thus the conversion rate is maximized.

The base cycles per conversion are variable depending on CMDLa[MODE] setting as summarized in the following table:

Table 264. Base cycles per conversion

Base ADCK cycles/conversion[1]	
16-bit CMDLa[MODE] = 1	12-bit CMDLa[MODE] = 0
24	19

1. This cycle count includes min sample time of 3.5 ADCK cycles.

In addition to the base cycles per conversion, the configured sample time needs to be considered. The sample time adder is variable depending on CMDHa[STS] setting and is summarized in the following table:

Table 265. Sample time cycle adder

CMDHa[STS] (default 000)	Add ADCK cycles/conversion
000	0
001	2
010	4
011	8
100	16
101	32
110	64
111	128

Table 266. Averaging multiplier

CMDHa[AVGS] (default 0000)	Averaging multiplier
0000	1
0001	2
0010	4
0011	8
0100	16
0101	32
0110	64
0111	128
1000	256
1010	512
1011	1024

When LOOPing is used:

CMDHa[LOOP] allows iteration of a command (that is a channel can be converted multiple times). This feature adds 3 additional cycles between conversions.

NOTE

When commands are chained using CMDHa[NEXT] to execute back-to-back conversions the ADC does not have the 3 stall cycles between commands.

For a command that executes multiple conversions of the same channel using LOOPing the total cycle count is:

$$CycleCount\ /\ Command = [(BaseCycleCount + SampleTimeAdder) * AverageMultiplier * (CMDHa[LOOP] + 1)] + (3 * CMDHa[LOOP])$$

Equation 3. Cycle Count/Command

37.3.11 Clocking

ADC uses the ADCK clock input provided by an on-chip clock select block. It is used by the SAR conversion-control sequencing logic and the FIFO storage buffer. The ADCK frequency must be within the specified frequency range for ADCK, and varies based on CFG[PWRSEL]. See the device data sheet for supported frequency ranges.

ADC continues operating in low-power mode as long as CTRL[DOZEN] = 0 and the on-chip clock select block supplies an ADCK clock source.

NOTE

When in low-power mode with CTRL[DOZEN] = 0, the bus clock can be shut off, and asynchronous interrupts and DMA requests can be configured. ADC continues processing commands and writing data to the internal FIFO.

ADC has four sources for asynchronous interrupts during low-power mode: watermark, FIFO overflow, TCOMP, and TEXC. To enable them, configure IE[FWMIEx], IE[FOFIEx], IE[TCOMP_IE], and IE[TEXC_IE] before entering low-power mode.

When CTRL[DOZEN] = 1 in low-power mode, ADC waits for the current averaging iteration or FIFO storage to complete before acknowledging the low-power mode entry. Any pending triggers are dropped when a low-power mode request is made in this mode. ADC is forced into its lowest-power setting after acknowledging the low-power mode request.

37.3.12 Resets

Table 267. ADC Resets

Reset source	Description
Chip reset	Resets the ADC logic and registers to their default states.
Software reset	Resets, by using CTRL[RST], logic and registers (except Control Register (CTRL), Gain Calculation Result (GCR0 - GCR1), Calibration General A-Side Registers (CAL_GAR0 - CAL_GAR32), and Calibration General B-Side Registers (CAL_GBR0 - CAL_GBR32) to their default states.
FIFO reset	Resets CTRL[RSTFIFO0] and CTRL[RSTFIFO1] by implementing write-only control. After a FIFO is reset, that FIFO becomes empty.

37.3.13 Interrupts and DMA requests

ADC includes several sources for interrupts and DMA requests. The table below summarizes these sources.

A programmable watermark threshold supports configurable notification of data availability and can generate either an interrupt exception or a DMA request. When FCTRLn[COUNT] is greater than FCTRLn[FWMARK], the associated STAT[RDYn] flag is asserted. The IE[FWMIEn] and DE[FWMDEn] control fields control the masking for this exception. When STAT[RDYn] becomes 1 and IE[FWMIEn] = 1, a watermark interrupt request is issued. When STAT[RDYn] becomes 1 and DE[FWMDEn] = 1, a DMA request is issued.

The other exception sources can only generate interrupts and do not have a DMA request option. Each source has a mask control field in the IE register and no corresponding field in the DE register.

Table 268. ADC Interrupts and DMA Requests

Status Register (STAT)		Description	Can generate		
Flag	Name		Interrupt?	DMA request?	Low-power wake-up?
RDYn	Result FIFO n Ready Flag	Conversion result data is written to Result FIFO and has a watermark configurable trigger level to generate an exception request as controlled by FCTRLn[FWMARK].	Y	Y	Y

Table continues on the next page...

Table 268. ADC Interrupts and DMA Requests (continued)

Status Register (STAT)		Description	Can generate		
Flag	Name		Interrupt?	DMA request?	Low-power wake-up?
FOFn	Result FIFO n Overflow Flag	Attempting to store data to the FIFO when the FIFO is full is an error condition.	Y	N	Y
TCOMP_INT	Trigger Completion Flag	A trigger sequence has been completed. All associated commands have been run.	Y	N	Y
TEXC_INT	High Priority Trigger Flag	A high priority trigger exception has occurred.	Y	N	Y

37.4 External signals

The ADC module supports analog channel inputs with differential and single-ended conversion options for all channels.

See chip-specific section for supply and ground connections.

Table 269. ADC signal descriptions

Signal	Description	I/O
CHnA - CH0A[1]	A-side Analog Channel Inputs	I
CHnB - CH0B[1]	B-side Analog Channel Inputs	I

1. where n is the maximum channel number supported in the chip. See the chip-specific information for the number of channels supported on your device.

37.4.1 Analog channel inputs (CHnA and CHnB)

CMDLn[ADCH] and CMDLn[CTYPE] control selection of paired or individual input channels. Each ADC command independently makes a channel and conversion type selection. Each CMDLn[ADCH] channel selection has an associated A side and an associated B side input. Each CMDLn[ADCH] pair can be converted in differential mode, but only limited pairs should be converted as differential channels (for example, adjacent pins designed with matched impedance). For the pin pairings available for differential conversions for your device, see the Chip Configuration details.

NOTE

Some input channels from on-chip sources, such as temperature sensors and reference voltage sources, may only be connected to individual instances of ADC. Some input channel options in the field-setting descriptions may not be available for your device. See chip-specific information for the channels supported on this device.

37.5 Initialization

37.5.1 Calibration functions

The ADC module has multiple calibration functions that must be executed as part of ADC setup to achieve the specified accuracy. Calibration must be run after any reset and before a conversion is initiated. Before offset calibration or calibration, the user must configure the clock source and frequency of ADC for the clock source availability and needs of the application. ADC must be enabled (CTRL[ADCEN] = 1h) before a calibration function runs. If calibration is requested while ADC is actively converting, that sequence completes before starting calibration.

Averaging multiple conversions can achieve improved accuracy during the calibration routines. CTRL[CAL_AVGS] is used during a calibration routine to control how many samples are averaged together. If the application uses ADC in a wide variety of

configurations, the configuration for which the highest accuracy is required should be selected. Alternatively, multiple calibrations can be done for the different configurations.

37.5.1.1 Offset calibration

The Offset Trim Register (OFSTRIM) is used to trim for ADC comparator offset voltage. The ADC supports an offset calibration function in which the OFSTRIM register is automatically updated. To perform offset calibration:

1. Configure for the desired averaging via CTRL[CAL_AVGS].
2. Initiate Offset Calibration by setting CTRL[CALOFS].
3. Poll the STAT[CAL_RDY] flag. When STAT[CAL_RDY] is asserted, the offset calibration function has completed, and the OFSTRIM register has updated.

37.5.1.2 ADC Calibration

ADC includes hardware calibration logic in which the A-side and B-side converters are calibrated for gain error and linearity error correction of the raw conversion result. GCR0[GCALR] and the CAL_GAR registers control calibration for the A-side converter. GCR1[GCALR] and the CAL_GBR registers control calibration for the B-side converter. ADC supports a calibration function in which the CAL_GAR and CAL_GBR registers are automatically updated. The calibration function also updates GCC0[GAIN_CAL] (associated with A-side calibration) and GCC1[GAIN_CAL] (associated with B-side calibration). For A-side calibration, a software calculation is required to derive GCR0[GCALR] from GCC0[GAIN_CAL]. For B-side calibration, a corresponding calculation is required to derive GCR1[GCALR] from GCC1[GAIN_CAL].

To complete calibration setup:

1. Execute Offset calibration steps. The Offset Trim Register (OFSTRIM) is used during calibration to trim for comparator offset voltage.
2. Configure the averaging via CTRL[CAL_AVGS].
3. Initiate the calibration routine by writing 1 to CTRL[CAL_REQ]. CTRL[CAL_REQ] remains 1 until the CAL routine has been accepted by the ADC. After acceptance, CTRL[CAL_REQ] automatically becomes 0.
4. The A-side calibration data is updated first. Poll the GCC0[RDY] flag. When it is asserted, the hardware controlled A-side calibration operation is complete, and CAL_GAR and GCC0[GAIN_CAL] registers are updated. The updated value in GCC0[GAIN_CAL] is required for further software processing described in the following steps.
5. Read GCC0[GAIN_CAL] and store for use in the gain_adjustment calculation.
6. Calculate the A-side gain_adjustment: (131072)/(131072-GCC0[GAIN_CAL]). GCC0[GAIN_CAL] is a 16-bit unsigned value. This calculation results in a floating point value between 1 and 2.
7. The integer value of the gain_adjustment calculation is always 1 and can be discarded. The fractional component must be stored to GCR0[GCALR]. Write the fractional component value to GCR0[GCALR].
8. Execute the same calculation for the B-side converter. Poll the GCC1[RDY] flag. When it is asserted, the hardware controlled B-side calibration operation is complete, and CAL_GBR and GCC1[GAIN_CAL] registers are updated. The updated value in GCC1[GAIN_CAL] is needed for further software processing.
9. Read the GCC1[GAIN_CAL] register and store for use in the gain_adjustment calculation.
10. Calculate the B-side gain_adjustment = (131072)/(131072-GCC1[GAIN_CAL]). Formatting for the value is the same as the A-side.
11. Like the A-side, round the fractional component of the B-side gain_adjustment to 16-bits and store it in GCR1[GCALR].
12. Once GCR0[GCALR] and GCR1[GCALR] contain the results from the gain_adjustment calculations, set the GCR0[RDY] and GCR1[RDY] flags to indicate they are valid. It is acceptable for the GCRn[GCALR] and corresponding GCRn[RDY] field to be updated on the same write cycle.

After completing the steps above, the calibration sequence is complete and the STAT[CAL_RDY] flag is set. The STAT[CAL_RDY] flag remains set until the user resets the system or requests a new calibration sequence.

When STAT[CAL_RDY] is set, ADC is configured to run in calibrated mode. Each conversion uses a combination of linearity and gain calibration results to correct SAR data. Calibration conversion latency is required to process each sample. However, due to the pipelined nature of data and control sequences, each conversion can still be initiated without experiencing this calibration delay.

37.5.1.3 Calibration General A-Side and B-Side Widths

The general calibration value registers CAL_GARn and CAL_GBRn have non-uniform widths. The following table defines the bit widths of each register.

Table 270. Calibration General Widths

Element CAL_GxR[N]	Width (Bits)
N = 00h, 20h	11
N = 01h	12
N = 02h–03h	13
N = 0x04–07h	14
N = 0x08–0Fh	15
N = 0x10–1Fh	16

These registers are typically updated automatically during the self-calibration sequence. To reduce the latency associated with ADC setup, the CAL_GxR values from a calibration sequence can be stored in non-volatile memory after an initial calibration. These values can then be written to the CAL_GxR registers via software prior to the first ADC conversion. If these registers are set to values not generated by the calibration function, the linearity error specifications may not be met.

NOTE

These values can only be written in a single access, byte accesses are not supported.

37.6 ADC register descriptions

This section describes the ADC registers.

37.6.1 ADC memory map

ADC0 base address: 4004_7000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID Register (VERID)	32	R	0200_2C0Bh
4h	Parameter Register (PARAM)	32	R	0F0F_1004h
10h	Control Register (CTRL)	32	RW	0000_0000h
14h	Status Register (STAT)	32	RW	0000_0000h
18h	Interrupt Enable Register (IE)	32	RW	0000_0000h
1Ch	DMA Enable Register (DE)	32	RW	0000_0000h
20h	Configuration Register (CFG)	32	RW	0080_0000h

Table continues on the next page...

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Offset	Register	Width (In bits)	Access	Reset value
24h	Pause Register (PAUSE)	32	RW	0000_0000h
34h	Software Trigger Register (SWTRIG)	32	RW	0000_0000h
38h	Trigger Status Register (TSTAT)	32	RW	0000_0000h
40h	Offset Trim Register (OFSTRIM)	32	RW	0000_0000h
A0h - ACh	Trigger Control Register (TCTRL0 - TCTRL3)	32	RW	0000_0000h
E0h - E4h	FIFO Control Register (FCTRL0 - FCTRL1)	32	RW	0000_0000h
F0h - F4h	Gain Calibration Control (GCC0 - GCC1)	32	R	0000_0000h
F8h - FCh	Gain Calculation Result (GCR0 - GCR1)	32	RW	0000_0000h
100h	Command Low Buffer Register (CMDL1)	32	RW	0000_0000h
104h	Command High Buffer Register (CMDH1)	32	RW	0000_0000h
108h	Command Low Buffer Register (CMDL2)	32	RW	0000_0000h
10Ch	Command High Buffer Register (CMDH2)	32	RW	0000_0000h
110h	Command Low Buffer Register (CMDL3)	32	RW	0000_0000h
114h	Command High Buffer Register (CMDH3)	32	RW	0000_0000h
118h	Command Low Buffer Register (CMDL4)	32	RW	0000_0000h
11Ch	Command High Buffer Register (CMDH4)	32	RW	0000_0000h
120h	Command Low Buffer Register (CMDL5)	32	RW	0000_0000h
124h	Command High Buffer Register (CMDH5)	32	RW	0000_0000h
128h	Command Low Buffer Register (CMDL6)	32	RW	0000_0000h
12Ch	Command High Buffer Register (CMDH6)	32	RW	0000_0000h
130h	Command Low Buffer Register (CMDL7)	32	RW	0000_0000h
134h	Command High Buffer Register (CMDH7)	32	RW	0000_0000h
138h	Command Low Buffer Register (CMDL8)	32	RW	0000_0000h
13Ch	Command High Buffer Register (CMDH8)	32	RW	0000_0000h
140h	Command Low Buffer Register (CMDL9)	32	RW	0000_0000h
144h	Command High Buffer Register (CMDH9)	32	RW	0000_0000h
148h	Command Low Buffer Register (CMDL10)	32	RW	0000_0000h
14Ch	Command High Buffer Register (CMDH10)	32	RW	0000_0000h
150h	Command Low Buffer Register (CMDL11)	32	RW	0000_0000h
154h	Command High Buffer Register (CMDH11)	32	RW	0000_0000h
158h	Command Low Buffer Register (CMDL12)	32	RW	0000_0000h

Table continues on the next page...

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Offset	Register	Width (In bits)	Access	Reset value
15Ch	Command High Buffer Register (CMDH12)	32	RW	0000_0000h
160h	Command Low Buffer Register (CMDL13)	32	RW	0000_0000h
164h	Command High Buffer Register (CMDH13)	32	RW	0000_0000h
168h	Command Low Buffer Register (CMDL14)	32	RW	0000_0000h
16Ch	Command High Buffer Register (CMDH14)	32	RW	0000_0000h
170h	Command Low Buffer Register (CMDL15)	32	RW	0000_0000h
174h	Command High Buffer Register (CMDH15)	32	RW	0000_0000h
200h - 238h	Compare Value Register (CV1 - CV15)	32	RW	0000_0000h
300h - 304h	Data Result FIFO Register (RESFIFO0 - RESFIFO1)	32	R	0000_0000h
400h	Calibration General A-Side Registers (CAL_GAR0)	32	RW	0000_0000h
404h	Calibration General A-Side Registers (CAL_GAR1)	32	RW	0000_0000h
408h - 40Ch	Calibration General A-Side Registers (CAL_GAR2 - CAL_GAR3)	32	RW	0000_0000h
410h - 41Ch	Calibration General A-Side Registers (CAL_GAR4 - CAL_GAR7)	32	RW	0000_0000h
420h - 43Ch	Calibration General A-Side Registers (CAL_GAR8 - CAL_GAR15)	32	RW	0000_0000h
440h - 47Ch	Calibration General A-Side Registers (CAL_GAR16 - CAL_GAR31)	32	RW	0000_0000h
480h	Calibration General A-Side Registers (CAL_GAR32)	32	RW	0000_0000h
500h	Calibration General B-Side Registers (CAL_GBR0)	32	RW	0000_0000h
504h	Calibration General B-Side Registers (CAL_GBR1)	32	RW	0000_0000h
508h - 50Ch	Calibration General B-Side Registers (CAL_GBR2 - CAL_GBR3)	32	RW	0000_0000h
510h - 51Ch	Calibration General B-Side Registers (CAL_GBR4 - CAL_GBR7)	32	RW	0000_0000h
520h - 53Ch	Calibration General B-Side Registers (CAL_GBR8 - CAL_GBR15)	32	RW	0000_0000h
540h - 57Ch	Calibration General B-Side Registers (CAL_GBR16 - CAL_GBR31)	32	RW	0000_0000h
580h	Calibration General B-Side Registers (CAL_GBR32)	32	RW	0000_0000h

37.6.2 Version ID Register (VERID)

Offset

Register	Offset
VERID	0h

Function

Indicates the version integrated for this instance on the device and the inclusion of optional features.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	MAJOR								MINOR							
W																
Reset	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	NUM_FIFO			NUM_SEC	CALOFSI	IADCKI	VR1RNGI	0	CSW			MVI	0	DIFFEN	RES
W																
Reset	0	0	1	0	1	1	0	0	0	0	0	0	1	0	1	1

Fields

Field	Function
31-24 MAJOR	Major Version Number Returns the major version number for the module specification.
23-16 MINOR	Minor Version Number Returns the minor version number for the module specification.
15 —	Reserved
14-12 NUM_FIFO	Number of FIFOs Indicates the number of result FIFOs implemented in the design. 000b - N/A 001b - One 010b - Two 011b - Three 100b - Four
11 NUM_SEC	Number of Single-Ended Outputs Supported Indicates the number of single-ended channels which can be processed simultaneously. 0b - One 1b - Two
10 CALOFSI	Calibration Function Implemented Indicates whether ADC contains hardware calibration functions. When supported, CTRL[CAL_REQ] can be used to request the calibration routine. 0b - Not implemented

Table continues on the next page...

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Field	Function
	1b - Implemented
9 IADCKI	Internal ADC Clock Implemented Indicates whether this implementation of the ADC block includes an internal clock source. 0b - Not implemented 1b - Implemented
8 VR1RNGI	Voltage Reference 1 Range Control Bit Implemented Indicates whether a control bit is implemented to select the input voltage range on Voltage Reference Option 1. 0b - Range control not required. 1b - Range control required.
7 —	Reserved
6-4 CSW	Channel Scale Width Indicates whether channel scaling is supported. When supported, each command buffer has a control field (CMDLn[CSCALE]) for setting input scaling. 000b - Not supported. 001b - Supported with one-bit CSCALE control field. 110b - Supported with six-bit CSCALE control field.
3 MVI	Multiple Vref Implemented Indicates whether multiple voltage reference high (VREFH) inputs are supported. When multiple voltage references are supported, CFG[REFSEL] selects voltage reference high options. 0b - Single VREFH input supported. 1b - Multiple VREFH inputs supported.
2 —	Reserved
1 DIFFEN	Differential Supported Indicates whether differential operation is supported. When supported, each command buffer has control fields (CMDLn[CTYPE]) for configuring for differential operation and expanding the number of supported channels from 32 to 64. 0b - Not supported 1b - Supported. CMDLn[CTYPE] controls fields implemented.
0	Resolution

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Field	Function
RES	Indicates the maximum accuracy supported. 0b - Up to 13-bit differential or 12-bit single-ended resolution supported. 1b - Up to 16-bit differential or 16-bit single-ended resolution supported. CMDLn[MODE] available for selecting the resolution of conversions for the associated command.

37.6.3 Parameter Register (PARAM)

Offset

Register	Offset
PARAM	4h

Function

The Parameter register indicates the size of several variable integration options for this instance on the device.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	CMD_NUM								CV_NUM							
W																
Reset	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	FIFOSIZE								TRIG_NUM							
W																
Reset	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0

Fields

Field	Function
31-24 CMD_NUM	Command Buffer Number Indicates number of command buffers implemented.
23-16 CV_NUM	Compare Value Number Indicates number of compare value registers implemented.
15-8 FIFOSIZE	Result FIFO Depth Indicates the maximum number of conversion data words that can be stored in the result FIFO before an overflow occurs.

Table continues on the next page...

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Field	Function
	0000_0001b - 2 0000_0100b - 4 0000_1000b - 8 0001_0000b - 16 0010_0000b - 32 0100_0000b - 64
7-0 TRIG_NUM	Trigger Number Number of Triggers implemented.

37.6.4 Control Register (CTRL)

Offset

Register	Offset
CTRL	10h

Function

Includes primary control bits.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0												CAL_AVGS			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0						0	0	0			CALOFS	CAL_REQ	DOZEN	RST	ADCEN
W							RSTFIFO1	RSTFIFO0								
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-20 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
19-16 CAL_AVGS	Auto-Calibration Averages Selects how many ADC conversions are averaged to calculate each calibration value. Selecting a higher number of averages will lead to more accurate conversions after completing calibration. The CAL_AVGS bit field applies to both CALOFS and CAL_REQ calibration types. This value should be fixed when requesting and running calibration with CTRL[CAL_REQ] or CTRL[CALOFS]. 0000b - Single conversion. 0001b - 2 conversions averaged. 0010b - 4 conversions averaged. 0011b - 8 conversions averaged. 0100b - 16 conversions averaged. 0101b - 32 conversions averaged. 0110b - 64 conversions averaged. 0111b - 128 conversions averaged. 1000b - 256 conversions averaged. 1001b - 512 conversions averaged. 1010b - 1024 conversions averaged.
15-10 —	Reserved
9 RSTFIFO1	Reset FIFO 1 0b - No effect. 1b - FIFO 1 is reset.
8 RSTFIFO0	Reset FIFO 0 0b - No effect. 1b - FIFO 0 is reset.
7-5 —	Reserved
4 CALOFS	Offset Calibration Request Indicates whether a request for a hardware calibration calculation has been made. Writing 1 to this field initiates a hardware offset calibration calculation. Any conversions in progress are completed before launching the offset calibration function. After being accepted, ADC calculates the OFSTRIM[OFSTRIM] value and updates the OFSTRIM register automatically. This field becomes 0 upon completion of the offset calibration calculation. STAT[CAL_RDY] indicates when the offset calibration routine has completed. 0b - Calibration function disabled 1b - Request for offset calibration function

Table continues on the next page...

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Field	Function
3 CAL_REQ	Auto-Calibration Request Indicates whether a request for the hardware calibration routine has been made. Automatically becomes 0 when the system accepts the hardware calibration request. STAT[CAL_RDY] indicates when this calibration routine has been completed. 0b - No request made. 1b - Request has been made.
2 DOZEN	Doze Enable Controls system transition to low-power modes while ADC is converting. When 0, immediate entries to low-power modes are allowed and ADC conversion functions remain enabled. Any conversion in progress is not disrupted. The selected clock source provided from the on-chip clock source must be able to continue operating. When 1, the ADC waits for the current averaging iteration or FIFO storage to complete before acknowledging the low-power entry request. After entering the low-power state, ADC is kept inactive until the system exits the low-power state. When the system enters a low-power mode in which ADC operation is not supported, the DOZEN bit is ignored and ADC waits for the current transfer to complete any pending operation. 0b - ADC is enabled in low-power mode. 1b - ADC is disabled in low-power mode.
1 RST	Software Reset Resets all internal logic and registers, except for Control Register (CTRL), Gain Calculation Result (GCR0 - GCR1), Calibration General A-Side Registers (CAL_GAR0 - CAL_GAR32) , and Calibration General B-Side Registers (CAL_GBR0 - CAL_GBR32). This field remains 1 until you write 0 to it. 0b - ADC logic is not reset. 1b - ADC logic is reset.
0 ADCEN	ADC Enable 0b - Disabled 1b - Enabled

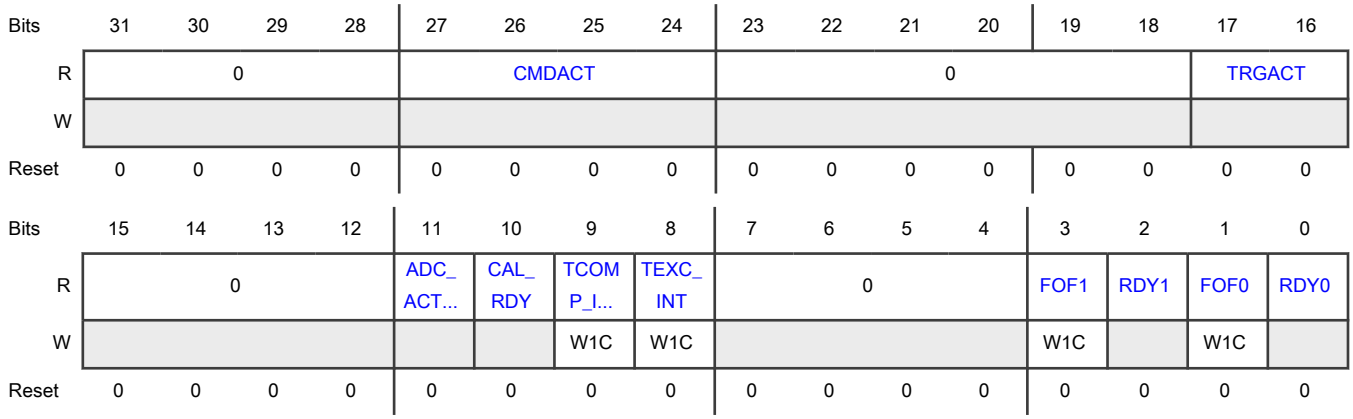
37.6.5 Status Register (STAT)

Offset

Register	Offset
STAT	14h

Function
Provides the status of the ADC module.

Diagram



Fields

Field	Function
31-28 —	Reserved
27-24 CMDACT	Command Active Indicates the command actively being processed. Commands are only shown here when they are actively being processed by the SAR routine. Use with STAT[ADC_ACTIVE] to determine which conversion is running. 0000b - No command currently in progress. 0001b - Command 1 currently being executed. 0010b - Command 2 currently being executed. 0011b-1111b - Associated command number currently being executed.
23-18 —	Reserved
17-16 TRGACT	Trigger Active Indicates the trigger actively being processed. This field can be used to determine which trigger is running through a trigger delay or being converted by the SAR routine. The command associated with this field is running through a conversion when STAT[CMDACT] is not zero. 00b - Command (sequence) associated with Trigger 0 currently being executed. 01b - Command (sequence) associated with Trigger 1 currently being executed. 10b - Command (sequence) associated with Trigger 2 currently being executed. 11b - Command (sequence) associated with Trigger 3 currently being executed.
15-12 —	Reserved
11	ADC Active

Table continues on the next page...

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Field	Function
ADC_ACTIVE	Indicates whether the module is processing a conversion, or has pending triggers to service. 0b - ADC is idle. There are no pending triggers to service and no active commands are being processed. 1b - ADC is processing a conversion, running through the power-up delay, or servicing a trigger.
10 CAL_RDY	Calibration Ready Indicates whether the ADC request for calibration (CTRL[CAL_REQ] or CTRL[CALOFS]) has been completed and the results are ready. This flag is automatically cleared when a new hardware calibration or OFSTRIM request is made. 0b - Calibration is incomplete or has not been run. 1b - ADC is calibrated.
9 TCOMP_INT	Interrupt Flag For Trigger Completion Indicates when a trigger sequence has been completed (all associated commands have been run). IE[TCOMP_IE] must be 1 for the specific trigger source to flag an interrupt upon completion. 0b - Either IE[TCOMP_IE] = 0, or no trigger sequences have run to completion. 1b - Trigger sequence has been completed and all data is stored in the associated FIFO.
8 TEXC_INT	Interrupt Flag For High-Priority Trigger Exception Indicates when a high-priority trigger exception has occurred and CFG[TRES] = 0. This flag only asserts if trigger exception interrupts are enabled (IE[TEXC_IE] = 1h). This flag can be used with TSTAT[TEXC_NUM] to resolve which trigger source was interrupted. 0b - No trigger exceptions have occurred. 1b - A trigger exception has occurred and is pending acknowledgment.
7-4 —	Reserved
3 FOF1	Result FIFO1 Overflow Flag Indicates that more data has been written to the Result FIFO 1 than it can hold. The newer data is not stored and the FIFO holds the original contents. This flag asserts regardless of the value of IE[FOFIE1]. However, an interrupt request is issued only if IE[FOFIE1] is 1. 0b - No result FIFO1 overflow has occurred since the last time that the flag was cleared. 1b - At least one result FIFO1 overflow has occurred since the last time that the flag was cleared.
2 RDY1	Result FIFO1 Ready Flag Indicates when the number of valid data words in the result FIFO 1 is greater than the level set in FCTRL0[FWMARK]. This flag asserts regardless of the value of IE[FWMIE1]. However, an interrupt request or DMA request occurs only when the associated control bit (IE[FWMIE1] and DE[FWMDE1]) is set. This flag is cleared when FCTRL0[FCOUNT] (which decrements on each read of the RESFIFO register) is less than or equal to the level set in FCTRL0[FWMARK].

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Field	Function
	0b - Not above watermark 1b - Above watermark
1 FOF0	Result FIFO 0 Overflow Flag Indicates that more data has been written to the Result FIFO 0 than it can hold. The newer data is not stored and the FIFO holds the original contents. This flag asserts regardless of the value of IE[FOFIE0]. However, an interrupt request is issued only if IE[FOFIE0] is 1. 0b - No result FIFO 0 overflow has occurred since the last time that the flag was cleared. 1b - At least one result FIFO 0 overflow has occurred since the last time that the flag was cleared.
0 RDY0	Result FIFO 0 Ready Flag Indicates when the number of valid data words in the result FIFO 0 is greater than the watermark set in FCTRL0[FWMARK]. This flag asserts regardless of the value of IE[FWMIE0]. However, an interrupt request or DMA request occurs only when the associated control field (IE[FWMIE0] and DE[FWMDE0]) is 1. This flag is cleared when the FCTRL0[FCOUNT] (which decrements on each read of the RESFIFO register) is less than or equal to the level set in FCTRL0[FWMARK]. 0b - Not above watermark 1b - Above watermark

37.6.6 Interrupt Enable Register (IE)

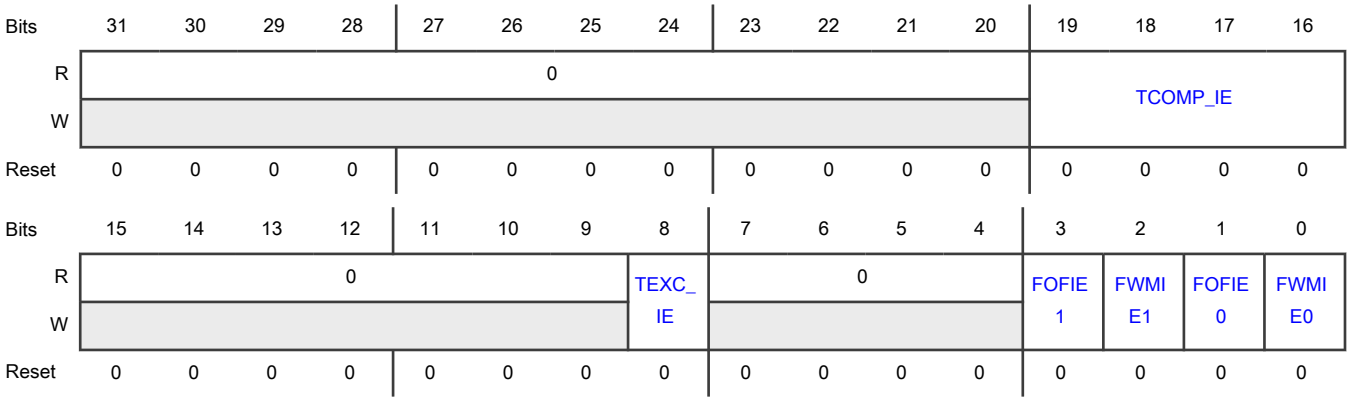
Offset

Register	Offset
IE	18h

Function

Includes system interrupt masking control bits.

Diagram



Fields

Field	Function
31-20 —	Reserved
19-16 TCOMP_IE	Trigger Completion Interrupt Enable Enables generation of interrupt requests to indicate when complete trigger command sequences are executed. Each bit in TCOMP_IE corresponds to a trigger source. (TCOMP_IE[0] corresponds to trigger 0, and so on.) All results are stored in the FIFO when a sequence is considered complete. 0000b - All disabled 0001b - Trigger completion interrupts are enabled for trigger source 0 only. 0010b - Trigger completion interrupts are enabled for trigger source 1 only. 0011b-1110b - Associated trigger completion interrupts are enabled. 1111b - All enabled
15-9 —	Reserved
8 TEXC_IE	Trigger Exception Interrupt Enable Enables ADC to assert an interrupt request when a high-priority trigger exception occurs. TSTAT[TEXC_NUM] contains the value of the corresponding trigger affected by the exception. 0b - Disabled 1b - Enabled
7-4 —	Reserved
3 FOFIE1	Result FIFO1 Overflow Interrupt Enable Enables generation of overflow interrupt requests when FOF1 flag is asserted. 0b - Disabled 1b - Enabled
2 FWMIE1	FIFO1 Watermark Interrupt Enable Enables generation of watermark interrupt requests when STAT[RDY1] flag is asserted. 0b - Disabled 1b - Enabled
1 FOFIE0	Result FIFO 0 Overflow Interrupt Enable Enables generation of overflow interrupt requests when FOF flag is asserted. 0b - Disabled 1b - Enabled

Table continues on the next page...

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Field	Function
0 FWMIE0	FIFO 0 Watermark Interrupt Enable Enables generation of watermark interrupt requests when STAT[RDY0] flag is asserted. 0b - Disabled 1b - Enabled

37.6.7 DMA Enable Register (DE)

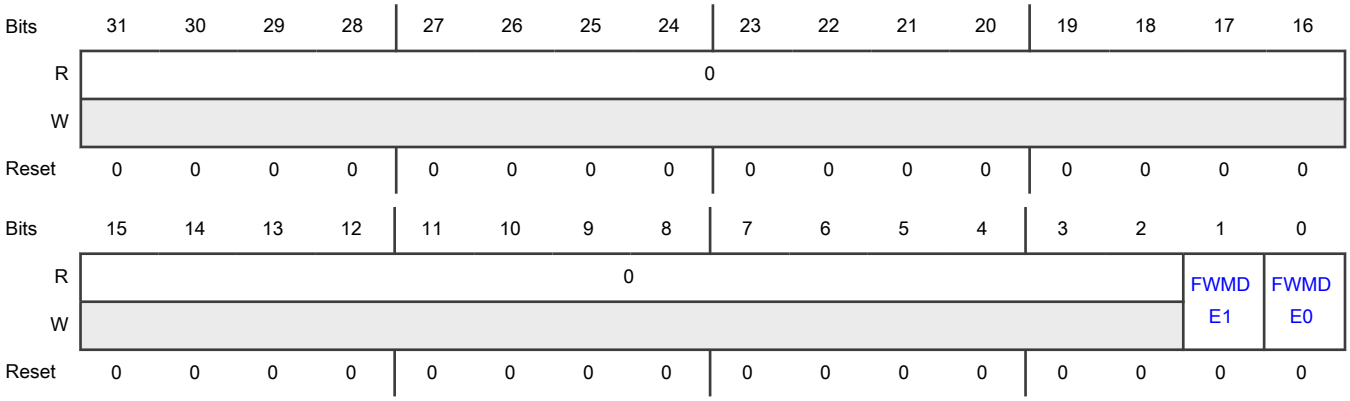
Offset

Register	Offset
DE	1Ch

Function

Includes DMA request-masking control bits.

Diagram



Fields

Field	Function
31-2 —	Reserved
1 FWMDE1	FIFO1 Watermark DMA Enable Enables generation of DMA requests when STAT[RDY1] flag is asserted. 0b - Disabled 1b - Enabled

Table continues on the next page...

Table continued from the previous page...

Field	Function
0 FWMDE0	FIFO 0 Watermark DMA Enable Enables generation of DMA requests when STAT[RDY0] flag is asserted. 0b - Disabled 1b - Enabled

37.6.8 Configuration Register (CFG)

Offset

Register	Offset
CFG	20h

Function

Controls ADC functions common to all commands. When CTRL[ADCEN] = 1, this register cannot be changed and writes to this register are ignored.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	0	0	PWREN	0				PUDLY							
W																
Reset	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0				HPT_EXDI	TCMDRES	TRES	REFSEL		PWRSEL		0		TPRICTRL	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 —	Reserved
30 —	Reserved
29	Reserved

Table continues on the next page...

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Field	Function
—	
28 PWREN	ADC Analog Pre-Enable Enables the ADC analog circuits. When setting this field, user code should delay for a period exceeding the analog startup time of $t_{ADCSTUP}$ before enabling ADC for operation. The module is still operational even when this field is 0, but command execution start is delayed for a period defined by CFG[PUDLY]. See the device data sheet for ADC idle and active power consumption parameters. 0b - ADC analog circuits are only enabled while conversions are active. Analog startup delays affect performance. 1b - ADC analog circuits are pre-enabled and ready to execute conversions without startup delays, at the cost of higher DC current consumption. A single power-up delay (CFG[PUDLY]) is executed immediately once PWREN is set. No detected triggers begin ADC operation until the power-up delay time has passed. After this initial delay expires, the analog circuits remain pre-enabled, and no additional delays are executed.
27-24 —	Reserved
23-16 PUDLY	Power-up Delay Defines the power-up delay executed after an initial trigger wakes ADC from its idle state. Must be programmed to a non-zero value to enable the ADC. Depending on the value of CFG[PWREN], the delay is executed in one of two modes: • When CFG[PWREN] = 0, the ADC analog circuits are only powered on while the module is active. The power-up delay allows time for the analog circuits to stabilize after being powered on. The startup delay count of (PUDLY * 4) ADCK cycles must result in a longer delay than the analog startup time of $t_{ADCSTUP}$. Accuracy of the initial conversions after activation is degraded if CFG[PUDLY] is set to too small a value. After active conversions, if no subsequent conversions are pending, the ADC analog circuits are automatically reverted to their low-power idle state. When ADC is awakened with a later trigger, the power-up delay runs again. • When CFG[PWREN] = 1 prior to ADC activation, the analog circuits are pre-enabled and the activation delay defined by CFG[PUDLY] is executed immediately. After the delay has been executed, the analog circuits remain enabled regardless of ADC activity. This configuration begins conversions immediately after trigger event detection, at the cost of increased DC power consumption in the analog circuits. **NOTE** ADC does not begin an initial conversion until the power-up delay has executed, regardless of the value of CFG[PWREN].
15 —	Reserved
14-11 —	Reserved

Table continues on the next page...

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Field	Function
10 HPT_EXDI	High-Priority Trigger Exception Disable Disables high-priority trigger exceptions. See Trigger detect and command execution for a detailed description on trigger exception handling. When 1, exceptions are disabled and CFG[TCMDRES], CFG[TRES], and CFG[TPRICTRL] are ignored. 0b - Enabled 1b - Disabled
9 TCMDRES	Trigger Command Resume Determines where a trigger sequence resumes when interrupted by a high-priority trigger exception. To use this field, CFG[TRES] must be 1. 0b - Trigger sequence automatically restarted. 1b - Trigger sequence resumed from the command that was executed prior to the exception.
8 TRES	Trigger Resume Enable Determines whether trigger sequences interrupted by a high-priority exception are automatically resumed or restarted. If 1, the sequence can be resumed along command boundaries or restarted from the beginning of a sequence, as determined by CFG[TCMDRES]. If 0, interrupted triggers can be resumed via software by monitoring STAT[TEXC_INT] (or via ISR handling for trigger exception interrupt when IE[TEXC_IE] = 1). Software determines which trigger was interrupted by reading TSTAT[TEXC_NUM] and restarts the trigger by writing 1 to the corresponding field in the SWTRIG register. 0b - Not automatically resumed or restarted 1b - Automatically resumed or restarted
7-6 REFSEL	Voltage Reference Selection Selects the voltage reference high used for conversions. **NOTE** See the chip-specific ADC information for voltage reference options specific to this packaged device. 00b - Option 1 01b - Option 2 10b - Option 3 11b - Reserved
5-4 PWRSEL	Power Configuration Select Configures the module for power and performance. In the highest-power setting, the highest conversion rates are possible. Refer to the device data sheet for power and performance capabilities for each setting.

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Field	Function
	00b - Lowest power 01b - Higher power than 00b 10b - Higher power than 01b 11b - Highest power
3-2 —	Reserved
1-0 TPRICTRL	ADC Trigger Priority Control Controls how higher-priority trigger exceptions are handled when they are received during command processing. See Trigger detect and command execution for a detailed explanation of trigger event handling. 00b - Current conversion is aborted and the new command specified by the trigger is started. 01b - Current command is stopped after completing the current conversion. If averaging is enabled, the averaging loop is completed. CMDHn[LOOP] is ignored and the higher-priority trigger is serviced. 10b - Current command is completed (averaging, looping, compare) before servicing the higher-priority trigger. 11b - Reserved

37.6.9 Pause Register (PAUSE)

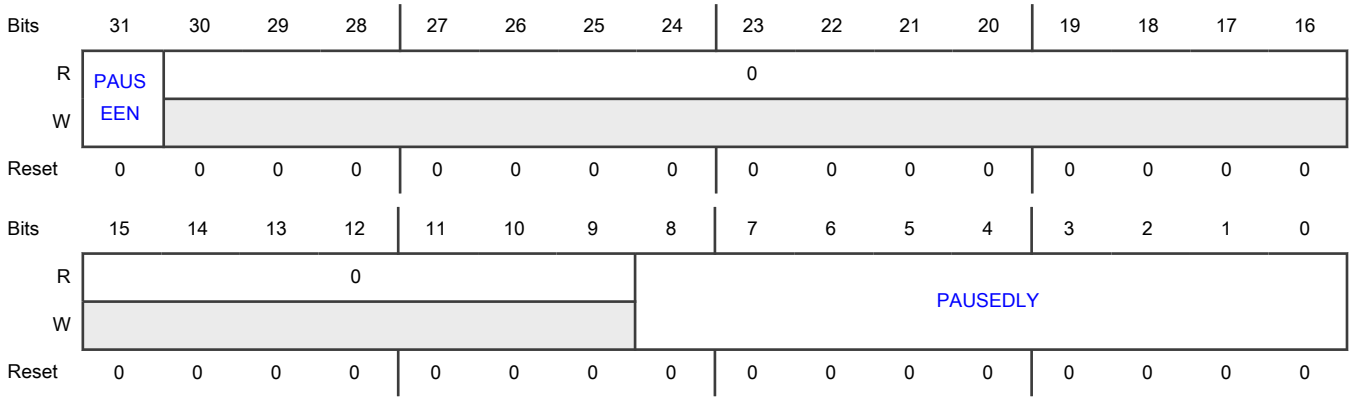
Offset

Register	Offset
PAUSE	24h

Function

Controls the optional inserted delay between conversions. When CTRL[ADCEN] = 1, this register should not be modified.

Diagram



Fields

Field	Function
31 PAUSEEN	Pause Enable Enables the ADC pausing function. When enabled, a programmable delay is inserted during command execution sequencing: • Between LOOP iterations. • Between commands in a sequence. • Between conversions, when a command is executing in compare-until-true configuration. **NOTE** CMDHn[WAIT_TRIG] and PAUSE are mutually exclusive. CMDHn[WAIT_TRIG] takes priority over PAUSE between commands when both are enabled. 0b - Disabled 1b - Enabled
30-9 —	Reserved
8-0 PAUSEDLY	Pause Delay Controls the duration of pauses during command execution sequencing when PAUSE[PAUSEEN] = 1. The pause delay is a count of (PAUSEDLY * 4) ADCK cycles.

37.6.10 Software Trigger Register (SWTRIG)

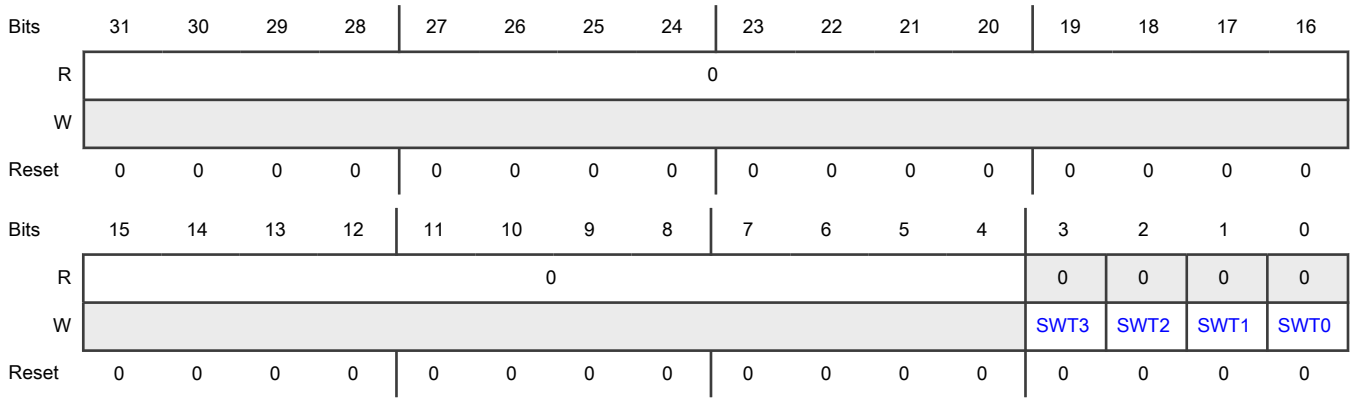
Offset

Register	Offset
SWTRIG	34h

Function

Initiates software-triggered conversions when written to. Writes to this register are ignored while CTRL[ADCEN] = 0. There is an approximately three ADC-clock-cycle synchronization delay between asserting CTRL[ADCEN] and when SWTRIG can be accepted.

Diagram



Fields

Field	Function
31-4 —	Reserved
3 SWT3	Software Trigger 3 Write 1 to SWT3 generates a trigger 3 event. Writing 1 to SWT3 is ignored while the trigger 3 event is being serviced or is pending. 0b - No trigger 3 event generated. 1b - Trigger 3 event generated.
2 SWT2	Software Trigger 2 Write 1 to SWT2 generates a trigger 2 event. Writing 1 to SWT2 is ignored while the trigger 2 event is being serviced or is pending. 0b - No trigger 2 event generated. 1b - Trigger 2 event generated.
1 SWT1	Software Trigger 1 Write 1 to SWT1 generates a trigger 1 event. Writing 1 to SWT1 is ignored while the trigger 1 event is being serviced or is pending. 0b - No trigger 1 event generated. 1b - Trigger 1 event generated.
0 SWT0	Software Trigger 0 Generates a trigger 0 event. Writing 1 to this field is ignored while the trigger 0 event is being serviced or is pending.

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Field	Function
	0b - No trigger 0 event generated. 1b - Trigger 0 event generated.

37.6.11 Trigger Status Register (TSTAT)

Offset

Register	Offset
TSTAT	38h

Function

Contains status flags to indicate when trigger sequences have been completed or interrupted by a high-priority trigger exception. Each field in this register is set by hardware and cleared by software.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0												TCOMP_FLAG			
W													W1C			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												TEXC_NUM			
W													W1C			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-20 —	Reserved
19-16 TCOMP_FLAG	Trigger Completion Flag Indicates which triggers have been completed. Each bit in this field corresponds to a trigger. When a trigger sequence has completed, the corresponding bit in TCOMP_FLAG is set. For example, if trigger 3 has been completed, then bit 19 is set in the TSTAT register. This register is active only if the corresponding bit in IE[TCOMP_IE] = 1.

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Field	Function
	NOTE A synchronization delay may be added to the end of the final conversion in a sequence, prior to this flag being set. This delay can range from two to four ADC CLK cycles. 0000b - No triggers have been completed. Trigger completion interrupts are disabled. 0001b - Trigger 0 has been completed and trigger 0 has enabled completion interrupts. 0010b - Trigger 1 has been completed and trigger 1 has enabled completion interrupts. 0011b-1110b - Associated trigger sequence has completed and has enabled completion interrupts. 1111b - Every trigger sequence has been completed and every trigger has enabled completion interrupts.
15-4 —	Reserved
3-0 TEXC_NUM	Trigger Exception Number Indicates which triggers have been interrupted by exceptions. Each bit in this field corresponds to a trigger. When the corresponding trigger sequence is interrupted by a high-priority trigger exception, the corresponding bit is set. For example, if trigger 3 has been interrupted, then bit 3 is set in this register. This register is active regardless of the value in IE[TEXC_IE]. 0000b - No triggers have been interrupted by a high-priority exception. Or CFG[TRES] = 1. 0001b - Trigger 0 has been interrupted by a high-priority exception. 0010b - Trigger 1 has been interrupted by a high-priority exception. 0011b-1110b - Associated trigger sequence has interrupted by a high-priority exception. 1111b - Every trigger sequence has been interrupted by a high-priority exception.

37.6.12 Offset Trim Register (OFSTRIM)

Offset

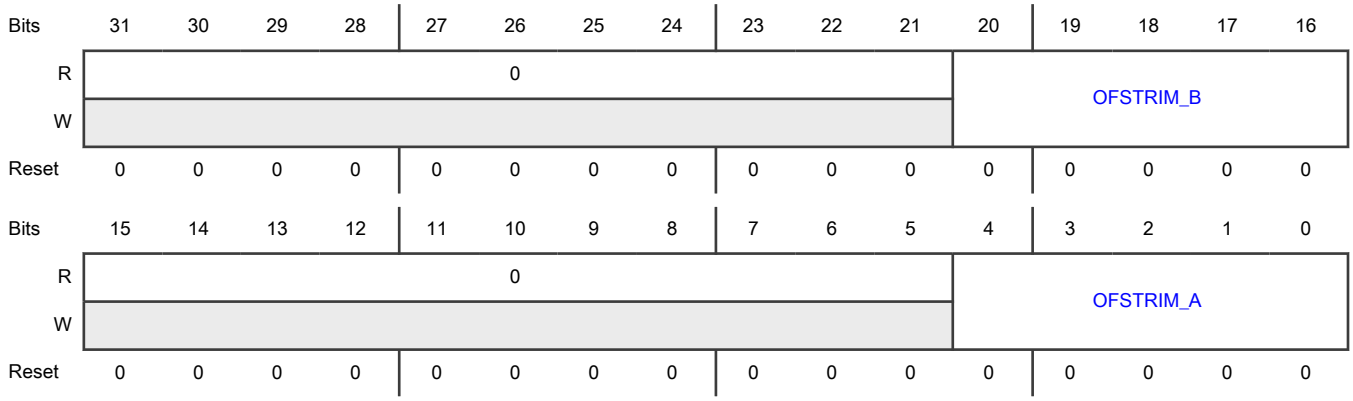
Register	Offset
OFSTRIM	40h

Function

Used to trim for offset. ADC supports a calibration step in which the ADC determines the value needed in the OFSTRIM register.

To determine the value to put in the OFSTRIM register, write 1 to CTRL[CALOFS]. This setting automatically begins a sequence to calculate this value. Once the sequence has completed, the OFSTRIM register is updated with a signed value between -16 and 15. This value is used to minimize offset during normal operation.

Diagram



Fields

Field	Function
31-21 —	Reserved
20-16 OFSTRIM_B	Trim for Offset OFSTRIM is a 5-bit signed value between -16 and 15. This value applies to the ADC B-side conversion results.
15-5 —	Reserved
4-0 OFSTRIM_A	Trim for Offset OFSTRIM_A is a 5-bit signed value between -16 and 15. This value applies to the ADC A-side conversion results.

37.6.13 Trigger Control Register (TCTRL0 - TCTRL3)

Offset

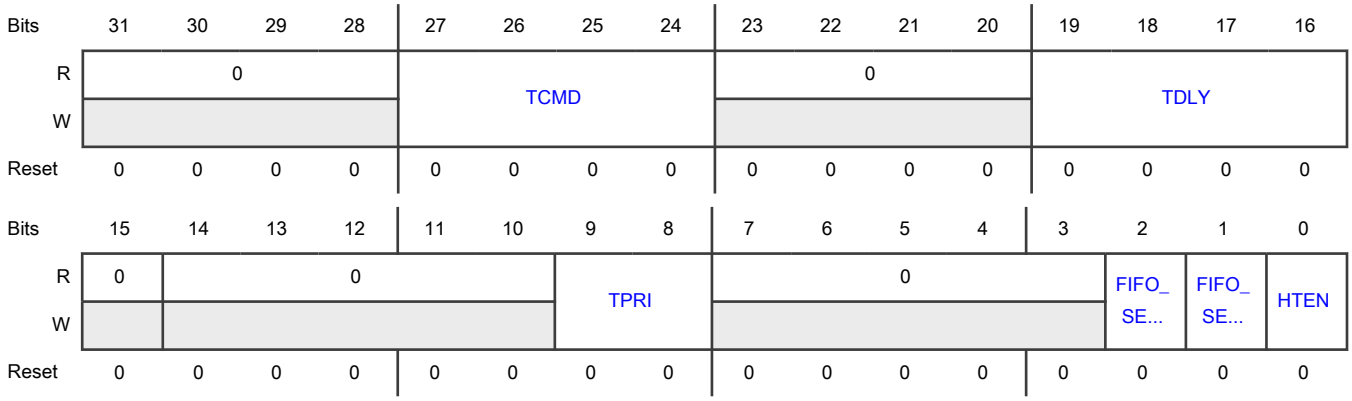
Register	Offset
TCTRL0	A0h
TCTRL1	A4h
TCTRL2	A8h
TCTRL3	ACh

Function

Implements control fields associated with each trigger source. When ADC is executing commands, only one TCTRLn register controls ADC conversions.

Do not update the controlling TCTRLn register while ADC is active. Writing to a TCTRLn register while that trigger control register controls the ADC operation may cause unpredictable behavior.

Diagram



Fields

Field	Function
31-28 —	Reserved
27-24 TCMD	Trigger Command Select Selects the command from the command buffer to execute upon detection of the associated trigger event. When a higher-priority trigger is received while ADC is converting, the command in this register associated with the new trigger is executed. This execution is done under the control of CFG[TPRICTRL]. See Trigger detect and command execution for details about the relationship between CFG[TPRICTRL] and TCMD. 0000b - Not a valid selection from the command buffer. Trigger event is ignored. 0001b - CMD1 0010b-1110b - Corresponding CMD is executed 1111b - CMD15
23-20 —	Reserved
19-16 TDLY	Trigger Delay Select Selects the trigger delay duration for the start of servicing a trigger event. Each trigger source has an associated programmable delay prior to beginning an initial conversion. When this field is 0, no delay is incurred. When this field is set to a non-zero value, the duration of the delay is 2^{TDLY} ADCK cycles.
15 —	Reserved
14-10 —	Reserved
9-8	Trigger Priority Setting

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Field	Function
TPRI	Specifies the priority of the associated trigger source. When determining ADC trigger aborts based on higher priority trigger interrupt, ADC hardware only considers if the new trigger TCTRLn[TPRI] is programmed with a lower value than the running trigger. If both triggers are programmed with the same priority no abort occurs. ADC determines the next active trigger number/order when detecting two or more triggers with the same TCTRLn[TPRI] value. In such case, the system processes the trigger with the lower order first. 00b - Highest priority, Level 1 01b-10b - Set to corresponding priority level. 11b - Lowest priority, Level 4
7-3 —	Reserved
2 FIFO_SEL_B	SAR Result Destination for Channel B Indicates the FIFO to which SAR results are written for Channel B. This field is only used in dual single-ended mode (CMDLn[CTYPE] = 11b). In this mode, the SAR result from Channel B is written to the FIFO number specified by this field. See Sampling Modes for more information. 0b - FIFO 0 1b - FIFO 1
1 FIFO_SEL_A	SAR Result Destination for Channel A Indicates the FIFO to which SAR results are written for Channel A. This field provides the destination for all single-ended and differential conversions and for all A-side conversions in dual single-ended mode. Conversion results are stored in the FIFO number specified, under the following conditions: • Single-ended mode: CMDLn[CTYPE] = 00b or CMDLn[CTYPE] = 01b. • Differential mode: CMDLn[CTYPE] = 10b. • Dual single-ended mode: CMDLn[CTYPE] = 11b. 0b - FIFO 0 1b - FIFO 1
0 HTEN	Trigger Enable Enables hardware trigger source to initiate conversion on the rising edge of the input trigger source. **NOTE** Enabling the hardware trigger does not disable software triggers. 0b - Disabled 1b - Enabled

37.6.14 FIFO Control Register (FCTRL0 - FCTRL1)

Offset

Register	Offset
FCTRL0	E0h
FCTRL1	E4h

Function

Contains control and status fields for each FIFO in the design. A programmable watermark can be set for each FIFO, which can be used to trigger an interrupt. In addition, the number of entries stored in each FIFO can be monitored by reading FCTRLn[FCOUNT].

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0												FWMARK			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												FCOUNT			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-20 —	Reserved
19-16 FWMARK	Watermark Level Selection Selects the storage threshold for the ADC Result FIFO. When the number of data words stored in the FIFO is greater than this value, the STAT[RDY0] flag is asserted. When IE[FWMIEn] = 1, an interrupt request is generated. When DE[FWMDEn] = 1, a DMA request is generated.
15-5 —	Reserved
4-0 FCOUNT	Result FIFO Counter Indicates the number of data words stored in the result FIFO. This value may be used with PARAM[FIFOSIZE] to calculate how much room is left in the result FIFO. This field is incremented with each storage of new data into the result FIFO and decrements with each read of the result FIFO. The FIFO is reset by writing to CTRL[RSTFIFOn], which initializes FCTRLn[FCOUNT] to 0h.

37.6.15 Gain Calibration Control (GCC0 - GCC1)

Offset

Register	Offset
GCC0	F0h
GCC1	F4h

Function

Holds intermediate values used as part of the calibration steps. GCC0 is associated with the A-side converter and GCC1 is associated with the B-side converter. GCCn[GAIN_CAL] is calculated with hardware and automatically updated during the calibration steps. Once the hardware calibration sequence has updated, GCCn[RDY] is asserted automatically.

Requesting a calibration routine automatically clears the GCCn[RDY] flag until the new GCCn[GAIN_CAL] value is calculated. To complete calibration, further software processing is needed, where GCCn[GAIN_CAL] is used to calculate the gain adjustment. The result is stored to GCRn[GCALR]. See Calibration functions.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0							RDY	0							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	GAIN_CAL															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-25 —	Reserved
24 RDY	Gain Calibration Value Valid Indicates whether the data stored in GCCn[GAIN_CAL] is valid and should be used to derive GCRn[GCALR]. If the data in GCCn[GAIN_CAL] is invalid, you can run the hardware calibration routine to correct this issue. 0b - Invalid 1b - Valid
23-16	Reserved

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Field	Function
—	
15-0 GAIN_CAL	Gain Calibration Value Indicates the calculated value of the gain calibration. As part of the hardware calibration steps, this field is automatically updated with a 16-bit unsigned number. It is used in the gain adjustment calculations to derive the value written to GCRn[GCALR]. See Calibration functions.

37.6.16 Gain Calculation Result (GCR0 - GCR1)

Offset

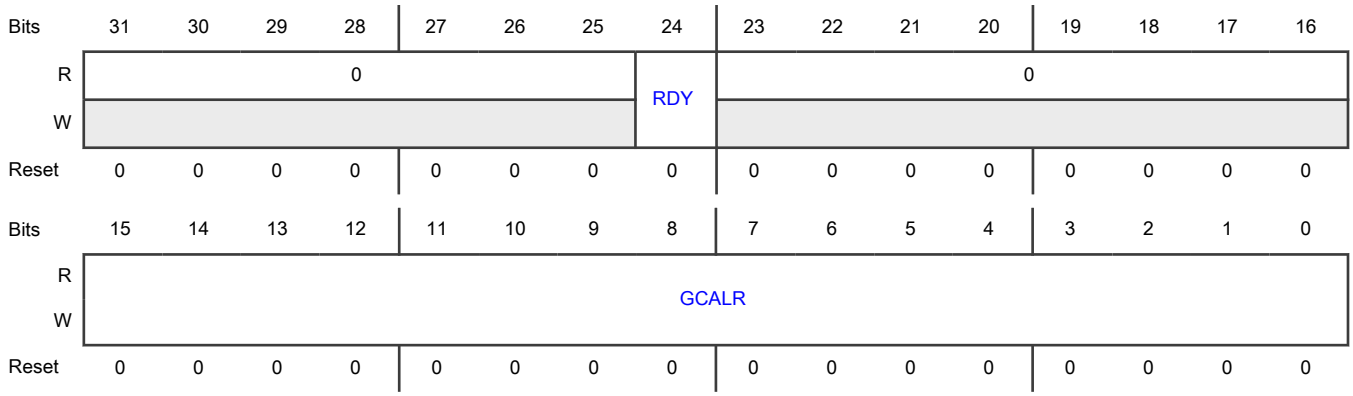
Register	Offset
GCR0	F8h
GCR1	FCh

Function

Used during ADC conversions for automated gain error adjustment. GCR0 is associated with the A-side converter and GCR1 is associated with the B-side converter. Determining the values to store to GCR0[GCALR] and GCR1[GCALR] is the result of software calculations described in setup steps in Calibration functions. Upon writing the GCRn[GCALR] value, the user should also write 1 to GCRn[RDY] to indicate that the gain adjustment result is valid.

A calibration sequence begins by writing 1 to CTRL[CAL_REQ], and the calibration sequence is not complete until GCRn[GCALR] is calculated and GCRn[RDY] is 1. The gain adjustment calculation produces a floating-point value between 1 and 2. GCRn[GCALR] holds the 16-bit fractional component of the gain adjustment calculation. To convert the GCRn[GCALR] value to the gain adjustment value in decimal format, use this formula: 1 + 0.5 * GCRn[15] + 0.25 * GCRn[14] + 0.125 * GCRn[13] + (and so on)

Diagram



Fields

Field	Function
31-25 —	Reserved
24 RDY	Gain Calculation Ready Indicates whether the data stored in GCRn[GCALR] is valid and is used for gain adjustment. GCRn[GCALR] must be written from memory or calculated each time the calibration routine is run. The user must write 1 to this GCRn[RDY] after writing valid data to GCRn[GCALR]. This field becomes 0 automatically when requesting a new calibration sequence. 0b - Invalid 1b - Valid
23-16 —	Reserved
15-0 GCALR	Gain Calculation Result Holds the 16-bit fractional component generated from the gain adjustment calculation during the auto-calibration routine.

37.6.17 Command Low Buffer Register (CMDL1 - CMDL15)

Offset

For a = 1 to 15:

Register	Offset
CMDLa	F8h + (a × 8h)

Function

Controls channel selection and conversion options. There are 15 command buffers (CMDn), each constructed from two 32-bit registers (CMDHn:CMDLn) that can be configured for different channel selection and varying conversion options. Any command buffer is selected and used as the controlling command by association with a trigger event via configuration of TCTRLn[TCMD]. When ADC is executing commands, only one of the CMD buffers controls ADC conversions. Do not update the controlling CMD buffer while ADC is active. A write to a CMD buffer while that CMD buffer controls the ADC operation may cause unpredictable behavior.

NOTE

The 15 command buffers are numbered [CMDH1:CMDL1] through [CMDH15:CMDL15]. In NXP-supplied header files, these buffers are likely to be defined as two 15-element arrays that are indexed from 0. For example, the type declaration would be:

```
unsigned int CMDH[15];
unsigned int CMDL[15];
```

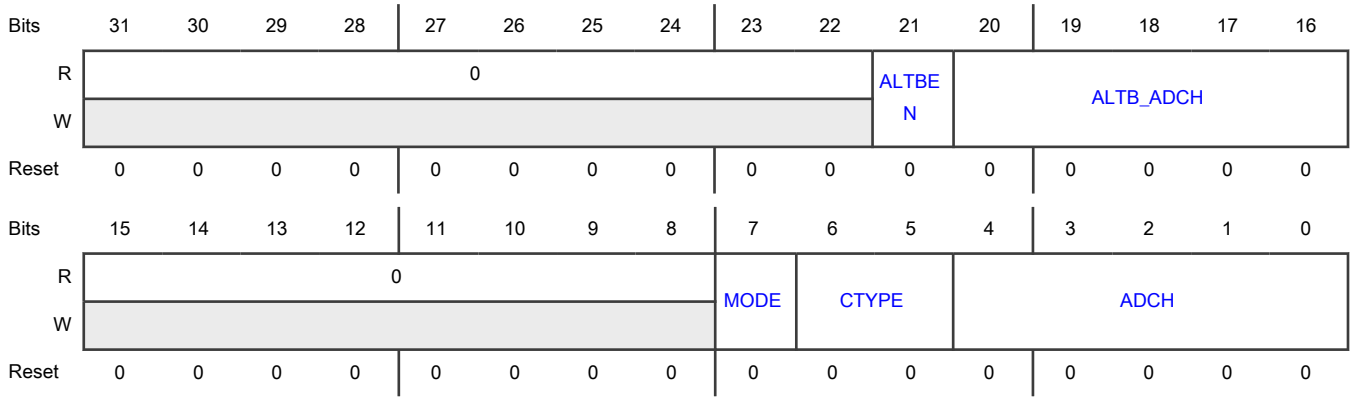
and software would access ADC0 CMDH1 as `ADC0->CMDH[0]` and ADC0 CMDL15 as `ADC0->CMDL[14]`.

The CMDLn[ADCH] and CMDLn[CTYPE] fields control selection of paired or individual input channels. Each ADC command independently makes a channel and conversion type selection. Each ADCH channel selection has an associated A-side and B-side input. Each ADCH pair can be converted in differential mode, but only limited pairs should be converted as differential channels (for example, adjacent pins designed with matched impedance). For the pin pairings available for differential conversions for your device, see the Chip Configuration details.

NOTE

Some input channels are from on-chip sources such as temperature sensors and reference voltage sources and may only be connected to individual instances of ADC. Some input channel options in the field descriptions may not be available for your device. See the chip-specific information for the channels supported on this device.

Diagram



Fields

Field	Function
31-22 —	Reserved
21 ALTBEN	Alternate Channel B Select Enable Enables the ALTB_ADCH to select the input for Channel B independent of ADCH register settings when CTYPE is configured to 01b or 11b. **NOTE** Setting CTYPE to differential (10b) still works but is not recommended. 0b - ALTBEN_ADCH disabled. Channel-A and Channel-B inputs are selected based on ADCH settings. 1b - ALTBEN_ADCH enabled. Channel-A inputs are selected by ADCH setting and Channel-B inputs are selected by ALTB_ADCH setting.
20-16 ALTB_ADCH	Alternate Channel B Input Channel Select When ALTBEN is set, ALTB_ADCH selects the Channel B input when CTYPE is configured to 01b or 11b.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	NOTE Some input channels are from internal resources such as temperature sensors and band gap voltage sources and may only be connected to individual instances of ADC. Some input channel options in field descriptions might not be available for your device. See the chip-specific information for the ADC channel assignments for your device. 0_0000b - Select CH0B 0_0001b - Select CH1B 0_0010b - Select CH2B 0_0011b - Select CH3B 0_0100b-1_1101b - Select corresponding channel CHnB 1_1110b - Select CH30B 1_1111b - Select CH31B
15-8 —	Reserved
7 MODE	Select Resolution of Conversions Selects the ADC resolution. 0b - Standard resolution. Single-ended 12-bit conversion; differential 13-bit conversion with 2's complement output. 1b - High resolution. Single-ended 16-bit conversion; differential 16-bit conversion with 2's complement output.
6-5 CTYPE	Conversion Type Chooses how a pair of A and B channels are converted. 00b - Single-Ended mode. Only A-side channel is converted. 01b - Single-Ended mode. Only B-side channel is converted. 10b - Differential mode. A-B. 11b - Dual-Single-Ended mode. Both A-side and B-side channels are converted independently.
4-0 ADCH	Input Channel Select Selects the input from one of the channel inputs or one of the input pairs, with CMDLn[CTYPE]. Each ADCH channel selection has an associated A-side and B-side input. **NOTE** Not all pairs should be converted as differential channels. See the chip-specific information for the pin pairings available for differential conversions for your device.

Table continues on the next page...

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Field	Function
	NOTE Some input channels are from internal resources such as temperature sensors and band gap voltage sources and may only be connected to individual instances of ADC. Some input channel options in field descriptions might not be available for your device. See the chip-specific information for the ADC channel assignments for your device. 0_0000b - CH0A or CH0B or CH0A/CH0B pair. 0_0001b - CH1A or CH1B or CH1A/CH1B pair. 0_0010b - CH2A or CH2B or CH2A/CH2B pair. 0_0011b - CH3A or CH3B or CH3A/CH3B pair. 0_0100b-1_1101b - Select corresponding channel CHnA or CHnB or CHnA/CHnB pair. 1_1110b - CH30A or CH30B or CH30A/CH30B pair. 1_1111b - CH31A or CH31B or CH31A/CH31B pair.

37.6.18 Command High Buffer Register (CMDH1 - CMDH15)

Offset

For a = 1 to 15:

Register	Offset
CMDHa	FCh + (a × 8h)

Function

Controls channel selection and conversion options. There are 15 command buffers (CMDn), each constructed from two 32-bit registers (CMDHn:CMDLn) that can be configured for different channel selection and conversion options. Any command buffer is selected and used as the controlling command by association with a trigger event via configuration of TCTRLn[TCMD]. When ADC is executing commands, only one of the CMD buffers controls ADC conversions. Do not update the controlling CMD buffer while ADC is active. A write to a CMD buffer while that CMD buffer controls the ADC operation may cause unpredictable behavior.

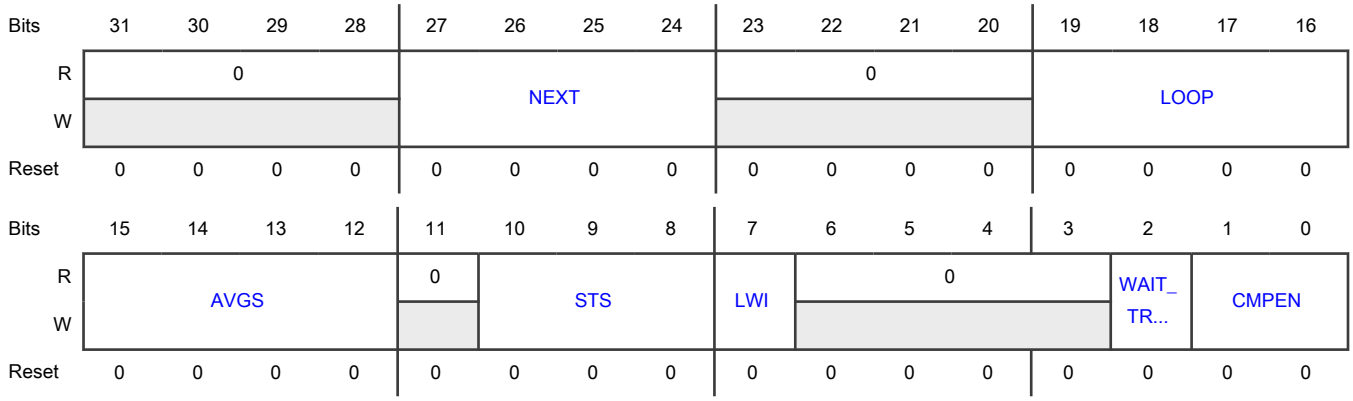
NOTE

The 15 command buffers are numbered [CMDH1:CMDL1] through [CMDH15:CMDL15]. In NXP-supplied header files, these buffers are likely to be defined as two 15-element arrays that are indexed from 0. For example, the type declaration would be:

```
unsigned int CMDH[15];
unsigned int CMDL[15];
```

and software would access ADC0 CMDH1 as `ADC0->CMDH[0]` and ADC0 CMDL15 as `ADC0->CMDL[14]`.

Diagram



Fields

Field	Function
31-28 —	Reserved
27-24 NEXT	Next Command Select Selects the next command to be executed after this command completes. Multiple commands can be configured in a scan configuration by linking the next command in a daisy-chain sequence. The command buffer number is not indicative of any particular order. The order of execution is strictly controlled by this field. For example, a sequence of commands could be CMD2 to CMD1 to CMD3. Unending circular command execution can be configured by setting the NEXT field in the last command in a sequence to the first command in the sequence. It is also allowed for a command to set the next command to itself, resulting in a continuous conversion configuration. Setting the next command to 0h causes conversions to terminate at the completion of the command. Lower-priority trigger events cannot be serviced until a higher-priority triggered command (or sequence of commands) completes. 0000b - No next command defined. Terminate conversions at completion of current command. If lower priority trigger pending, begin command associated with lower priority trigger. 0001b - CMD1 0010b-1110b - Select corresponding CMD command buffer register as next command 1111b - CMD15
23-20 —	Reserved
19-16 LOOP	Loop Count Select Selects the number of times that this command executes (and stores conversion result to RESFIFO) before finishing and transitioning to the next command or idle state. CMDHn[LWI] controls whether a single channel is converted on each iteration or an automatic channel increment results in channel scanning functionality. 0000b - Looping not enabled. Command executes one time. 0001b - Loop one time. Command executes two times.

Table continues on the next page...

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Field	Function
	0010b - Loop two times. Command executes three times. 0011b-1110b - Loop corresponding number of times. Command executes LOOP + 1 times. 1111b - Loop 15 times. Command executes 16 times.
15-12 AVGS	Hardware Average Select Selects how many ADC conversions are averaged to create the ADC result (2^{AVGS}). An internal storage buffer captures temporary results while the averaging iterations are executed. Hardware averaging is a nested loop control and does not extend across LOOP boundaries. See Functional description for usage of AVGS, LOOP, and NEXT fields in command execution sequencing. 0000b - Single conversion 0001b - 2 0010b - 4 0011b - 8 0100b - 16 0101b - 32 0110b - 64 0111b - 128 1000b - 256 1001b - 512 1010b - 1024
11 —	Reserved
10-8 STS	Sample Time Select Selects the total sampling time. When this field contains a non-zero value, the sample time is ($3.5 + 2^{STS}$) ADCK cycles. The shortest sample time maximizes conversion speed for lower-impedance inputs. Extending sample time allows higher-impedance inputs to be sampled accurately. Longer sample times can lower overall power consumption when command looping and sequencing are configured and high conversion rates are not required. 000b - Minimum sample time of 3.5 ADCK cycles. 001b - 5.5 ADCK cycles. ($3.5 + 2^1$ ADCK cycles) 010b - 7.5 ADCK cycles. ($3.5 + 2^2$ ADCK cycles) 011b - 11.5 ADCK cycles. ($3.5 + {}^3$ ADCK cycles) 100b - 19.5 ADCK cycles. ($3.5 + 2^4$ ADCK cycles) 101b - 35.5 ADCK cycles. ($3.5 + 2^5$ ADCK cycles) 110b - 67.5 ADCK cycles. ($3.5 + 2^6$ ADCK cycles) 111b - 131.5 ADCK cycles. ($3.5 + 2^7$ ADCK cycles)

Table continues on the next page...

Table continued from the previous page...

Field	Function
7 LWI	Loop with Increment Enables automatic channel incrementing. When 0, the LOOP field selects the number of times the selected channel is converted consecutively. When 1, automatic channel incrementing is enabled and the LOOP field defines how many consecutive channels are converted as part of the command execution. Example 1: LOOP = 8h, LWI = 0b, CMDLn[CTYPE] = 0h, CMDLn[ADCH] = Dh. Convert on channel 13A 9 times. Example 2: LOOP = 8h, LWI = 1b, CMDLn[CTYPE] = 0h, CMDLn[ADCH] = Dh. Run channels 13A-21A each one time. Maximum channel scanning using a single command buffer is defined by the maximum value of the LOOP field (16). 0b - Disabled 1b - Enabled
6-3 —	Reserved
2 WAIT_TRIG	Wait for Trigger Assertion Before Execution Selects whether commands execute automatically or a trigger must be received before execution. When 0, wait states are added before the command until the active trigger is asserted again. When WAIT_TRIG = 0, each command is automatically executed when called. 0b - Command executes automatically. 1b - Active trigger must be asserted again before executing this command.
1-0 CMPEN	Compare Function Enable Enables the automatic compare function. Selects whether to store only when the comparison operation is true, following ADC channel input sampling, conversion, and averaging. When the compare function is enabled, the conversion result is compared to the compare value registers (CVn[CVH] and CVn[CVL]). See Compare Function for details about the options for command sequencing related to the compare function. 00b - Disabled 01b - Reserved 10b - Enabled. Store on true. 11b - Enabled. Repeat channel acquisition (sample, convert, and compare) until true.

37.6.19 Compare Value Register (CV1 - CV15)

Offset

For a = 1 to 15:

Register	Offset
CVa	1FCh + (a × 4h)

Function

Contains values used to compare the conversion result when the compare function is enabled. This register is formatted like the D field in Data Result FIFO Register (RESFIFO0 - RESFIFO1), which has in different definitions for bit position and value format in different modes. There is a direct association of each compare value register to a specific command buffer register. For example, CV1 is only used during execution of CMD1 command.

When ADC is executing commands, do not update the CVn register associated with the active command (CMDn). Writes to associated CVn register during this time may result in unpredictable behavior.

NOTE

The 15 compare value registers are numbered [CV1] through [CV15]. In NXP-supplied header files, these registers are likely to be defined as a 15-element array indexed from 0. For example, the type declaration would be:

```
unsigned int CV[15];
```

and software would access ADC0 CV1 as `ADC0->CV[0]` and ADC0 CV15 as `ADC0->CV[14]`.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	CVH															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	CVL															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-16 CVH	Compare Value High Determines the high compare value. The compare function can be configured to check whether the result: • Is less than comparison values • Is greater than comparison values • Falls within a range of two comparison values • Falls outside a range of two comparison values. After the input is sampled and converted and any averaging iterations are performed, CVL and CVH can be used in a compare operation on the result. See Compare Function for a description of CVH usage.
15-0 CVL	Compare Value Low Determines the low compare value. The compare function can be configured to check whether the result:

Table continues on the next page...

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Field	Function
	• Is less than comparison values • Is greater than comparison values • Falls within a range of two comparison values • Falls outside a range of two comparison values. After the input is sampled and converted and any averaging iterations are performed, CVL and CVH can be used in a compare operation on the result. See Compare Function for a description of CVL usage.

37.6.20 Data Result FIFO Register (RESFIFO0 - RESFIFO1)

Offset

Register	Offset
RESFIFO0	300h
RESFIFO1	304h

Function

Stores the data result of ADC conversions in a 16-entry FIFO. Several tag fields of source command and trigger information are stored with the data. FCTRLn[FCOUNT] indicates how many valid data words are stored in the RESFIFO. Reading RESFIFO provides the oldest unread data word entry in the FIFO and decrements FCTRLn[FCOUNT]. The FIFO can be emptied by successive reads of RESFIFO. The FIFO is reset by writing 0b1 to CTRL[RSTFIFOn].

The following table describes the format of data in the result FIFO in different modes of operation. The sign bit is the MSB in signed 2's complement modes. For example, when configured for 12-bit single-ended mode, D[15] and D[2:0] become 0. When configured for 13-bit differential mode, D[15] is the sign bit, and D[2:0] becomes 0.

Table 271. Data result register format description

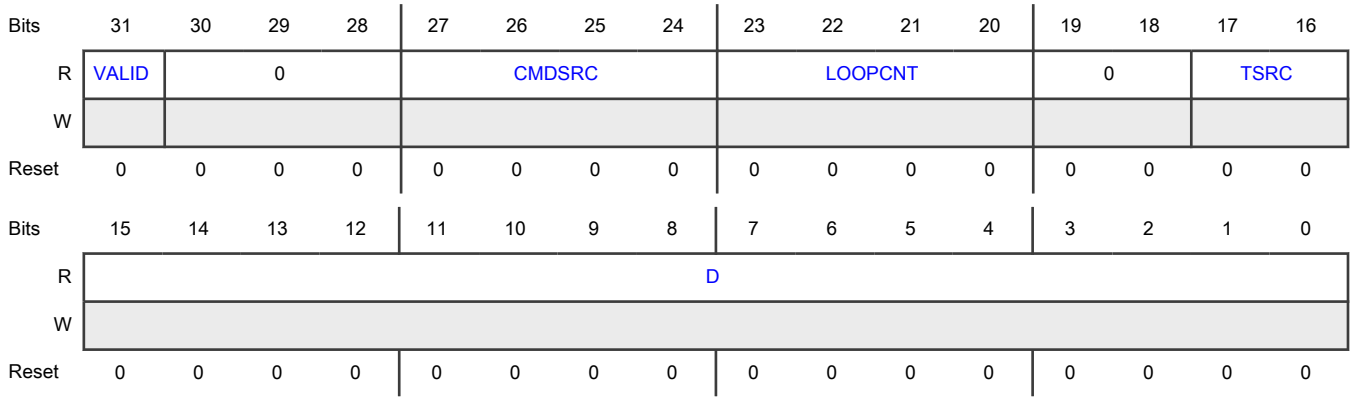
Conversion mode	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	Format
16-bit differential	S	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	Signed 2's complement
16-bit single-ended	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	Unsigned, 16-bit magnitude
13-bit differential	S	D	D	D	D	D	D	D	D	D	D	D	D	0	0	0	Signed 2's complement, left justified, zero extended
12-bit single-ended	0	D	D	D	D	D	D	D	D	D	D	D	D	0	0	0	Unsigned, zero in D[15] and D[2:0]

NOTE

S: Sign bit;

D: Data, 2's complement data when indicated

Diagram



Fields

Field	Function
31 VALID	FIFO Entry is Valid Indicates whether the FIFO entry is valid, which determines what happens to reads from RESFIFO. 0b - FIFO is empty. Discard any read from RESFIFO. 1b - FIFO contains data. FIFO record read from RESFIFO is valid.
30-28 —	Reserved
27-24 CMDSRC	Command Buffer Source Indicates the executed command buffer that generated this result. 0000b - Not a valid value CMDSRC value for a data word in RESFIFO. 0h is only found in the initial FIFO state, prior to the storage of an ADC conversion result into a RESFIFO buffer. 0001b - CMD1 0010b-1110b - Corresponding command buffer used as control settings for this conversion. 1111b - CMD15
23-20 LOOPCNT	Loop Count Value Indicates the loop count value during the command that generated this result. When CMDHn[LOOP] is non-zero, results are stored multiple times during command execution at the loop boundary. 0000b - Result is from initial conversion in command. 0001b - Result is from second conversion in command. 0010b-1110b - Result is from (LOOPCNT + 1) conversion in command. 1111b - Result is from 16th conversion in command.
19-18 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
17-16 TSRC	Trigger Source Indicates the trigger source that initiated a conversion and generated this result. When multiple commands are chained together using CMDHn[NEXT], this field indicates the trigger source that started the command sequence. 00b - Trigger source 0 01b - Trigger source 1 10b - Trigger source 2 11b - Trigger source 3
15-0 D	Data Result Contains the result of an ADC conversion. The formatting for the data in D is summarized in Table 271.

37.6.21 Calibration General A-Side Registers (CAL_GAR0)

Offset

Register	Offset
CAL_GAR0	400h

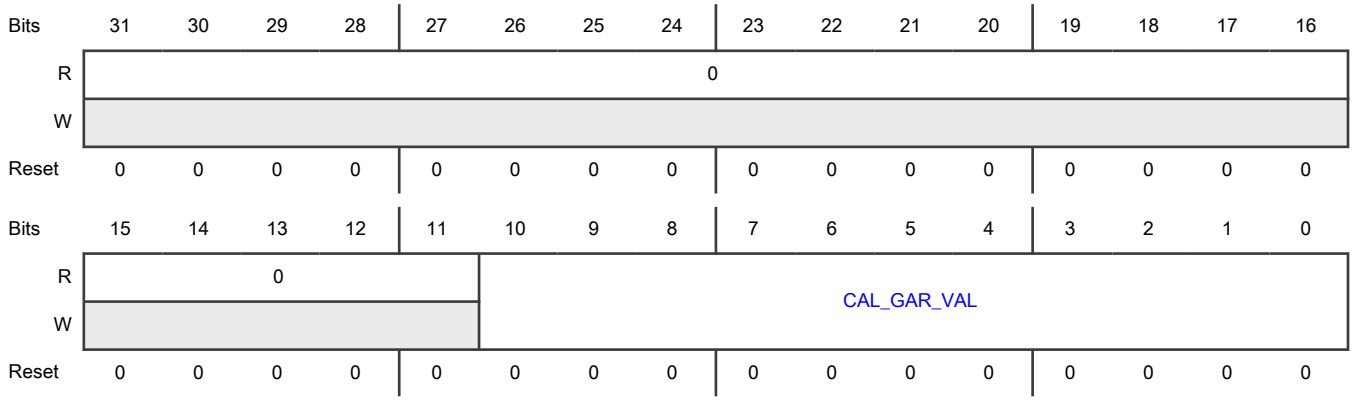
Function

Corrects for linearity errors of the A-side converter. All 33 A-side general calibration value registers (CAL_GAR0-CAL_GAR32) contain calibration information that is automatically updated during the self-calibration sequence. See Calibration functions for more information on completing ADC calibration steps.

The calibration values in the CAL_GAR registers affect the conversion result by conditionally being subtracted from the conversion before the result is transferred into the FIFOs. Calibration must be run each time ADC is powered down or a hard reset is issued. To reduce the latency required to run calibration, the CAL_GAR values can be stored in non-volatile memory after an initial calibration. These values can be recovered prior to the first ADC conversion. If these registers are set to values not generated by the calibration function, the linearity error specifications may not be met.

The CAL_GAR registers are only read-and-write accessible when ADC is disabled with CTRL[ADCEN] = 0. Access time when writing to these registers is larger than three ADC clock cycles. Wait states are inserted on the bus to meet synchronization timing to the associated CAL_GAR register. The width of each register in this array is non-uniform. The exact width of each register is summarized in Calibration General A-Side and B-Side Widths.

Diagram



Fields

Field	Function
31-11 —	Reserved
10-0 CAL_GAR_VAL	Calibration General A Side Register Element

37.6.22 Calibration General A-Side Registers (CAL_GAR1)

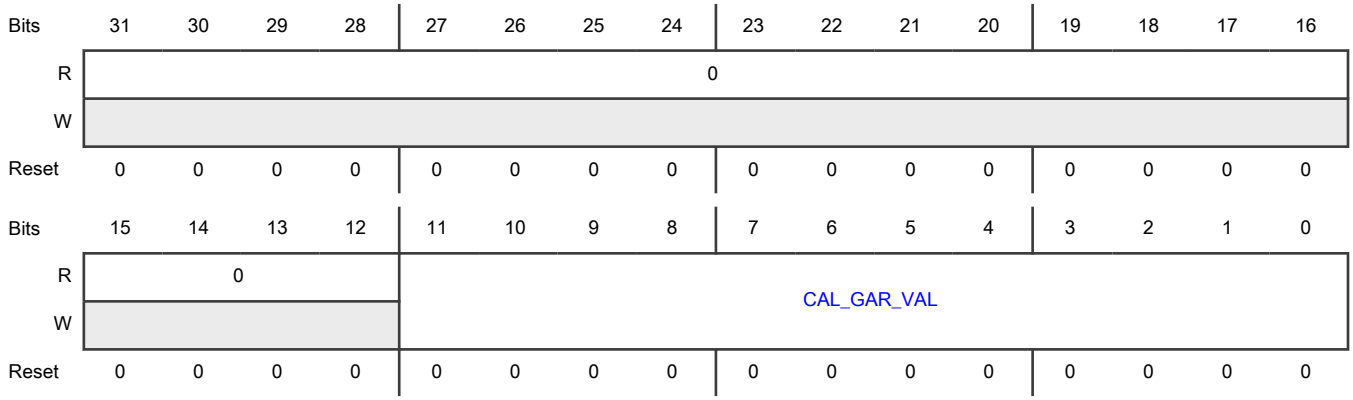
Offset

Register	Offset
CAL_GAR1	404h

Function

Calibration register CAL_GAR1. For more detail, see Calibration General A-Side Registers (CAL_GAR0).

Diagram



Fields

Field	Function
31-12 —	Reserved
11-0 CAL_GAR_VAL	Calibration General A Side Register Element

37.6.23 Calibration General A-Side Registers (CAL_GAR2 - CAL_GAR3)

Offset

Register	Offset
CAL_GAR2	408h
CAL_GAR3	40Ch

Function

Calibration registers CAL_GAR2 and CAL_GAR3. For more detail, see Calibration General A-Side Registers (CAL_GAR0).

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				CAL_GAR_VAL											
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-13 —	Reserved
12-0 CAL_GAR_VAL	Calibration General A Side Register Element

37.6.24 Calibration General A-Side Registers (CAL_GAR4 - CAL_GAR7)

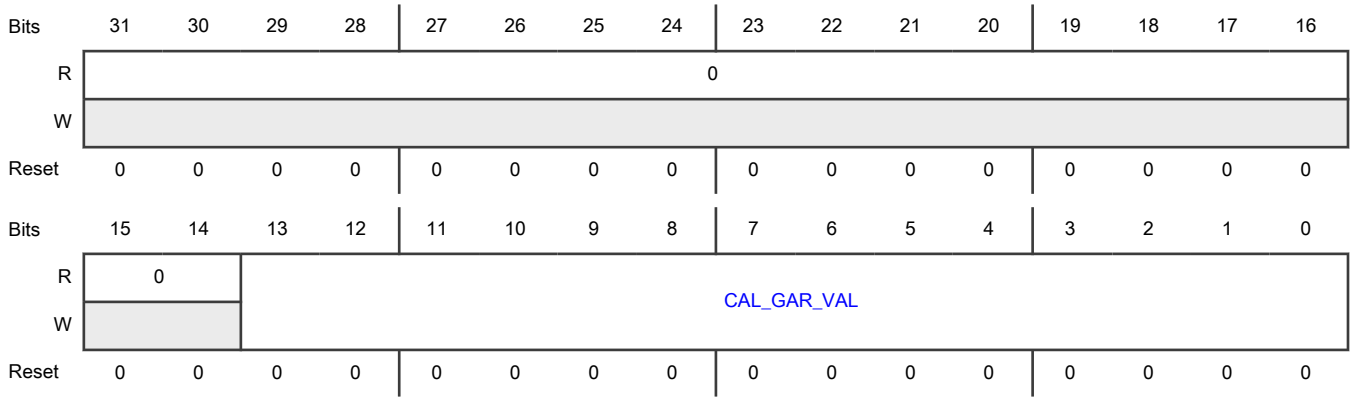
Offset

Register	Offset
CAL_GAR4	410h
CAL_GAR5	414h
CAL_GAR6	418h
CAL_GAR7	41Ch

Function

Calibration registers CAL_GAR4 through CAL_GAR7. For more detail, see Calibration General A-Side Registers (CAL_GAR0).

Diagram



Fields

Field	Function
31-14 —	Reserved
13-0 CAL_GAR_VAL	Calibration General A Side Register Element

37.6.25 Calibration General A-Side Registers (CAL_GAR8 - CAL_GAR15)

Offset

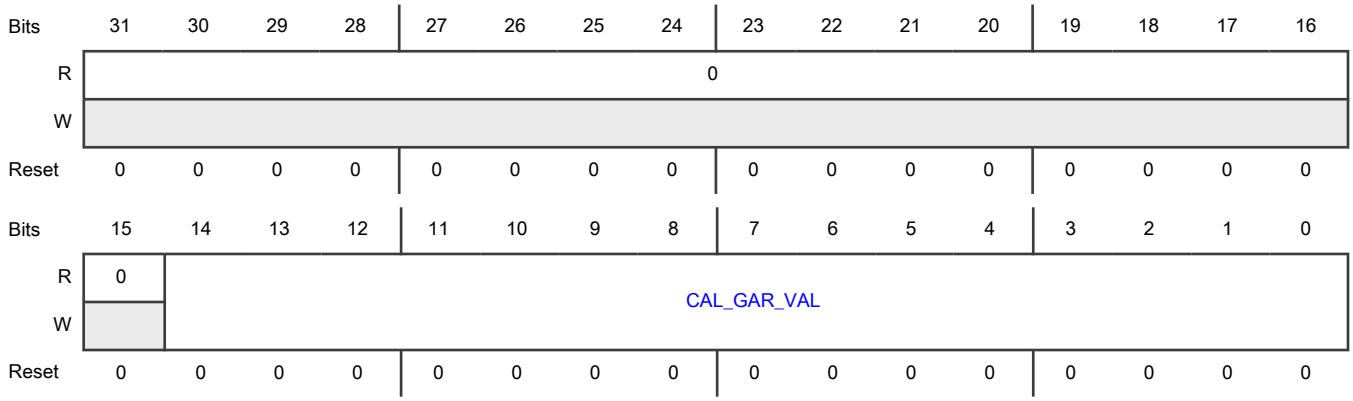
For a = 8 to 15:

Register	Offset
CAL_GARa	400h + (a × 4h)

Function

Calibration registers CAL_GAR8 through CAL_GAR15. For more detail, see Calibration General A-Side Registers (CAL_GAR0).

Diagram



Fields

Field	Function
31-15 —	Reserved
14-0 CAL_GAR_VAL	Calibration General A Side Register Element

37.6.26 Calibration General A-Side Registers (CAL_GAR16 - CAL_GAR31)

Offset

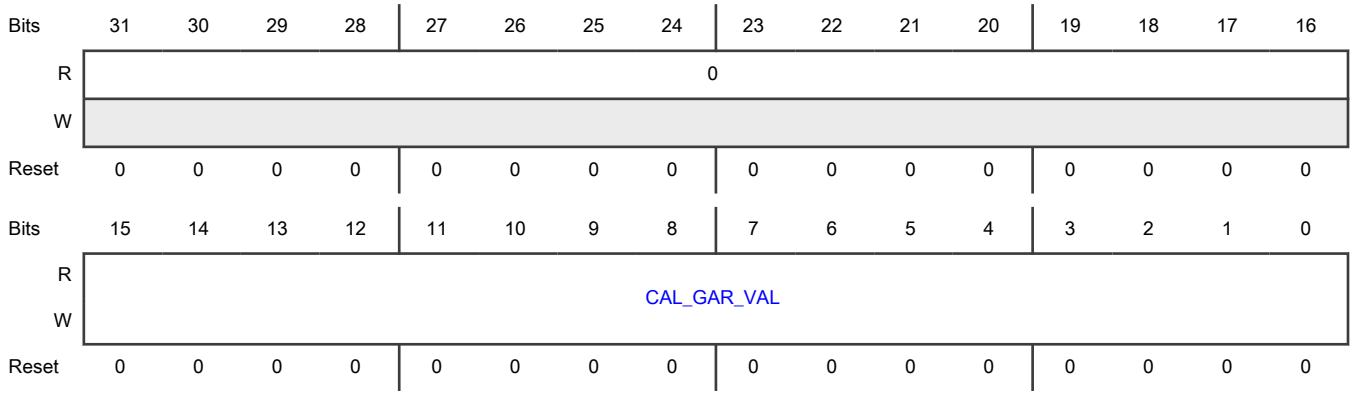
For a = 16 to 31:

Register	Offset
CAL_GARa	400h + (a × 4h)

Function

Calibration registers CAL_GAR16 through CAL_GAR31. For more detail, see Calibration General A-Side Registers (CAL_GAR0).

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 CAL_GAR_VAL	Calibration General A Side Register Element

37.6.27 Calibration General A-Side Registers (CAL_GAR32)

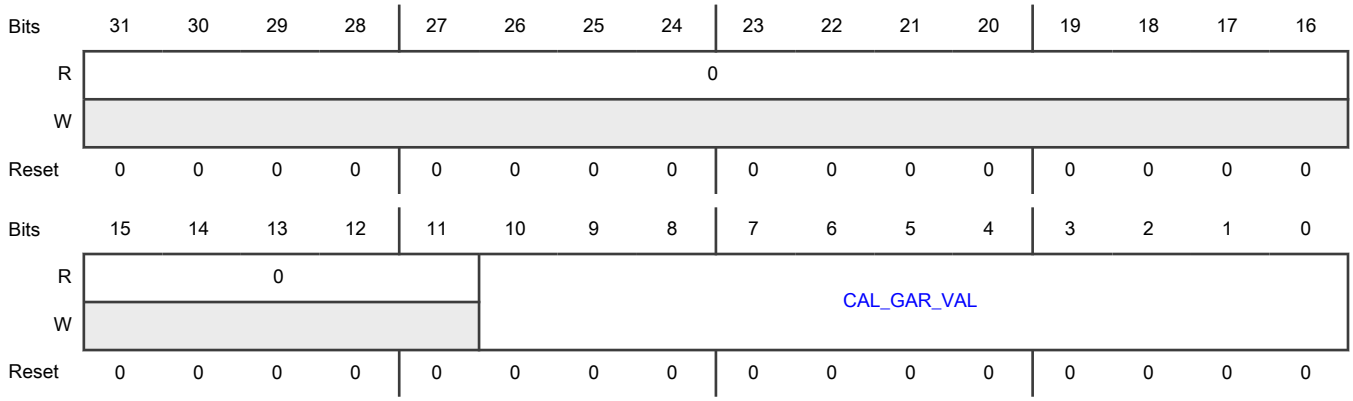
Offset

Register	Offset
CAL_GAR32	480h

Function

Calibration register CAL_GAR32. For more detail, see Calibration General A-Side Registers (CAL_GAR0).

Diagram



Fields

Field	Function
31-11 —	Reserved
10-0 CAL_GAR_VAL	Calibration General A Side Register Element

37.6.28 Calibration General B-Side Registers (CAL_GBR0)

Offset

Register	Offset
CAL_GBR0	500h

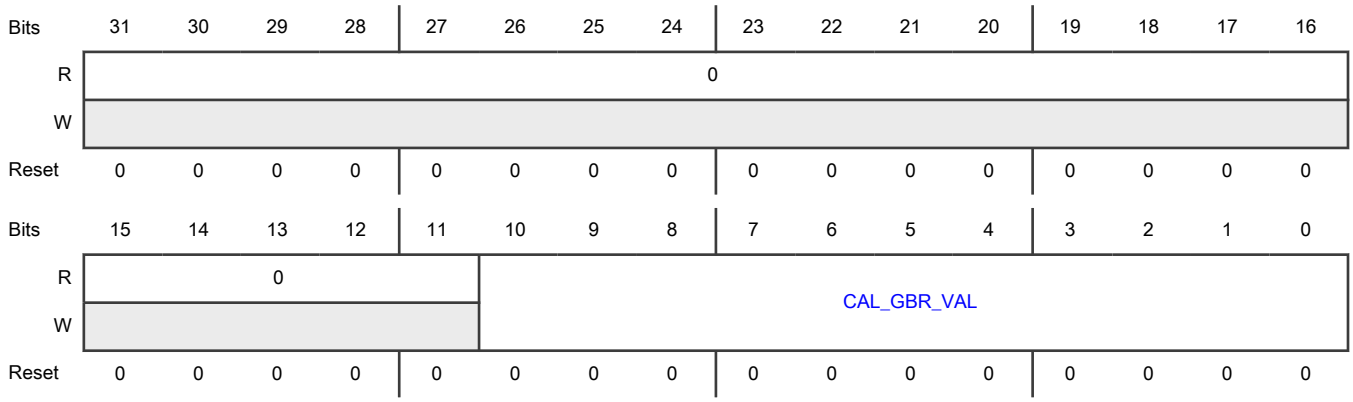
Function

Corrects for linearity errors of the B-side converter. All 33 B-side general calibration value registers (CAL_GBR0-CAL_GBR32) contain calibration information that is automatically updated during the self-calibration sequence. See Calibration functions for more information on completing ADC calibration steps.

The calibration values in the CAL_GBR registers affect the conversion result by conditionally being subtracted from the conversion before the result is transferred into the FIFOs. Calibration must be run each time ADC is powered down or a hard reset is issued. To reduce the latency required to run calibration, the CAL_GBR values can be stored in non-volatile memory after an initial calibration. These values can be recovered prior to the first ADC conversion. If these registers are set to values not generated by the calibration function, the linearity error specifications may not be met.

The CAL_GBR registers are only read-and-write accessible when ADC is disabled with CTRL[ADCEN] = 0. Access time when writing to these registers is larger than three ADC clock cycles. Wait states are inserted on the bus to meet synchronization timing to the associated CAL_GBR register. The width of each register in this array is non-uniform. The exact width of each register is summarized in Calibration General A-Side and B-Side Widths.

Diagram



Fields

Field	Function
31-11 —	Reserved
10-0 CAL_GBR_VAL	Calibration General B Side Register Element

37.6.29 Calibration General B-Side Registers (CAL_GBR1)

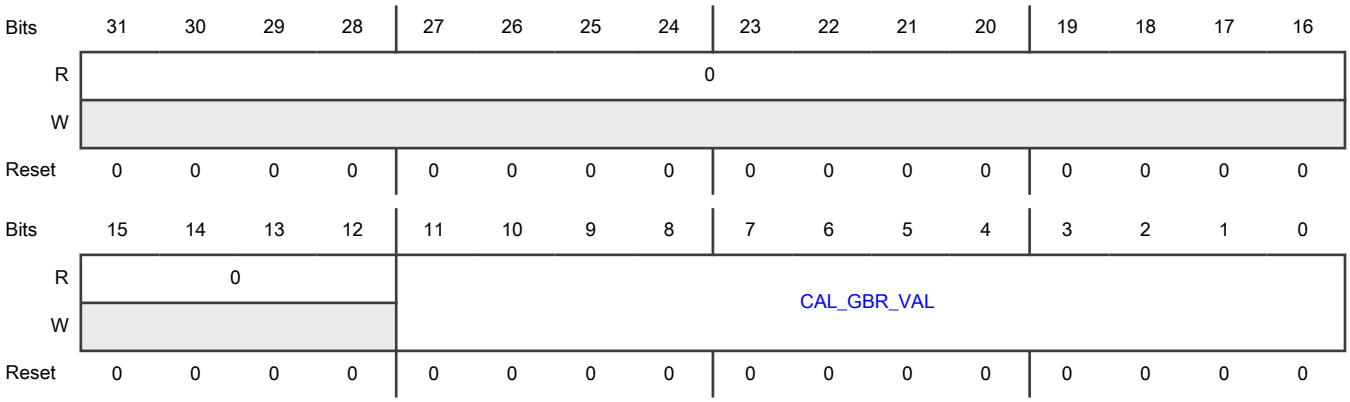
Offset

Register	Offset
CAL_GBR1	504h

Function

Calibration register CAL_GBR1. For more detail, see Calibration General B-Side Registers (CAL_GBR0).

Diagram



Fields

Field	Function
31-12 —	Reserved
11-0 CAL_GBR_VAL	Calibration General B Side Register Element

37.6.30 Calibration General B-Side Registers (CAL_GBR2 - CAL_GBR3)

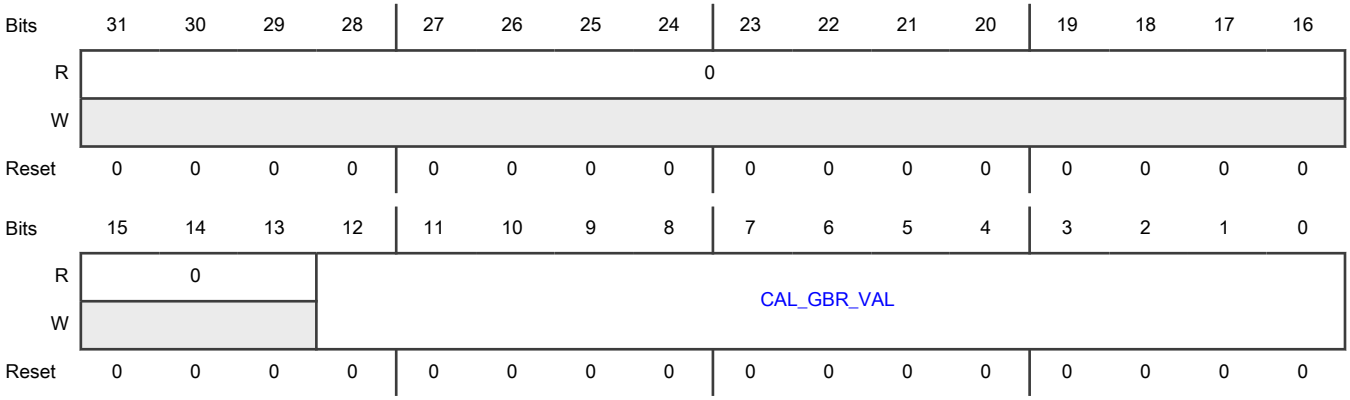
Offset

Register	Offset
CAL_GBR2	508h
CAL_GBR3	50Ch

Function

Calibration registers CAL_GBR2 and CAL_GBR3. For more detail, see Calibration General B-Side Registers (CAL_GBR0).

Diagram



Fields

Field	Function
31-13 —	Reserved
12-0 CAL_GBR_VAL	Calibration General B Side Register Element

37.6.31 Calibration General B-Side Registers (CAL_GBR4 - CAL_GBR7)

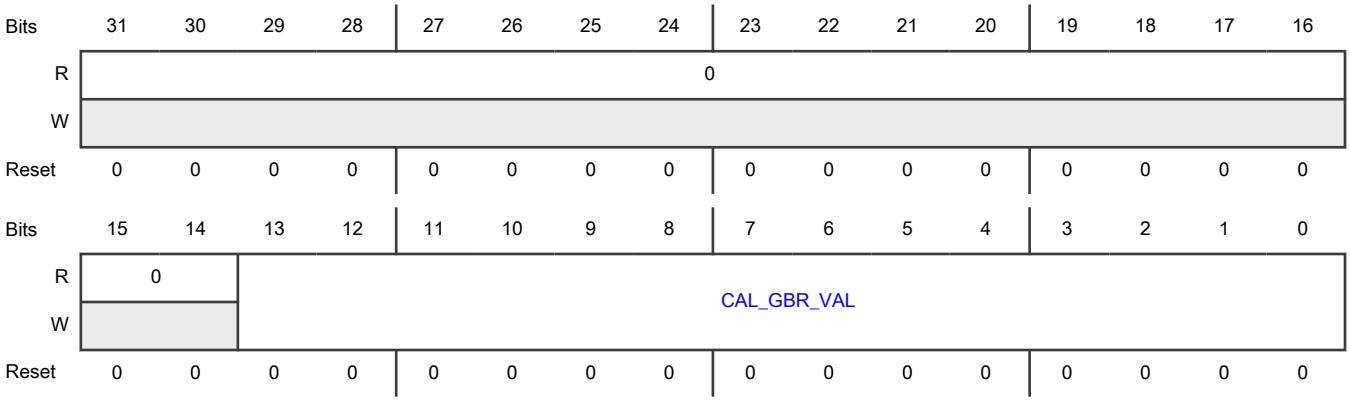
Offset

Register	Offset
CAL_GBR4	510h
CAL_GBR5	514h
CAL_GBR6	518h
CAL_GBR7	51Ch

Function

Calibration registers CAL_GBR4 through CAL_GBR7. For more detail, see Calibration General B-Side Registers (CAL_GBR0).

Diagram



Fields

Field	Function
31-14 —	Reserved
13-0 CAL_GBR_VAL	Calibration General B Side Register Element

37.6.32 Calibration General B-Side Registers (CAL_GBR8 - CAL_GBR15)

Offset

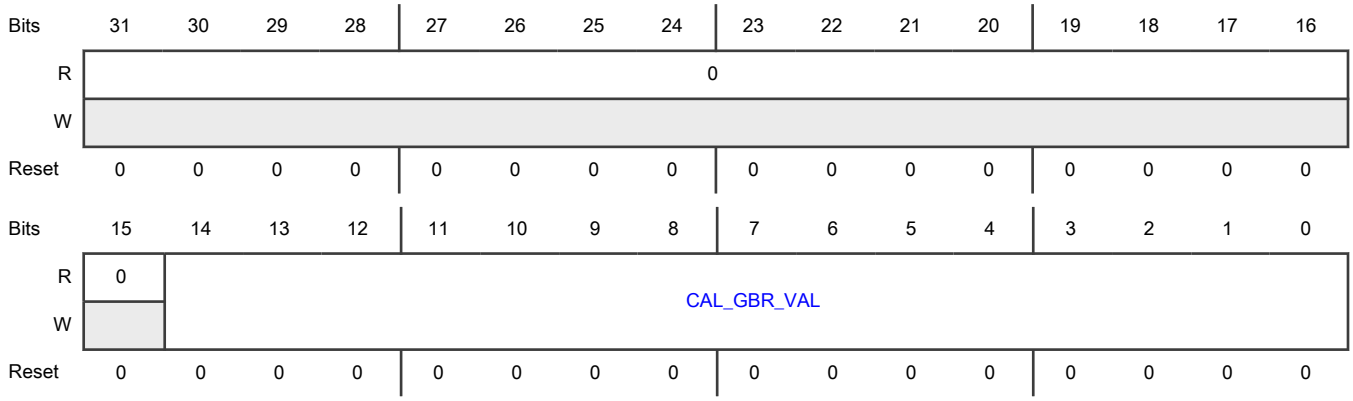
For a = 8 to 15:

Register	Offset
CAL_GBRa	500h + (a × 4h)

Function

Calibration registers CAL_GBR8 through CAL_GBR15. For more detail, see Calibration General B-Side Registers (CAL_GBR0).

Diagram



Fields

Field	Function
31-15 —	Reserved
14-0 CAL_GBR_VAL	Calibration General B Side Register Element

37.6.33 Calibration General B-Side Registers (CAL_GBR16 - CAL_GBR31)

Offset

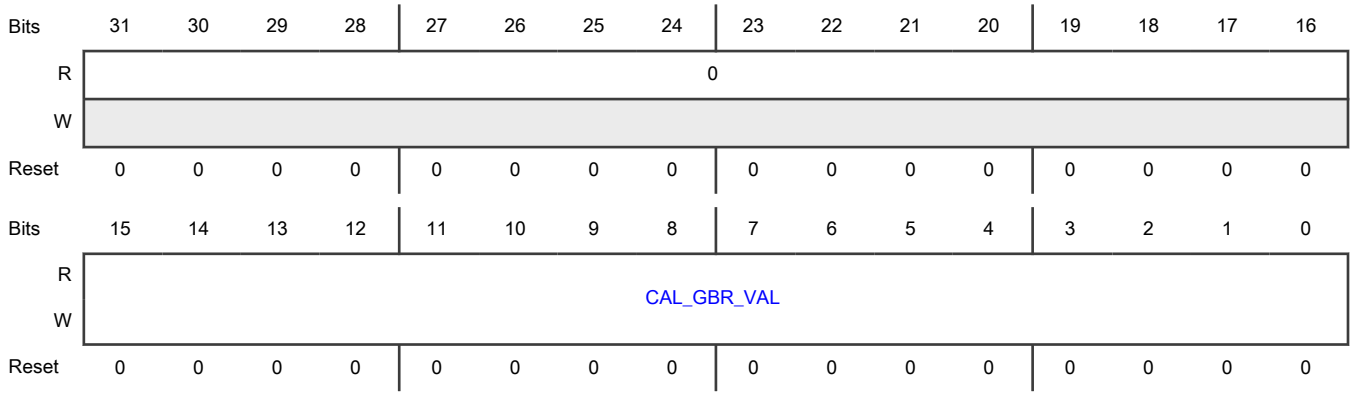
For a = 16 to 31:

Register	Offset
CAL_GBRa	500h + (a × 4h)

Function

Calibration registers CAL_GBR16 through CAL_GBR31. For more detail, see Calibration General B-Side Registers (CAL_GBR0).

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 CAL_GBR_VAL	Calibration General B Side Register Element

37.6.34 Calibration General B-Side Registers (CAL_GBR32)

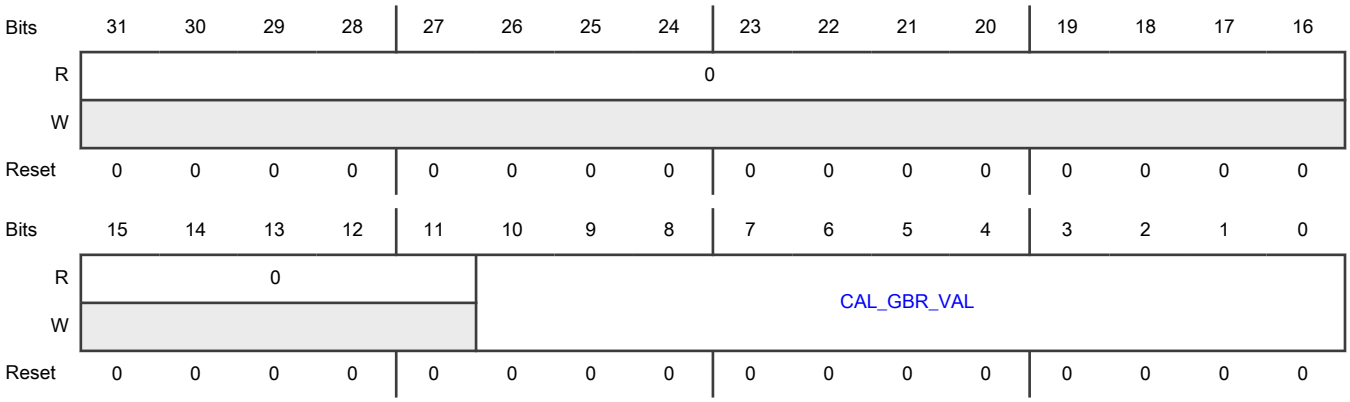
Offset

Register	Offset
CAL_GBR32	580h

Function

Calibration register CAL_GBR32. For more detail, see Calibration General B-Side Registers (CAL_GBR0).

Diagram



Fields

Field	Function
31-11 —	Reserved
10-0 CAL_GBR_VAL	Calibration General B Side Register Element

Chapter 38
Low Power Comparator (LPCMP)

38.1 Chip-specific LPCMP information

Table 272. Reference links to related information

Topic	Related module	Reference
Full description	LPCMP	LPCMP
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

38.1.1 Module instances

This device has two instances of the LPCMP module, LPCMP0 and LPCMP1.

38.1.2 Input connections

Table 273. Input connections

Index	CMP0	CMP1	Description
0	CMP0_IN0	CMP1_IN0	Pinned out in VDD_IO
1	CMP0_IN1	CMP1_IN1	VDD_IO domain
2	CMP0_IN2	CMP1_IN2	VDD_IO domain
3	CMP0_IN3	CMP1_IN3	VDD_IO domain
4	PMC BG	PMC BG	VDD_SYS domain
5	VREFO	VREFO	VDD_ANA domain
7	CMP0 8-bit DAC	CMP1 8-bit DAC	Internal DAC

38.1.3 VREFH_EXT

The DCR[VRSEL] is used to configure the VREFH_EXT:

- VRSEL=0, VREFH0 is selected, which is VDD_IO_ABC
- VRSEL=1, VREFH1 is selected, which is VREF_OUT (must be in VREFH / VDD_ANA domain)

38.2 Overview

The LPCMP module provides a circuit to compare two analog input voltages. It includes the following:

- A low power comparator (CMP)
- A DAC
- An analog mux (ANMUX)

See Block diagram for more information.

LPCMP can operate across the full range of the supply voltage, known as rail-to-rail operation.

DAC is a 256-tap resistor ladder network that provides a selectable voltage reference for applications requiring a voltage reference. DAC divides the supply reference V_{in} into 256 voltage levels. An 8-bit digital signal input selects the output voltage level, which varies from V_{in} to $V_{in}/256$.

You can select V_{in} from the following voltage sources:

- VREFH0
- VREFH1

See the Chip-specific LPCMP information for more information on source of VREFH0 and VREFH1.

NOTE

The LPCMP's internal DAC output is available as an on-chip internal signal only and is not available for an external chip pin.

ANMUX allows you to select an analog input signal from among eight channel options. One channel option is the DAC output. Other chip resources are connected to the other channels. See the Chip-specific LPCMP information section for more information. ANMUX can operate across the full range of the supply voltage.

38.2.1 Block diagram

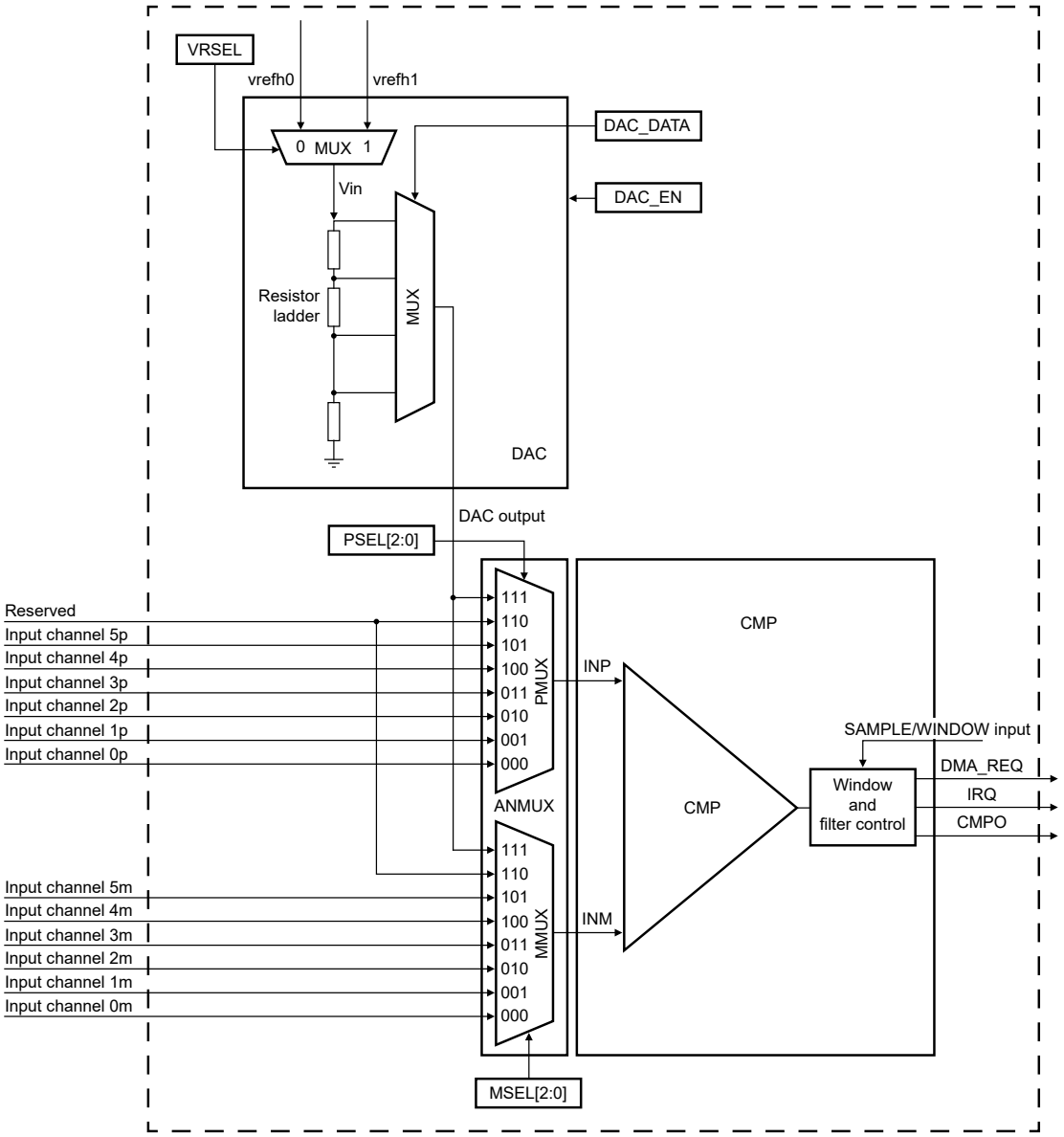


Figure 100. Block diagram

38.2.2 Features

The features of the LPCMP module include：

- Includes two 8-to-1 channel MUXes to select input signal from eight channels
- Supports multiple operation modes to produce a wide range of outputs such as:
  - Sampled
  - Windowed, which is ideal for certain PWM zero-crossing-detection applications
  - Digitally filtered
- Provides the following advance features for window and sample:

- Window and sample signals can be inverted.
- CMPO rising, falling or both edges closes the window.
- CMPO level can be defined when window is closed.

- Provides selectable performance levels:
  - Nano-Power mode
  - Low-Power (speed) mode
  - High-Power (speed) mode
- Supports programmable hysteresis control
- Provides a selectable inversion on comparator output
- Uses an external hysteresis at the same time the output filter is used for internal functions
- Provides interrupt and DMA support
- Includes an 8-bit resolution DAC
- Provides a selectable supply reference source for DAC
- Provides a configurable Low-Power (speed) mode or High-Power (speed) mode for DAC

38.3 Functional description

38.3.1 Functional block diagram

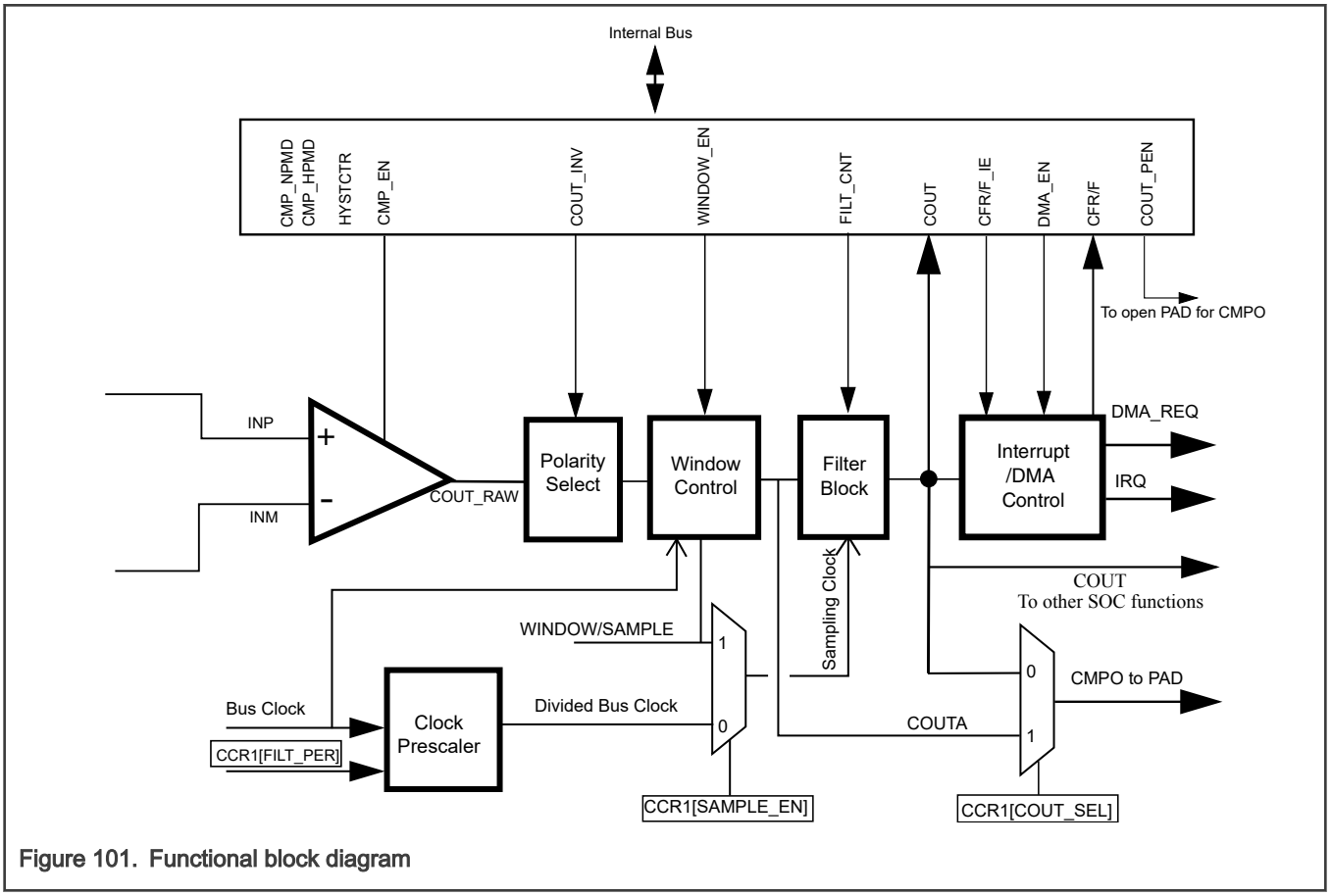


Figure 101. Functional block diagram

As shown in the block diagram, the functions are:

- Compared two analog input voltages applied to INP and INM, COUT_RAW is high when the INP input voltage is greater than the INM input voltage, and COUT_RAW is low when the INP input voltage is less than the INM input voltage.
- The COUT_RAW signal can be inverted by enabling CCR1[COUT_INV].
- The optionally inverted comparator output COUT_RAW is sampled on every bus clock when you enable the CCR1[WINDOW_EN] to generate COUTA. In this case, the comparator output is ignored during time periods when the input voltages are not valid. This is useful when you implement zero-crossing-detection for certain PWM applications.
- The window control block is bypassed when CCR1[WINDOW_EN] is disabled.
- The filter block acts as a simple sampler when CCR1[FILT_CNT] is set to 01h.
- The filter block acts as a filter based on multiple samples when CCR1[FILT_CNT] is set to be greater than 01h.
  - If CCR1[SAMPLE_EN] is set to 1, use the external SAMPLE input as the sampling clock.
  - If CCR1[SAMPLE_EN] is set to 0, use the divided bus clock as the sampling clock.
- Bypasses the filter block when it is not in use.

```
Bypass_Filter_Block = (FILT_CNT == 0x00) |  (~SAMPLE_EN & (FILT_PER == 0x00))
```

- Both COUTA and COUT can be configured as module output CMPO by configuring CCR1[COUT_SEL], and are used for different purposes within the system.
- The optionally filtered COUT can be read directly in CSR[COUT].
- The SAMPLE/WINDOW signal can be inverted by setting CCR1[WINDOW_INV].
- The SAMPLE/WINDOW signal can be closed by CMPO's falling edge and/or rising edge by setting CCR1[WINDOW_CLS] in Window mode.
- In Window mode, when window is closed, define the COUTA value as CCR1[COUTA_OW] by setting CCR1[COUTA_OWEN]. If CCR1[COUTA_OWEN] is not set, COUTA holds the last sampled value.

NOTE

See the chip configuration section for the source of SAMPLE/WINDOW input.

38.3.2 Low-pass filter mode

The low-pass filter mode operates on an unfiltered, optionally inverted comparator output COUTA, and generates the filtered and synchronized output COUT. You can configure both COUTA and COUT as module outputs and use for different purposes within the system.

Synchronization and edge detection determine the bit values of status register. They also apply to COUT for all sampling and windowed modes. You can perform filtering using an internal timebase defined by CCR1[FILT_PER], or use an external sample input to determine sample time.

The need for digital filtering and the amount of filtering depends on your requirements. Filtering can become more useful in the absence of an external hysteresis circuit. Without external hysteresis, generate a high-frequency oscillations at COUTA when the selected INM and INP input voltages differ by less than the offset voltage of the differential comparator.

38.3.2.1 Enabling low-pass filter mode

You can enable low-pass filter mode by setting the following:

- CCR1[FILT_CNT] > 01h
- CCR1[FILT_PER] to a nonzero value or writing 1 to CCR1[SAMPLE_EN].

If you use the divided bus clock to drive the low-pass filter, it samples COUTA every CCR1[FILT_PER] bus clock cycle.

If CCR1[SAMPLE_EN] is set to 1, the low-pass filter samples COUTA on each positive transition of the sample input. The output state of the filter changes when all the consecutive CCR1[FILT_CNT] samples agree that the output value has changed.

38.3.2.2 Latency issues

Program the value of CCR1[FILT_PER] or sample period such that the sampling period is longer than the period of the expected noise, ensuring that a given noise spike corrupts only one sample. You must choose the value of CCR1[FILT_CNT] to reduce the probability of noisy samples causing an incorrect transition to recognize. The probability of an incorrect transition is defined as the probability of an incorrect sample raised to the power of CCR1[FILT_CNT].

You must trade off the values of CCR1[FILT_PER] or sample period and CCR1[FILT_CNT] against the need for minimal latency in recognizing actual comparator output transitions. The probability of detecting an actual output change within the nominal latency is the probability of a correct sample raised to the power of CCR1[FILT_CNT].

Table 275 summarizes maximum latency values for the various modes of operation in the absence of noise. Filtering latency restarts each time the noise masks an actual output transition.

38.3.3 Low power mode operation

Below table introduces the mode of operation of lower power.

Table 274. Low power mode operation

Mode of operation	Description
Sleep	LPCMP can operate only in Continuous mode.

38.3.4 Functional modes

You can combine the comparator window and filter features as shown in the following table.

Table 275. Functional modes

Mode #	CMP_EN	WINDOW_EN	SAMPLE_EN	FILT_CNT	FILT_PER	Operation	Maximum latency[1]
1	0	X	X	X	X	See the Disabled mode (#1).	N/A
2A	1	0	X	0x00	X	See the Continuous mode (#2A and #2B).	T_{PD}
2B	1	0	0	X	0x00		
3A	1	0	1	0x01	X	See the Sampled, non-filtered mode (#3A and #3B).	$T_{PD} + T_{SAMPLE} + 3T_{per}$
3B	1	0	0	0x01	> 0x00		$T_{PD} + (FILT_PER * T_{per}) + 3T_{per}$
4A	1	0	1	> 0x01	X	See the Sampled, filtered mode (#4A and #4B).	$T_{PD} + (FILT_CNT * T_{SAMPLE}) + 3T_{per}$
4B	1	0	0	> 0x01	> 0x00		$T_{PD} + (FILT_CNT * FILT_PER \times T_{per}) + 3T_{per}$
5A	1	1	0	0x00	X	See the Windowed mode (#5A and #5B).	$T_{PD} + 2T_{per}$
5B	1	1	0	X	0x00		

Table continues on the next page...

Table 275. Functional modes (continued)

Mode #	CMP_EN	WINDOW_EN	SAMPLE_EN	FILT_CNT	FILT_PER	Operation	Maximum latency[1]
6	1	1	0	0x01	> 0x00	See the Windowed/ Resampled mode (#6).	T_{PD} + (FILT_PER * T_{per}) + $3T_{per}$
7	1	1	0	> 0x01	> 0x00	See the Windowed/ Filtered mode (#7).	T_{PD} + (FILT_CNT * FILT_PER x T_{per}) + $3T_{per}$
All other combinations of CMP_EN, WINDOW_EN, SAMPLE_EN, FILT_CNT, and FILT_PER are illegal.							

1. T_{PD} represents the intrinsic delay of the analog component plus the polarity select logic. T_{SAMPLE} is the clock period of the external sample clock. T_{per} is the period of the bus clock.

38.3.4.1 Disabled mode (#1)

In this mode:

- The analog comparator is non-functional and consumes no power.
- CSR[COUT] and CMPO are the same as CCR1[COUT_INV].

38.3.4.2 Continuous mode (#2A and #2B)

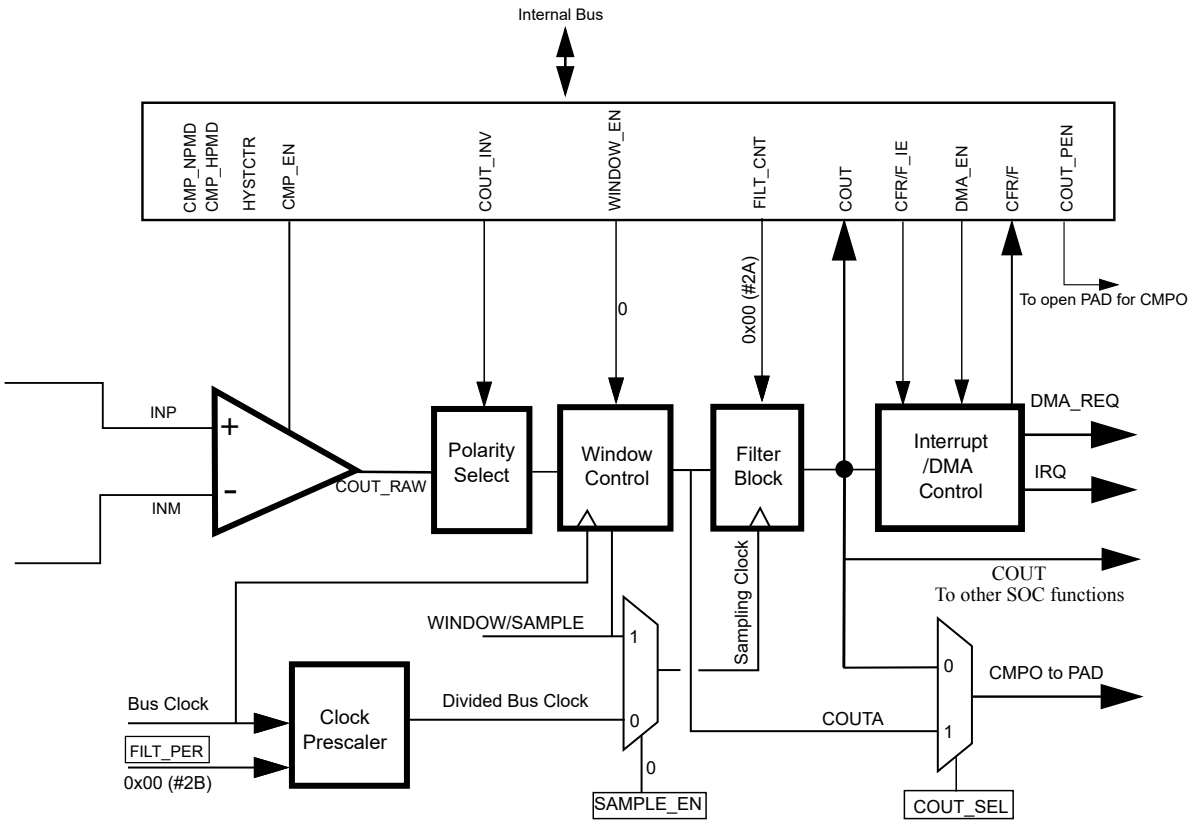


Figure 102. Comparator operation in continuous mode

COUT_RAW is optionally inverted in this mode but is not subject to external sampling or filtering. Both window control and filter blocks bypass completely, and CSR[COUT] updates continuously. The path from comparator input pins to output pins operates in a combinational (unclocked) mode. COUT and COUTA are identical in this mode.

For cases where a comparator drives a fault input, you must configure it to operate in Continuous mode so that an external fault can immediately pass to the target fault circuitry through the comparator.

38.3.4.3 Sampled, non-filtered mode (#3A and #3B)

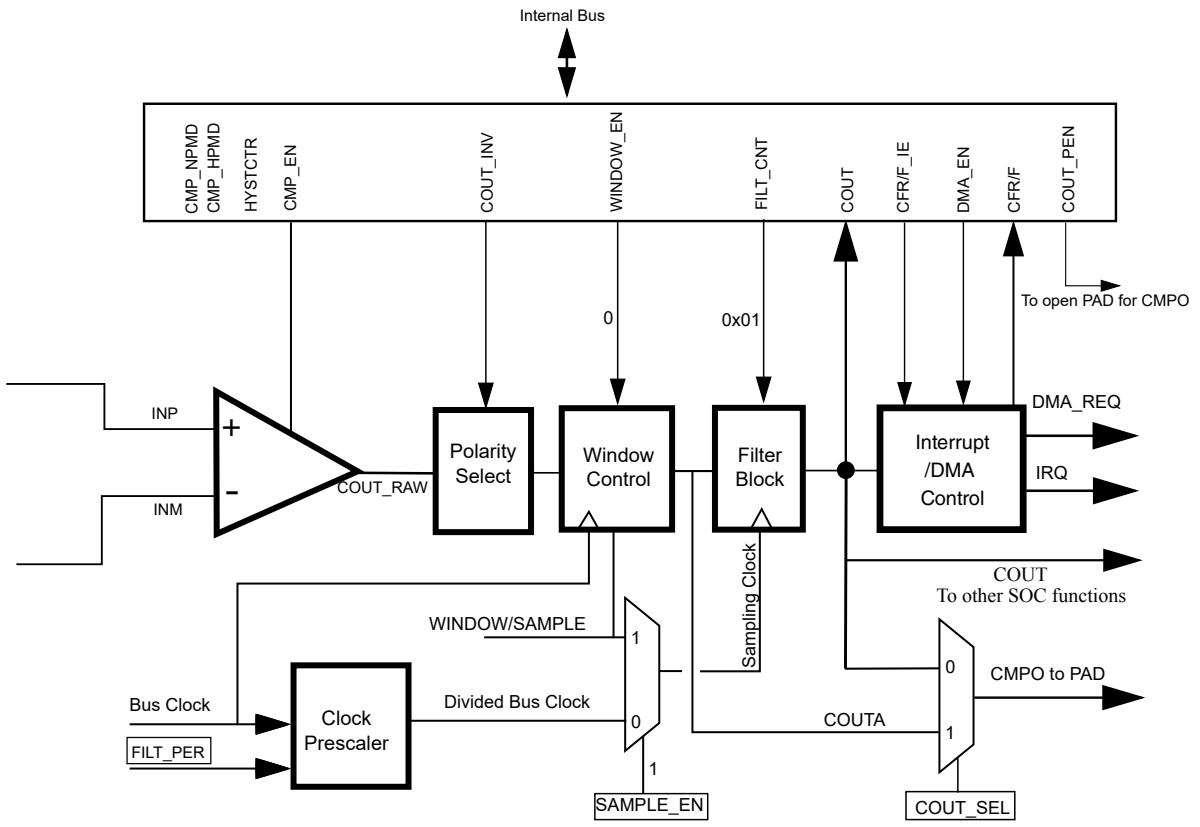


Figure 103. Sampled, non-filtered (#3A): sampling point externally derived

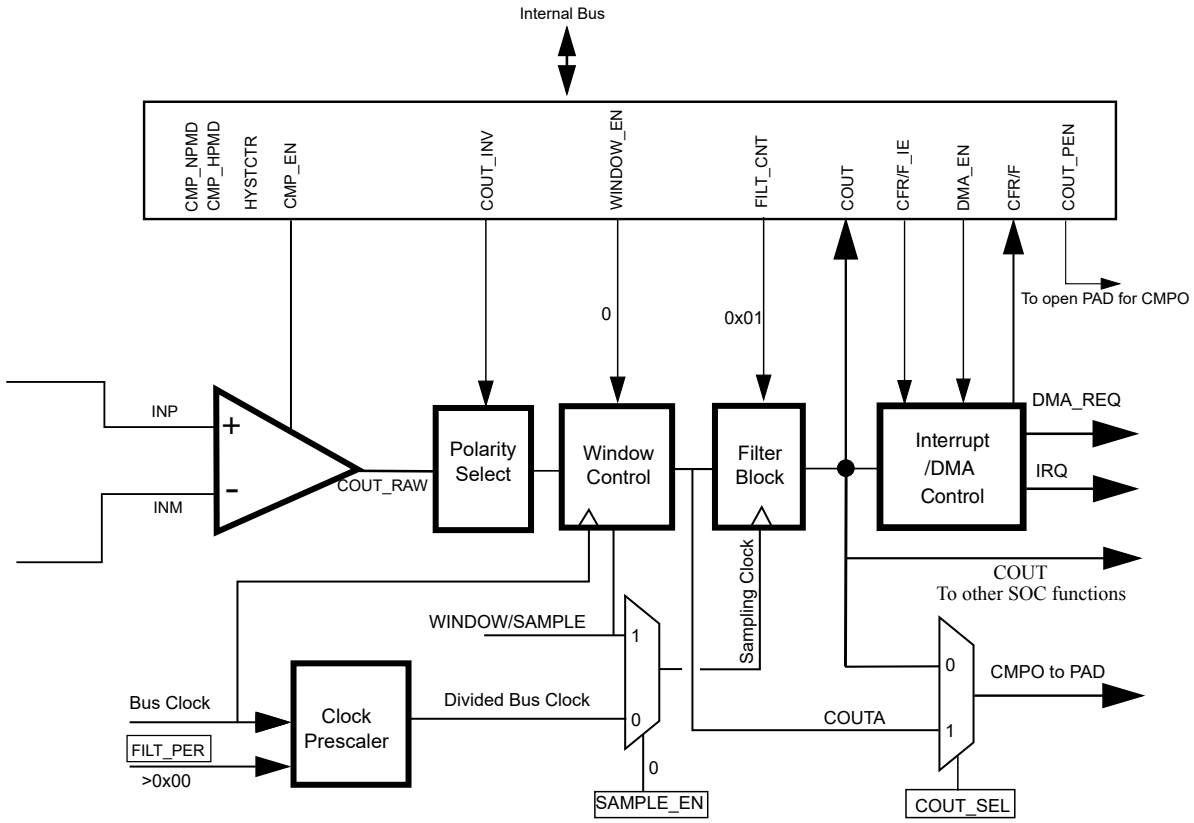


Figure 104. Sampled, Non-Filtered (#3B): sampling interval internally derived

In this mode, the path from analog inputs to COUTA is combinational (unclocked). Windowing control bypasses completely. You can sample COUTA whenever you detect a rising edge on the sampling clock.

The difference in two operation modes (#3A and #3B) of sampled, non-filtered mode is that how you drive the clock to the filter block. In #3A, the clock to filter block drives externally, and in #3B, the clock to filter block drives internally.

The filter block has no other function than sample or hold of the comparator output in this mode.

The following figure shows the comparator operation in this mode, assuming that the polarity select sets to a non-inverting state.

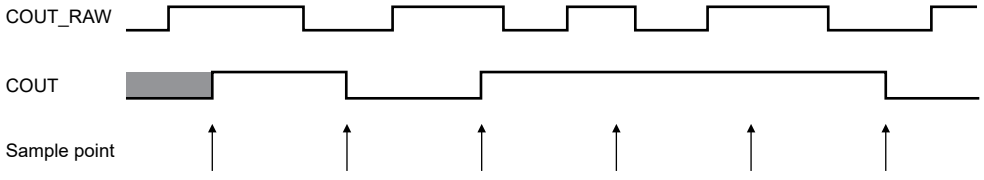


Figure 105. Sampled, Non-Filtered mode timing diagram

38.3.4.4 Sampled, filtered mode (#4A and #4B)

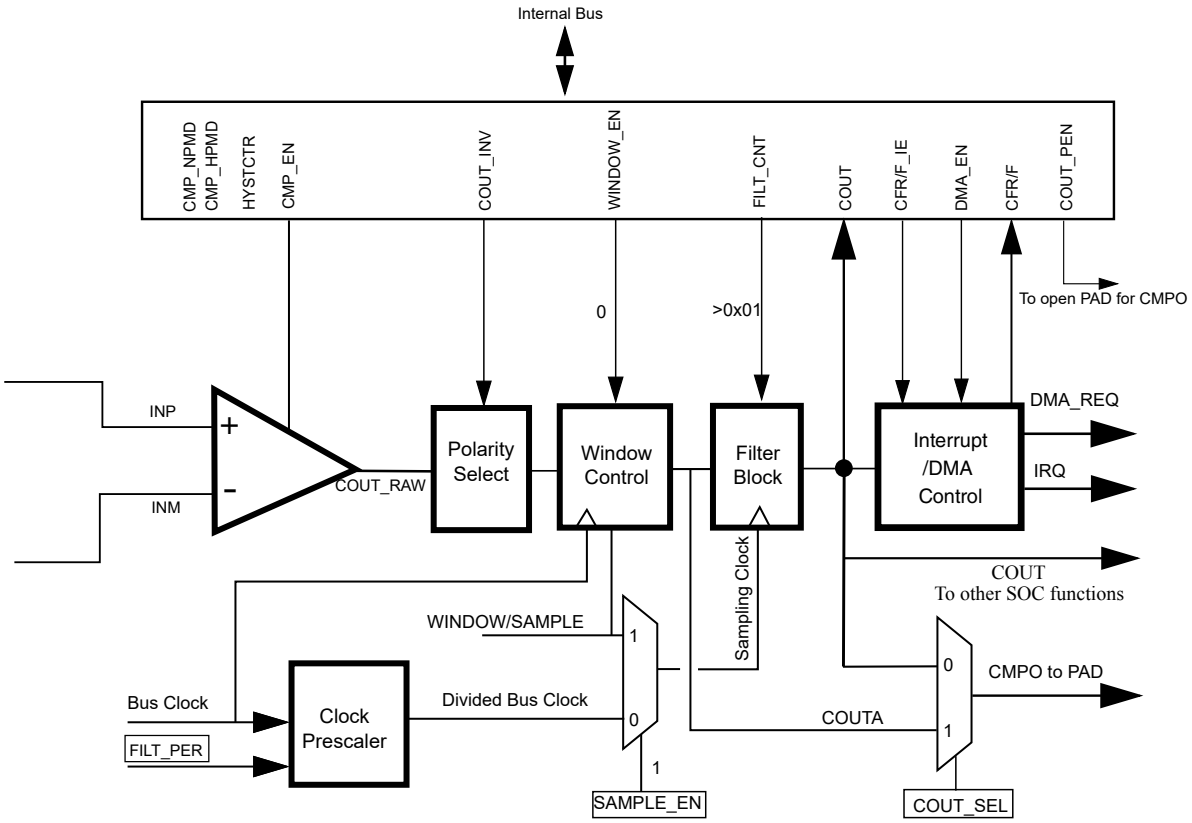


Figure 106. Sampled, filtered (#4A): sampling point externally derived

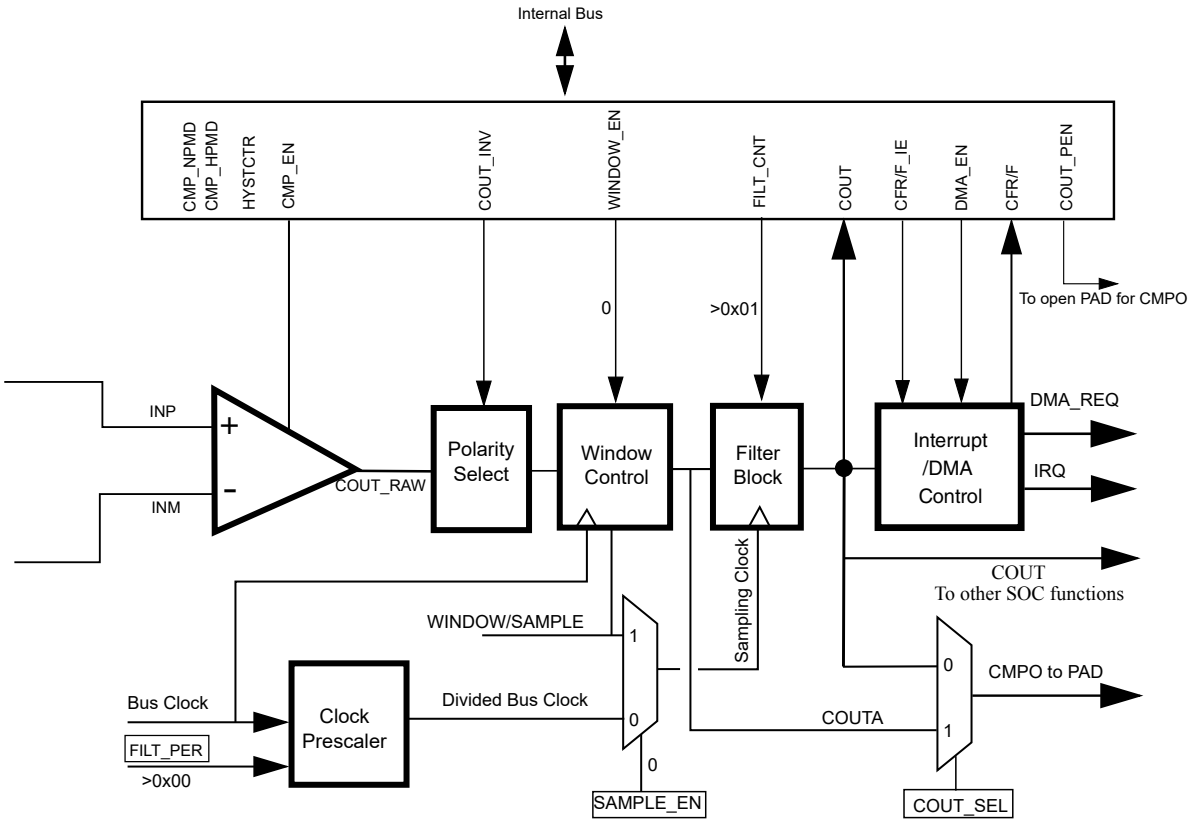


Figure 107. Sampled, filtered (#4B): sampling point internally derived

In this mode, the path from the analog inputs to COUTA is combinational(unclocked). Windowing control bypasses completely. You can sample COUTA whenever you detect a rising edge on the sampling clock.

The only difference in operation between sampled, non-filtered (#3A) mode and sampled, filtered (#4A) mode is that CCR1[FILT_CNT] is larger than 1, which activates filter operation.

The only difference in operation between sampled, non-filtered (#3B) mode and sampled, filtered (#4B) mode is that CCR1[FILT_CNT] is larger than 1, which activates filter operation.

38.3.4.5 Windowed mode (#5A and #5B)

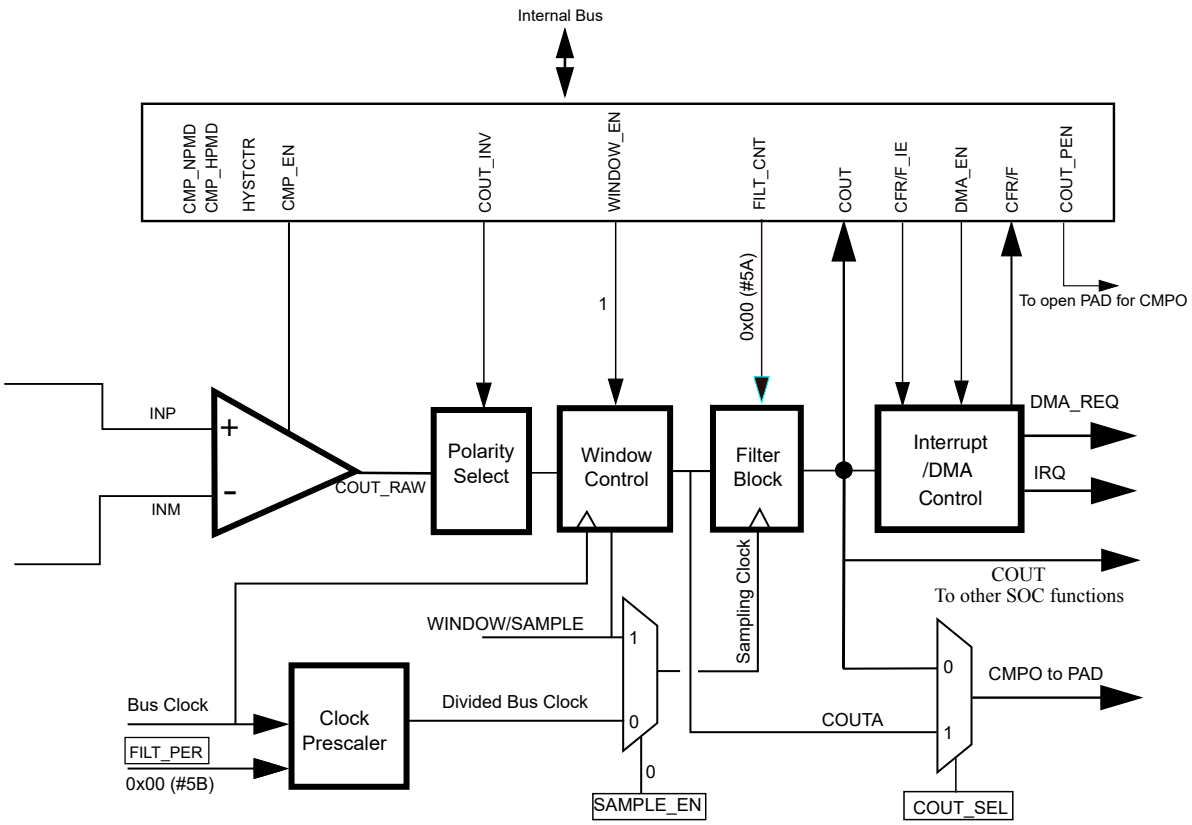


Figure 108. Windowed mode

The bus clock clocks COUTA whenever you enable the window in this mode. The last latched value holds after you disable the window and the filter block is bypassed.

The following figure shows the comparator operation in this mode, ignoring the latency of the analog comparator, polarity select, and window control block. The polarity select sets to a non-inverting state.

COUTA may lag the analog inputs by up to two functional clock cycles plus the combinational path delay through the comparator and polarity select logic in the actual operation.

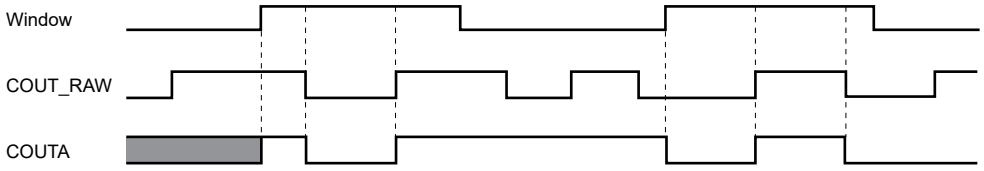


Figure 109. Windowed mode timing diagram

The following figure shows that if CCR1[COUTA_OWEN] becomes 1, you can define COUTA level as CCR1[COUTA_OW], after you closes the window.

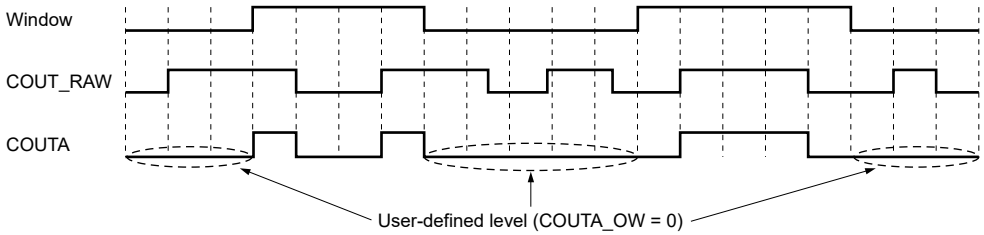


Figure 110. Windowed mode timing diagram with user defined value 0 outside window

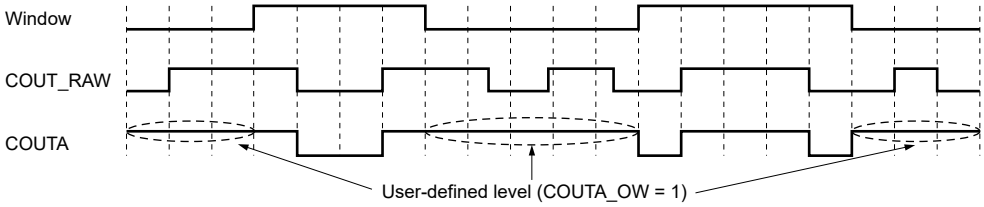


Figure 111. Windowed mode timing diagram with user defined value 1 outside window

NOTE

When the window is open, COUT_A will switch from COUTA_OW to COUT_RAW. When the window is closed, COUT_A will switch from COUT_RAW to COUTA_OW. This may generate unnecessary transition flags, for instance, CFR or CFF. User needs to choose COUTA_OW carefully according to the actual application, and select the appropriate flag CFR or CFF to generate interrupt.

If CCR1[WINDOW_CLS] becomes 1, you can define the CMPO event (rising edge, falling edge or both edges that CCR1[EVT_SEL] selects) to close the window. The external window signal has to go to zero and back to one to enable the internal window again. The following figure shows an example that CMPO rising edge closes the internal window.

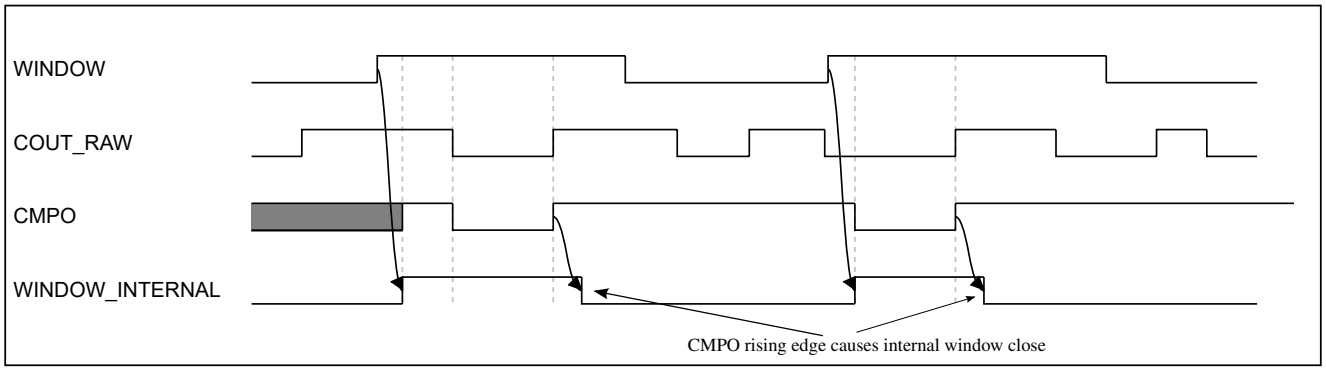


Figure 112. Windowed mode timing diagram with CMPO rising edge close window

The following figure shows that if CCR1[WINDOW_INV] becomes 1, you can invert the window signal before you use it.

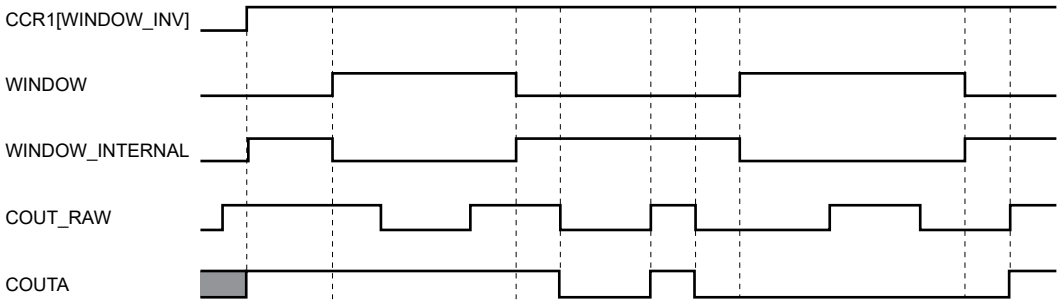


Figure 113. Windowed mode timing diagram with window signal inverted

38.3.4.6 Windowed/Resampled mode (#6)

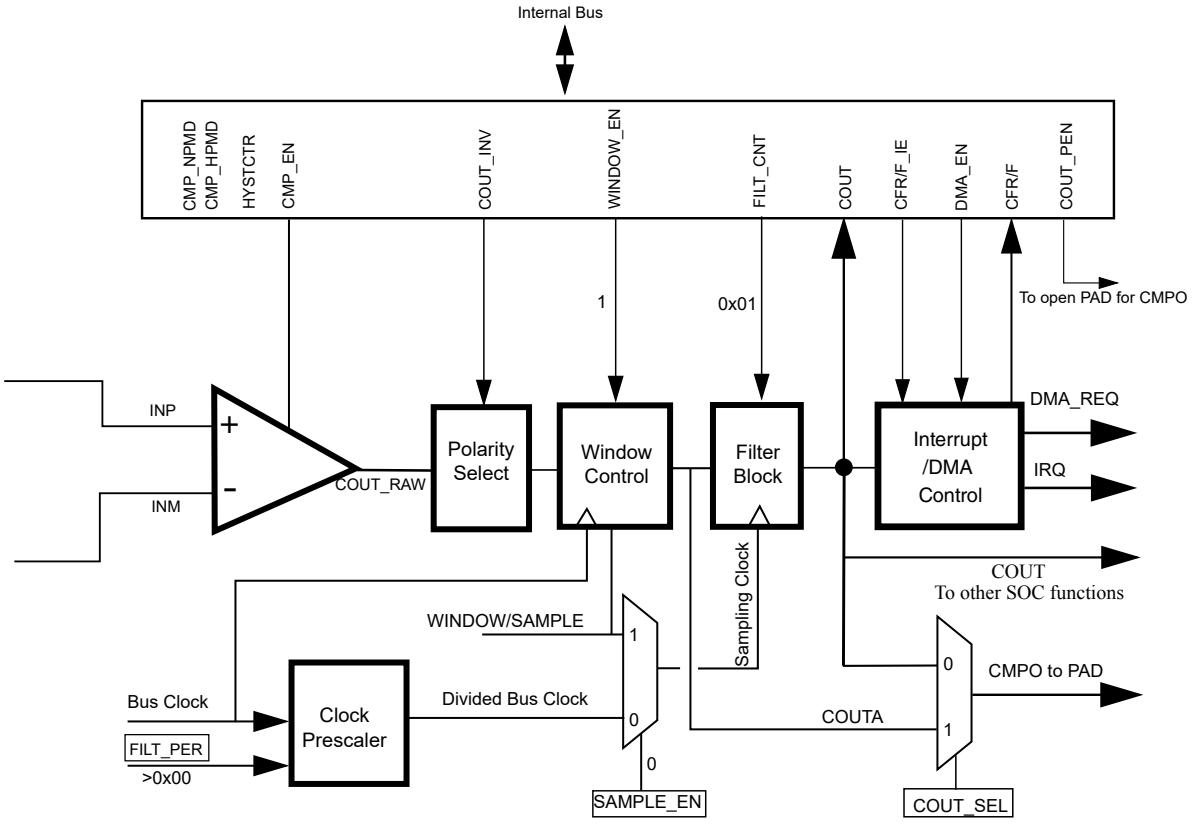


Figure 114. Windowed/Resampled mode

This mode of operation results in an unfiltered string of comparator samples where CCR1[FILT_PER] and the bus clock rate determines the interval between the samples. The following section shows that the configuration for this mode is virtually identical to that for the Windowed/Filtered mode. The only difference is that the value of CCR1[FILT_CNT] must be 1 in this mode.

The following figure uses the same input stimulus shown in Figure 109, and adds resampling of COUTA to generate COUT. The arrows in the figure indicate the time points at which the samples are taken. You can ignore prop delays and latency for clarity.

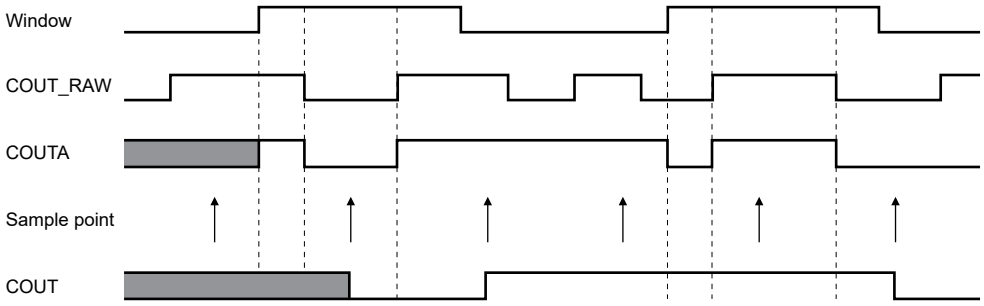


Figure 115. Windowed/Resampled mode operation

This example demonstrates the operation of the comparator in Windowed/Resampled mode, and does not reflect any specific application. Based on the sampling rate and window placement, COUT may not see zero-crossing events that the analog comparator detects. You must carefully consider the sampling period and/or window placement for a given application.

38.3.4.7 Windowed/Filtered mode (#7)

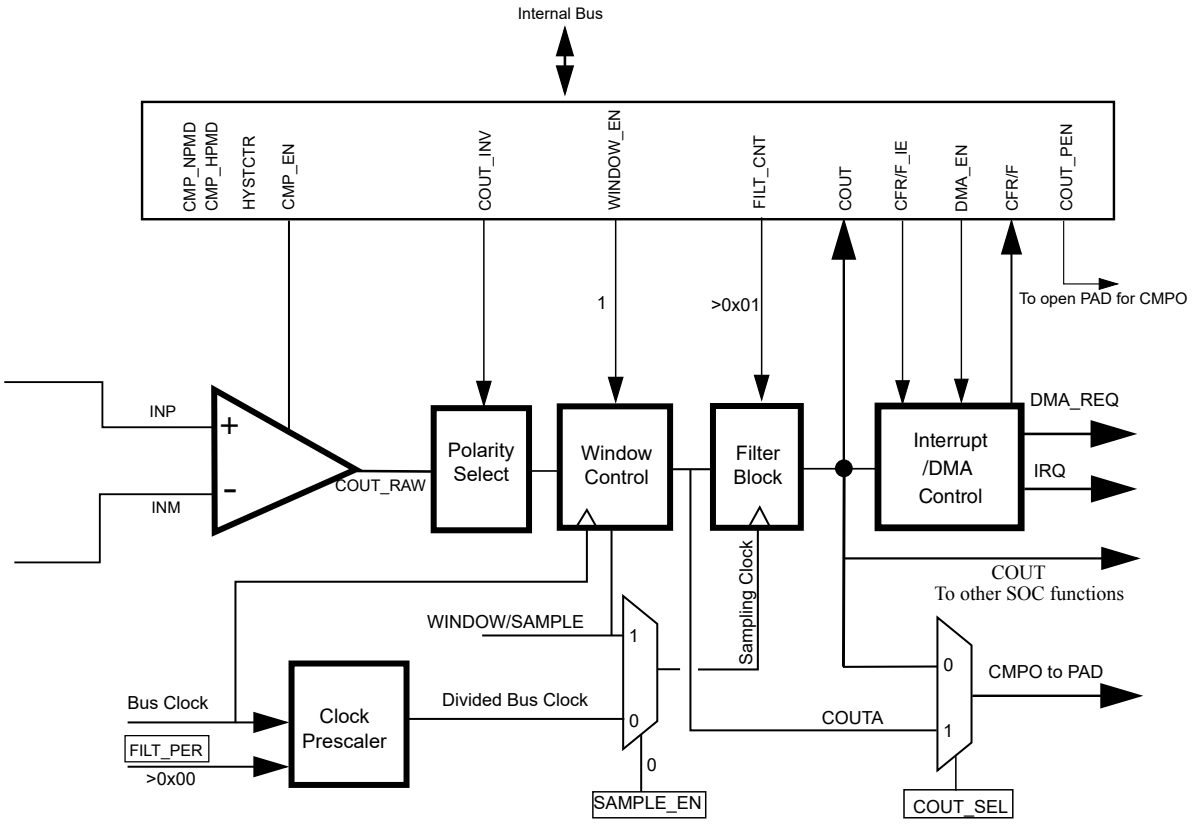


Figure 116. Windowed/Filtered mode

The only difference in operation between Windowed/Resampled mode (#6) and Windowed/Filtered mode (#7) is that CCR1[FILT_CNT] is >1, which activates filter operation.

This mode is the most complex mode of operation for the comparator block, as it utilizes both windowing and filtering features. It also has the highest latency of any of the modes. This is approximately: up to 2 peripheral clock synchronization in the window function + ((CCR1[FILT_CNT] x CCR1[FILT_PER]) + 1) x peripheral clock for the filter function.

38.3.5 DMA

After DMA is enabled by writing 1 to CCR1[DMA_EN] and interrupt is enabled by writing 1 to IER[CFR_IE], IER[CFF_IE], or both, the corresponding change on COUT forces a DMA transfer request rather than a CPU interrupt. After the DMA completes the transfer, it sends a transfer completing indicator signal that deasserts the DMA transfer request and clears the flags (both CSR[CFR] and CSR[CFF]) to allow a subsequent change on comparator output to occur and forces another DMA request.

The comparator can remain functional in Sleep modes if CCR0[CMP_STOP_EN] becomes 1.

A DMA transfer request wakes up the system from Sleep mode. After completing the data transfer, the system go back again to Sleep mode. See the DMA chapters in this document for more information on the asynchronous DMA function.

38.3.6 Clocking

LPCMP requires the following clocks to operate:

Table 276. LPCMP clocks

Type of clock	Description
Bus	Controls the access to LPCMP registers and window/ filter function.

38.3.7 Resets

The global chip reset signal resets LPCMP.

38.3.8 Interrupts

After the corresponding IER becomes 1, CSR[CFR], CSR[CFF], and can generate an interrupt, assuming that CCR1[DMA_EN] is not 1. You can clear either the flag or IER to deassert the interrupt.

38.4 External signal descriptions

Below table introduces external signals.

Table 277. External signal descriptions

Signal	Description	I/O
CMPO	Filtered or unfiltered comparator output	O
Input_Analog_Channels	Analog input channels (see the chip-specific information for more on the connections).	I
VREFH_EXT	External reference voltage for the CMP-DAC (see the chip-specific information for more on the connections).	I

38.5 Initialization

You can enable LPCMP by writing 1 to CCR0[CMP_EN], and then configuring the control registers (CCR1, CCR2, DCR, and so on).

To disable LPCMP, write 0 to CCR0[CMP_EN]. Switching operation modes or changing control register fields on-the-fly (when CCR0[CMP_EN] is set to 1) may cause noise on the COUT or COUTA signals. To avoid unwanted signal noise, you must ensure to disable the module before switching modes or changing control fields.

The time required to stabilize COUT is the power-on delay of the comparators plus the largest propagation delay from a selected analog source through the analog comparator, windowing function, and filter (see the Comparator and 8-bit DAC electrical specifications section of LPCMP datasheet for more information on propagation delay and power-up delay). Table 275 specifies the delay that the windowing and filter function causes.

During operation, you must always consider the propagation delay of the selected data paths. It can take many bus clock cycles for COUT and CSR[CFR]/CSR[CFF] to reflect an input change or a configuration change to one of the components involved in the data path.

38.6 Application information

38.6.1 Hysteresis

The following diagram illustrates implementation of an external hysteresis resistor bridge between the asynchronous comparator output and the INP input of the Comparator. Since positive feedback is required, CCR1[COUT_INV] must be set to 0 when the hysteresis resistor bridge is added to the INP input of the comparator. CCR1[COUT_INV] must be set to 1 when the hysteresis resistor bridge is added to the INM input of the comparator.

The option of adding an external resistor bridge for the purpose of adding hysteresis to the comparator and the amount of hysteresis depends on the user's individual requirements. Hysteresis can be important in some system designs. In the absence of hysteresis, the continuous comparison of nearly identical analog inputs may add noise and waste power by generating high-frequency oscillations at CMPO.

If external hysteresis is added to the comparator, the bridge must be designed to consider other issues than simply how much hysteresis is needed. The resistor values must be sufficiently high so that they do not cause the drive strength of the digital output driver in the CMPO IO cell to be exceeded. Also, if any digital function other than CMPO must operate on the CMPO pad in the presence of such a bridge, the resistor values must be sufficiently high so that the IO cell can function appropriately in its digital role.

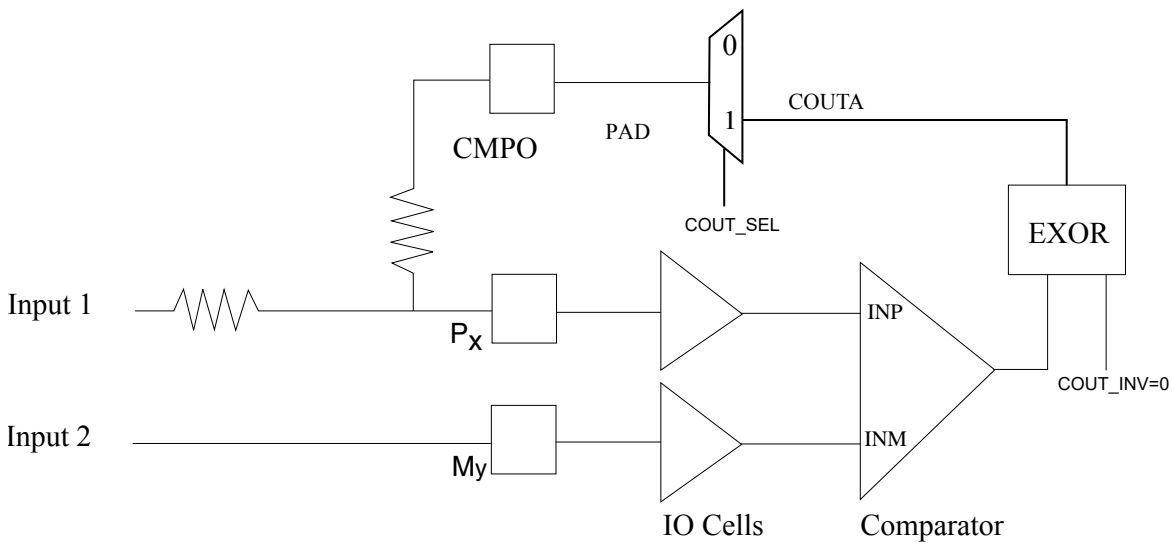


Figure 117. External hysteresis circuit

38.7 LPCMP register descriptions

The memory map comprises of 32-bit aligned registers, which you can access via 8-, 16- or 32-bit reads and 32-bit write. Attempted accesses using unsupported write data sizes, writes to read-only resources, or to reserved spaces terminate with an error. Read access to reserved address generates a transfer error and the read data bus shows all 0s.

38.7.1 LPCMP memory map

LPCMP0 base address: 4004_8000h

LPCMP1 base address: 4004_9000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	0100_0000h
4h	Parameter (PARAM)	32	R	0000_0002h
8h	Comparator Control Register 0 (CCR0)	32	RW	0000_0002h
Ch	Comparator Control Register 1 (CCR1)	32	RW	0000_0000h
10h	Comparator Control Register 2 (CCR2)	32	RW	0000_0000h
18h	DAC Control (DCR)	32	RW	0000_0000h
1Ch	Interrupt Enable (IER)	32	RW	0000_0000h
20h	Comparator Status (CSR)	32	RW	0000_0000h

38.7.2 Version ID (VERID)

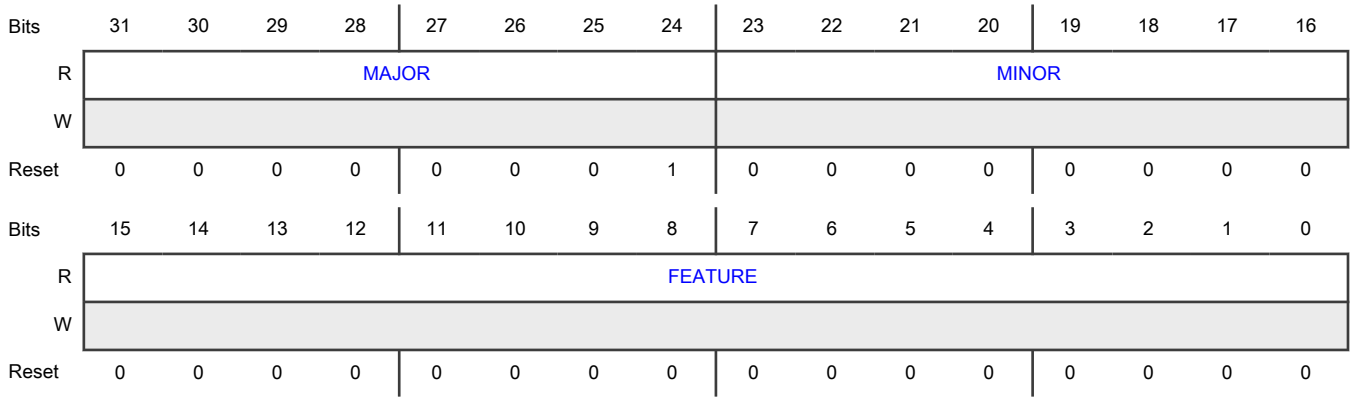
Offset

Register	Offset
VERID	0h

Function

Contains version numbers for the module design and feature set.

Diagram



Fields

Field	Function
31-24 MAJOR	Major Version Number Returns the major version number for the module design.

Table continues on the next page...

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Field	Function
23-16 MINOR	Minor Version Number Returns the minor version number for the module design.
15-0 FEATURE	Feature Specification Number Returns the feature set number. 0000_0000_0000_0001b - Round robin feature

38.7.3 Parameter (PARAM)

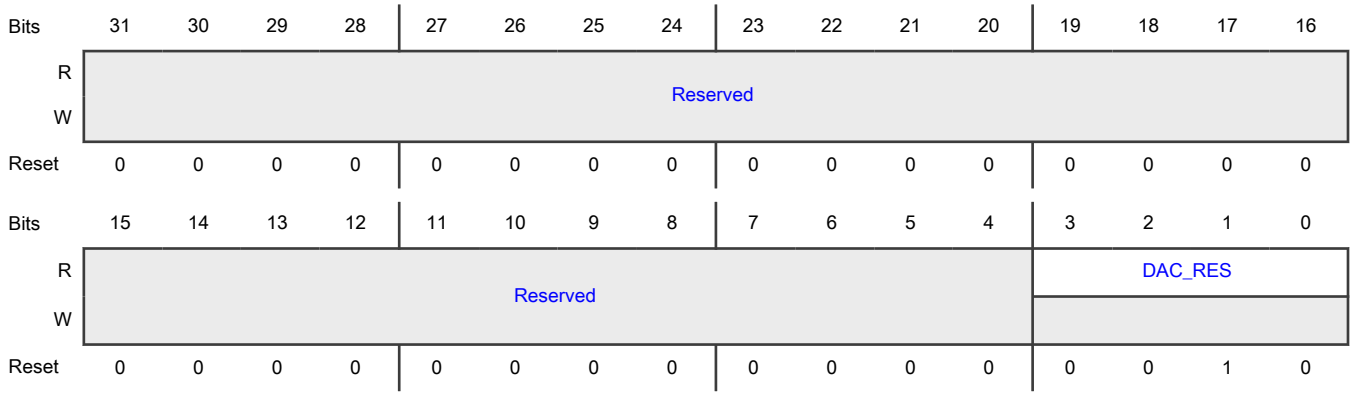
Offset

Register	Offset
PARAM	4h

Function

Contains parameter values that are implemented in the module.

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 DAC_RES	DAC Resolution Indicates supported DAC resolutions.

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Field	Function
	NOTE All other bit field values are reserved. 0000b - 4-bit DAC 0001b - 6-bit DAC 0010b - 8-bit DAC 0011b - 10-bit DAC 0100b - 12-bit DAC 0101b - 14-bit DAC 0110b - 16-bit DAC

38.7.4 Comparator Control Register 0 (CCR0)

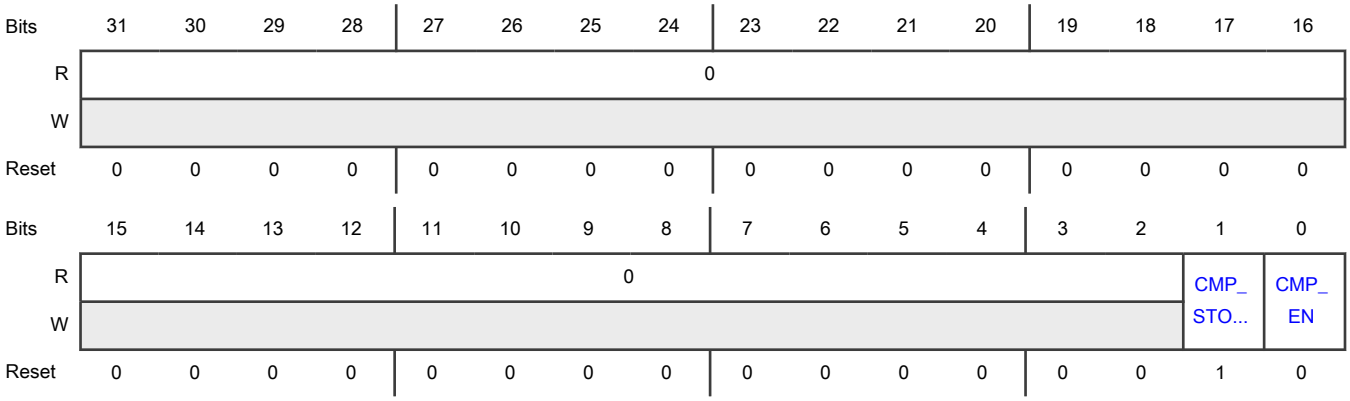
Offset

Register	Offset
CCR0	8h

Function

Contains configuration options for enabling the analog comparator.

Diagram



Fields

Field	Function
31-2	Reserved

Table continues on the next page...

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Field	Function
—	
1 CMP_STOP_EN	Comparator Sleep Mode Enable Enables the analog comparator or the DAC when the module is in Sleep mode. 0b - Disables the analog comparator regardless of CMP_EN. 1b - Allows CMP_EN to enable the analog comparator.
0 CMP_EN	Comparator Enable Enables the analog comparator. 0b - Disable (The analog logic remains off and consumes no power.) 1b - Enable

38.7.5 Comparator Control Register 1 (CCR1)

Offset

Register	Offset
CCR1	Ch

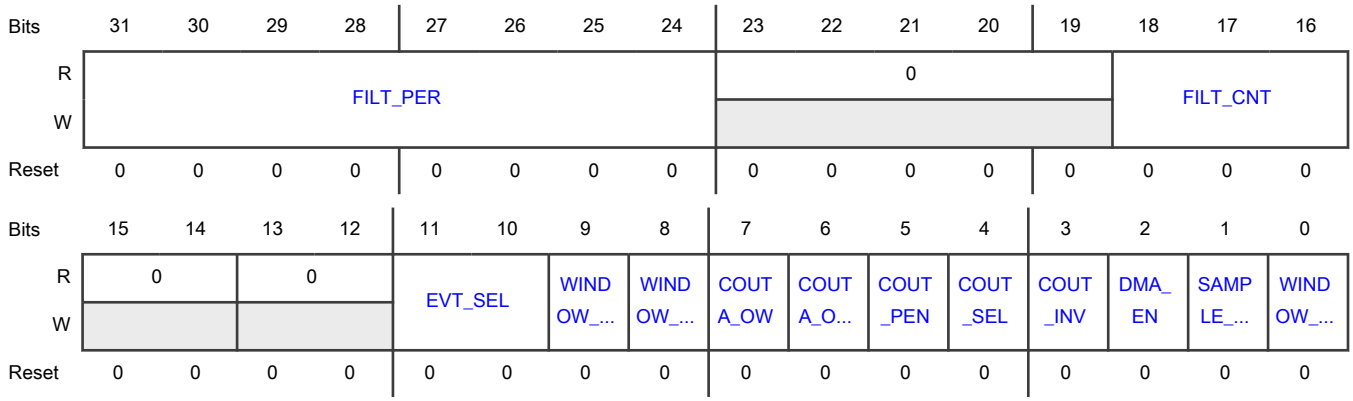
Function

Contains configuration options for the comparator operation, such as enabling Sampling or Windowing mode.

NOTE

You cannot enable Sampling and Windowing modes both at the same time. Sampling mode takes precedence over Windowing mode. If you write 1 to both SAMPLE_EN and WINDOW_EN, only SAMPLE_EN becomes 1.

Diagram



Fields

Field	Function
31-24 FILT_PER	Filter Sample Period Specifies the sampling period (in bus clock cycles) of the comparator output filter. Programming this field to 00h bypasses the filter. See Functional description for more information on filter programming and latency. **NOTE** FILT_PER has no effect in Sampling mode (CCR1[SAMPLE_EN] = 1).
23-19 —	Reserved
18-16 FILT_CNT	Filter Sample Count Specifies the number of consecutive samples that must agree before the comparator output filter accepts the sample as a new valid output state. See Functional description for more information on filter programming and latency. 000b - Filter is bypassed: COUT = COUTA 001b - 1 consecutive sample (Comparator output is simply sampled.) 010b - 2 consecutive samples 011b - 3 consecutive samples 100b - 4 consecutive samples 101b - 5 consecutive samples 110b - 6 consecutive samples 111b - 7 consecutive samples
15-14 —	Reserved
13-12 —	Reserved
11-10 EVT_SEL	CMPO Event Select Selects which CMPO signal edge (rising, falling, or both) defines a CMPO event. **NOTE** Valid only in Windowing mode. 00b - Rising edge 01b - Falling edge 1xb - Both edges
9 WINDOW_CLS	CMPO Event Window Close Enables a CMPO event (defined as a CMPO rising edge, falling edge, or both) to close an active window. See EVT_SEL to configure the CMPO event.

Table continues on the next page...

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Field	Function
	NOTE The WINDOW signal has to go to zero and back to one again to re-activate the window. Valid only in Windowing mode. 0b - CMPO event cannot close the window 1b - CMPO event can close the window
8 WINDOW_INV	WINDOW/SAMPLE Signal Invert Inverts the window/sample signal. 0b - Do not invert 1b - Invert
7 COUTA_OW	COUTA Output Level for Closed Window Defines the COUTA signal value when the window is closed. **NOTE** Valid only in Windowing mode and when COUTA_OWEN=1. 0b - COUTA is 0 1b - COUTA is 1
6 COUTA_OWEN	COUTA_OW Enable Enables the COUTA signal value to be defined by COUTA_OW when the window is closed. **NOTE** Valid only in Windowing mode. 0b - COUTA holds the last sampled value. 1b - Enables the COUTA signal value to be defined by COUTA_OW.
5 COUT_PEN	Comparator Output Pin Enable Enables the comparator output to become an available signal option for a selected package pin. 0b - Not available 1b - Available
4 COUT_SEL	Comparator Output Select Selects which comparator output option, COUT or COUTA, to use for CMPO. 0b - Use COUT (filtered) 1b - Use COUTA (unfiltered)
3 COUT_INV	Comparator Invert Selects the polarity of the analog comparator function, affecting the value driven to the COUT output (on both the chip pin and as CSR[COUT]) when CCR0[CMP_EN] is 0.

Table continues on the next page...

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Field	Function
	0b - Do not invert 1b - Invert
2 DMA_EN	DMA Enable Enables DMA transfers triggered from the LPCMP module. After this field and the corresponding interrupt enable field becomes 1, a DMA request is asserted when CFR or CFF becomes 1. 0b - Disable 1b - Enable
1 SAMPLE_EN	Sampling Enable Enables Sampling mode. 0b - Disable 1b - Enable
0 WINDOW_EN	Windowing Enable Enables Windowing mode. **NOTE** Valid only when SAMPLE_EN = 0. 0b - Disable 1b - Enable

38.7.6 Comparator Control Register 2 (CCR2)

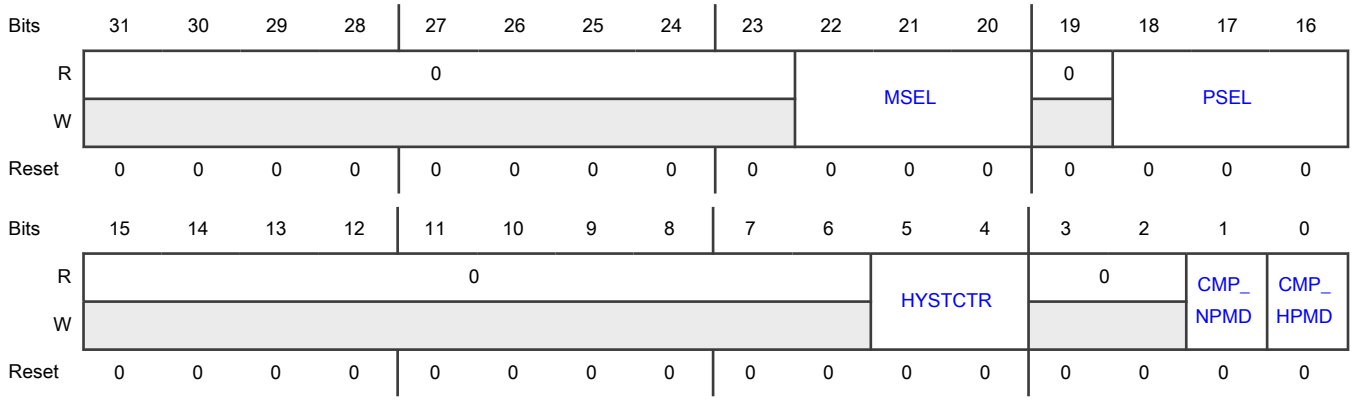
Offset

Register	Offset
CCR2	10h

Function

Contains the configuration options for the comparator operation, such as selecting the plus and minus comparator inputs and the hysteresis levels.

Diagram



Fields

Field	Function
31-23 —	Reserved
22-20 MSEL	Minus Input MUX Select Selects the input used for the negative mux. See the chip-specific LPCMP information for more on connections. 000b - Input 0m 001b - Input 1m 010b - Input 2m 011b - Input 3m 100b - Input 4m 101b - Input 5m 110b - Reserved 111b - Internal DAC output
19 —	Reserved
18-16 PSEL	Plus Input MUX Select Selects the input used for the positive mux. See the chip-specific LPCMP information for more on connections. 000b - Input 0p 001b - Input 1p 010b - Input 2p 011b - Input 3p

Table continues on the next page...

Table continued from the previous page...

Field	Function
	100b - Input 4p 101b - Input 5p 110b - Reserved 111b - Internal DAC output
15-6 —	Reserved
5-4 HYSTCTR	Comparator Hysteresis Control Selects the level of internally generated hysteresis for the comparator output. **NOTE** This applies to the comparator hard block. 00b - Level 0: Analog comparator hysteresis 0 mV. 01b - Level 1: Analog comparator hysteresis 10 mV. 10b - Level 2: Analog comparator hysteresis 20 mV. 11b - Level 3: Analog comparator hysteresis 30 mV.
3-2 —	Reserved
1 CMP_NPMD	CMP Nano Power Mode Select Enables Nano Power mode for the comparator. **NOTE** If the LPCMP is used in deep sleep (or lower) power modes, LPCMP need to enable the nano-power mode via LPCMP_CRR2_CMP_NPMD. 0b - Disables CMP Nano power mode. CCR2[CMP_HPMD] determines the mode for the comparator. 1b - Enables CMP Nano power mode.
0 CMP_HPMD	CMP High Power Mode Select Selects Low or High Power(Speed) mode for the comparator. **NOTE** Valid only when not in Nano Power mode (CMP_NPMD = 0). 0b - Low power (speed) comparison mode 1b - High power (speed) comparison mode

38.7.7 DAC Control (DCR)

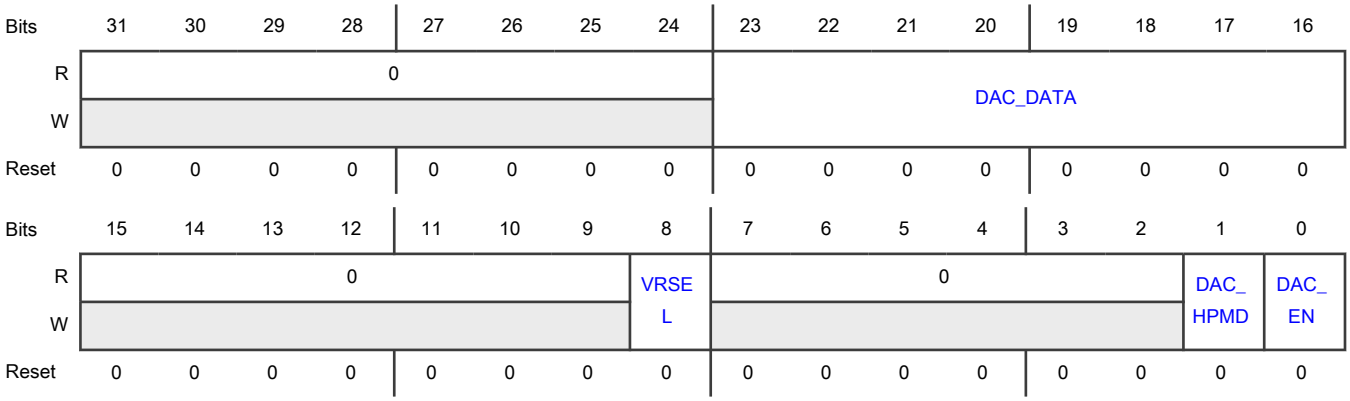
Offset

Register	Offset
DCR	18h

Function

Contains the configuration options to enable the DAC.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 DAC_DATA	DAC Output Voltage Select Selects the DAC output (DACO) voltage from one of 256 distinct levels by configuring the value of DAC_DATA. The DACO ranges from Vin/256 to Vin. **NOTE** DACO = (Vin/256) * (DAC_DATA + 1)
15-9 —	Reserved
8 VRSEL	DAC Reference High Voltage Source Select Selects the high voltage reference source for the Vin supply of the DAC's resistor ladder network. See the chip-specific LPCMP information for the source of vrefh0 and vrefh1. 0b - VREFH0 1b - VREFH1

Table continues on the next page...

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Field	Function
7-2 —	Reserved
1 DAC_HPMD	DAC High Power Mode Enables the DAC high power mode. 0b - Disable 1b - Enable
0 DAC_EN	DAC Enable Enables the DAC. When disabled, power-down the DAC to conserve power. 0b - Disable 1b - Enable

38.7.8 Interrupt Enable (IER)

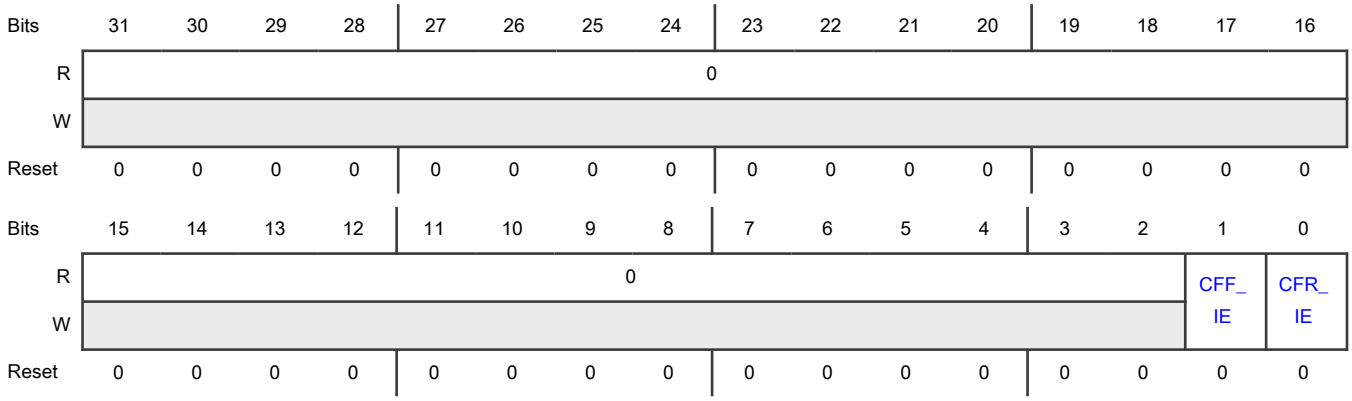
Offset

Register	Offset
IER	1Ch

Function

Provides enable fields for the comparator and round-robin flag interrupts.

Diagram



Fields

Field	Function
31-2 —	Reserved
1 CFF_IE	Comparator Flag Falling Interrupt Enable Enables or disables the comparator flag falling interrupt. 0b - Disables the comparator flag falling interrupt. 1b - Enables the comparator flag falling interrupt when CFF is set.
0 CFR_IE	Comparator Flag Rising Interrupt Enable Enables or disables the comparator flag rising interrupt. 0b - Disables the comparator flag rising interrupt. 1b - Enables the comparator flag rising interrupt when CFR is set.

38.7.9 Comparator Status (CSR)

Offset

Register	Offset
CSR	20h

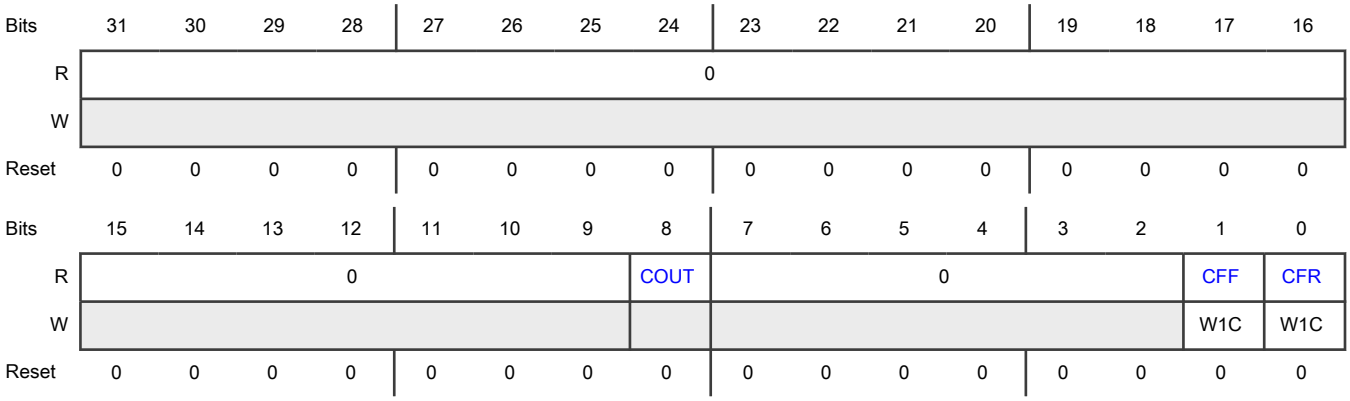
Function

Indicates comparator status, including COUT, CFF, CFR.

NOTE

LPCMP may output a glitch and affect the value of CSR[CFF] and CSR[CFR] at the moment of enabling CMP. In order to ensure correctness, it is recommended to write one to clear (W1C) CSR[CFF] and CSR[CFR] before further configuring CMP.

Diagram



Fields

Field	Function
31-9 —	Reserved
8 COUT	Analog Comparator Output Returns the current value of the analog comparator output when read. This field resets to 0 and reads as CCR1[COUT_INV] after the analog comparator module disables when CCR0[CMP_EN] = 0. Writing to this field is ignored.
7-2 —	Reserved
1 CFF	Analog Comparator Flag Falling Detects when a falling edge on COUT occurs. Write 1 to clear this field when CCR1[DMA_EN] is disabled. If CCR1[DMA_EN] is enabled, the flag automatically clears after DMA is done. This field clears when CCR0[CMP_EN] is not 1. 0b - Not detected 1b - Detected
0 CFR	Analog Comparator Flag Rising Detects when a rising edge on COUT occurs. Write 1 to clear this field when CCR1[DMA_EN] is disabled. If CCR1[DMA_EN] is enabled, the flag automatically clears after DMA is done. This field clears when CCR0[CMP_EN] is not 1. 0b - Not detected 1b - Detected

Chapter 39
Voltage Reference (VREF)

39.1 Chip-specific VREF information

Table 278. Reference links to related information

Topic	Related module	Reference
Full description	VREF	VREF
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

NOTE

The VREF_OUT signal introduced in this chapter is the VREFO signal in the Signal Muxing and Pinout.

39.1.1 Module instances

This device has one instance of the VREF module, VREF0.

39.2 Overview

VREF provides a buffered reference voltage that you can set to levels ranging from 1.0 V to 2.1 V for use as an external reference. When VREF is enabled, the reference voltage, VREF_OUT, is connected to a dedicated output pin. In addition, the buffered reference is available internally for use with on-chip peripherals.

You can trim the VREF voltage output in fine or coarse voltage steps:

- For fine-tuning, use UTRIM[VREFTRIM] to trim the output with (0.05% x VREF_OUT) resolution, where VREF_OUT is the value of the voltage reference output (measured in volts) after using UTRIM[TRIM2V1] to trim the output. For example, after using UTRIM[TRIM2V1] to trim the output VREF_OUT = 1 V, the fine step resolution is : (0.05% x 1) = 0.5 mV.
- For coarse-tuning, use UTRIM[TRIM2V1] to trim the output with 100 mV resolution. For details about possible configurations of the voltage reference, see Table 279

39.2.1 Features

- Programmable User Trim (UTRIM) with 0.05% x VREF_OUT steps in fine-tuning and 100 mV in coarse-tuning. When reset, User Trim (UTRIM) is automatically loaded with a factory-trimmed value.
- Programmable Buffer mode selection:
  - Off
  - Standby mode (Bandgap enabled and output buffer disabled)
  - High-Power Buffer mode (output buffer enabled in High-Power mode)
  - Low-Power Buffer mode (output buffer enabled in Low-Power mode)
- Low-power bandgap and high-accurate bandgap selection
- Support for a dedicated output pin, VREF_OUT

39.2.2 Block diagram

Figure 118 shows the VREF block diagram.

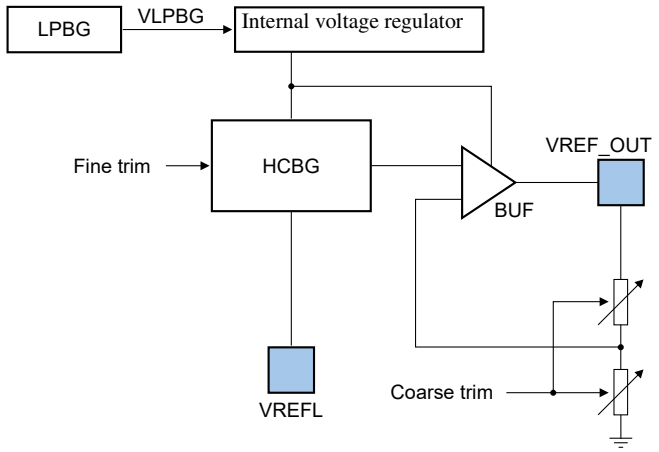


Figure 118. VREF block diagram

39.3 Functional description

VREF is a bandgap buffer system that uses unity gain amplifiers. Both internal and external peripherals use the VREF_OUT signal in Low- and High-Power Buffer modes.

NOTE

When using VREF, a 220 nF capacitor must always be connected between VREF_OUT and Analog Domain Power Supply Ground.

If CSR[HCBGEN] = 1, the voltage reference is enabled, you must set different modes by using CSR[BUF21EN] and CSR[HI_PWR_LV].

The following table shows possible configurations of the voltage reference.

Table 279. VREF_OUT values and related settings

UTRIM[TRIM2V1]	VREF_OUT (V)
0000	1.0
0001	1.1
0010	1.2
0011	1.3
0100	1.4
0101	1.5
0110	1.6
0111	1.7
1000	1.8
1001	1.9
1010	2.0
1011	2.1
11XX	1.0

39.3.1 Voltage reference disabled

When CSR[LPBGEN] = 0, CSR[HCBGEN] = 0, and CSR[BUF21EN] = 0, the voltage reference is disabled and the VREF bandgap and output buffers are disabled. VREF is in Off mode.

39.3.2 Voltage reference enabled

Enabling voltage reference results into the following main high-level configuration options:

- Write 1 to CSR[LPBGEN] and CSR[LPBG_BUF_EN]. This configuration enables the low power bandgap (LPBG) bias current and voltage output.
- Write 1 to CSR[LPBGEN], CSR[REGEN], CSR[BUF21EN], and CSR[HCBGEN], this configuration enables the VREF supply voltage on VREF_OUT.

39.3.2.1 CSR[BUF21EN] = 0, CSR[HI_PWR_LV] = X

In Standby mode, the internal VREF bandgap is enabled to generate an accurate 1.0 V output that you can trim by using UTRIM[VREFTRIM]. The bandgap requires time for startup and stabilization. Monitor CSR[VREFST] to determine whether the stabilization and startup are complete when the chop oscillator is not enabled. When chop oscillator is used, the internal bandgap reference voltage settles within the chop oscillator startup time, Tchop_osc_stup.

The output buffer is disabled in this mode, and there is no buffered voltage output. VREF is in Standby mode. If you select this mode first and Low-Power or High-Power Buffer mode is subsequently enabled, there is a delay before the buffer output settles to its final value. This is the buffer startup delay (Tstup), as specified in the appropriate chip data sheet.

39.3.2.2 CSR[BUF21EN] = 1, CSR[HI_PWR_LV] = 1

In High-Power buffer mode, the internal VREF bandgap is on, and the High-Power Buffer is enabled to generate a buffered voltage to VREF_OUT. The available voltage levels range from 1.0 to 2.1 V and can be adjusted in 0.1 V steps using UTRIM[TRIM2V1]. VREF bandgap can also be used as a reference to internal analog peripherals such as an ADC channel or analog comparator input.

If this mode is entered from Standby mode (CSR[BUF21EN] = 0), there is a delay before the buffer output settles to its final value. This is the buffer startup delay (Tstup), as specified in the appropriate device data sheet.

If this mode is entered when VREF is enabled, you must wait longer than Tstup or until CSR[VREFST] = 1 when the chop oscillator is not enabled. If the chop oscillator is being used, wait for the time specified by Tchop_osc_stup (chop oscillator startup time) to ensure that the VREF output has stabilized.

NOTE

In this mode, a 220-nF capacitor is required to connect between the VREF_OUT pin and Analog Domain Power Supply Ground.

39.3.2.3 CSR[BUF21EN] = 1, CSR[HI_PWR_LV] = 0

In Low-Power buffer mode, the internal VREF bandgap is on, and the low-power buffer is enabled to generate a buffered voltage to VREF_OUT. The available voltage levels range from 1.0 to 2.1 V and you can adjust them in 0.1 V steps using UTRIM[TRIM2V1]. VREF bandgap can be used as a reference to internal analog peripherals such as an ADC channel or analog comparator input.

If this mode is entered from Standby mode (CSR[BUF21EN] = 0), there is a delay before the buffer output settles to its final value. This is the buffer startup delay (Tstup), as specified in the appropriate chip data sheet.

If this mode is entered when the VREF module is enabled, you must wait longer than Tstup or until CSR[VREFST] = 1 when the chop oscillator is not enabled. If the chop oscillator is being used, wait for the time specified by Tchop_osc_stup (chop oscillator startup time) to ensure that the VREF output has stabilized.

NOTE

In this mode, a 220-nF capacitor connects the VREF_OUT pin and Analog Domain Power Supply Ground.

39.3.3 Internal voltage regulator

VREF contains an internal voltage regulator that you can enable to provide additional supply noise rejection. The module also contains an internal chop oscillator to generate the chop clock. When possible, enable the internal regulator and chop oscillator to attain optimum VREF performance.

When using the chop function, you must also enable the internal voltage regulator. Perform the following procedure when enabling the internal regulator:

1. Enable the internal regulator by writing 1 to CSR[REGEN].
2. Enable the chop oscillator by writing 1 to CSR[CHOPEN].
3. Write 1 to CSR[LPBGEN] and CSR[HCBGEN].

39.3.4 Low-Power modes

VREF can run when the chip is in a low-power mode. To use the VREF regulator and/or the chop oscillator in a low-power mode, the system reference voltage (also known as the bandgap voltage reference) must also be enabled in these modes. See the chip-specific VREF information on how to enable the system reference voltage.

Having the VREF regulator enabled increases the current consumption. Depending on the requirements of the system application, consider disabling the VREF regulator to minimize the current consumption in low-power modes. However, not using the VREF regulator reduces the accuracy of the output voltage by as much as several mV.

39.3.5 Clocking

See the chip-specific VREF information for the required clocking.

39.3.6 Reset

System reset, VREF convert to initial state with buffer cleared and waiting to load new register.

39.3.7 Interrupts

This module has no interrupts.

39.4 External signals

Table 280. External signals

Signal	Description	I/O
VREF_OUT	Internally generated voltage reference output. When the VREF output buffer is disabled, the VREF_OUT signal state is high-impedance.	O

39.5 Initialization

VREF_OUT requires time for startup and stabilization. After writing 1 to CSR[HCBGEN], monitor CSR[VREFST] to determine whether the stabilization and startup are complete when the chop oscillator is not enabled. If the chop oscillator is enabled, Tchop_osc_stup defines the settling time of the internal bandgap reference. You must wait for this time (Tchop_osc_stup) after the internal bandgap is enabled to ensure that the VREF internal reference voltage is stabilized.

After VREF_OUT is enabled and stabilized, changing the value of CSR[HI_PWR_LV] temporarily destabilizes the output voltage at the VREF_OUT pin, even though CSR[VREFST] remains 1. The time it takes for VREF_OUT to settle again is the same as the buffer startup delay (Tstup), as specified in the appropriate device data sheet. Also, applying a step change of the load current to the VREF_OUT pin incurs some time delay to resettle.

To enable the internal 1.75 V VREF regulator, see Internal voltage regulator for the required sequence. When the internal regulator is disabled, the VREF_OUT voltage is more sensitive to supply voltage variation. Use the internal regulator to achieve optimum VREF_OUT performance.

NOTE

You must write 1 to CSR[CHOPEN], CSR[REGEN], and CSR[ICOMPEN] to achieve the performance stated in the device data sheet.

39.6 Register descriptions

39.6.1 VREF register descriptions

Register support 32-bit write and support 8-bit, 16-bit, and 32-bit read.

39.6.1.1 VREF memory map

VREF0 base address: 4004_A000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	0100_0000h
8h	Control and Status (CSR)	32	RW	0000_0000h
10h	User Trim (UTRIM)	32	RW	0000_0000h

39.6.1.2 Version ID (VERID)

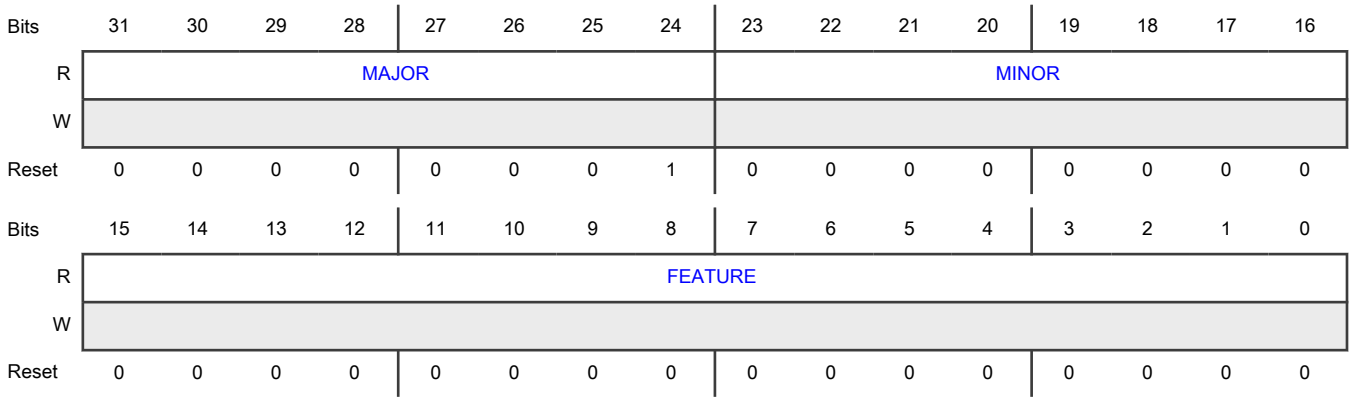
Offset

Register	Offset
VERID	0h

Function

Contains version numbers for the module design and feature set.

Diagram



Fields

Field	Function
31-24 MAJOR	Major Version Number Returns the major version number for the module specification.
23-16 MINOR	Minor Version Number Returns the minor version number for the module specification.
15-0 FEATURE	Feature Specification Number Returns the feature set number.

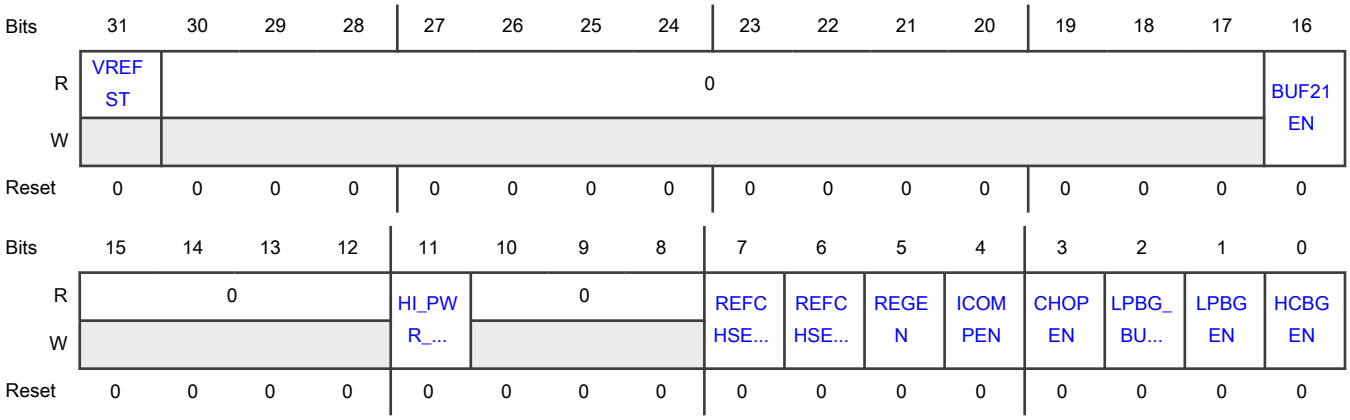
39.6.1.3 Control and Status (CSR)

Offset

Register	Offset
CSR	8h

Function
Contains the VREF control and status fields.

Diagram



Fields

Field	Function
31 VREFST	Internal HC Voltage Reference Stable Indicates whether the bandgap reference within VREF has completed its startup and stabilization. **NOTE** This field is valid only when you do not use the chop oscillator.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Disabled and unstable 1b - Stable
30-17 —	Reserved
16 BUF21EN	Internal Buffer21 Enable Enables the Buffer21 programmable output voltage from 1.0 to 2.1 V. 0b - Disables 1b - Enables
15-12 —	Reserved
11 HI_PWR_LV	High-Power Level Controls the power mode of Buffer21. 0b - Low-power 1b - High-power
10-8 —	Reserved
7 REFCHSELP_EN	Reference Channel Select Positive Enable Enables the ADC positive channel to receive the reference voltage. 0b - Disables 1b - Enables
6 REFCHSELN_EN	Reference Channel Select Negative Enable Enables the ADC negative channel to receive the reference voltage. 0b - Disables 1b - Enables
5 REGEN	Regulator Enable Enables the internal 1.75 V regulator to produce a constant internal voltage supply to reduce the sensitivity to external supply noise and variation. See Internal voltage regulator for the required sequence to enable the internal regulator. To keep the regulator enabled in low-power modes, see the chip-specific VREF information for details. **NOTE** You must write 1 to this field to achieve the performance stated in the data sheet.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Disables 1b - Enables
4 ICOMPEN	Current Compensation Enable Enables second-order curvature compensation. **NOTE** You must write 1 to this field to achieve the performance stated in the data sheet. 0b - Disables 1b - Enables
3 CHOPEN	Chop Oscillator Enable Enables the chop oscillator. When set, the internal chopping operation is enabled and the internal analog offset is minimized. When using the internal voltage regulator CSR[REGEN] = 1, you must also enable the chop oscillator. If the chop oscillator is used in low-power modes, you must also enable the HC bandgap voltage reference. See the chip-specific VREF information for details. 0b - Disables 1b - Enables
2 LPBG_BUF_EN	Low-Power Bandgap Buffer Enable Enables the low-power buffer for the low-power bandgap with latch function enabled. **NOTE** You can enable this field only when CSR[LPBGEN] = 1. 0b - Disables 1b - Enables
1 LPBGEN	Low-Power Bandgap Enable Enables the low-power bandgap. 0b - Disables 1b - Enables
0 HCBGEN	HC Bandgap Enabled Enables the HC bandgap. **NOTE** You can enable this field only when CSR[LPBGEN] = 1. 0b - Disables 1b - Enables

39.6.1.4 User Trim (UTRIM)

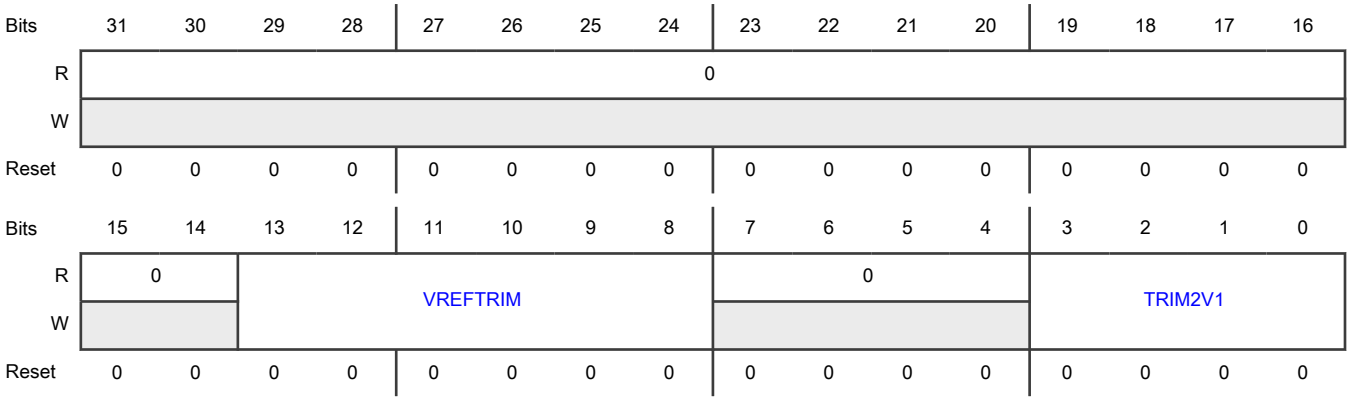
Offset

Register	Offset
UTRIM	10h

Function

Contains the trim data. You can read and write to this register in User mode. After reset, UTRIM is automatically loaded with a factory-trimmed value.

Diagram



Fields

Field	Function
31-14 —	Reserved
13-8 VREFTRIM	VREF Trim This is an unsigned number that adjusts the VREF output by (0.5 x VREF_OUT_Nom) mV, where VREF_OUT_Nom is the target output determined by the TRIM2V1 setting. For example, if TRIM2V1 is set to output 1.0 V, VREFTRIM adjusts the output in 0.5 mV steps.
7-4 —	Reserved
3-0 TRIM2V1	VREF 2.048 V Trim Changes the resulting VREF output by approximately ± 100 mV for each step. For details about possible configurations of the voltage reference, see Table 279.

Chapter 40
Real Time Clock (RTC)

40.1 Chip-specific RTC information

Table 281. Reference links to related information

Topic	Related module	Reference
Full description	RTC	RTC
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

40.1.1 Module instances

- This device has one instance of the RTC module, RTC0.
- In this device, the supply of RTC OSC32K is internally tied to VDD_IO_D.
- Not all the tamper pins are available for each package, see Package pinout for details.

40.1.2 RTC_CLKOUT and RTC_WAKEUP_b

This device has no direct pinout for RTC_CLKOUT or RTC_WAKEUP_b, but the TAMPER pins can be configured to get these signals:

- CR[CPE] can be used to enable RTC_CLKOUT function on TAMPER1 or TAMPER2 if available
- CR[WPE] can be used to enable RTC_WAKEUP_b function on TAMPER0 if available.

40.2 Overview

40.2.1 Block diagram

The following figure is the block diagram of this module.

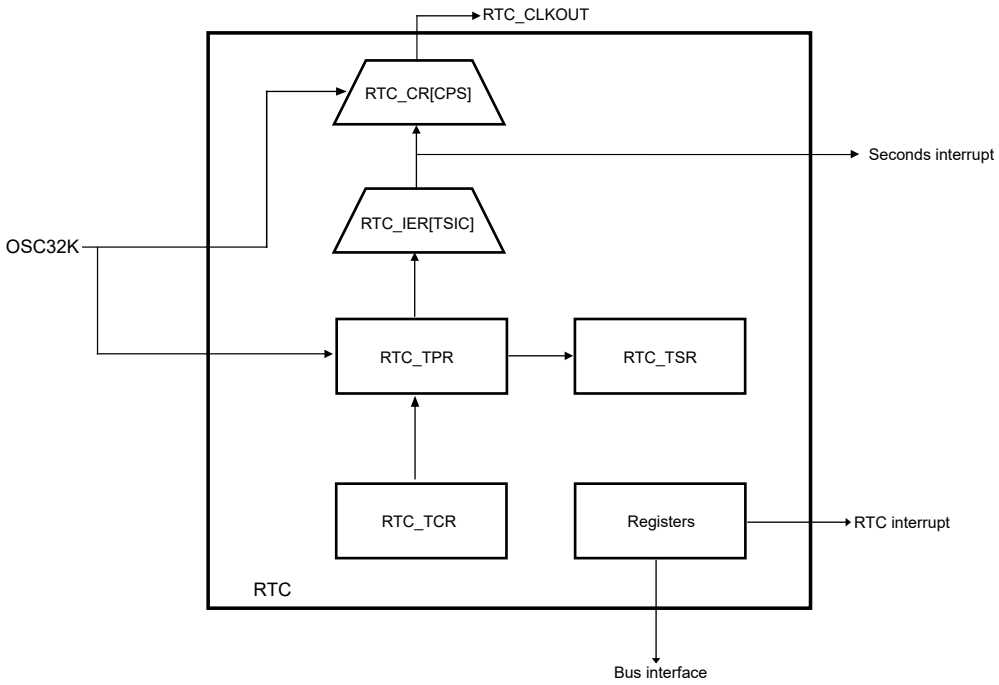


Figure 119. RTC module block diagram

40.2.2 Features

The RTC module features include:

- 32-bit seconds counter with roll-over protection and 32-bit alarm
- 16-bit prescaler with compensation that can correct errors between 0.12 ppm and 3906 ppm
- Register write protection
  - Lock register requires POR or software reset to enable write access
- Configurable 1, 2, 4, 8, 16, 32, 64 or 128 Hz square wave output with optional interrupt
- 64-bit monotonic counter with roll-over protection
- Up to 8 tamper input pins with optional interrupt and seconds timestamp when interrupt asserts

40.3 Functional description

40.3.1 Power

The RTC is an always powered block that remains active in all low power modes.

40.3.2 Time counter

The time counter consists of a 32-bit seconds counter that increments once every second and a 16-bit prescaler register that increments once every 32.768 kHz clock cycle.

Reading the time counter (either seconds or prescaler) while it is incrementing may return invalid data due to synchronization of the read data bus. If it is necessary for software to read the prescaler or seconds counter when they could be incrementing, it is recommended that two read accesses are performed and that software verifies that the same data was returned for both reads.

The time seconds register and time prescaler register can be written only when SR[TCE] is clear. Always write to the prescaler register before writing to the seconds register, because the seconds register increments on the falling edge of bit 14 of the prescaler register.

The time prescaler register increments provided SR[TCE] is set, SR[TIF] is clear, SR[TOF] is clear, and the 32.768 kHz (or 1 kHz) clock source is present. After enabling the oscillator, wait the oscillator startup time before setting SR[TCE] to allow time for the oscillator clock output to stabilize.

If the time seconds register overflows, SR[TOF] is set and the time prescaler register stops incrementing. Clear SR[TOF] by initializing the time seconds register. The time seconds register and time prescaler register read as zero whenever SR[TOF] is set.

SR[TIF] is set on VBAT POR, software reset, and when an enabled tamper source is detected. It is cleared by clearing the enabled tamper detect flag and then initializing the time seconds register. The time seconds register and time prescaler register read as zero whenever SR[TIF] is set.

40.3.3 Compensation

The compensation logic provides an accurate and wide compensation range and can correct errors as high as 3906 ppm and as low as 0.12 ppm. The compensation factor must be calculated externally to the RTC and supplied by software to the compensation register. The RTC itself does not calculate the amount of compensation that is required, although the 1 Hz clock is output to an external pin in support of external calibration logic.

Crystal compensation can be supported by using firmware and crystal characteristics to determine the compensation amount. Temperature compensation can be supported by firmware that periodically measures the external temperature via ADC and updates the compensation register based on a look-up table that specifies the change in crystal frequency over temperature.

The compensation logic alters the number of 32.768 kHz clock cycles it takes for the prescaler register to overflow and increment the time seconds counter. The time compensation value is used to adjust the number of clock cycles between -127 and +128. Cycles are added or subtracted from the prescaler register when the prescaler register equals 0x3FFF and then increments. The compensation interval is used to adjust the frequency at which the time compensation value is used, that is, from once a second to once every 256 seconds.

Updates to the time compensation register do not take effect until the next time the time seconds register increments and provided the previous compensation interval has expired. When the compensation interval is set to other than once a second then the compensation is applied in the first second interval and the remaining second intervals receive no compensation.

Compensation is disabled by configuring the time compensation register to zero.

40.3.4 Time alarm

The Time Alarm register (TAR), SR[TAF], and IER[TAIE] allow the RTC to generate an interrupt at a predefined time. The 32-bit TAR is compared with the 32-bit Time Seconds register (TSR) each time it increments. SR[TAF] is set when TAR equals TSR and TSR increments.

SR[TAF] is cleared by writing TAR. This is usually the next alarm value, although writing a value that is less than TSR (such as 0) prevents SR[TAF] from setting again. SR[TAF] cannot otherwise be disabled, although the interrupt it generates is enabled or disabled by IER[TAIE].

40.3.5 Update mode

The Update Mode field in the Control register (CR[UM]) configures software write access to the Time Counter Enable (SR[TCE]) field. When CR[UM] is clear, SR[TCE] can be written only when LR[SRL] is set. When CR[UM] is set, SR[TCE] can also be written when SR[TCE] is clear or when SR[TIF] or SR[TOF] are set. This allows the time seconds and prescaler registers to be initialized whenever time is invalidated, while preventing the time seconds and prescaler registers from being changed on the fly. When LR[SRL] is set, CR[UM] has no effect on SR[TCE].

CR[UM] also configures software write access to the Monotonic Counter Enable (MER[MCE]) bit. When CR[UM] is clear, MER[MCE] can be written only when LR[MEL] is set. When CR[UM] is set, MER[MCE] can also be written when MER[MCE] is clear or when SR[TIF] or SR[MOF] are set. This allows the monotonic counter register to be initialized whenever the monotonic counter is invalid, while preventing the monotonic counter from being changed on the fly. When LR[MEL] is set, CR[UM] has no effect on MCR[MCE].

40.3.6 Monotonic counter

The 64-bit Monotonic Counter is a counter that cannot be exhausted or return to any previous value, once it has been initialized. If the monotonic overflow flag is set, the monotonic counter returns zero and does not increment.

Depending on the value of the monotonic counter enable bit, writing to the monotonic counter either initializes the register with the value written, or increments the register by one (and the value written is ignored).

When the monotonic counter is enabled, the monotonic counter high increments on either a write to the monotonic counter high register or if the monotonic counter low register overflows (due to a write to the monotonic counter low register). The monotonic overflow flag sets when the monotonic counter high register overflows and is cleared by writing the monotonic counter high register when the monotonic counter is disabled.

The monotonic counter is held in reset whenever the time invalid flag is set. Always clear the time invalid flag before initializing the monotonic counter.

40.3.7 Tamper detect

Each external tamper pin and internal tamper source can be configured to generate a tamper interrupt. The contents of the seconds register are latched in the tamper time seconds register when the tamper interrupt asserts. Read the tamper time seconds register before clearing the flag in the tamper detect register.

Writing the tamper time seconds register at any time will set the time invalid flag. Since this is a software initiated tamper, there is no status flag to indicate this tamper source. To disable the software initiated tamper, lock the tamper time seconds register to prevent write accesses to that register.

40.3.8 Register lock

The Lock register (LR) can be used to block write accesses to certain registers until the next POR or software reset. Locking the Control register (CR) disables the software reset. Locking LR blocks future updates to LR.

Write accesses to a locked register are ignored and do not generate a bus error.

40.3.9 Modes of operation

The RTC remains functional in all low power modes and can generate an interrupt to exit any low power mode.

40.3.10 Clocking

The time counter within the RTC is clocked by default from a 32.768 kHz clock.

The 32.768 kHz crystal oscillator is disabled at POR and must be enabled by software. After enabling the crystal oscillator, wait the oscillator startup time before setting SR[TCE] or using the oscillator clock external to the RTC.

The crystal oscillator includes tunable capacitors that can be configured by software. Do not change the capacitance unless the oscillator is disabled.

40.3.11 Reset

The power-on-reset signal initializes all RTC registers to their default state. A software reset bit can also initialize all RTC registers.

Writing 1 to CR[SWR] forces the equivalent of a POR to the rest of the RTC module. CR[SWR] is not affected by the software reset and must be cleared by software.

40.3.12 Interrupts

The RTC interrupt is asserted whenever a status flag and the corresponding interrupt enable bit are both set. It is always asserted on POR, and software reset. The RTC interrupt is enabled at the chip level by enabling the chip-specific RTC clock gate control bit. The RTC interrupt can be used to wakeup the chip from any low-power mode. If the RTC wakeup pin is enabled and the chip is powered down, the RTC interrupt causes the wakeup pin to assert.

The RTC interrupt is also asserted when a configured tamper flag asserts and the corresponding tamper interrupt enable bit is set. Both internal tamper events and external tamper pins can cause the tamper interrupt to assert. The contents of the seconds register are recorded in the tamper time seconds register when the tamper interrupt asserts.

The RTC seconds interrupt is an edge-sensitive interrupt with a dedicated interrupt vector that is generated once a second and requires no software overhead (there is no corresponding status flag to clear). It is enabled in the RTC by the time seconds interrupt enable bit and enabled at the chip level by setting the chip-specific RTC clock gate control bit. The frequency of the seconds interrupt defaults to 1 Hz, but can instead be configured to trigger every 2, 4, 8, 16, 32, 64 or 128 Hz. The RTC seconds interrupt does not cause the RTC wakeup pin to assert.

40.4 External signals

Table 282. RTC external signals description

Signal	Description	I/O
RTC_CLKOUT	Prescaler square-wave output or RTC 32.768 kHz clock	O
RTC_WAKEUP_b	Active low wakeup for external device	O
RTC_TAMPER[7:0]	Tamper pin input	I

40.4.1 RTC clock output

The RTC_CLKOUT signal can output either a square wave prescaler output (configurable to 1, 2, 4, 8, 16, 32, 64 or 128 Hz) or the RTC 32.768 kHz clock.

40.4.2 RTC wakeup pin

The RTC wakeup pin is an open drain, active low, output that allows the RTC to wakeup the chip via an external component. The wakeup pin asserts when the wakeup pin enable is set and either the RTC interrupt is asserted or the wakeup pin is turned on via a register bit. The wakeup pin does not assert from the RTC seconds interrupt.

NOTE

The wakeup pin is optional and may not be implemented on all devices.

40.4.3 RTC Tamper pins

The RTC tamper pins are input pins that can be used to generate an interrupt or invalidate the time counter. The first tamper pin to assert an interrupt will also capture a timestamp of the seconds register.

40.5 Initialization

To initialize the RTC time counter:

1. Enable the desired clock source for the RTC.
2. Initialize the time prescaler register by writing RTC_TPR[TPR] with the appropriate time value between 0x0 and 0x7FFF.
3. Initialize the time second register by writing RTC_TSR[TSR] with the appropriate time value that is greater than 0x0.
4. Enable the time counter by writing RTC_SR[SR]=0x10.

40.6 Register descriptions

All registers must be accessed using 32-bit writes and all register accesses incur three wait states.

When the supervisor access control bit is clear, only supervisor mode software can write to the RTC registers or read the RTC tamper and monotonic registers. Writes to the RTC registersor reads of the RTC tamper and monotonic registers by non-supervisor mode software generate a bus error. Both supervisor and non-supervisor mode software can always read the otherRTC registers.

Writing to a register protected by the lock register does not generate a bus error, but the writes can not be completed.

40.6.1 RTC register descriptions

40.6.1.1 RTC memory map

RTC base address: 4002_C000h

Offset	Register	Width (In bits)	Access	Reset value
0h	RTC Time Seconds (TSR)	32	RW	0000_0000h
4h	RTC Time Prescaler (TPR)	32	RW	0000_0000h
8h	RTC Time Alarm (TAR)	32	RW	0000_0000h
Ch	RTC Time Compensation (TCR)	32	RW	0000_0000h
10h	RTC Control (CR)	32	RW	0000_0002h
14h	RTC Status (SR)	32	RW	0000_0001h
18h	RTC Lock (LR)	32	RW	00FF_FFFFh
1Ch	RTC Interrupt Enable (IER)	32	RW	0000_0007h
20h	RTC Tamper Time Seconds (TTSR)	32	R	See section
24h	RTC Monotonic Enable (MER)	32	RW	0000_0000h
28h	RTC Monotonic Counter Low (MCLR)	32	RW	0000_0000h
2Ch	RTC Monotonic Counter High (MCHR)	32	RW	0000_0000h
34h	RTC Tamper Detect (TDR)	32	RW	0000_0001h
3Ch	RTC Tamper Interrupt (TIR)	32	RW	0000_0000h
40h - 5Ch	RTC Pin Configuration (PCR0 - PCR7)	32	RW	0000_0000h

40.6.1.2 RTC Time Seconds (TSR)

Offset

Register	Offset
TSR	0h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	TSR															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	TSR															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 TSR	Time Seconds Register When the time counter is enabled, the TSR is read only and increments once a second provided SR[TOF] or SR[TIF] is not set. The time counter reads as zero when SR[TOF] or SR[TIF] is set. When the time counter is disabled, the TSR can be read or written. Writing to the TSR when the time counter is disabled clears SR[TOF] or SR[TIF]. Writing to TSR with zero is supported, but not recommended because TSR reads as zero when SR[TIF] or SR[TOF] is set (indicating the time is invalid).

40.6.1.3 RTC Time Prescaler (TPR)

Offset

Register	Offset
TPR	4h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	TPR															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

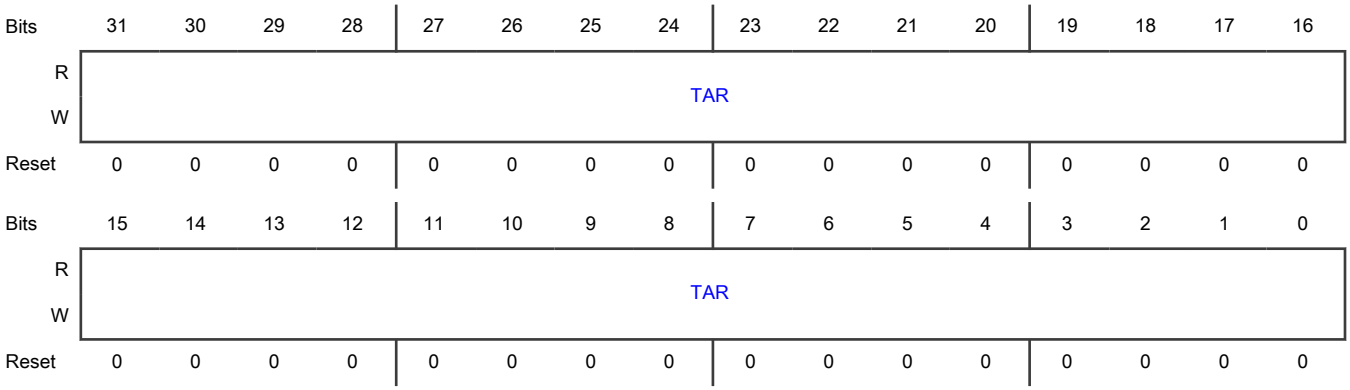
Field	Function
31-16 —	Reserved
15-0 TPR	Time Prescaler Register When the time counter is enabled, the TPR is read only and increments every 32.768 kHz clock cycle. The time counter reads as zero when SR[TOF] or SR[TIF] are set. When the time counter is disabled, the TPR can be read or written. The TSR[TSR] increments when bit 14 of the TPR transitions from a logic one to a logic zero.

40.6.1.4 RTC Time Alarm (TAR)

Offset

Register	Offset
TAR	8h

Diagram



Fields

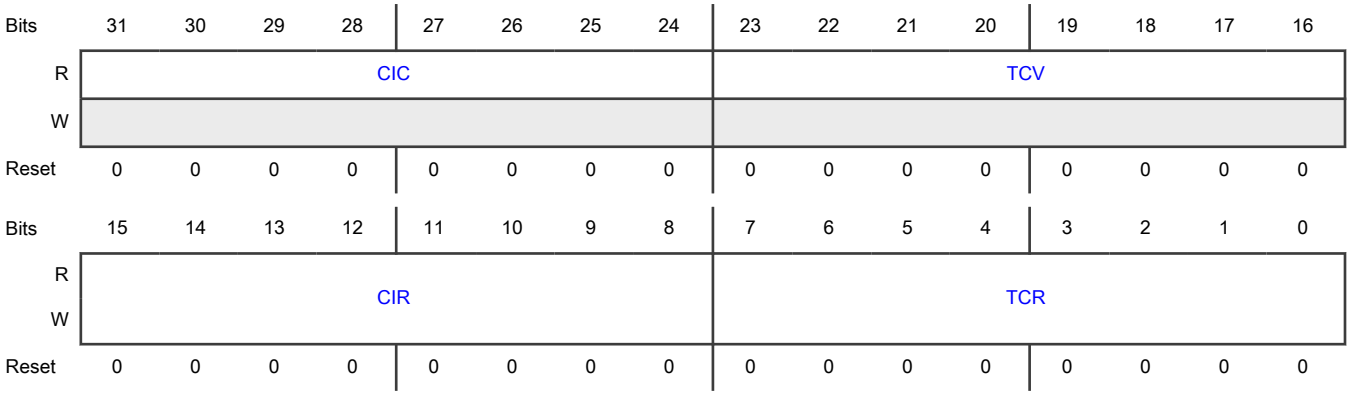
Field	Function
31-0 TAR	Time Alarm Register When the time counter is enabled, the SR[TAF] is set whenever the TAR[TAR] equals the TSR[TSR] and the TSR[TSR] increments. Writing to the TAR clears the SR[TAF].

40.6.1.5 RTC Time Compensation (TCR)

Offset

Register	Offset
TCR	Ch

Diagram



Fields

Field	Function
31-24 CIC	Compensation Interval Counter Current value of the compensation interval counter. If the compensation interval counter equals zero then it is loaded with the contents of the CIR. If the CIC does not equal zero then it is decremented once a second. Reading this register at the same time as the seconds counter is incrementing can result in an incorrect value being read.
23-16 TCV	Time Compensation Value Current value used by the compensation logic for the present second interval. Updated once a second if the CIC equals 0 with the contents of the TCR field. If the CIC does not equal zero then it is loaded with zero (compensation is not enabled for that second increment). Reading this register at the same time as the seconds counter is incrementing can result in an incorrect value being read.
15-8 CIR	Compensation Interval Register Configures the compensation interval in seconds from 1 to 256 to control how frequently the TCR should adjust the number of 32.768 kHz cycles in each second. The value written should be one less than the number of seconds. For example, write zero to configure for a compensation interval of one second. This register is double buffered and writes do not take effect until the end of the current compensation interval.
7-0 TCR	Time Compensation Register Configures the number of 32.768 kHz clock cycles in each second, equal to 32,768 - TCR (where TCR is a twos complement sign extended value). This register is double buffered and writes do not take effect until the end of the current compensation interval. Some example values are shown below.

Table continues on the next page...

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Field	Function
	0000_0000b - Time Prescaler Register overflows every 32768 clock cycles. 0000_0001b - Time Prescaler Register overflows every 32767 clock cycles. 0111_1110b - Time Prescaler Register overflows every 32642 clock cycles. 0111_1111b - Time Prescaler Register overflows every 32641 clock cycles. 1000_0000b - Time Prescaler Register overflows every 32896 clock cycles. 1000_0001b - Time Prescaler Register overflows every 32895 clock cycles. 1111_1111b - Time Prescaler Register overflows every 32769 clock cycles.

40.6.1.6 RTC Control (CR)

Offset

Register	Offset
CR	10h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0					CPE			0						Reserved	
W															0	
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	CLKO	Reserved	Reserved	0	CPS	Reserved	UM	Reserved	WPE	SWR
W	0	0	0	0	0	0		0	0			0		0		
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Fields

Field	Function
31-27 —	Reserved
26-24 CPE	Clock Pin Enable Specifies whether to enable or disable RTC_CLKOUT: 000b - Disables

Table continues on the next page...

Table continued from the previous page...

Field	Function
	001b - Enables RTC_CLKOUT function on RTC_TAMPER[1]. 010b - Enables RTC_CLKOUT function on RTC_TAMPER[2]. 011b - Enables RTC_CLKOUT function on RTC_TAMPER[3]. 100b - Enables RTC_CLKOUT function on RTC_TAMPER[4]. 101b - Enables RTC_CLKOUT function on RTC_TAMPER[5]. 110b - Enables RTC_CLKOUT function on RTC_TAMPER[6]. 111b - Enables RTC_CLKOUT function on RTC_TAMPER[7].
23-18 —	Reserved
17-16 —	Reserved
15 —	Reserved
14 —	Reserved
13 —	Reserved
12 —	Reserved
11 —	Reserved
10 —	Reserved
9 CLKO	Clock Output 0b - The 32 kHz clock is output to other peripherals. 1b - The 32 kHz clock is not output to other peripherals.
8 —	Reserved
7 —	Reserved

Table continues on the next page...

Table continued from the previous page...

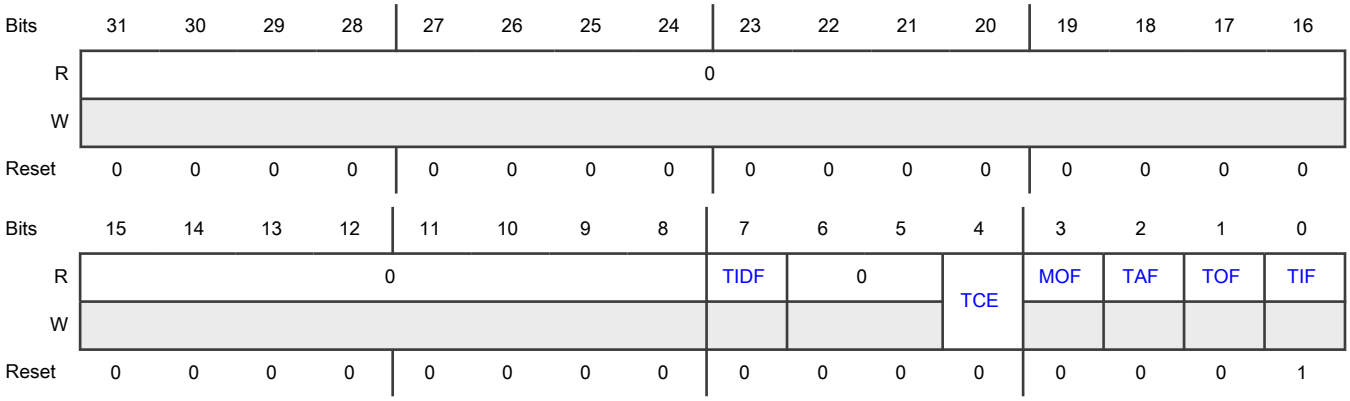
Field	Function
6 —	Reserved
5 CPS	Clock Pin Select 0b - The prescaler output clock (as configured by TSIC) is output on RTC_CLKOUT. 1b - The RTC 32.768 kHz clock is output on RTC_CLKOUT, provided it is output to other peripherals.
4 —	Reserved
3 UM	Update Mode Allows SR[TCE] to be written even when the Status Register is locked. When set, the SR[TCE] can be written if the SR[TIF] or SR[TOF] are set or if the SR[TCE] is clear. Whenever both SR[TCE] and CR[UM] are set, then SR[TCE] should only be written once either SR[TIF] or SR[TOF] are set. Allows the monotonic enable register to be written when it is locked. When set, the monotonic enable register can always be written if the SR[TIF] or SR[MOF] are set or if the montonic counter enable is clear. Allows the tamper detect register to be written when it is locked. When set, the tamper detect register can always be written if the SR[TIF] is clear. 0b - Registers cannot be written when locked. 1b - Registers can be written when locked under limited conditions.
2 —	Reserved
1 WPE	Wakeup Pin Enable The RTC_WAKEUP pin is optional and not available on all devices. 0b - RTC_WAKEUP pin is disabled. 1b - RTC_WAKEUP pin is enabled and asserts if the RTC interrupt asserts or if the wakeup pin is forced on.
0 SWR	Software Reset 0b - No effect. 1b - Resets all RTC registers except for this bit . This bit is cleared by POR and by software explicitly clearing it.

40.6.1.7 RTC Status (SR)

Offset

Register	Offset
SR	14h

Diagram



Fields

Field	Function
31-8 —	Reserved
7 TIDF	Tamper Interrupt Detect Flag Indicates whether the tamper interrupt has asserted: • The Tamper Interrupt Detect Flag is set whenever the Tamper interrupt is asserted, as configured by the Tamper Status Register and Tamper Interrupt Enable Register. 0b - Tamper interrupt has not asserted. 1b - Tamper interrupt has asserted.
6-5 —	Reserved
4 TCE	Time Counter Enable Specifies whether to enable or disable time counter: 0b - Disables. When time counter is disabled the TSR register and TPR register are writeable, but do not increment. 1b - Enables. When time counter is enabled the TSR register and TPR register are not writeable, but increment.
3 MOF	Monotonic Overflow Flag Indicates whether monotonic overflow has occurred: • Monotonic overflow flag is set when the monotonic counter is enabled and the monotonic counter high overflows. The monotonic counter does not increment and will read as zero when this bit is set. • This bit is cleared by writing the monotonic counter high register when the monotonic counter is disabled. 0b - Monotonic counter overflow has not occurred.

Table continues on the next page...

Table continued from the previous page...

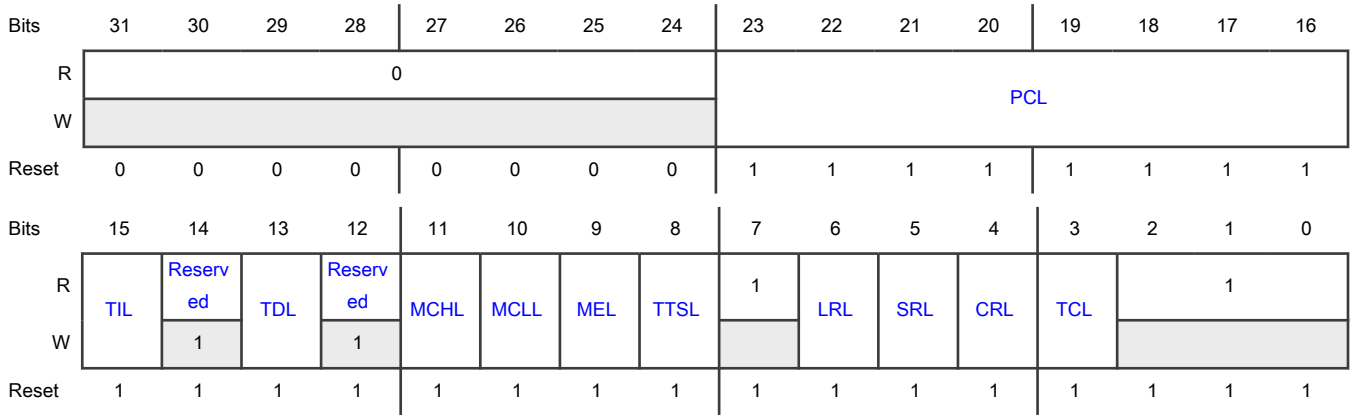
Field	Function
	1b - Monotonic counter overflow has occurred and monotonic counter is read as zero.
2 TAF	Time Alarm Flag • Is set when the TAR[TAR] equals the TSR[TSR] and the TSR[TSR] increments. • Is cleared by writing the TAR register. • Indicates whether time alarm has occured: 0b - Time alarm has not occurred. 1b - Time alarm has occurred.
1 TOF	Time Overflow Flag • Is set when the time counter is enabled and overflows. The TSR and TPR do not increment and read as zero when this bit is set. • Is cleared by writing the TSR register when the time counter is disabled. • Indicates whether time overflow has occured: 0b - Time overflow has not occurred. 1b - Time overflow has occurred and time counter reads as zero.
0 TIF	Time Invalid Flag • The time invalid flag is set on POR or software reset. • The TSR and TPR do not increment and read as zero when this bit is set. • This bit is cleared by writing the TSR register when the time counter is disabled. • The monotonic counter register is held in reset whenever the time invalid flag is set. • Indicates whether the time is valid or invalid: 0b - Time is valid. 1b - Time is invalid and time counter is read as zero.

40.6.1.8 RTC Lock (LR)

Offset

Register	Offset
LR	18h

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 PCL	Pin Configuration Lock After being cleared, this bit can be set only by VBAT POR or software reset. 0000_0000b - Pin Configuration Register is locked and writes are ignored. 0000_0001b - Pin Configuration Register is not locked and writes complete as normal.
15 TIL	Tamper Interrupt Lock After being cleared, this bit can be set only by VBAT POR or software reset. 0b - Tamper Interrupt Register is locked and writes are ignored. 1b - Tamper Interrupt Register is not locked and writes complete as normal.
14 —	Reserved
13 TDL	Tamper Detect Lock After being cleared, this bit can be set only by VBAT POR or software reset. 0b - Tamper Detect Register is locked and writes are ignored. 1b - Tamper Detect Register is not locked and writes complete as normal.
12 —	Reserved
11 MCHL	Monotonic Counter High Lock After being cleared, this bit can be set only by VBAT POR or software reset.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Monotonic Counter High Register is locked and writes are ignored. 1b - Monotonic Counter High Register is not locked and writes complete as normal.
10 MCLL	Monotonic Counter Low Lock After being cleared, this bit can be set only by VBAT POR or software reset. 0b - Monotonic Counter Low Register is locked and writes are ignored. 1b - Monotonic Counter Low Register is not locked and writes complete as normal.
9 MEL	Monotonic Enable Lock After being cleared, this bit can be set only by VBAT POR or software reset. 0b - Monotonic Enable Register is locked and writes are ignored. 1b - Monotonic Enable Register is not locked and writes complete as normal.
8 TTSL	Tamper Time Seconds Lock After being cleared, this bit can be set only by VBAT POR or software reset. 0b - Tamper Time Seconds Register is locked and writes are ignored. 1b - Tamper Time Seconds Register is not locked and writes complete as normal.
7 —	Reserved
6 LRL	Lock Register Lock After being cleared, this bit can be set only by POR or software reset. 0b - Lock Register is locked and writes are ignored. 1b - Lock Register is not locked and writes complete as normal.
5 SRL	Status Register Lock After being cleared, this bit can be set only by POR or software reset. 0b - Status Register is locked and writes are ignored. 1b - Status Register is not locked and writes complete as normal.
4 CRL	Control Register Lock After being cleared, this bit can only be set by POR. 0b - Control Register is locked and writes are ignored. 1b - Control Register is not locked and writes complete as normal.
3 TCL	Time Compensation Lock After being cleared, this bit can be set only by POR or software reset.

Table continues on the next page...

Table continued from the previous page...

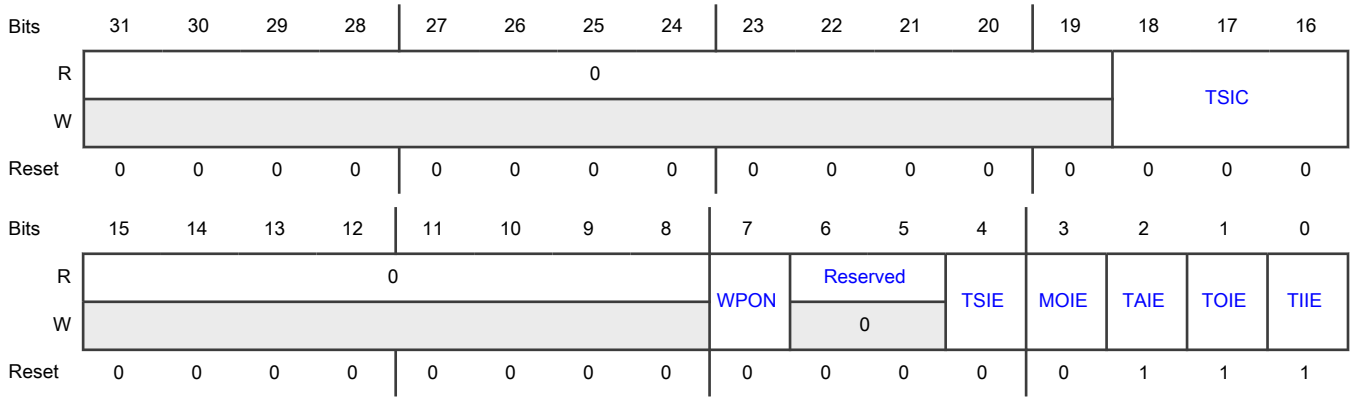
Field	Function
	0b - Time Compensation Register is locked and writes are ignored. 1b - Time Compensation Register is not locked and writes complete as normal.
2-0 —	Reserved

40.6.1.9 RTC Interrupt Enable (IER)

Offset

Register	Offset
IER	1Ch

Diagram



Fields

Field	Function
31-19 —	Reserved
18-16 TSIC	Timer Seconds Interrupt Configuration Configures the frequency of the RTC Seconds interrupt and the RTC_CLKOUT prescaler output. This field should only be altered when TSIE is clear. 000b - 1 Hz. 001b - 2 Hz. 010b - 4 Hz.

Table continues on the next page...

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Field	Function
	011b - 8 Hz. 100b - 16 Hz. 101b - 32 Hz. 110b - 64 Hz. 111b - 128 Hz.
15-8 —	Reserved
7 WPON	Wakeup Pin On The RTC_WAKEUP pin is optional and not available on all devices. Whenever the RTC_WAKEUP pin is enabled and this bit is set, it asserts. 0b - No effect. 1b - If the RTC_WAKEUP pin is enabled, the pin asserts.
6-5 —	Reserved
4 TSIE	Time Seconds Interrupt Enable • Is an edge-sensitive interrupt with a dedicated interrupt vector. It is generated at least once a second and requires no software overhead (there is no corresponding status flag to clear). • The frequency of the seconds interrupt is configured by TSIC. • Specifies whether to enable or disable the time seconds interrupt: 0b - Disables 1b - Enables
3 MOIE	Monotonic Overflow Interrupt Enable Specifies whether an interrupt is generated by the monotonic overflow flag: 0b - No interrupt is generated. 1b - An interrupt is generated.
2 TAIE	Time Alarm Interrupt Enable Specifies whether an interrupt is generated by the time alarm flag: 0b - No interrupt is generated. 1b - An interrupt is generated.
1 TOIE	Time Overflow Interrupt Enable Specifies whether an interrupt is generated by the time overflow flag:

Table continues on the next page...

Table continued from the previous page...

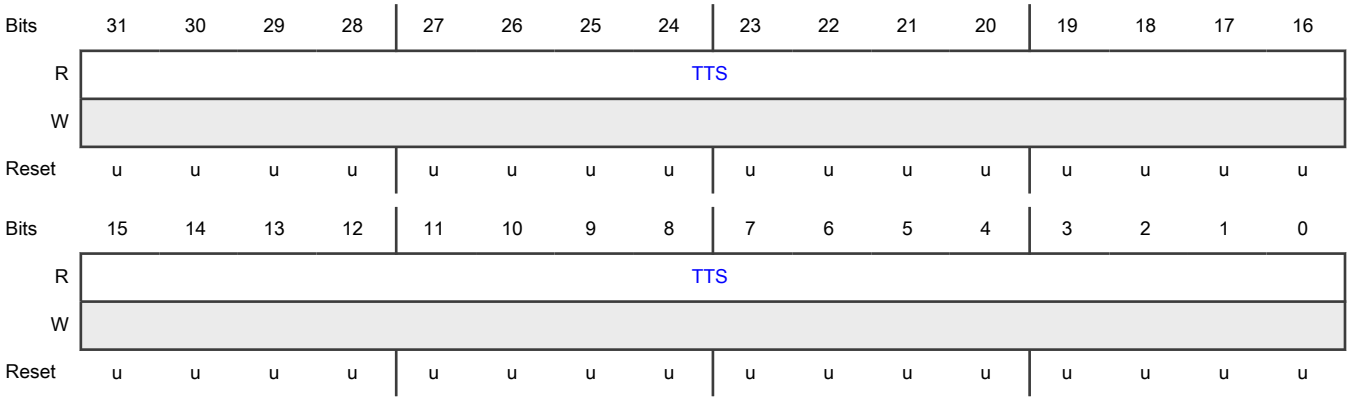
Field	Function
	0b - No interrupt is generated. 1b - An interrupt is generated.
0 TIIE	Time Invalid Interrupt Enable Specifies whether an interrupt is generated by the time invalid flag: 0b - No interrupt is generated. 1b - An interrupt is generated.

40.6.1.10 RTC Tamper Time Seconds (TTSR)

Offset

Register	Offset
TTSR	20h

Diagram



Fields

Field	Function
31-0 TTS	Tamper Time Seconds If the time invalid flag is set then reading this register returns the contents of the time seconds register at the point at which the time invalid flag was set. If the time invalid flag is clear, but the tamper interrupt detect flag is set then reading this register returns the point at which the tamper interrupt was set. If both the time invalid flag and tamper detect interrupt are clear, then reading this register returns zero. Writing the tamper time seconds register with any value will set the time invalid flag, allowing software to invalidate the time.

40.6.1.11 RTC Monotonic Enable (MER)

Offset

Register	Offset
MER	24h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0											MCE	0			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-5 —	Reserved
4 MCE	Monotonic Counter Enable 0b - Writes to the monotonic counter load the counter with the value written. 1b - Writes to the monotonic counter increment the counter.
3-0 —	Reserved

40.6.1.12 RTC Monotonic Counter Low (MCLR)

Offset

Register	Offset
MCLR	28h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	MCL															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	MCL															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 MCL	Monotonic Counter Low When the time invalid flag is set, the monotonic counter is held in reset. When the monotonic counter enable is clear, a write to this register will load the counter with the value written. When the monotonic counter enable is set, a write to this register will cause it to increment. A write to monotonic counter low that causes it to overflow will also increment monotonic counter high.

40.6.1.13 RTC Monotonic Counter High (MCHR)

Offset

Register	Offset
MCHR	2Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	MCH															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	MCH															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 MCH	Monotonic Counter High When the time invalid flag is set, the monotonic counter is held in reset. When the monotonic counter enable is clear, a write to this register will load the counter with the value written. When the monotonic counter enable is set, a write to this register will cause it to increment. A write to monotonic counter low that causes it to overflow will also increment monotonic counter high.

40.6.1.14 RTC Tamper Detect (TDR)

Offset

Register	Offset
TDR	34h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0								TPF							
W									W1C							
Reset [1]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								TMF	FSF	STF	LCTF	0	0	0	1
W									W1C	W1C	W1C	W1C				
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

1. A software reset will clear all tamper flags, but flags can set again once software reset is negated.

Fields

Field	Function
31-24 —	Reserved
23-16 TPF	Tamper Pin Flag These flags are set whenever the corresponding tamper pin asserts. To clear, write logic one to the corresponding flag after that tamper pin negates. 0b - Tamper not detected. 1b - Tamper pin tamper detected.

Table continues on the next page...

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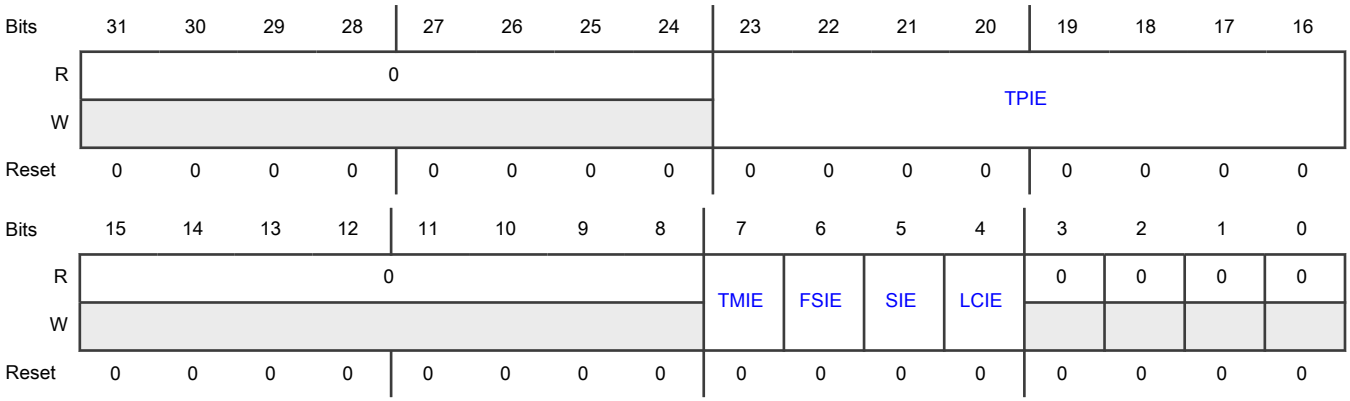
Field	Function
15-8 —	Reserved
7 TMF	Test Mode Flag This flag is set whenever any test mode is entered. To clear, write logic one to this flag after exiting from all test modes. 0b - Tamper not detected. 1b - Test mode tamper detected.
6 FSF	Flash Security Flag This flag is set whenever flash security is disabled. To clear, write logic one to this flag after flash security is enabled. 0b - Tamper not detected. 1b - Flash security tamper detected.
5 STF	Security Tamper Flag This flag is set whenever security module asserts its tamper detect. To clear, write logic one to this flag after security module has negated its tamper detect. 0b - Tamper not detected. 1b - Security module tamper detected.
4 LCTF	Loss of Clock Tamper Flag This flag is set whenever loss of clock is detected. To clear, write logic one to this flag after loss of clock negates. 0b - Tamper not detected. 1b - Loss of Clock tamper detected.
3 —	Reserved
2 —	Reserved
1 —	Reserved
0 —	Reserved

40.6.1.15 RTC Tamper Interrupt (TIR)

Offset

Register	Offset
TIR	3Ch

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 TPIE	Tamper Pin Interrupt Enable 0b - Interrupt disabled. 1b - An interrupt is generated when the corresponding tamper pin flag is set.
15-8 —	Reserved
7 TMIE	Test Mode Interrupt Enable 0b - Interrupt disabled. 1b - An interrupt is generated when the test mode flag is set.
6 FSIE	Flash Security Interrupt Enable 0b - Interrupt disabled. 1b - An interrupt is generated when the flash security flag is set.
5 SIE	Security Module Interrupt Enable 0b - Interrupt disabled. 1b - An interrupt is generated when the security module flag is set.

Table continues on the next page...

Table continued from the previous page...

Field	Function
4 LCIE	Loss of Clock Interrupt Enable 0b - Interrupt disabled. 1b - An interrupt is generated when the loss of clock flag is set.
3 —	Reserved
2 —	Reserved
1 —	Reserved
0 —	Reserved

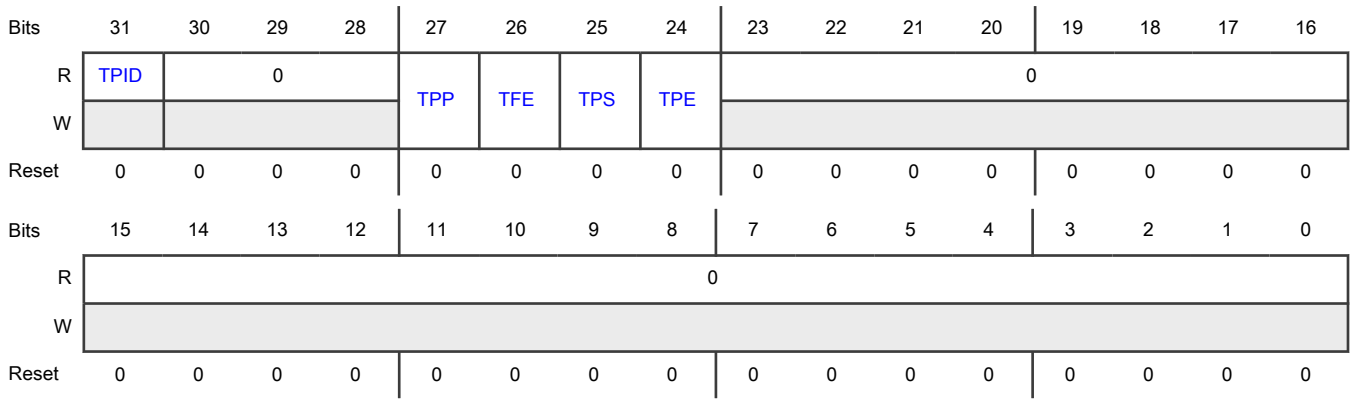
40.6.1.16 RTC Pin Configuration (PCR0 - PCR7)

Offset

For a = 0 to 7:

Register	Offset
PCRa	40h + (a × 4h)

Diagram



Fields

Field	Function
31 TPID	Tamper Pin Input Data 0b - Tamper pin input data is logic zero. 1b - Tamper pin input data is logic one.
30-28 —	Reserved
27 TPP	Tamper Pin Polarity Configures the polarity of the tamper pin. 0b - Tamper pin is active high. 1b - Tamper pin is active low.
26 TFE	Tamper Filter Enable Enables the passive input filter on the tamper pin. 0b - Input filter is disabled on the tamper pin. 1b - Input filter is enabled on the tamper pin.
25 TPS	Tamper Pull Select Configures the direction of the tamper pin pull resistor. 0b - Tamper pin pull resistor direction will assert the tamper pin. 1b - Tamper pin pull resistor direction will negate the tamper pin.
24 TPE	Tamper Pull Enable Enables the pull resistor on the tamper pin. 0b - Pull resistor is disabled on tamper pin. 1b - Pull resistor is enabled on tamper pin.
23-0 —	Reserved

Chapter 41
Low-Power Timer (LPTMR)

41.1 Chip-specific LPTMR information

Table 283. Reference links to related information

Topic	Related module	Reference
Full description	LPTMR	LPTMR
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

41.1.1 Module instances

This device has three instances of the LPTMR module, LPTMR0, LPTMR1 and LPTMR2.

41.1.2 LPTMR clocks

The prescaler and glitch filter of the LPTMR module (the module functional clock) can be clocked from one of four sources determined by LPTMRx_PSR[PCS]. The following table shows the clock assignments for this field.

NOTE

The chosen clock must remain enabled if the LPTMR is to continue operating in all required low-power modes.

The LPTMR allows the maximum clock frequency of 24 MHz.

Table 284. LPTMRn prescaler/glitch filter clocking options

LPTMRn_PSR[PCS]	Prescaler/glitch filter clock number	Chip clock
01	1	Reserved
10	2	32K_CLK - Selectable clock output from the Battery Backed domain produced by either the OSC-32K or the FRO-32K.
11	3	OSC_RF/2

41.1.3 LPTMR pulse counter input options

LPTMRn_CSR[TPS] configures the input source used in pulse counter mode. The following table shows the input assignments for this field.

Table 285. LPTMRn pulse counter input options

LPTMRn_CSR[TPS]	Pulse counter input number	Chip input
00	0	CMP0_OUT
01	1	CMP1_OUT
10	2	LPTMRn_Alt2
11	3	LPTMRn_Alt3

41.2 Overview

You can configure LPTMR to operate as a time counter with an optional prescaler, or as a pulse counter with an optional glitch filter, across all power modes, including low-power modes. It is reset only on Power on Reset (POR), allowing it to be used as a time-of-day counter.

41.2.1 Block diagram

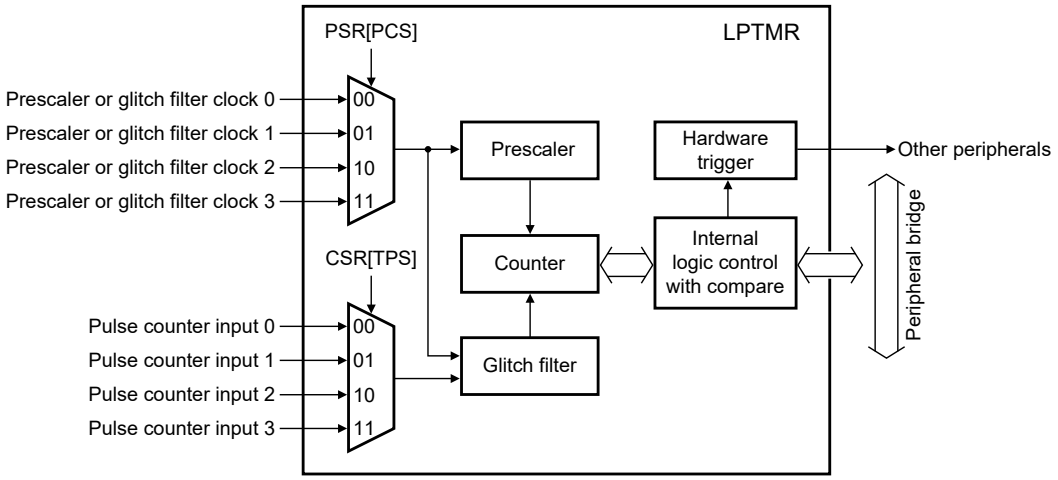


Figure 120. Block diagram

41.2.2 Features

- 32-bit time counter or pulse counter with compare:
  - Optional interrupt that can generate an asynchronous wake-up from any low-power mode
  - Hardware trigger output
  - Counter that supports a free-running mode or reset on compare
- Configurable clock source for prescaler and glitch filter
- Configurable input source for pulse counter (rising-edge or falling-edge)

41.3 Functional description

41.3.1 Low-power modes

In low-power modes, LPTMR continues to operate normally. You can configure LPTMR to exit a low-power mode by generating either an interrupt or a DMA request.

41.3.2 Clocks

The LPTMR prescaler and glitch filter can be clocked by one of the clocks that you configure by using PSR[PCS]. You must enable the clock source before you enable LPTMR.

In Pulse Counter mode, with the glitch filter bypassed, the selected input source directly clocks Counter (CNR), and no other clock source is required. To minimize power in this case, configure the glitch filter clock source for a clock that is disabled.

NOTE

- You may need to configure the clock source that you select in PSR[PCS] for it to remain enabled in low-power modes. Otherwise, LPTMR does not operate in low-power modes.
- The clock source or pulse input source selected for LPTMR must not exceed the maximum frequency of f_{LPTMR} defined in the chip data sheet.

41.3.3 Reset

LPTMR is reset only on Power on Reset (POR). When configuring LPTMR registers, you must initially write to Control Status (CSR) with LPTMR disabled, before configuring Prescaler and Glitch Filter (PSR) and Compare (CMR). Then, you must write 1 to CSR[TEN] as the last step in the initialization. Doing so ensures that LPTMR is configured correctly and the LPTMR counter is reset to zero following a Power on Reset (POR).

41.3.4 Prescaler and glitch filter

The LPTMR prescaler and glitch filter share the same logic, which operates as a prescaler in Time Counter mode and as a glitch filter in Pulse Counter mode.

NOTE

You must not alter the prescaler and glitch filter configuration when LPTMR is enabled.

41.3.4.1 Prescaler enabled

In Time Counter mode, when the prescaler is enabled, the output of the prescaler directly clocks Counter (CNR). When LPTMR is enabled, CNR increments every 2^1 to 2^{16} prescaler clock cycles. After LPTMR is enabled, the first increment of CNR takes an additional one or two prescaler clock cycles because of the synchronization logic.

41.3.4.2 Prescaler bypassed

In Time Counter mode, when the prescaler is bypassed, the selected prescaler clock increments Counter (CNR) on every clock cycle. When LPTMR is enabled, the first increment takes an additional one or two prescaler clock cycles because of the synchronization logic.

41.3.4.3 Glitch filter enabled

In Pulse Counter mode, when the glitch filter is enabled, the output of the glitch filter directly clocks Counter (CNR). When LPTMR is first enabled, the output of the glitch filter is asserted, that is, logic 1 for active-high and logic 0 for active-low. The following table shows the change in glitch filter output with the selected input source.

Table 286. Glitch filter output with the selected input source

If	Then
The selected input source remains deasserted for at least 2^1 to 2^{15} consecutive prescaler clock rising edges	The glitch filter output also deasserts.
The selected input source remains asserted for at least 2^1 to 2^{15} consecutive prescaler clock rising edges	The glitch filter output also asserts.

NOTE

The input is sampled only on the rising clock edge.

The value of CNR increments each time the glitch filter output asserts. In Pulse Counter mode, the maximum rate at which CNR can increment is once every 2^2 to 2^{16} glitch filter clock edges. When first enabled, the glitch filter waits for an additional one or two glitch filter clock edges because of the synchronization logic.

41.3.4.4 Glitch filter bypassed

In Pulse Counter mode, when the glitch filter is bypassed, the selected input source increments the value of Counter (CNR) every time it asserts. Before LPTMR is first enabled, the selected input source is forced to be asserted. This prevents CNR from incrementing if the selected input source is already asserted when LPTMR is first enabled.

41.3.5 Counter

The value of Counter (CNR) increments by 1 on every:

- Prescaler clock in Time Counter mode, with prescaler bypassed.
- Prescaler output in Time Counter mode, with prescaler enabled.
- Input source assertion in Pulse Counter mode, with glitch filter bypassed.
- Glitch filter output in Pulse Counter mode, with glitch filter enabled.

CNR is reset when LPTMR is disabled or if the counter register overflows. If CSR[TFC] = 0, then CNR is also reset whenever CSR[TCF] = 1.

When the core is halted in Debug mode:

- CNR continues incrementing if configured for Pulse Counter mode.
- CNR stops incrementing if configured for Time Counter mode.

You cannot initialize CNR but can read it at any time. On each read of CNR, you must first write a value to it. This synchronizes and registers the current value of CNR into a temporary register. The contents of the temporary register are returned on each read of CNR.

When reading CNR, the bus clock must be at least two times faster than the rate at which the LPTMR counter is incrementing; otherwise, incorrect data may be returned.

41.3.6 Compare

After the next Counter (CNR) increment (when its value is equal to that of Compare (CMR)), the following events occur:

- CSR[TCF] is read as 1b.
- LPTMR generates an interrupt if CSR[TIE] is 1 as well.
- LPTMR generates a hardware trigger.
- LPTMR writes 0 to CNR if CSR[TFC] is 0.

When LPTMR is enabled, you can modify the value of CMR only when CSR[TCF] is 1. When updating CMR, you must write to it and clear CSR[TCF] before the LPTMR counter increments past the new LPTMR compare value.

NOTE

When LPTMR is enabled in Time Counter mode, the first increment takes an additional one or two clock cycles because of the synchronization logic. This results in the first compare (and therefore interrupt and hardware trigger) occurring slightly later. A faster prescaler clock or larger prescaler value minimizes this impact.

41.3.7 Interrupt

LPTMR generates an interrupt whenever CSR[TIE] and CSR[TCF] are 1. CSR[TCF] is cleared by disabling LPTMR or writing a logic 1 to it.

You can modify the value of CSR[TIE] and write 1 to CSR[TCF] when LPTMR is enabled.

LPTMR generates an interrupt asynchronously to the system clock. The interrupt can be used to generate a wake-up from any low-power mode, provided LPTMR is enabled as a wake-up source.

41.3.8 Hardware trigger

The LPTMR hardware trigger asserts at the same time CSR[TCF] is set and can be used to trigger hardware events in other peripherals without your intervention. The hardware trigger is always enabled.

Table 287. Hardware trigger

When	Then
CMR[COMPARE] and CSR[TFC] are 0	The LPTMR hardware trigger asserts on the first compare and does not deassert.
CMR[COMPARE] is set to a nonzero value, or if CSR[TFC] = 1	The LPTMR hardware trigger asserts on each compare and deasserts on the following increment of Counter (CNR).

41.4 External signals

Table 288. External signals

Signal	Description		Direction
LPTMR_ALT*n*	Pulse Counter Input LPTMR can select one of the input pins to be used in Pulse Counter mode.		Input
	State meaning	Assertion—If configured for Pulse Counter mode with an active-high input, assertion causes Counter (CNR) to increment. Deassertion—If configured for Pulse Counter mode with an active-low input, deassertion causes CNR to increment.	
	Timing	Assertion or deassertion may occur at any time; input may assert asynchronously to the bus clock.	

41.5 Initialization

Perform the following procedure to initialize LPTMR:

1. Configure Control Status (CSR) for the selected mode and pin configuration, when CSR[TEN] is 0. This resets the counter and clears the flag.
2. Configure Prescaler and Glitch Filter (PSR) with the selected clock source and prescaler or glitch filter configuration.
3. Configure Compare (CMR) with the selected compare point.
4. Write 1 to CSR[TEN] to enable LPTMR.

41.6 Application information

41.6.1 Application 1: Generate an interrupt every 100 ms using 32.768 kHz clock source

1. Disable LPTMR by writing 0 to CSR[TEN].
2. Select a 32.768 kHz clock source by configuring PSR[PCS].
3. Bypass the prescaler and glitch filter by writing 1 to PSR[PBYP].
4. Assert an interrupt every 3277 cycles by configuring CMR[COMPARE] = 0CCCh.
5. Enable LPTMR by writing 1 to CSR[TEN].

6. Enable the LPTMR interrupt by writing 1 to CSR[TIE].

NOTE

This is just an example. See the chip-specific LPTMR information for the clocks supported on a given chip.

41.6.2 Application 2: Generate an interrupt once a minute using 32.768 kHz clock source

1. Disable LPTMR by writing 0 to CSR[TEN].
2. Select a 32.768 kHz clock source by configuring PSR[PCS].
3. Select the prescaler to divide the prescaler clock by 32768 to increment the counter once a second by configuring PSR[PRESCALE] = 0Eh.
4. Assert an interrupt every 60 seconds by configuring CMR[COMPARE] = 003Bh.
5. Enable LPTMR by writing 1 to CSR[TEN].
6. Enable the LPTMR interrupt by writing 1 to CSR[TIE].

NOTE

This is just an example. See the chip-specific LPTMR information for the clocks supported on a given chip.

41.7 Memory map and register definition

NOTE

The LPTMR registers are reset only on Power on Reset (POR). See Reset for more information.

41.7.1 LPTMR register descriptions

41.7.1.1 LPTMR memory map

LPTMR0 base address: 4002_D000h

LPTMR1 base address: 4002_E000h

LPTMR2 base address: 4898_6000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Control Status (CSR)	32	RW	0000_0000h
4h	Prescaler and Glitch Filter (PSR)	32	RW	0000_0000h
8h	Compare (CMR)	32	RW	0000_0000h
Ch	Counter (CNR)	32	RW	0000_0000h

41.7.1.2 Control Status (CSR)

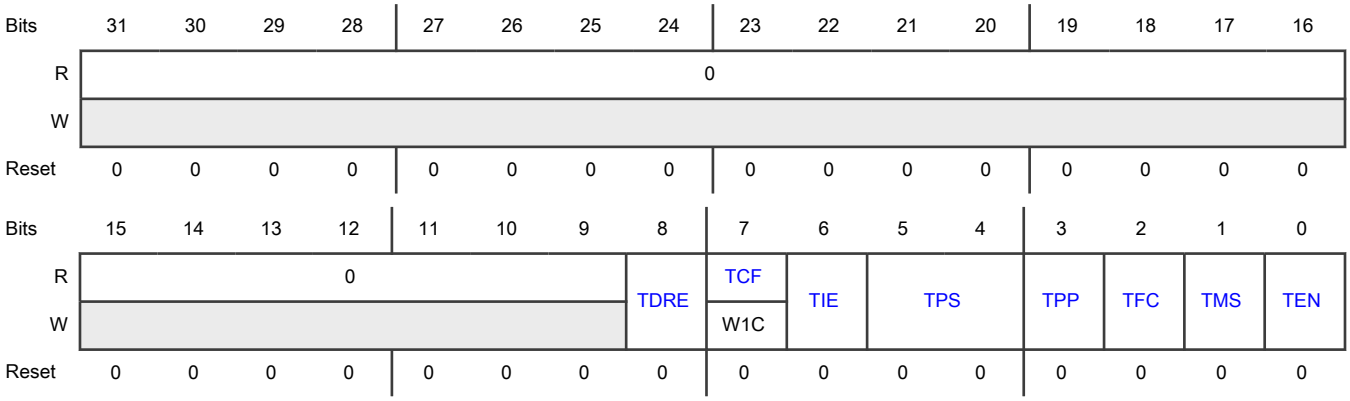
Offset

Register	Offset
CSR	0h

Function

Controls various features of LPTMR.

Diagram



Fields

Field	Function
31-9 —	Reserved
8 TDRE	Timer DMA Request Enable Enables the timer DMA request. When TDRE is 1, the LPTMR DMA request is generated whenever CSR[TCF] is also set. Then, CSR[TCF] is cleared after the DMA controller completes execution. 0b - Disable 1b - Enable
7 TCF	Timer Compare Flag Compares the timer. TCF sets on the next Counter (CNR) increment when LPTMR is enabled and Counter (CNR) equals Compare (CMR). TCF is cleared when LPTMR is disabled or a logic 1 is written to it. **NOTE** You must clear this flag before enabling the timer interrupt or DMA request. **NOTE** This field behaves differently for register reads and writes. When reading 0b - CNR ≠ (CMR + 1) 1b - CNR = (CMR + 1) When writing 0b - No effect 1b - Clear the flag

Table continues on the next page...

Table continued from the previous page...

Field	Function
6 TIE	Timer Interrupt Enable Enables the timer interrupt. If TIE is 1, then LPTMR generates an interrupt if CSR[TCF] is 1 as well. 0b - Disable 1b - Enable
5-4 TPS	Timer Pin Select Configures the input source to be used in Pulse Counter mode. The input connections vary by chip. For details, see the chip configuration information about connections to these inputs. You must modify this field only when LPTMR is disabled. 00b - Input 0 01b - Input 1 10b - Input 2 11b - Input 3
3 TPP	Timer Pin Polarity Configures the polarity of the input source in Pulse Counter mode. If TPP is 0, then the pulse counter input source is active-high, and Counter (CNR) increments on the rising edge. If TPP is 1, then the pulse counter input source is active-low, and CNR increments on the falling edge. You must modify this field only when LPTMR is disabled. 0b - Active-high 1b - Active-low
2 TFC	Timer Free-Running Counter Specifies when the counter resets. If TFC is 0, Counter (CNR) resets on the count cycle following Counter (CNR) becoming equal to Compare (CMR). If TFC is 1, CNR resets on overflow. In both cases, CSR[TCF] sets to 1 on the cycle after CNR and CMR match. You must modify this field only when LPTMR is disabled. 0b - Reset when TCF asserts 1b - Reset on overflow
1 TMS	Timer Mode Select Configures the mode of LPTMR. You must modify this field only when LPTMR is disabled. 0b - Time Counter 1b - Pulse Counter
0 TEN	Timer Enable Enables the LPTMR timer. If TEN is 0, it resets the LPTMR internal logic, including CNR[COUNTER] and CSR[TCF]. If TEN is 1, LPTMR is enabled.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	Do not alter CSR[5:1] when writing 1 to this field. 0b - Disable 1b - Enable

41.7.1.3 Prescaler and Glitch Filter (PSR)

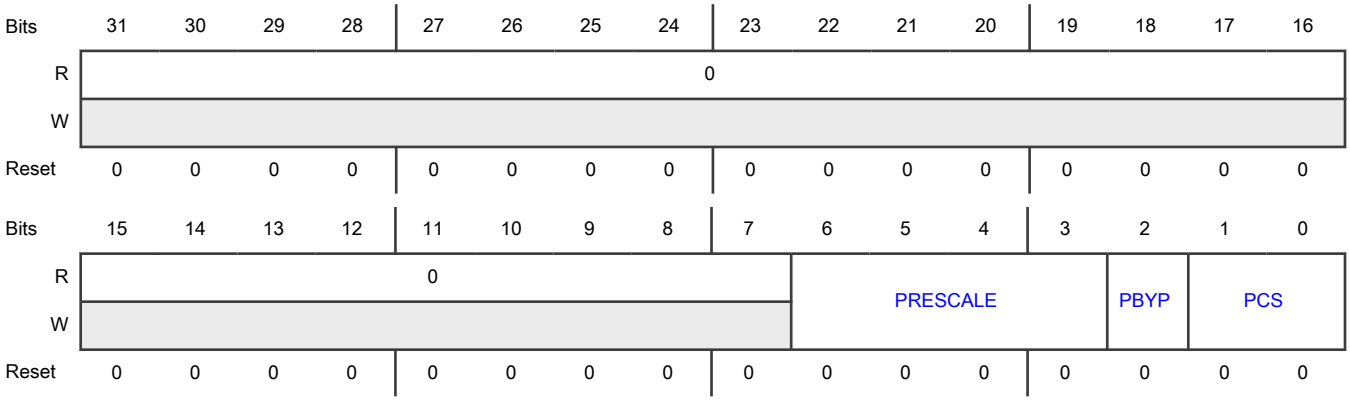
Offset

Register	Offset
PSR	4h

Function

Configures features related to the prescaler and glitch filter.

Diagram



Fields

Field	Function
31-7 —	Reserved
6-3 PRESCALE	Prescaler and Glitch Filter Value Configures the size of the prescaler in Time Counter mode and the width of the glitch filter in Pulse Counter mode. The width of the glitch filter can vary by one cycle because of the pulse counter input synchronization. You must modify this field only when LPTMR is disabled. 0000b - Prescaler divides the prescaler clock by 2; glitch filter does not support this configuration

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0001b - Prescaler divides the prescaler clock by 4; glitch filter recognizes change on input pin after two rising clock edges 0010b - Prescaler divides the prescaler clock by 8; glitch filter recognizes change on input pin after four rising clock edges 0011b - Prescaler divides the prescaler clock by 16; glitch filter recognizes change on input pin after eight rising clock edges 0100b - Prescaler divides the prescaler clock by 32; glitch filter recognizes change on input pin after 16 rising clock edges 0101b - Prescaler divides the prescaler clock by 64; glitch filter recognizes change on input pin after 32 rising clock edges 0110b - Prescaler divides the prescaler clock by 128; glitch filter recognizes change on input pin after 64 rising clock edges 0111b - Prescaler divides the prescaler clock by 256; glitch filter recognizes change on input pin after 128 rising clock edges 1000b - Prescaler divides the prescaler clock by 512; glitch filter recognizes change on input pin after 256 rising clock edges 1001b - Prescaler divides the prescaler clock by 1024; glitch filter recognizes change on input pin after 512 rising clock edges 1010b - Prescaler divides the prescaler clock by 2048; glitch filter recognizes change on input pin after 1024 rising clock edges 1011b - Prescaler divides the prescaler clock by 4096; glitch filter recognizes change on input pin after 2048 rising clock edges 1100b - Prescaler divides the prescaler clock by 8192; glitch filter recognizes change on input pin after 4096 rising clock edges 1101b - Prescaler divides the prescaler clock by 16,384; glitch filter recognizes change on input pin after 8192 rising clock edges 1110b - Prescaler divides the prescaler clock by 32,768; glitch filter recognizes change on input pin after 16,384 rising clock edges 1111b - Prescaler divides the prescaler clock by 65,536; glitch filter recognizes change on input pin after 32,768 rising clock edges
2 PBYP	Prescaler and Glitch Filter Bypass Controls the clocking of Counter (CNR). If PBYP is 0, the output of the prescaler or glitch filter clocks CNR. If PBYP is 1, the selected prescaler clock in Time Counter mode, or else the selected input source in Pulse Counter mode, directly clocks CNR. You must modify this field only when LPTMR is disabled. 0b - Prescaler and glitch filter enable 1b - Prescaler and glitch filter bypass
1-0	Prescaler and Glitch Filter Clock Select

Table continues on the next page...

Table continued from the previous page...

Field	Function
PCS	Selects the clock to be used by the LPTMR prescaler and glitch filter. In Time Counter mode, PCS selects the input clock to the prescaler. In Pulse Counter mode, PCS selects the input clock to the glitch filter. See the chip configuration details for information on connections to these inputs. You must modify this field only when LPTMR is disabled. 00b - Clock 0 01b - Clock 1 10b - Clock 2 11b - Clock 3

41.7.1.4 Compare (CMR)

Offset

Register	Offset
CMR	8h

Function

Configures the compare values to Counter (CNR) (see Compare for more information).

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	COMPARE															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	COMPARE															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 COMPARE	Compare Value Configures the compare values to Counter (CNR).

Table continues on the next page...

Field	Function
	On the next CNR increment, if LPTMR is enabled and Counter (CNR) equals Compare (CMR), then: 1. LPTMR writes 1 to CSR[TCF]. 2. The hardware trigger asserts until the next time CNR increments. If CMR = 0, the hardware trigger remains asserted until LPTMR is disabled. If LPTMR is enabled, you must modify the value of CMR only if CSR[TCF] is 1.

41.7.1.5 Counter (CNR)

Offset

Register	Offset
CNR	Ch

Function

Specifies counter values (see Counter for more information).

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	COUNTER															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	COUNTER															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 COUNTER	Counter Value Contains the current value of the LPTMR counter at the time you last wrote to this register.

Chapter 42
Low Power Periodic Interrupt Timer (LPIT)

42.1 Chip-specific LPIT information

Table 289. Reference links to related information

Topic	Related module	Reference
Full description	LPIT	LPIT
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

42.1.1 Module instances

This device has one instance of the LPIT module, LPIT0. The LPIT0 contains 4 channels.

42.1.2 External trigger source

If the TCTRLx[TRG_SRC] is set to 1, it selects to use external trigger source from TRGMUX, refer to TRGMUX0 outputs for more details.

42.2 Overview

LPIT is a low-power periodic interrupt timer with multiple timer channels. After a timer reaches a programmed count, the respective timer channels generate pre-trigger and trigger output signals, and these outputs can be used to trigger other modules on the chip.

42.2.1 Block diagram

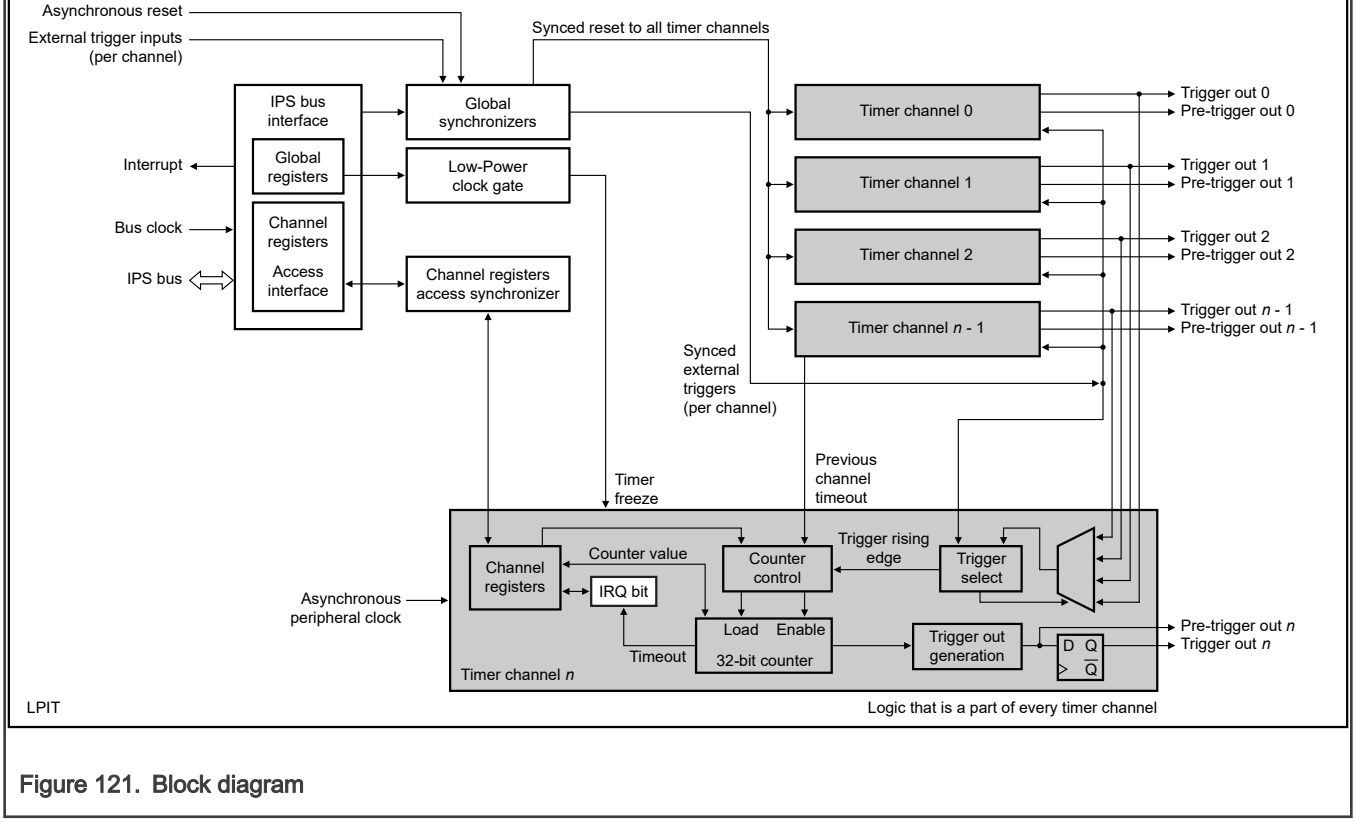


Figure 121. Block diagram

42.2.2 Features

LPIT allows you to configure timer channels in a way that they could be:

- Controlled using external triggers (triggers from outside LPIT).
- Controlled using internal triggers (triggers from other timer channels inside LPIT).
- Chained together, to form a larger width timer.
- Reloaded and counted again, or stopped after reaching the programmed count, depending on the timer modes used.

42.3 Functional description

42.3.1 Programming model

The LPIT programming model (see Figure 122) comprises:

- A global register set (common to all timer channels).
- Registers for each timer channel (that control their respective timer channels).

Access to these registers is synchronized with the asynchronous peripheral clock and then affects the timer channel registers:

- Each timer channel contains a 32-bit counter that loads the starting value and down counts after every peripheral clock's positive edge.
- After reaching a zero value (a channel timer timeout), a trigger output is generated.
- A timer enable register control field, external or internal triggers, or a previous channel timeout (when using timer chaining) control the counter enable.

- After a channel timer timeout, an interrupt flag is also set to tell the CPU about the timer timeout.

You must configure the following global registers only once:

- Module Control (MCR)
- Module Status (MSR)
- Module Interrupt Enable (MIER)
- Set Timer Enable (SETTEN)
- Clear Timer Enable (CLRTEN)

You must configure the following channel registers for each channel:

- Timer Value (TVAL0 - TVAL3)
- Timer Control (TCTRL0 - TCTRL3)

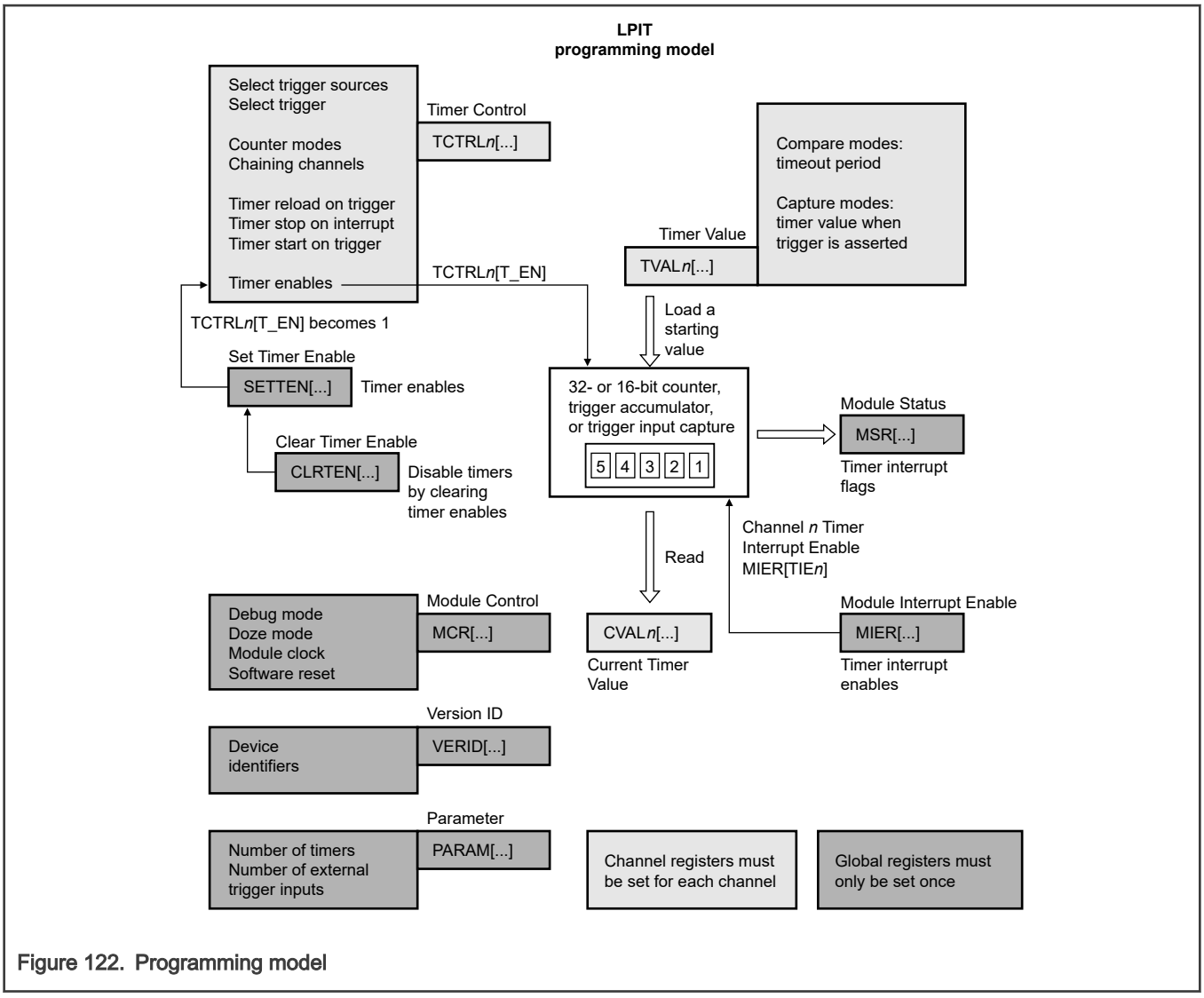


Figure 122. Programming model

42.3.2 Interfacing with other modules

The following figure shows the interface of an LPIT module with other modules on the chip:

- The CPU interface provides the clock, reset, and register read and write bus interface. It handles LPIT interrupts.

- The LPIT trigger output signals may trigger other modules on the chip.
- Similarly, other timer modules may provide trigger inputs to LPIT to control when an LPIT timer channel must start.

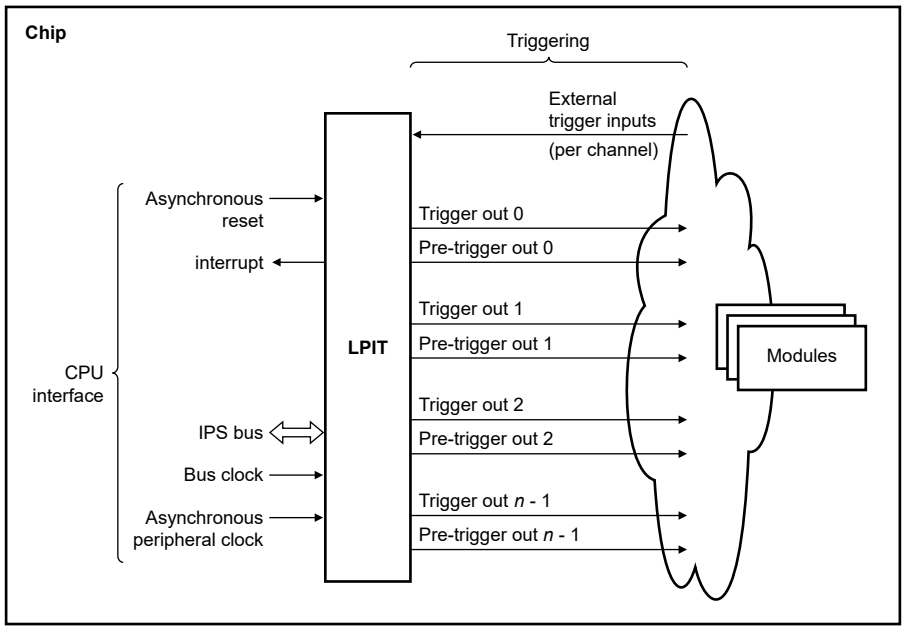


Figure 123. Interfacing with other modules

42.3.3 Chip power modes

LPIT supports the following chip power modes.

Table 290. Chip power modes

Chip mode	LPIT operation
Run	Normal operation
Sleep	Can continue operating in this mode if MCR[DOZE_EN] = 1 and LPIT is using an external or internal clock source that remains operational during Sleep mode
Low Power Stop (also called Deep Sleep)	The Doze Enable (MCR[DOZE_EN]) bit is ignored and the LPIT will be disabled for the duration of Low Power mode.
Debug	Can continue operating in this mode if MCR[DBG_EN] = 1

42.3.4 Supported timer modes

To configure a timer mode, you must select an appropriate value using TCTRL*n*[MODE].

Table 291. Supported timer modes

Timer mode	Operation
32-bit periodic counter	The counter loads and decrements down to 0, and this sets the timer interrupt flag and asserts the output pretrigger.

Table continues on the next page...

Table 291. Supported timer modes (continued)

Timer mode	Operation
Dual 16-bit periodic counter	• The counter loads and then the lower 16 bits decrement down to 0. This asserts the output pretrigger. • The upper 16 bits then decrement down to 0. This sets the timer interrupt flag and negates the output pretrigger.
32-bit trigger accumulator	The counter loads after the first trigger rising edge and then decrements down to 0 after each trigger rising edge. This sets the timer interrupt flag and asserts the output pretrigger.
32-bit trigger input capture	• The counter loads with a value of FFFF_FFFFh and then decrements down to 0. • If a trigger rising edge is detected, it stores the inverse of the current counter value in Timer Value (TVAL0 - TVAL3). This sets the timer interrupt flag and asserts the output pretrigger.

TCTRL*n*[TSOT], TCTRL*n*[TSOI], and TCTRL*n*[TROT] control the timer operation. These fields control the timer load, reload, start, and restart of the timers.

NOTE

- The trigger output is asserted one peripheral timer clock cycle after the pre-trigger output. The trigger and pre-trigger outputs deassert at the same time.
- The pre-trigger output is asserted for two clock cycles and the trigger output is asserted for one clock cycle (except in 16-bit Periodic Counter mode, where both pre-trigger and trigger outputs are asserted for many cycles depending on the value of TVAL*n*[TMR_VAL][31:16]).
- Timer changes (that are based on external triggers) take effect after four peripheral clocks, after the actual external trigger assertion. This is because of clock synchronization, rise edge detection, and timer update.

42.3.5 Timer channel modes

You can configure each timer channel in LPIT to work in either compare modes or capture modes.

The timer channels operate on an asynchronous clock, which is independent of the register read and write access clock. Clock synchronization between clock domains ensures normal operations.

Table 292. Timer channel modes

Mode	Function
Compare	The timers decrement when enabled and generate an output pretrigger and trigger output. The trigger output is one clock cycle delayed of the pre-trigger pulse. You can configure certain control fields to control each timer channel's start, reload, and restart (see Trigger control for timers for more information). You can also configure the timer to always decrement from a programmed start value, on selected trigger inputs, or previous channel timeout (when channels are chained). By chaining timer channels, applications can achieve larger timeout durations.
Capture	You can use the timer to perform measurements by using Timer Value (TVAL0 - TVAL3), as the timer value is captured when a selected trigger input is asserted. The timer can support once-off or multiple measurements, such as frequency measurements.

42.3.6 Trigger control for timers

You can configure various LPIT register fields to control how trigger inputs and the timer operate:

- TCTRL*n*[TRG_SEL] helps you select the input trigger for the channel from all other channels' trigger outputs.
- TCTRL*n*[TRG_SRC] helps you select between the internal and external trigger inputs to the channel.

The selected trigger affects how the timer operates, using the configuration of TCTRL*n*[TSOT], TCTRL*n*[TSOI], and TCTRL*n*[TROT] (see Table 293).

Table 293. Fields that control timer operations

If	=	Then
Timer stop on interrupt (TCTRL*n*[TSOI])	1	The counter stops after MSR[TIF*n*] assertion. To reload and decrement, it requires: • A trigger (if TCTRL*n*[TSOT] = 1). • A T_EN rising edge (if TCTRL*n*[TSOT] = 0).
	0	The counter does not stop after timeout.
Timer reload on trigger (TCTRL*n*[TROT])	1	The counter is loaded after each trigger.
	0	The counter is loaded after every T_EN rising edge or timeout rising edge (timeout is not used in Capture modes).
Timer start on trigger (TCTRL*n*[TSOT])	1	The counter starts decrementing after a trigger. Subsequent triggers are ignored until the counter times out.
	0	The counter decrements immediately after the next clock edge. When the channel is chained or is in Capture mode, TCTRL*n*[TSOT] has no effect.

In different timer modes, the programmable fields listed in Table 294 affect the timer operation differently.

Table 294. Timer modes and programmable fields

Mode (TCTRL*n*[MODE])	Fields affecting timer operations
32-bit periodic counter	TCTRL*n*[TSOT], TCTRL*n*[TSOI], and TCTRL*n*[TROT] affect the timer operation as described in Table 293.
Dual 16-bit periodic counter	
32-bit trigger accumulator	• Only TCTRL*n*[TSOI] controls the timer function. • TCTRL*n*[TROT] and TCTRL*n*[TSOT] have no effect on timer operations.
32-bit input trigger capture	• Only TCTRL*n*[TSOI] and TCTRL*n*[TROT] control the timer function. • TCTRL*n*[TSOT] has no effect on timer operations.

42.3.7 Channel chaining

You can chain individual timer channels together to achieve a larger value of timeout. Chaining enables these channels to work in a "nested loop" manner, thereby leading to an effective timeout value of $TVAL_{CHn} \times (TVAL_{CHn-1} + 1)$.

To chain the channels together, write 1 to TCTRL*n*[CHAIN] for the corresponding channel. When a channel is chained, that channel's timer decrements after the previous channel's timeout pulse, regardless of the timer mode that TCTRL*n*[MODE] defines.

TCTRL*n*[TSOT] does not have any effect if you chain the channel timer (channel *n*) to the previous channel's timer (channel *n* - 1).

42.3.8 Detailed timing

The following table represents various timing diagrams. The diagrams are not "cycle-accurate," which means, they may not show some of the cycles, but they do show the timer channel behavior across several clock cycles.

Table 295. Timing diagrams

Mode (TCTRL*n*[MODE]) setting		Timing diagram	TCTRL*n*[TSOT]	TCTRL*n*[TROT]	TCTRL*n*[TSOI]	TCTRL*n*[CHAIN]
32-bit periodic counter (Compare mode)	00	Case 1: TCTRL*n*[MODE] = 0 • For a use case requiring repeated interrupts with reload • Trigger outputs have equal periods	0	0	0	0
		Case 2: TCTRL*n*[MODE] = 0 • Useful for One-Shot Trigger mode • Trigger starts again after TCTRL*n*[T_EN] becomes 1	0	0	1	0
		Case 3: TCTRL*n*[MODE] = 0 • For a use case requiring repeated interrupts with reload • Trigger outputs have unequal periods	0	1	0	0
		Case 4: TCTRL*n*[MODE] = 0 • For a one-shot timer with reload before timeout of Timer mode • Timer starts again after you write 1 to TCTRL*n*[T_EN]	0	1	1	0
		Case 5: TCTRL*n*[MODE] = 0 • Useful for generating periodic interrupts after a predefined event (input trigger) • Output triggers have equal periods	1	0	0	0
		Case 6: TCTRL*n*[MODE] = 0 • Triggers One-Shot Timer mode • Output trigger period depends on the input trigger	1	0	1	0
		Case 7: TCTRL*n*[MODE] = 0 • Repeated interrupts with Reload Timer mode • Outputs triggers have unequal periods	1	1	0	0
		Case 8: TCTRL*n*[MODE] = 0 • Case shown for a nonperiodic input trigger (might not be a use case)	1	1	1	0

Table continues on the next page...

Table 295. Timing diagrams (continued)

Mode (TCTRL*n*[MODE]) setting		Timing diagram	TCTRL*n*[TSOT]	TCTRL*n*[TROT]	TCTRL*n*[TSOI]	TCTRL*n*[CHAIN]
		• If input trigger is periodic and greater than timer timeout, it is the same as TCTRL*n*[TROT] = 0 • If input trigger is periodic and less than timer timeout, the timer never times out and always reloads on the input trigger (not a valid use case)				
16-bit dual periodic counter (Compare mode)	01	Case 1: TCTRL*n*[MODE] = 1 • The effect of TCTRL*n*[TSOT], TCTRL*n*[TROT], and TCTRL*n*[TSOI] is the same as that of TCTRL*n*[MODE] = 0 (32-bit Counter Compare mode) • Both halves of the counter are affected in the same way	0	0	0	0
32-bit trigger accumulator mode	10	Case 1: TCTRL*n*[MODE] = 10 • Useful for a continuous pulse counting mode • Trigger and timeout generated after programmed number of pulses are accumulated	X	X	0	0
		Case 2: TCTRL*n*[MODE] = 10 • Useful for One-Shot Pulse Counting mode • Trigger and timeout generated after programmed number of pulses are accumulated	X	X	1	0
32-bit trigger capture mode	11	Case 1: TCTRL*n*[MODE] = 11 • Useful for determining the duration between pulses • Proper clock selection can ensure that the timer does not rollover more than once between two pulses	X	0	0	0
		Case 2: TCTRL*n*[MODE] = 11 • Useful for determining the duration between pulses • Selecting a fast timer clock provides accurate measurements but it can also cause timer rollover between pulses	X	1	0	0

Table continues on the next page...

Table 295. Timing diagrams (continued)

Mode (TCTRL*n*[MODE]) setting		Timing diagram	TCTRL*n*[TSOT]	TCTRL*n*[TROT]	TCTRL*n*[TSOI]	TCTRL*n*[CHAIN]
		Case 3: TCTRL*n*[MODE] = 11 • One-Shot Timer Count mode • You can enable it again by writing 1 to TCTRL*n*[T_EN]	X	0	1	0
Timer chaining: effects on timing operations	XX	Timer chaining	X	X	X	1

42.3.8.1 Case 1: TCTRL*n*[MODE] = 0

The following figure represents case 1 in which TCTRL*n*[MODE] = 0 (32-bit periodic counter). LPIT works in Compare mode and is configured as follows:

- TCTRL*n*[TSOT] = 0
- TCTRL*n*[TROT] = 0
- TCTRL*n*[TSOI] = 0
- TCTRL*n*[CHAIN] = 0

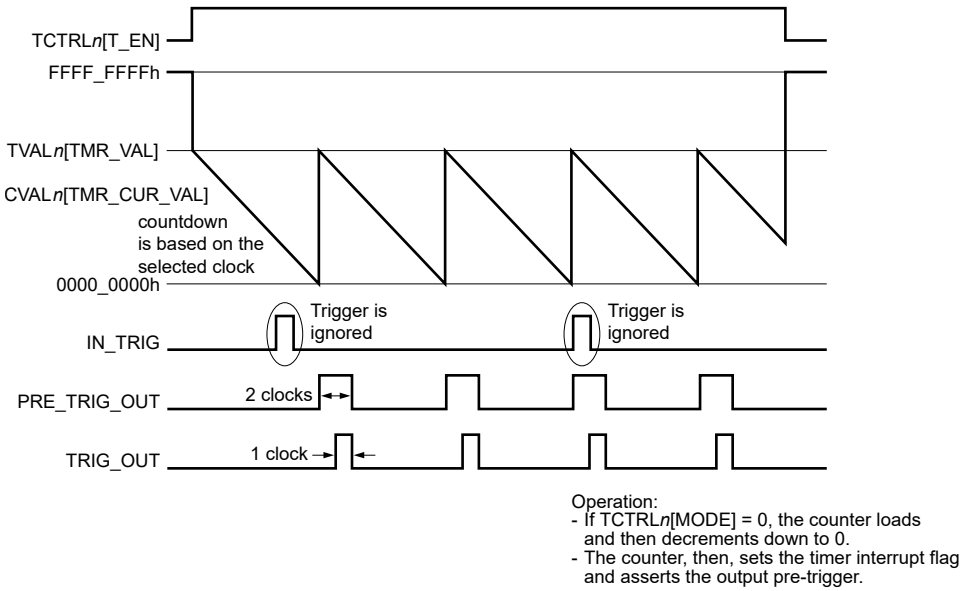


Figure 124. Case 1: TSOT = 0, TROT = 0, TSOI = 0, CHAIN = 0

42.3.8.2 Case 2: TCTRL*n*[MODE] = 0

The following figure represents case 2 in which TCTRL*n*[MODE] = 0 (32-bit periodic counter). LPIT works in Compare mode and is configured as follows:

- TCTRL*n*[TSOT] = 0
- TCTRL*n*[TROT] = 0
- TCTRL*n*[TSOI] = 1
- TCTRL*n*[CHAIN] = 0

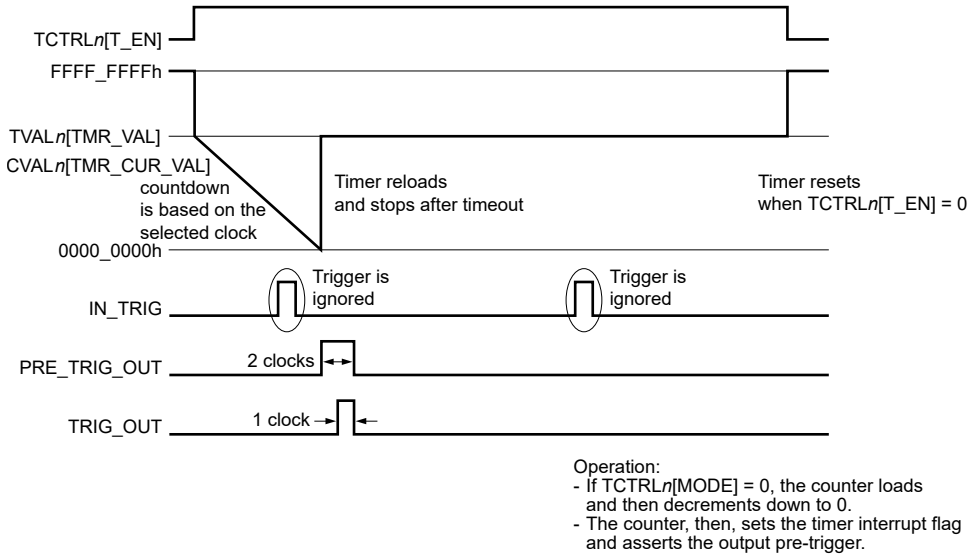


Figure 125. Case 2: TSOT = 0, TROT = 0, TSOI = 1, CHAIN = 0

42.3.8.3 Case 3: TCTRL*n*[MODE] = 0

The following figure represents case 3 in which TCTRL*n*[MODE] = 0 (32-bit periodic counter). LPIT works in Compare mode and is configured as follows:

- TCTRL*n*[TSOT] = 0
- TCTRL*n*[TROT] = 1
- TCTRL*n*[TSOI] = 0
- TCTRL*n*[CHAIN] = 0

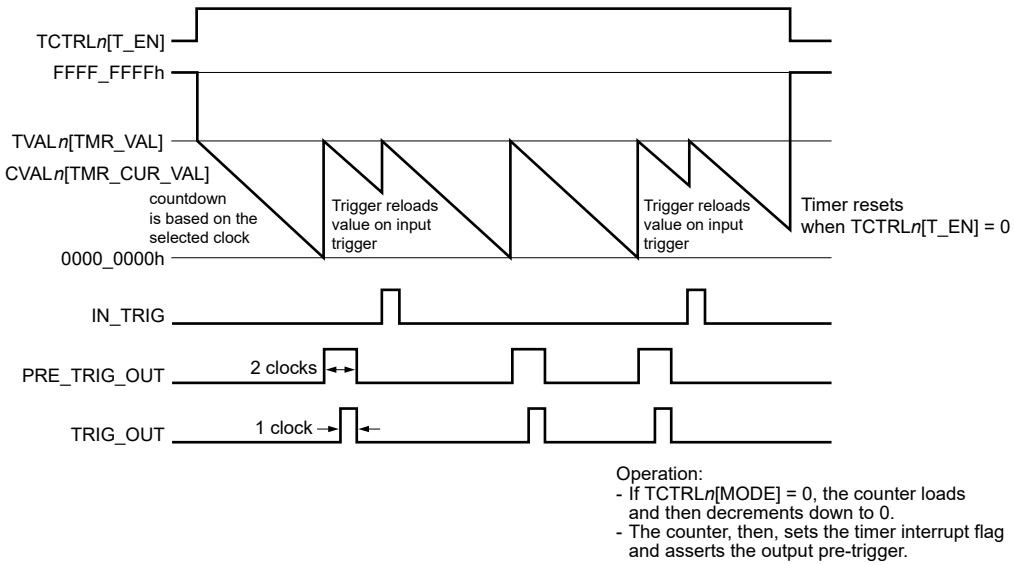


Figure 126. Case 3: TSOT = 0, TROT = 1, TSOI = 0, CHAIN = 0

42.3.8.4 Case 4: TCTRL*n*[MODE] = 0

The following figure represents case 4 in which TCTRL*n*[MODE] = 0 (32-bit periodic counter). LPIT works in Compare mode and is configured as follows:

- TCTRL*n*[TSOT] = 0
- TCTRL*n*[TROT] = 1
- TCTRL*n*[TSOI] = 1
- TCTRL*n*[CHAIN] = 0

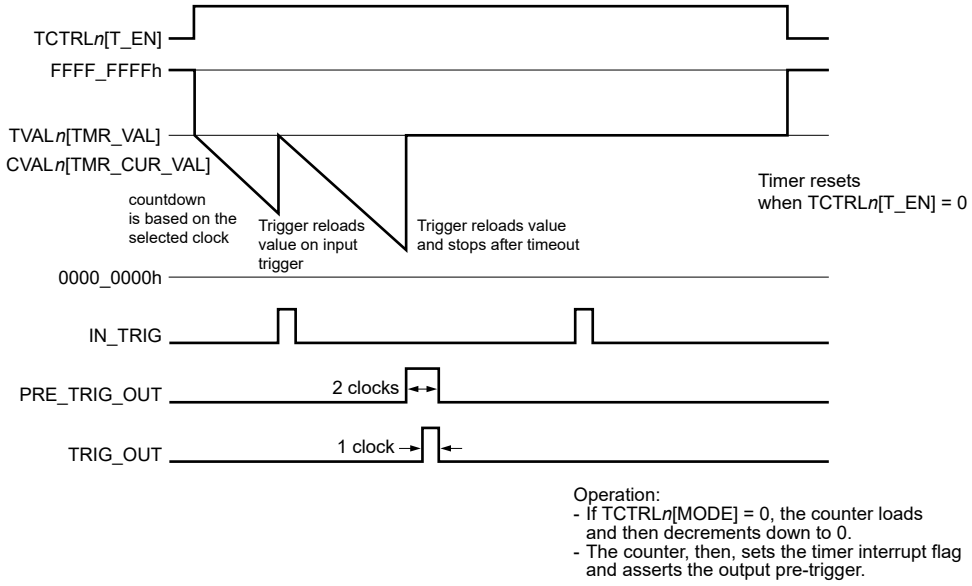


Figure 127. Case 4: TSOT = 0, TROT = 1, TSOI = 1, CHAIN = 0

42.3.8.5 Case 5: TCTRL*n*[MODE] = 0

The following figure represents case 5 in which TCTRL*n*[MODE] = 0 (32-bit periodic counter). LPIT works in Compare mode and is configured as follows:

- TCTRL*n*[TSOT] = 1
- TCTRL*n*[TROT] = 0
- TCTRL*n*[TSOI] = 0
- TCTRL*n*[CHAIN] = 0

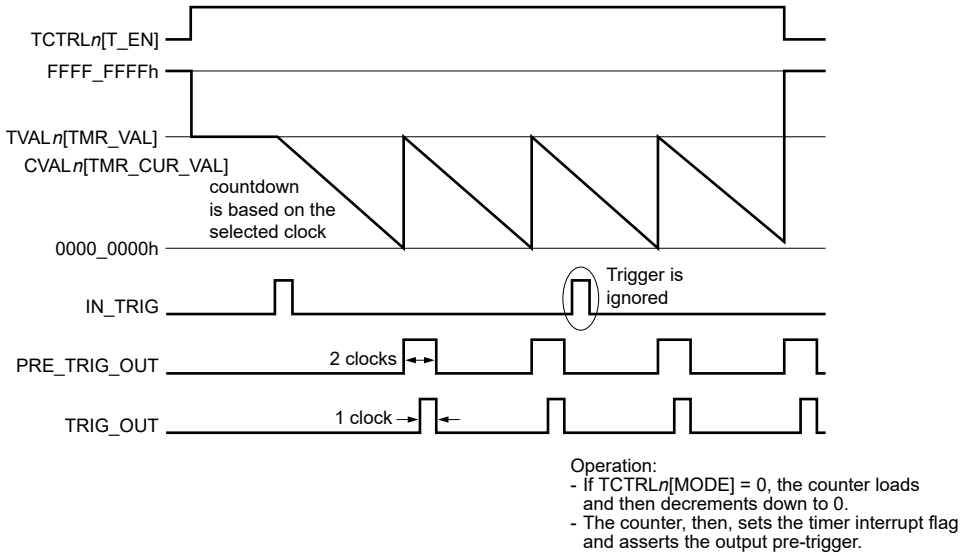


Figure 128. Case 5: TSOT = 1, TROT = 0, TSOI = 0, CHAIN = 0

42.3.8.6 Case 6: TCTRL*n*[MODE] = 0

The following figure represents case 6 in which TCTRL*n*[MODE] = 0 (32-bit periodic counter). LPIT works in Compare mode and is configured as follows:

- TCTRL*n*[TSOT] = 1
- TCTRL*n*[TROT] = 0
- TCTRL*n*[TSOI] = 1
- TCTRL*n*[CHAIN] = 0

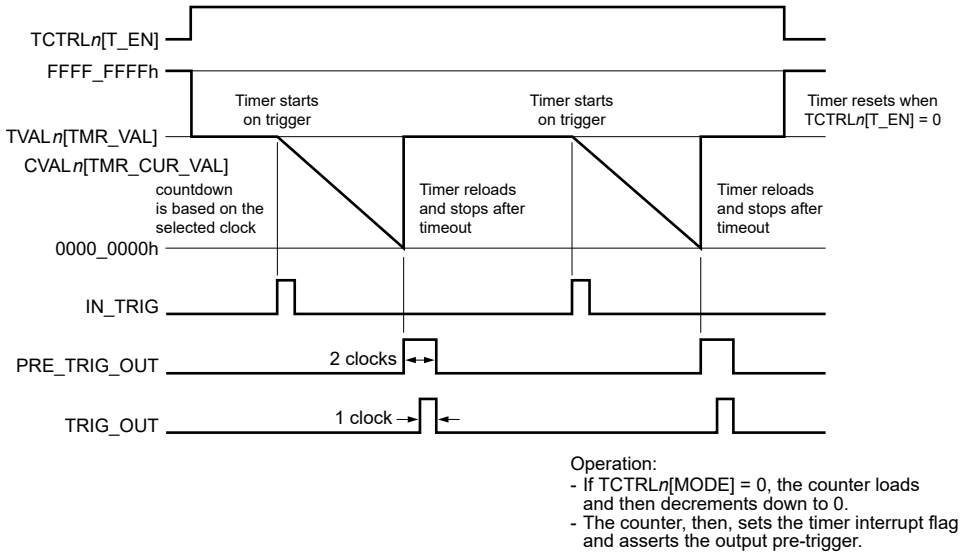


Figure 129. Case 6: TSOT = 1, TROT = 0, TSOI = 1, CHAIN = 0

42.3.8.7 Case 7: TCTRL*n*[MODE] = 0

The following figure represents case 7 in which TCTRL*n*[MODE] = 0 (32-bit periodic counter). LPIT works in Compare mode and is configured as follows:

- TCTRL*n*[TSOT] = 1
- TCTRL*n*[TROT] = 1
- TCTRL*n*[TSOI] = 0
- TCTRL*n*[CHAIN] = 0

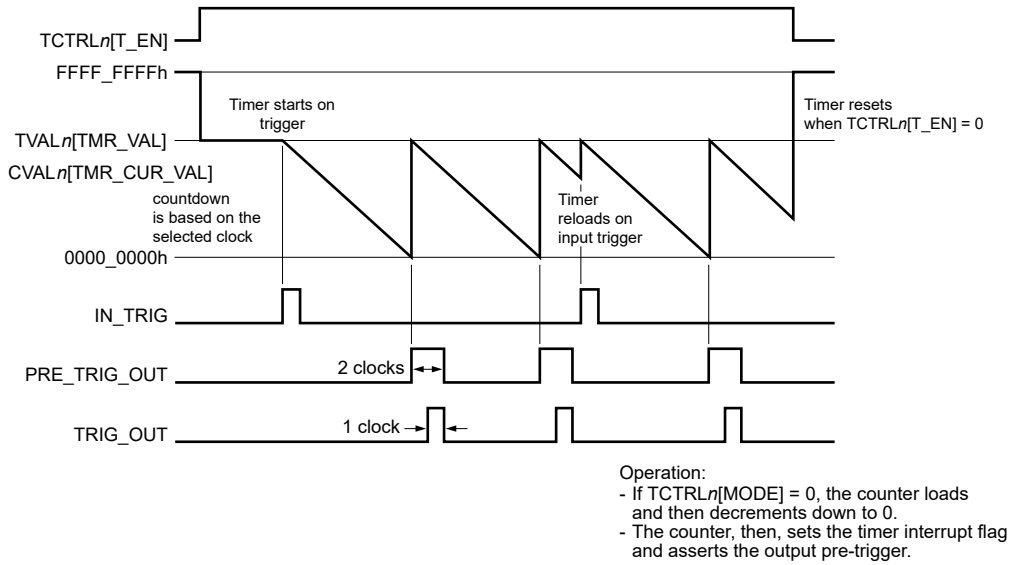


Figure 130. Case 7: TSOT = 1, TROT = 1, TSOI = 0, CHAIN = 0

42.3.8.8 Case 8: TCTRL*n*[MODE] = 0

The following figure represents case 8 in which TCTRL*n*[MODE] = 0 (32-bit periodic counter).

LPIT works in Compare mode and is configured as follows:

- TCTRL*n*[TSOT] = 1
- TCTRL*n*[TROT] = 1
- TCTRL*n*[TSOI] = 1
- TCTRL*n*[CHAIN] = 0

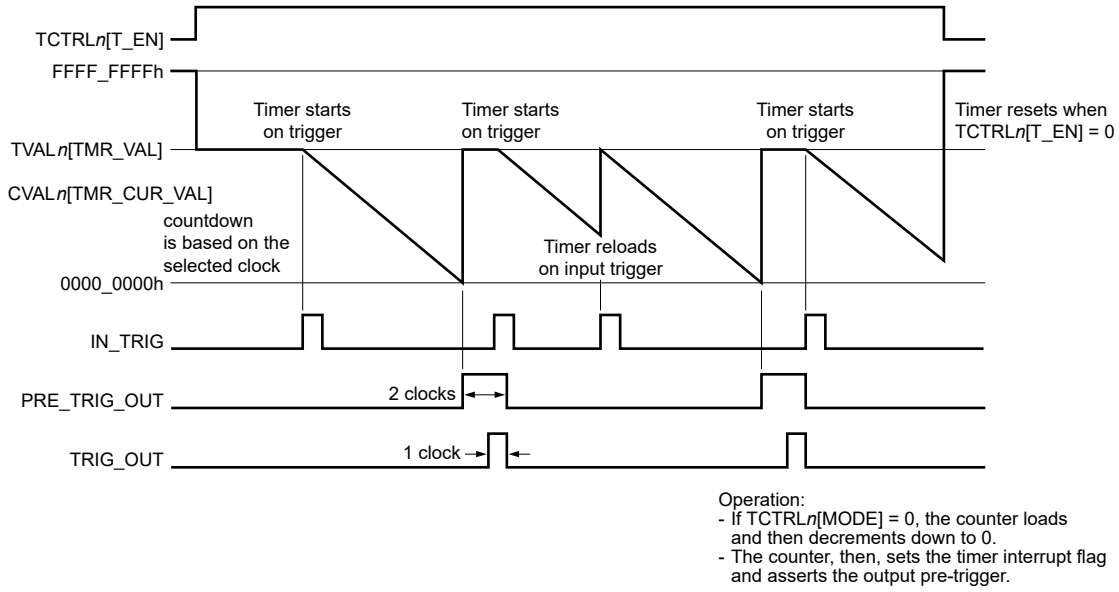


Figure 131. Case 8: TSOT = 1, TROT = 1, TSOI = 1, CHAIN = 0

42.3.8.9 Case 1: TCTRL*n*[MODE] = 1

The following figure represents case 1 in which TCTRL*n*[MODE] = 1 (16-bit dual periodic counter). LPIT works in Compare mode and is configured as follows:

- TCTRL*n*[TSOT] = 0
- TCTRL*n*[TROT] = 0
- TCTRL*n*[TSOI] = 0
- TCTRL*n*[CHAIN] = 0

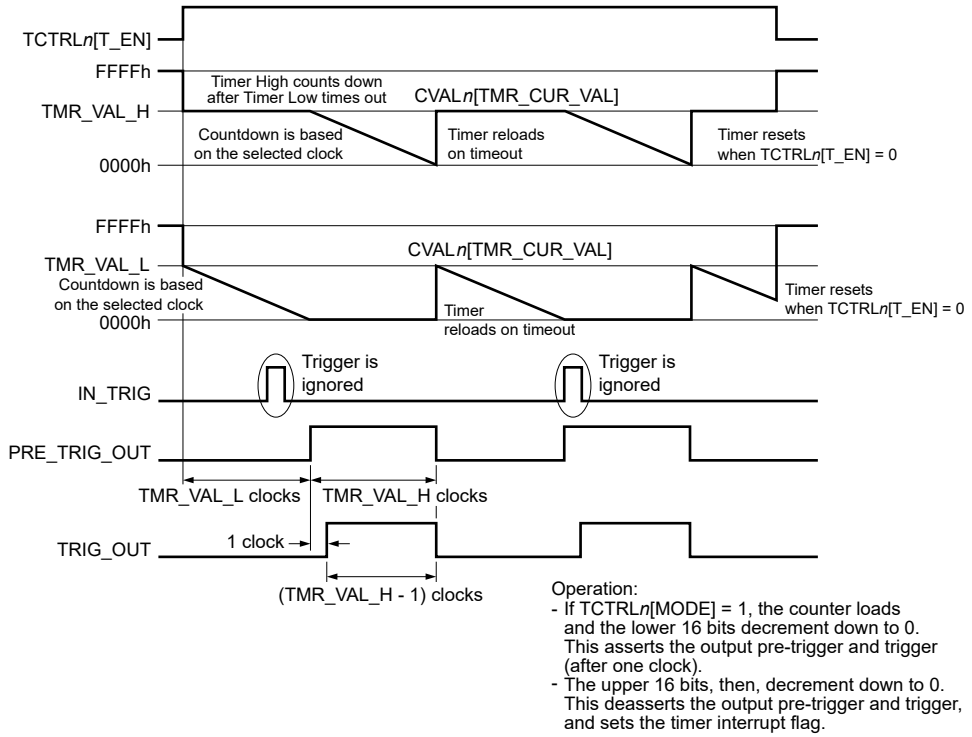


Figure 132. Case 1: TSOT = 0, TROT = 0, TSOI = 0, CHAIN = 0

If TCTRL*n*[MODE] = 1:

- The effect of timing control fields is similar to the effect of timer control fields when TCTRL*n*[MODE] = 0. See the individual timing diagrams for cases with TCTRL*n*[MODE] = 0 for more information.
- The timer interrupt (timeout) asserts when {TMR_H,TMR_L} = 0000_0000h.

See the following table for the behavior of timer control fields when TCTRL*n*[MODE] = 1.

Table 296. Timer control fields when TCTRL*n*[MODE] = 1

TCTRL*n*[TSOT]	TCTRL*n*[TROT]	TCTRL*n*[TSOI]	Function	Effect on timer
0	0	0	• For repeated interrupts with reload • Trigger outputs have equal periods	Similar to Case 1: TCTRL*n*[MODE] = 1.
0	0	1	One-shot mode	• Similar to Case 2: TCTRL*n*[MODE] = 0. • Both timers stop after first count down and then time out. • Timers do not count again until TCTRL*n*[T_EN] becomes 1.
0	1	0	• For repeated interrupts with reload • Trigger outputs have unequal periods	• Similar to Case 3: TCTRL*n*[MODE] = 0 . • Both timers reload the value of TVAL*n*[TMR_VAL] after the trigger rising edge.

Table continues on the next page...

Table 296. Timer control fields when TCTRL*n*[MODE] = 1 (continued)

TCTRL*n*[TSOT]	TCTRL*n*[TROT]	TCTRL*n*[TSOI]	Function	Effect on timer
				• Output triggers clear after reload, if asserted.
0	1	1	Reloadable one-shot mode	• Similar to Case 4: TCTRL*n*[MODE] = 0. • If a trigger occurs before timeout, then both timers reload and count down (as shown); the timers stop after timeout. • A trigger assertion after timeout reloads the value of TVAL*n*[TMR_VAL] into the timers. • The timers do not count again until TCTRL*n*[T_EN] becomes 1 again.
1	0	0	• For generating periodic interrupts after a predefined event (input trigger) • Output triggers have equal periods	• Similar to Case 5: TCTRL*n*[MODE] = 0. • After TCTRL*n*[T_EN] rises, the timers do not start until after the first trigger's rising edge. • Subsequent triggers have no effect.
1	0	1	• Triggered one-shot timer mode • Output trigger period depends on the input trigger	• Similar to Case 6: TCTRL*n*[MODE] = 0. • After TCTRL*n*[T_EN] becomes 1, the timers do not start until after the first trigger's rising edge. • The timer stops counting after a timeout assertion. • The timer does not start counting again until a new trigger's rising edge is detected.
1	1	0	• For repeated interrupts with reload timer mode • Output triggers have unequal periods	• Similar to Case 7: TCTRL*n*[MODE] = 0. • After TCTRL*n*[T_EN] becomes 1, the timers do not start until the first trigger's rising edge. • Subsequent triggers cause the timer to reload the value of TVAL*n*[TMR_VAL] into both counters. • The output triggers clear after a reload, if asserted.
1	1	1	• For a nonperiodic input trigger • If input trigger is periodic and greater than timer timeout, then it is the	• Similar to Case 8: TCTRL*n*[MODE] = 0. • After TCTRL*n*[T_EN] becomes 1, the timers do not start until the first trigger's rising edge.

Table continues on the next page...

Table 296. Timer control fields when TCTRL*n*[MODE] = 1 (continued)

TCTRL*n*[TSOT]	TCTRL*n*[TROT]	TCTRL*n*[TSOI]	Function	Effect on timer
			same as TCTRL*n*[TROT] = 0 (which is triggered one-shot timer mode; output trigger period depends on the input trigger)	• The timers stop counting after a timeout assertion. • A trigger's rising edge causes the timers to reload and then count down.

42.3.8.10 Case 1: TCTRL*n*[MODE] = 10

The following figure represents case 1 in which TCTRL*n*[MODE] = 10. LPIT works in 32-bit trigger accumulator mode and is configured as follows:

- TCTRL*n*[TSOT] = X
- TCTRL*n*[TROT] = X
- TCTRL*n*[TSOI] = 0
- TCTRL*n*[CHAIN] = 0

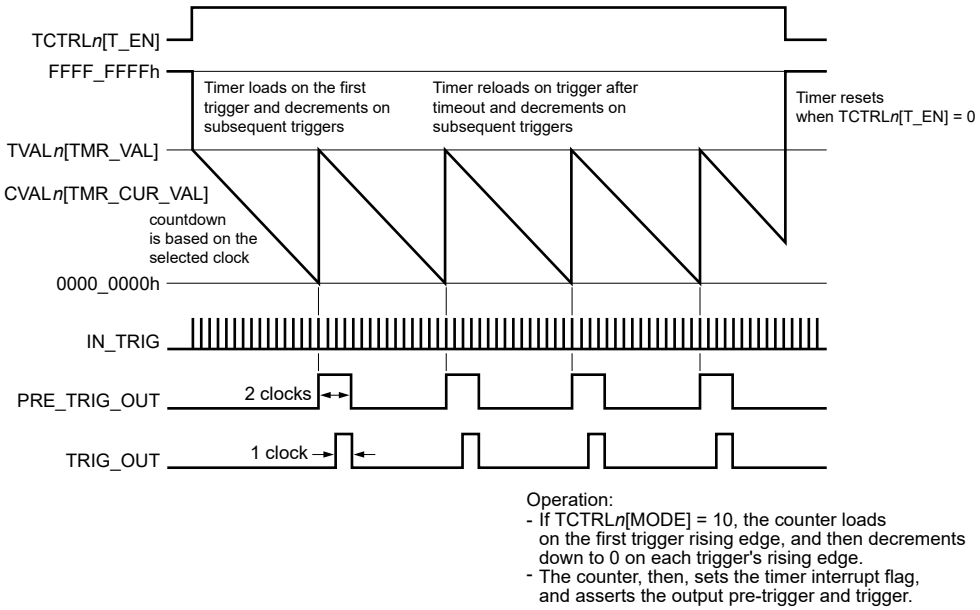


Figure 133. Case 1: TSOT = X, TROT = X, TSOI = 0, CHAIN = 0

42.3.8.11 Case 2: TCTRL*n*[MODE] = 10

The following figure represents case 2 in which TCTRL*n*[MODE] = 10. LPIT works in 32-bit trigger accumulator mode and is configured as follows:

- TCTRL*n*[TSOT] = X
- TCTRL*n*[TROT] = X
- TCTRL*n*[TSOI] = 1
- TCTRL*n*[CHAIN] = 0

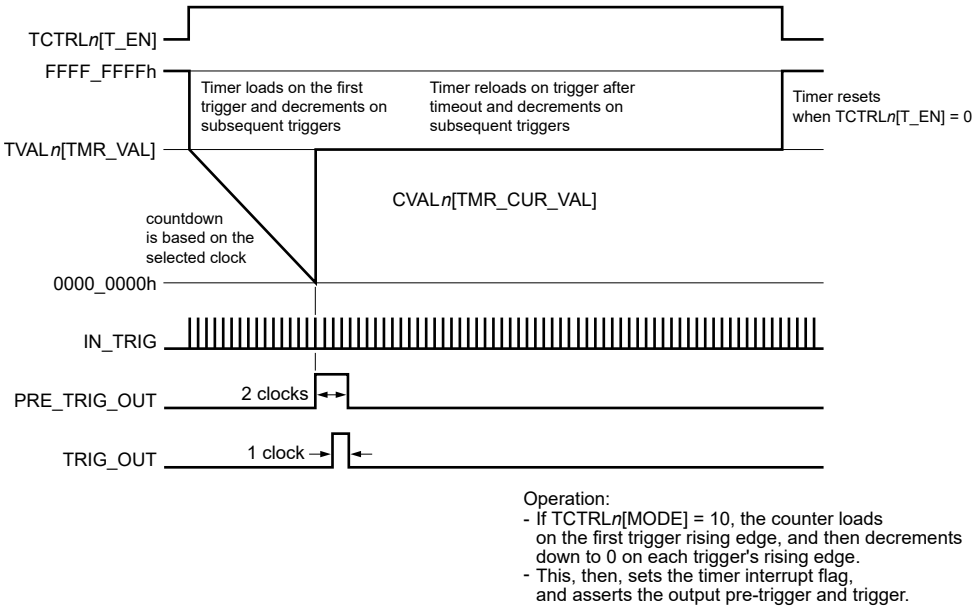


Figure 134. Case 2: TSOT = X, TROT = X, TSOI = 1, CHAIN = 0

42.3.8.12 Case 1: TCTRL*n*[MODE] = 11

The following figure represents case 1 in which TCTRL*n*[MODE] = 11. LPIT works in 32-bit trigger capture mode and is configured as follows:

- TCTRL*n*[TSOT] = X
- TCTRL*n*[TROT] = 0
- TCTRL*n*[TSOI] = 0
- TCTRL*n*[CHAIN] = 0

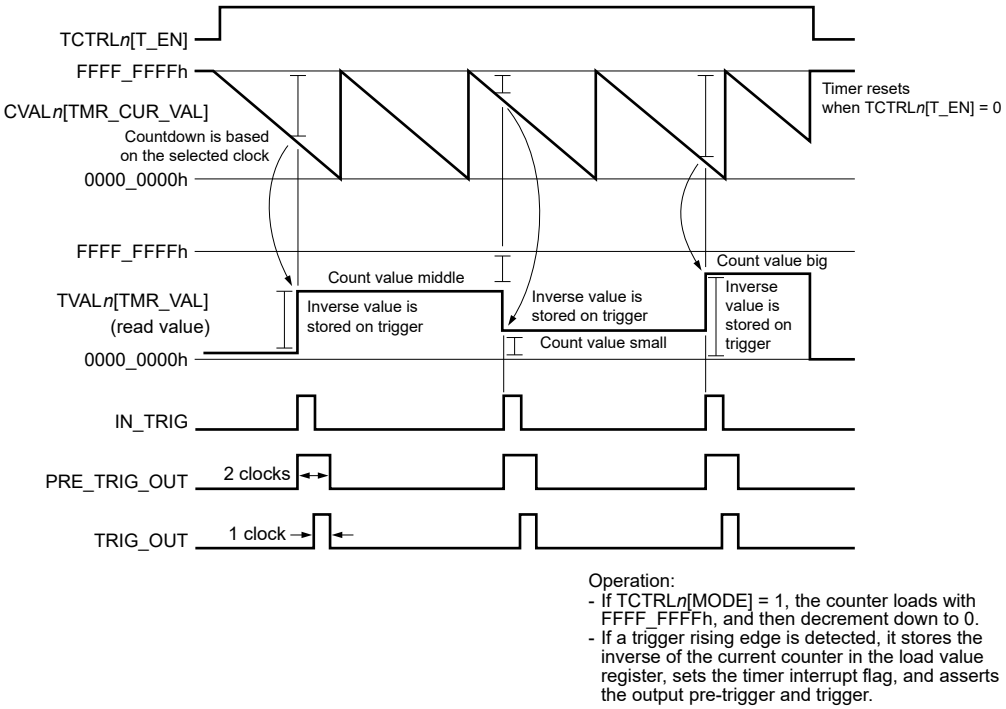


Figure 135. Case 1: TSOT = X, TROT = 0, TSOI = 0, CHAIN = 0

42.3.8.13 Case 2: TCTRL*n*[MODE] = 11

The following figure represents case 2 in which TCTRL*n*[MODE] = 11. LPIT works in 32-bit trigger capture mode and is configured as follows:

- TCTRL*n*[TSOT] = X
- TCTRL*n*[TROT] = 1
- TCTRL*n*[TSOI] = 0
- TCTRL*n*[CHAIN] = 0

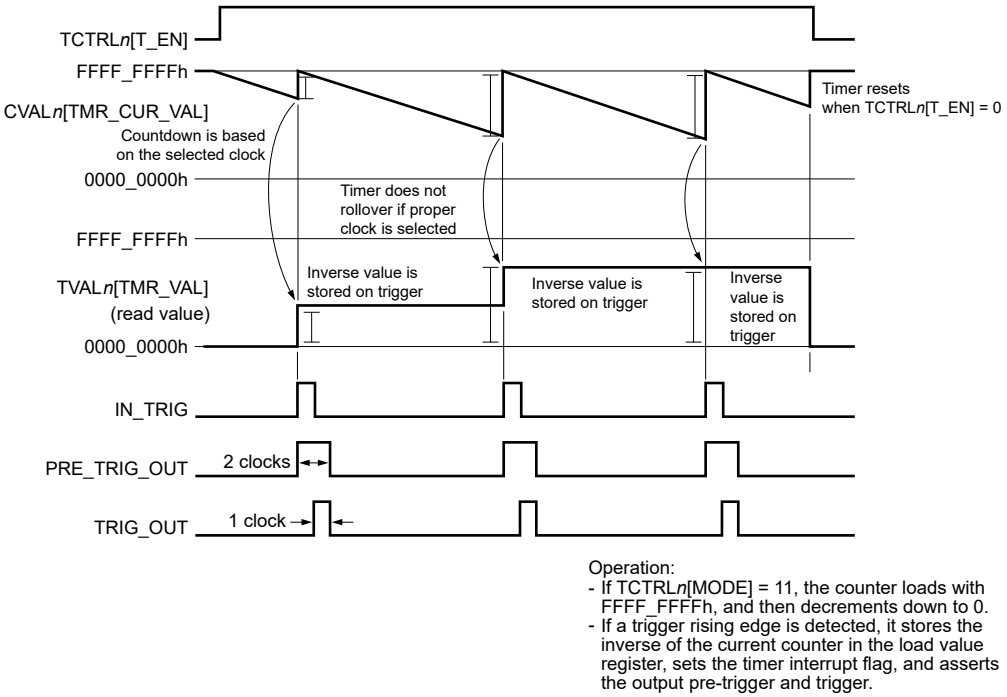


Figure 136. Case 2: TSOT = X, TROT = 1, TSOI = 0, CHAIN = 0

42.3.8.14 Case 3: TCTRL*n*[MODE] = 11

The following figure represents case 3 in which TCTRL*n*[MODE] = 11. LPIT works in 32-bit trigger capture mode and is configured as follows:

- TCTRL*n*[TSOT] = X
- TCTRL*n*[TROT] = 0
- TCTRL*n*[TSOI] = 1
- TCTRL*n*[CHAIN] = 0

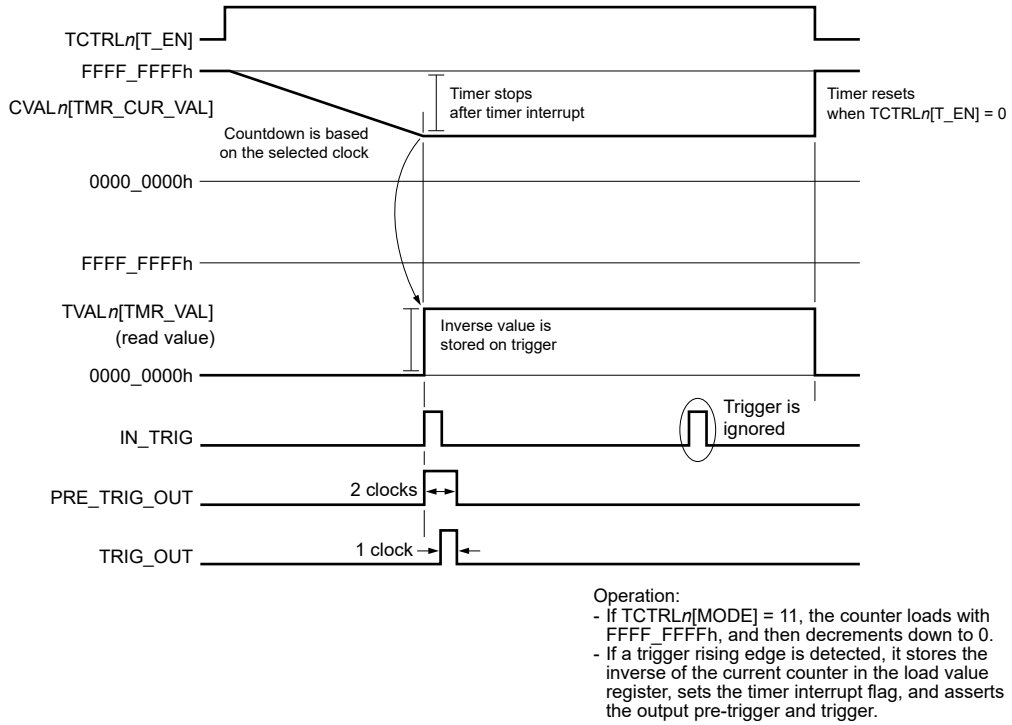


Figure 137. Case 3: TSOT = X, TROT = 0, TSOI = 1, CHAIN = 0

42.3.8.15 Case 4: TCTRL*n*[MODE] = 11

Case 4, in which TCTRL*n*[MODE] = 11, is the same as case 3, except that the timer reloads to FFFF_FFFFh and then stops. The timer does not start until TCTRL*n*[T_EN] becomes 1 again. In this case, LPIT works in 32-bit trigger capture mode and is configured as follows:

- TCTRL*n*[TSOT] = X
- TCTRL*n*[TROT] = 1
- TCTRL*n*[TSOI] = 1
- TCTRL*n*[CHAIN] = 0

42.3.9 Timer chaining

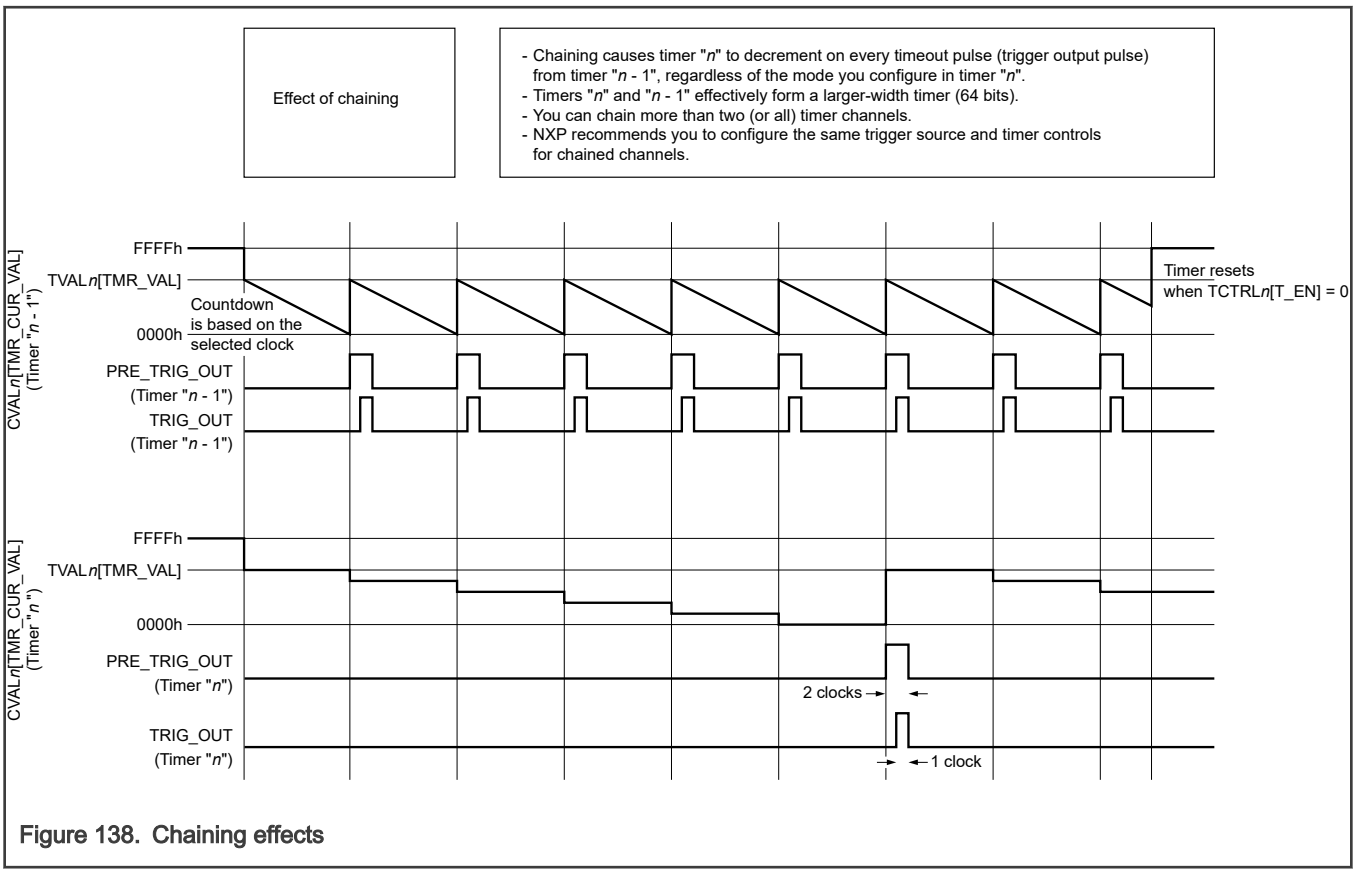


Figure 138. Chaining effects

42.4 Initialization

Table 297. Initializing LPIT

Step	Action	How or why to perform the step
1	Enable the peripheral clock	By writing 1 to MCR[M_CEN]. **NOTE** • Accessing certain registers (Module Status (MSR), Set Timer Enable (SETTEN), Clear Timer Enable (CLRTEN), Timer Value (TVAL0 - TVAL3), Current Timer Value (CVAL0 - CVAL3), and Timer Control (TCTRL0 - TCTRL3)) while MCR[M_CEN] = 0 leads to the assertion of a transfer error for that bus access. However, writing to CVAL*n* and reserved registers generates a transfer error. • There might be additional clock gating fields in the chip that gate the peripheral clock to this module. When enabling the clock to this module, you must configure those additional clock gating fields (in addition to configuring MCR[M_CEN]).
2	Wait for four peripheral clock cycles	To allow time for clock synchronization and reset deassertion.

Table continues on the next page...

Table 297. Initializing LPIT (continued)

Step	Action	How or why to perform the step
3	Configure timer control fields	For each timer channel that is to be enabled: • Timer mode of operation fields, TCTRL*n*[MODE] • Trigger source selection fields, TCTRL*n*[TRG_SEL] and TCTRL*n*[TRG_SRC] • Trigger control fields, TCTRL*n*[TROT], TCTRL*n*[TSOT], and TCTRL*n*[TSOI] **NOTE** You must not update timer control fields when the timer is disabled. You can disable a timer by using any one of the following methods: • Write 1 to the specific timer's CLRTEN[CLR_T_EN_*n*] field. • Write 0 to TCTRL*n*[T_EN] for that channel.
4	Configure the channels that are to be chained	By writing 1 to TCTRL*n*[CHAIN] in the corresponding channel's Timer Control (TCTRL0 - TCTRL3).
5	Set the timer timeout value	By programming an appropriate value in TVAL*n*[TMR_VAL] for the channels that you configure in Compare mode.
6	Configure MIER[TIE*n*]	For those channels that are required to generate interrupts after timer timeouts.
7	Configure the low-power modes of the module	By writing 1 to MCR[DBG_EN] and MCR[DOZE_EN]. This is common to all timer channels.
8	Enable the channel timers	By writing 1 to the corresponding TCTRL*n*[T_EN].

NOTE

When you enable a timer channel in Compare mode, the first decrement takes an additional one or two clock cycles because of synchronization logic. This results in the first compare (and therefore interrupt and hardware trigger) occurring slightly later. A faster counter clock minimizes this impact.

Additionally,

- For channels that you configure in Capture mode, you can read the timer value from Timer Value (TVAL0 - TVAL3) when a channel timeout occurs.
- At any time, you can read the current value of the timer for any channel by reading the corresponding channel's Current Timer Value (CVAL0 - CVAL3). Ensure that MCR[M_CEN] = 1 when doing so.
- MSR[TIF*n*] are asserted after timer timeout. To clear these timer interrupt flags, write 1 to them.

42.5 Memory map and registers

42.5.1 LPIT register descriptions

The LPIT memory map comprises 32-bit aligned registers, which you can access via 8-bit, 16-bit, or 32-bit accesses. Read and write accesses to reserved locations generate a transfer error, and the read bus shows all 0s.

NOTE

- The memory map and complete module are in big-endian (BE) format.
- LPIT does not check whether programmed values in these registers are correct—you must write the correct values.

42.5.1.1 LPIT memory map

LPIT0 base address: 4002_F000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	0100_0000h
4h	Parameter (PARAM)	32	R	0000_0404h
8h	Module Control (MCR)	32	RW	0000_0000h
Ch	Module Status (MSR)	32	RW	0000_0000h
10h	Module Interrupt Enable (MIER)	32	RW	0000_0000h
14h	Set Timer Enable (SETTEN)	32	RW	0000_0000h
18h	Clear Timer Enable (CLRTEN)	32	RW	0000_0000h
20h	Timer Value (TVAL0)	32	RW	0000_0000h
24h	Current Timer Value (CVAL0)	32	R	FFFF_FFFFh
28h	Timer Control (TCTRL0)	32	RW	0000_0000h
30h	Timer Value (TVAL1)	32	RW	0000_0000h
34h	Current Timer Value (CVAL1)	32	R	FFFF_FFFFh
38h	Timer Control (TCTRL1)	32	RW	0000_0000h
40h	Timer Value (TVAL2)	32	RW	0000_0000h
44h	Current Timer Value (CVAL2)	32	R	FFFF_FFFFh
48h	Timer Control (TCTRL2)	32	RW	0000_0000h
50h	Timer Value (TVAL3)	32	RW	0000_0000h
54h	Current Timer Value (CVAL3)	32	R	FFFF_FFFFh
58h	Timer Control (TCTRL3)	32	RW	0000_0000h

42.5.1.2 Version ID (VERID)

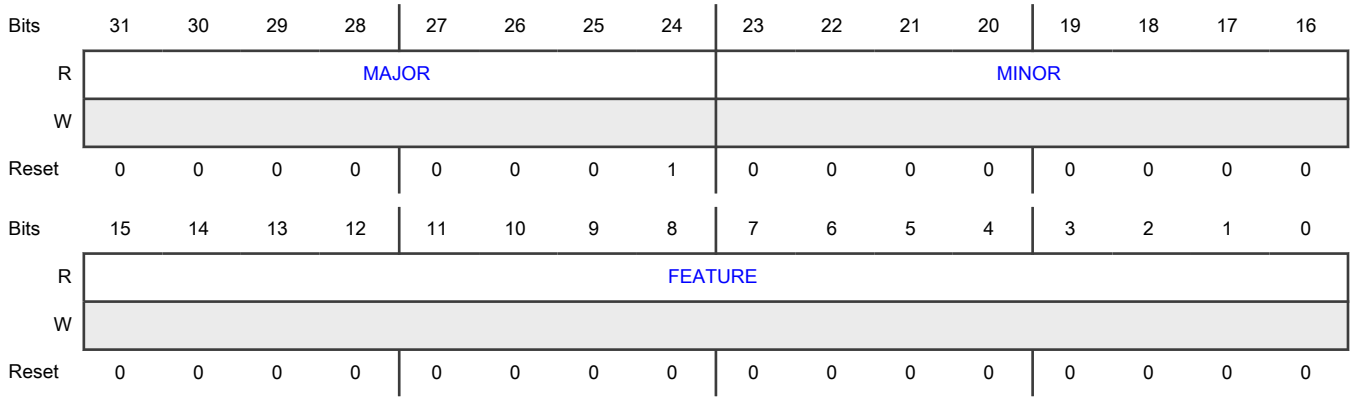
Offset

Register	Offset
VERID	0h

Function

Contains design version specification numbers.

Diagram



Fields

Field	Function
31-24 MAJOR	Major Version Number Indicates the major version number for the module design specification.
23-16 MINOR	Minor Version Number Indicates the minor version number for the module design specification.
15-0 FEATURE	Feature Number Indicates the feature set number.

42.5.1.3 Parameter (PARAM)

Offset

Register	Offset
PARAM	4h

Function

Provides parameter settings that are used when incorporating this module into the chip.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	EXT_TRIG								CHANNEL							
W																
Reset	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0

Fields

Field	Function
31-16 —	Reserved
15-8 EXT_TRIG	Number of External Trigger Inputs Specifies the number of external triggers implemented in this chip.
7-0 CHANNEL	Number of Timer Channels Specifies the number of timer channels implemented in this chip.

42.5.1.4 Module Control (MCR)

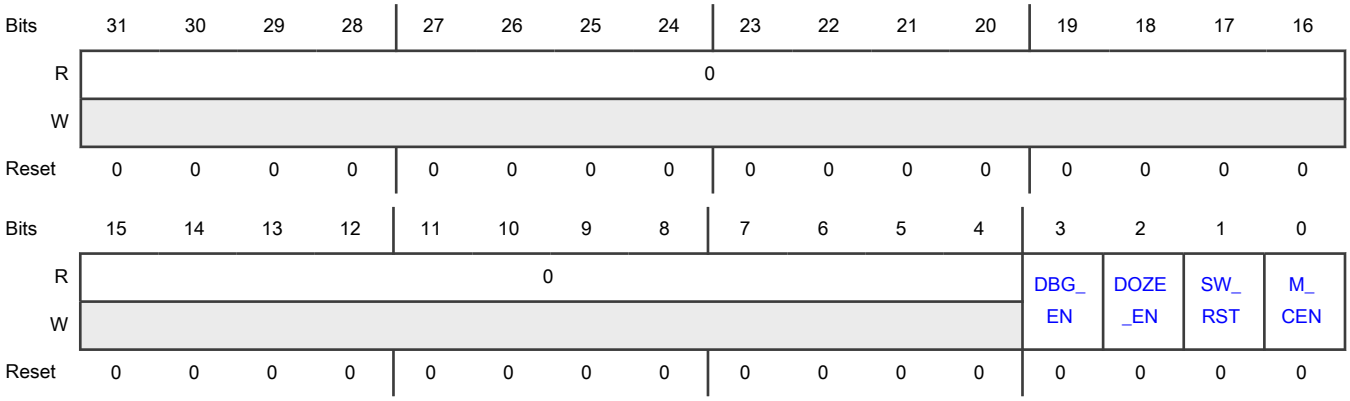
Offset

Register	Offset
MCR	8h

Function

Contains software reset, clock enable, and mode enable fields.

Diagram



Fields

Field	Function
31-4 —	Reserved
3 DBG_EN	Debug Mode Enable Stops the timer channels when the chip enters Debug mode. 0b - Stops timer channels 1b - Allows timer channels to continue running
2 DOZE_EN	DOZE Mode Enable Stops the timer channels when the chip enters Doze mode. 0b - Stops timer channels 1b - Allows timer channels to continue running
1 SW_RST	Software Reset Resets all timer channels and registers, except Module Status (MSR). This field remains 1 until software clears it. Before clearing this field, software must wait for four peripheral clocks (for clock synchronization and reset propagation). 0b - Does not reset 1b - Resets
0 M_CEN	Module Clock Enable Enables the peripheral clock to LPIT module timers. This field must become 1 when accessing the following registers: • Module Status (MSR) • Set Timer Enable (SETTEN) • Clear Timer Enable (CLRTEN)

Table continues on the next page...

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Field	Function
	• Timer Value (TVAL0 - TVAL3) • Current Timer Value (CVAL0 - CVAL3) • Timer Control (TCTRL0 - TCTRL3) The following considerations apply when using this field: • You must enable both the bus and peripheral clocks to allow clock synchronization and update of the aforementioned registers. Accessing these registers when MCR[M_CEN] = 0 asserts a transfer error for that bus cycle. • Writing to Current Timer Value (CVAL0 - CVAL3) and reserved registers always generates a transfer error. **NOTE** There may be additional clock gating fields available in this chip that gate the peripheral clock to LPIT. You must configure those additional clock gating fields appropriately to enable the peripheral clock to LPIT. 0b - Disable 1b - Enable

42.5.1.5 Module Status (MSR)

Offset

Register	Offset
MSR	Ch

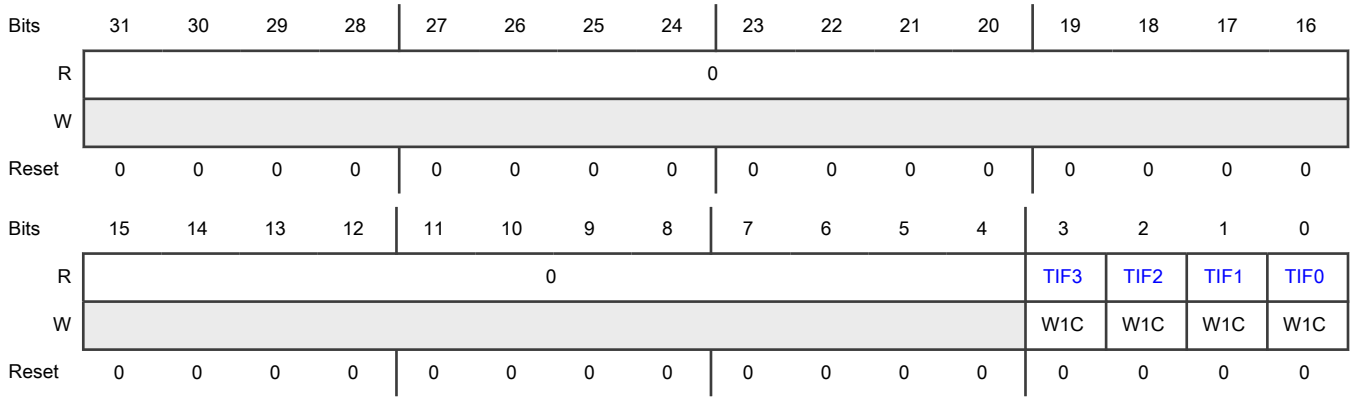
Function

Contains channel timer interrupt flags.

NOTE

Unless the peripheral clock to the timers is enabled (MCR[M_CEN] = 1), reading or writing to this register generates a transfer error.

Diagram



Fields

Field	Function
31-4 —	Reserved
3 TIF3	Channel 3 Timer Interrupt Flag Specifies whether the channel 3 timer has timed out. In compare modes, at the end of the timer period, this flag becomes 1. In capture modes, when the trigger asserts, this flag becomes 1. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not timed out 1b - Timed out When writing 0b - No effect 1b - Clear the flag
2 TIF2	Channel 2 Timer Interrupt Flag Specifies whether the channel 2 timer has timed out. In compare modes, at the end of the timer period, this flag becomes 1. In capture modes, when the trigger asserts, this flag becomes 1. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not timed out

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Timed out When writing 0b - No effect 1b - Clear the flag
1 TIF1	Channel 1 Timer Interrupt Flag Specifies whether the channel 1 timer has timed out. In compare modes, this flag becomes 1 at the end of the timer period. In capture modes, this flag becomes 1 when the trigger asserts. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not timed out 1b - Timed out When writing 0b - No effect 1b - Clear the flag
0 TIF0	Channel 0 Timer Interrupt Flag Specifies whether the channel 0 timer has timed out. In compare modes, this flag becomes 1 at the end of the timer period. In capture modes, this flag becomes 1 when the trigger asserts. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not timed out 1b - Timed out When writing 0b - No effect 1b - Clear the flag

42.5.1.6 Module Interrupt Enable (MIER)

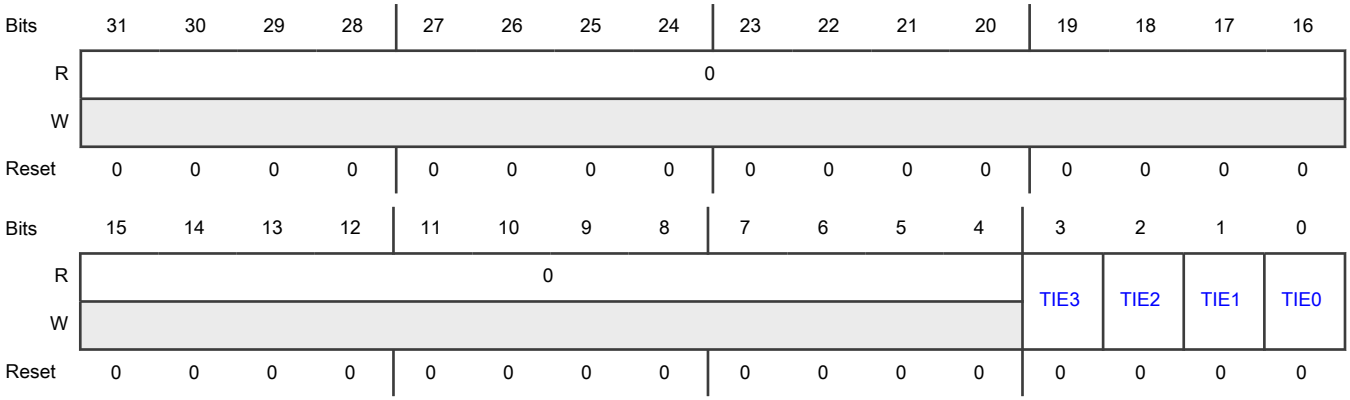
Offset

Register	Offset
MIER	10h

Function

Contains channel timer interrupt enable fields.

Diagram



Fields

Field	Function
31-4 —	Reserved
3 TIE3	Channel 3 Timer Interrupt Enable Enables interrupt generation when: • This field = 1. • The corresponding timer interrupt flag, MSR[TIF3] = 1. 0b - Disable 1b - Enable
2 TIE2	Channel 2 Timer Interrupt Enable Enables interrupt generation when: • This field = 1. • The corresponding timer interrupt flag, MSR[TIF2] = 1. 0b - Disable 1b - Enable

Table continues on the next page...

Table continued from the previous page...

Field	Function
1 TIE1	Channel 1 Timer Interrupt Enable Enables interrupt generation when: • This field = 1. • The corresponding timer interrupt flag, MSR[TIF1] = 1. 0b - Disable 1b - Enable
0 TIE0	Channel 0 Timer Interrupt Enable Enables interrupt generation when: • This field = 1. • The corresponding timer interrupt flag, MSR[TIF0] = 1. 0b - Disable 1b - Enable

42.5.1.7 Set Timer Enable (SETTEN)

Offset

Register	Offset
SETTEN	14h

Function

Allows the simultaneous enabling of timer channels.

You can enable timer channels by using either of the following ways:

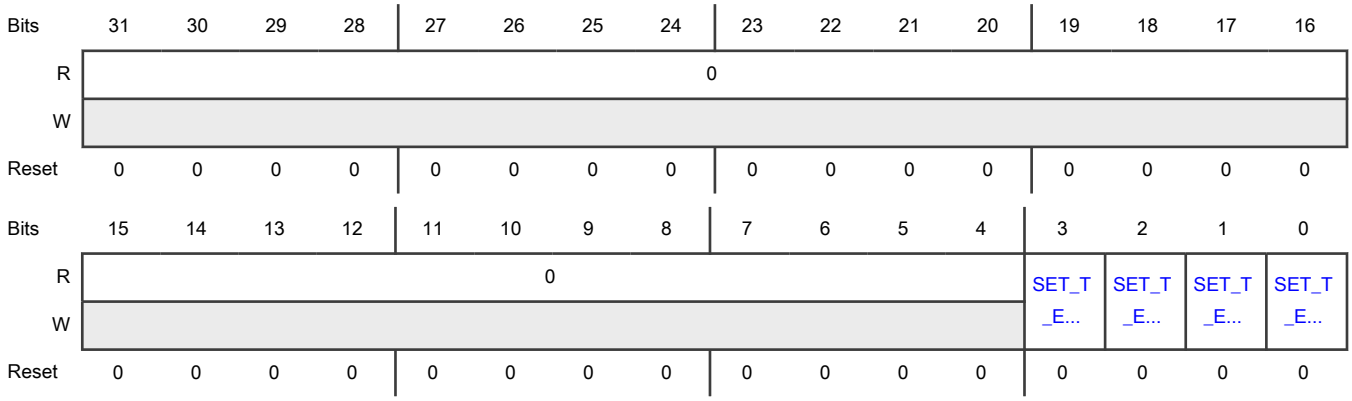
- Writing 1 to TCTRL*n*[T_EN] in the respective TCTRL*n* register.
- Writing 1 to the corresponding SETTEN[SET_T_EN_*n*] field.

To disable timer channels simultaneously, use Clear Timer Enable (CLRTEN). Writing 0 to the fields of this register has no effect.

NOTE

Unless the peripheral clock to the timers is enabled (MCR[M_CEN] = 1), reading or writing to this register generates a transfer error.

Diagram



Fields

Field	Function
31-4 —	Reserved
3 SET_T_EN_3	Set Timer 3 Enable Works with TCTRL3[T_EN] and enables timer channel 3. Writing 0 to this field does not disable the counter; rather it has no effect. This field becomes 0 if any of the following conditions is true: • TCTRL3[T_EN] = 0 • You write 1 to CLRTEN[CLR_T_EN_3] 0b - No effect 1b - Enables timer channel 3
2 SET_T_EN_2	Set Timer 2 Enable Works with TCTRL2[T_EN] and enables timer channel 2. Writing 0 to this field does not disable the counter; rather it has no effect. This field becomes 0 if any of the following conditions is true: • TCTRL2[T_EN] = 0 • You write 1 to CLRTEN[CLR_T_EN_2] 0b - No Effect 1b - Enables timer channel 2
1 SET_T_EN_1	Set Timer 1 Enable Works with TCTRL1[T_EN] and enables timer channel 1. Writing 0 to this field does not disable the counter; rather it has no effect. This field becomes 0 if any of the following conditions is true:

Table continues on the next page...

Table continued from the previous page...

Field	Function
	• TCTRL1[T_EN] = 0 • You write 1 to CLRTEN[CLR_T_EN_1] 0b - No Effect 1b - Enables timer channel 1
0 SET_T_EN_0	Set Timer 0 Enable Works with TCTRL0[T_EN] and enables timer channel 0. Writing 0 to this field does not disable the counter; rather it has no effect. This field becomes 0 if any of the following conditions is true: • TCTRL0[T_EN] = 0 • You write 1 to CLRTEN[CLR_T_EN_0] 0b - No effect 1b - Enables timer channel 0

42.5.1.8 Clear Timer Enable (CLRTEN)

Offset

Register	Offset
CLRTEN	18h

Function

Allows the simultaneous disabling of timer channels.

NOTE

Unless the peripheral clock to the timers is enabled (MCR[M_CEN] = 1), reading or writing to this register generates a transfer error.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												0	0	0	0
W													CLR_T_E...	CLR_T_E...	CLR_T_E...	CLR_T_E...
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-4 —	Reserved
3 CLR_T_EN_3	Clear Timer 3 Enable Works with TCTRL3[T_EN] and disables timer channel 3. Writing 1 to this self-clearing field does not enable the counter. It disables timer channel 3. It also turns TCTRL3[T_EN] = 0 for timer channel 3. 0b - No action 1b - Turns TCTRL3[T_EN] = 0 for timer channel 3
2 CLR_T_EN_2	Clear Timer 2 Enable Works with TCTRL2[T_EN] and disables timer channel 2. Writing 1 to this self-clearing field does not enable the counter. It disables timer channel 2. It also turns TCTRL2[T_EN] = 0 for timer channel 2. 0b - No action 1b - Turns TCTRL2[T_EN] = 0 for timer channel 2
1 CLR_T_EN_1	Clear Timer 1 Enable Works with TCTRL1[T_EN] and disables timer channel 1. Writing 1 to this self-clearing field does not enable the counter. It disables timer channel 1. It also turns TCTRL1[T_EN] = 0 for timer channel 1. 0b - No action 1b - Turns TCTRL1[T_EN] = 0 for timer channel 1
0 CLR_T_EN_0	Clear Timer 0 Enable Works with TCTRL0[T_EN] and disables timer channel 0. Writing 1 to this self-clearing field does not enable the counter. It disables timer channel 0. It also turns TCTRL0[T_EN] = 0 for timer channel 0. 0b - No action 1b - Turns TCTRL0[T_EN] = 0 for timer channel 0

42.5.1.9 Timer Value (TVAL0 - TVAL3)

Offset

Register	Offset
TVAL0	20h
TVAL1	30h

Table continues on the next page...

Table continued from the previous page...

Register	Offset
TVAL2	40h
TVAL3	50h

Function

Contains timer values:

- In compare modes, this register selects the timeout period for the timer channels.
- In capture modes, this register is loaded with the value of the counter when the trigger asserts.

NOTE

Unless the peripheral clock to the timers is enabled (MCR[M_CEN] = 1), reading or writing to this register generates a transfer error.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	TMR_VAL															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	TMR_VAL															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 TMR_VAL	Timer Value Specifies the timer value and whether it is valid. • In Compare mode, this field specifies the timer channel start value: — The timer counts down for (TVAL*n* + 1) cycles until the timer reaches 0, then the timer generates an interrupt and loads the TVAL*n* value again. — Writing a new value to TVAL*n* does not restart the timer channel; instead, the new value is loaded "after the timer expires." — To abort the current timer cycle and start a timer period with a new value, you must disable the timer channel and then enable it again. • In Capture mode, whenever the trigger asserts, this register stores the inverse of the counter value.

Table continues on the next page...

Field	Function
	0000_0000_0000_0000_0000_0000_0000_0000b,0000_0000_0000_0000_0000_0000_0000_0001b - Invalid load value in Compare mode 0000_0000_0000_0000_0000_0000_0000_0010b-1111_1111_1111_1111_1111_1111_1111_1111b - In Compare mode: the value to be loaded; in Capture mode, the value of the timer

42.5.1.10 Current Timer Value (CVAL0 - CVAL3)

Offset

Register	Offset
CVAL0	24h
CVAL1	34h
CVAL2	44h
CVAL3	54h

Function

Indicates the current timer counter value.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	TMR_CUR_VAL															
W																
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	TMR_CUR_VAL															
W																
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-0 TMR_CUR_VAL	Current Timer Value Represents the current timer value, if the timer is enabled.

42.5.1.11 Timer Control (TCTRL0 - TCTRL3)

Offset

Register	Offset
TCTRL0	28h
TCTRL1	38h
TCTRL2	48h
TCTRL3	58h

Function

Contains control fields for each timer channel:

- TRG_SEL for trigger selection
- TRG_SRC for trigger source selection
- TROT for timer reload
- TSOI for timer stoppage
- TSOT for timer decrementing
- MODE for timer operation mode selection
- CHAIN for channel chaining

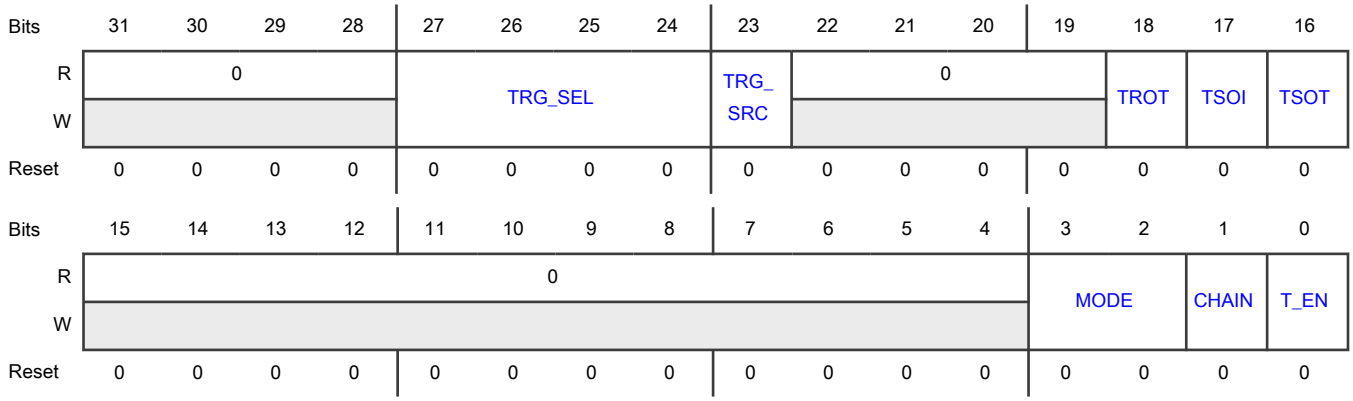
You must update timer controls when the timer is disabled, and use either of the following ways to disable a timer:

- By writing 1 to the specific timer's CLRTEN[CLR_T_EN_*n*] field.
- By writing 0 to T_EN for that channel.

NOTE

Unless the peripheral clock to the timers is enabled (MCR[M_CEN] = 1), reading or writing to this register generates a transfer error.

Diagram



Fields

Field	Function
31-28 —	Reserved
27-24 TRG_SEL	Trigger Select Selects the trigger to use for starting and/or reloading the LPIT timer. This field selects one trigger from the set of internal or external triggers that TRG_SRC provides. TRG_SRC helps you make a choice between internal and external trigger signals for each channel. **NOTE** You must change the value of this field when the LPIT timer channel is disabled. 0000b-0011b - Timer channel 0–3 trigger source 0100b-1111b - Reserved
23 TRG_SRC	Trigger Source Selects whether to use internal or external trigger sources. You can select the trigger to be used by using this field or the TRG_SEL field. If a channel does not have an associated external trigger, write 1 to TRG_SRC. See LPIT chip-specific information for the available external trigger options. 0b - External 1b - Internal
22-19 —	Reserved
18 TROT	Timer Reload on Trigger Specifies whether the timer reloads after the selected trigger. If this field = 1, the LPIT timer reloads when a rising edge is detected on the selected trigger input. The trigger input is ignored if LPIT is disabled during Debug mode (MCR[DBG_EN] = 0) or Doze mode (MCR[DOZE_EN] = 0). 0b - Does not reload 1b - Reloads
17 TSOI	Timer Stop on Interrupt Controls whether the channel timer stops after being timed out. If this field = 0, the channel timer does not stop after timeout. If this field = 1, the channel timer stops after a timeout and then restarts based on the configuration of TSOT. If TSOT = 0, the channel timer restarts after a rising edge on T_EN is detected, which means that the timer channel is disabled and then enabled. If TSOT = 1, the channel timer restarts after a rising edge on the selected trigger is detected. 0b - Does not stop 1b - Stops

Table continues on the next page...

Table continued from the previous page...

Field	Function
16 TSOT	Timer Start on Trigger Controls when the timer starts decrementing. If this field = 0, the timer starts decrementing immediately based on the restart condition (controlled by TSOI). If this field = 1, the timer starts decrementing when a rising edge on a selected trigger is detected. 0b - Immediately 1b - When a rising edge is detected
15-4 —	Reserved
3-2 MODE	Timer Operation Mode Configures the channel timer's mode of operation. This field controls how the timer decrements. 00b - 32-bit periodic counter 01b - Dual 16-bit periodic counter 10b - 32-bit trigger accumulator 11b - 32-bit trigger input capture
1 CHAIN	Chain Channel Specifies whether channel chaining is enabled. If channel chaining is enabled, the timer channel decrements after the previous channel's timeout (when timer channel N-1 trigger asserts). Timer channel 0 cannot be chained. If channel chaining is disabled, the channel timer runs independently. 0b - Disabled 1b - Enabled
0 T_EN	Timer Enable Enables the timer channel. 0b - Disable 1b - Enable

Chapter 43
Timer/PWM Module (TPM)

43.1 Chip-specific TPM information

Table 298. Reference links to related information

Topic	Related module	Reference
Full description	TPM	TPM
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

43.1.1 Module instances

This device has three instances of the TPM module, TPM0, TPM1, and TPM2.

43.1.2 Trigger options

Table 299. TPM trigger options

TPM2	0 = LPTMR0 trigger
	1 = LPTMR1 trigger
	2 = LPTMR2 trigger

43.2 Overview

TPM is a 6-channel timer that controls electric motor and power management applications by supporting:

- Input capture
- Output comparison
- Generation of PWM signals

An asynchronous clock that can remain enabled in low-power modes clocks the counter, compare, and capture registers.

43.2.1 Block diagram

TPM uses one input/output (I/O) pin per channel: CH*n* (TPM channel *n*) where *n* is the channel number.

The central component of TPM is a 32-bit counter with a programmable final value. Its counting can be up or up-down.

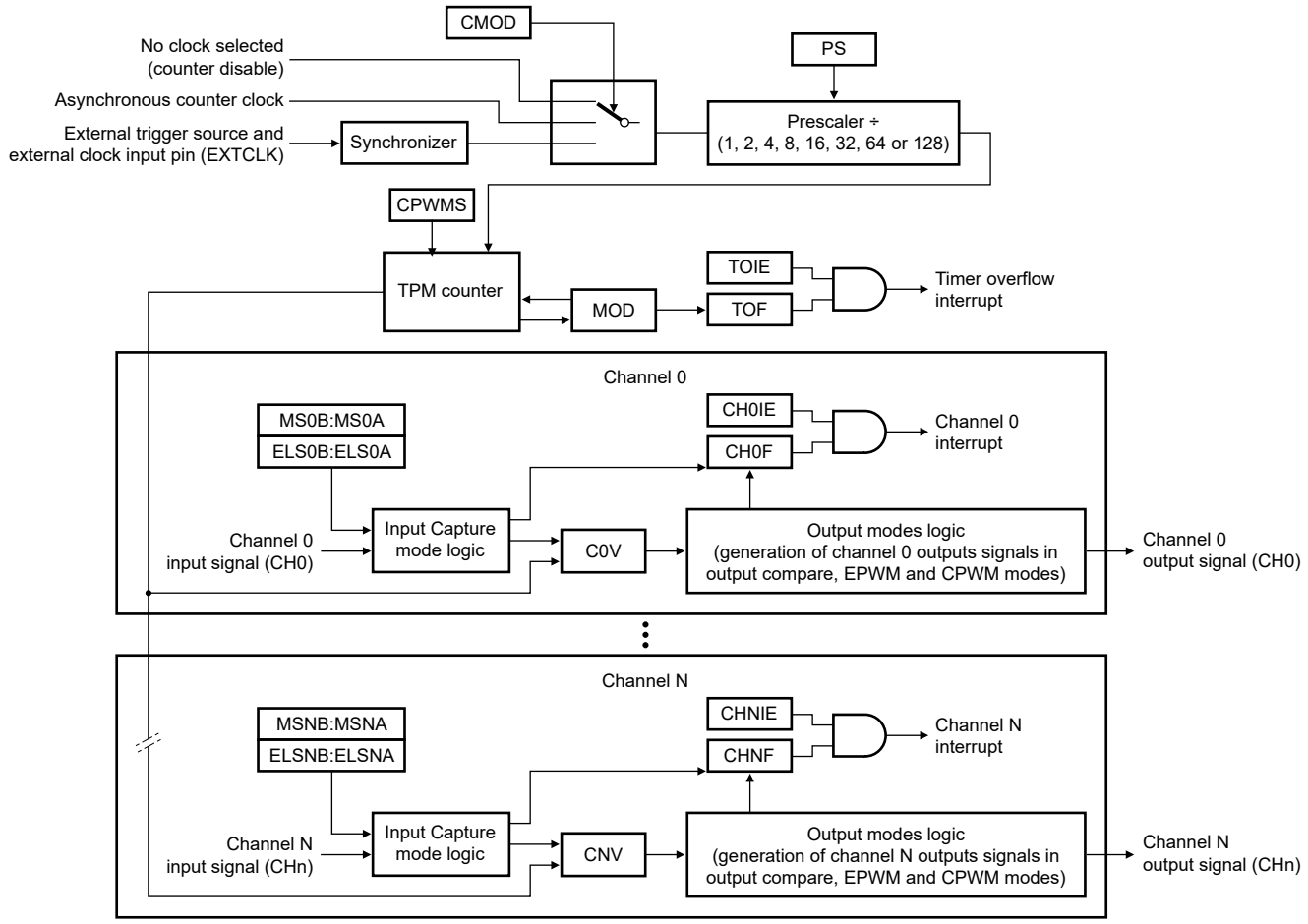


Figure 139. Block diagram

43.2.2 Features

- Supports selectable clock modes:
  - Can increment on every edge of the asynchronous counter clock
  - Can increment on the rising edge of an external clock input that is synchronized to the asynchronous counter clock
- Includes a prescaler divided by 1, 2, 4, 8, 16, 32, 64, or 128
- Includes a 32-bit TPM counter:
  - Can be a free-running counter or a modulo counter
  - The counting can be up or up-down
- Includes 6 channels that can be configured as follows:
  - Input Capture mode: the capture can occur on rising edges, falling edges, or both edges.
  - Output Compare mode: the output signal can be set, cleared, pulsed, or toggled on the match.
  - Edge-Aligned or Center-Aligned PWM mode for all channels.
- Supports the generation of an interrupt and DMA request per channel
- Supports the generation of an interrupt and DMA request when the counter overflows

- Supports selectable trigger input to either reset the counter to 0 or else cause the counter to start incrementing
  - The counter can also optionally stop incrementing on counter overflow.
- Supports the generation of hardware triggers per channel when the channel-interrupt-status flag is set
- Supports the generation of a hardware trigger when the counter overflows

43.3 Functional description

43.3.1 Counter

TPM has a 32-bit counter that the channels use for either input or output modes. The counter updates from the selected clock after it has been divided by the prescaler. The TPM counter can perform one of the following modes of operation:

- Up counting
- Up-down counting

43.3.1.1 Counter Clock mode

SC[CMOD] either disables the TPM counter or enables one of the three possible clock sources for the TPM counter. After any reset, SC[CMOD] becomes 0, which disables the TPM counter. You can configure SC[CMOD] for one of the following counter clock sources:

- Asynchronous counter clock
- External clock input pin
- External trigger source

You can read or write to SC[CMOD] at any time. Disabling the TPM counter by writing 0 to SC[CMOD] does not affect the TPM counter value or other registers, but the TPM counter clock domain must acknowledge this disabling action before SC[CMOD] becomes 0.

The external clock input and external trigger source pass through a synchronizer. The TPM counter clock clocks this synchronizer to ensure that counter transitions are properly aligned to counter clock transitions. Therefore, to meet Nyquist criteria, and also considering jitter, the frequency of the external clock source must be less than half of the counter clock frequency.

43.3.1.2 Prescaler

The counter clock source that you select passes through a prescaler that is a 7-bit counter. SC[PS] defines the value of the prescaler. The following figure shows an example of the prescaler counter and TPM counter.

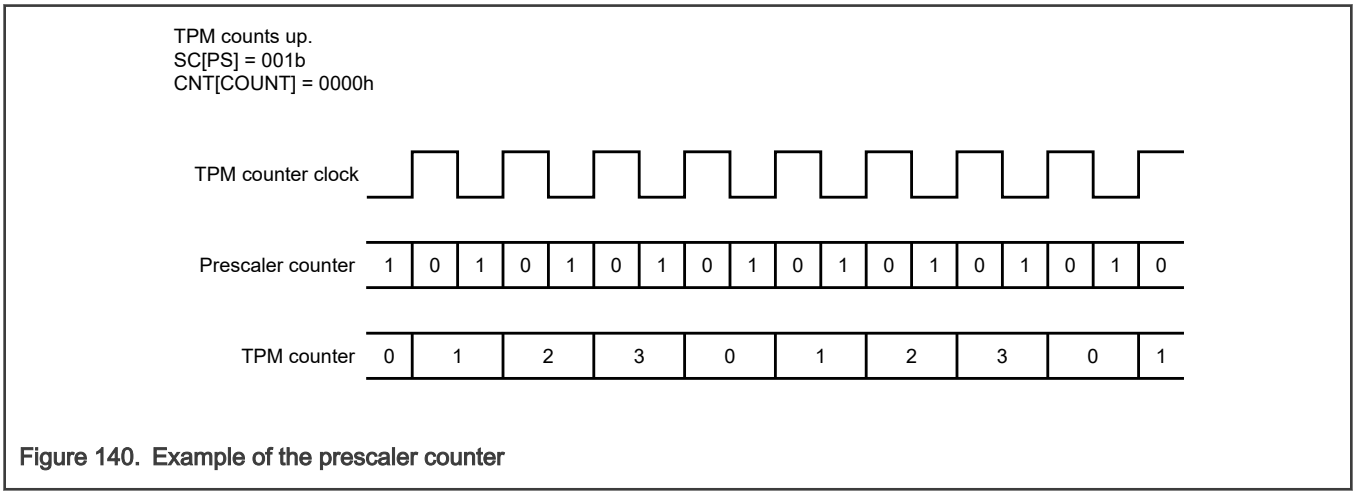


Figure 140. Example of the prescaler counter

43.3.1.3 Up counting

Up counting is enabled when you write 0 to SC[CPWMS].

In this mode, the TPM counter loads with value 0 and increments until it reaches the value defined in MOD[MOD], then the counter reloads with 0.

The TPM period when using up counting is (MOD[MOD] + 0001h) × period of the TPM counter clock.

SC[TOF] becomes 1 when the TPM counter changes from the value defined in MOD[MOD] to 0.

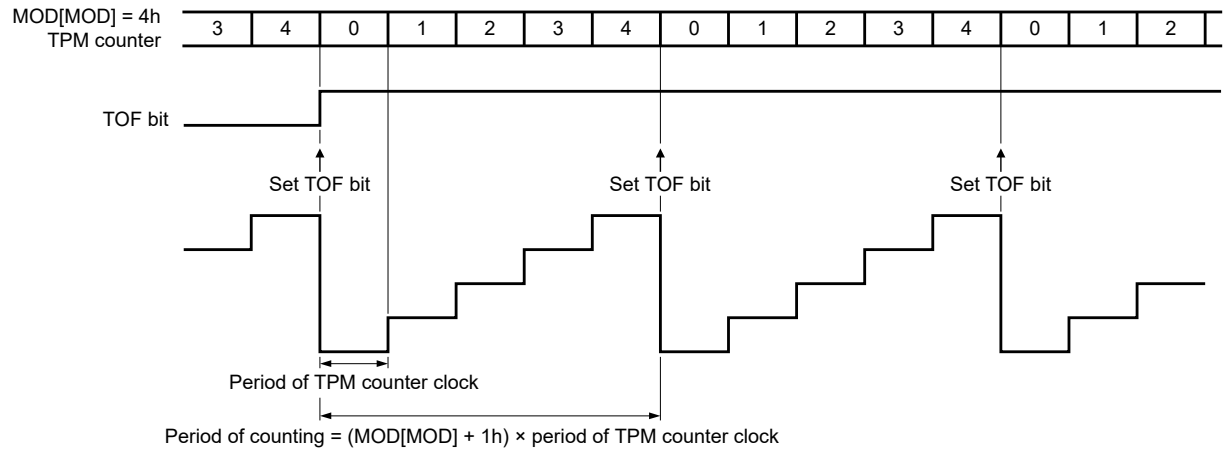


Figure 141. Example of TPM up counting

NOTE

- Configuring MOD[MOD] = 0 is a redundant condition. In this case, the TPM counter is always equal to the value of MOD[MOD], and SC[TOF] remains 1 for each rising edge of the TPM counter clock.
- Configuring MOD[MOD] = 1 and SC[PS] = 0 causes TPM to attempt to set SC[TOF] every second TPM counter clock. Because of synchronization delays between the TPM counter clock and the bus clock, you must write 1 to SC[TOF] to clear it two counter clock cycles before SC[TOF] can become 1 again.

43.3.1.4 Up-down counting

You enable up-down counting when you write 1 to SC[CPWMS]. This mode does not support configuring the value of Modulo (MOD) to be less than 2.

In this mode, the TPM counter loads with value 0 and increments until it reaches the value defined in MOD[MOD]. Then the counter starts decrementing until it returns to 0 and the up-down counting restarts.

The TPM period when using up-down counting is 2 × MOD[MOD] × period of the TPM counter clock.

TPM writes 1 to SC[TOF] when the TPM counter changes from the value defined in MOD[MOD] to (MOD[MOD] – 1).

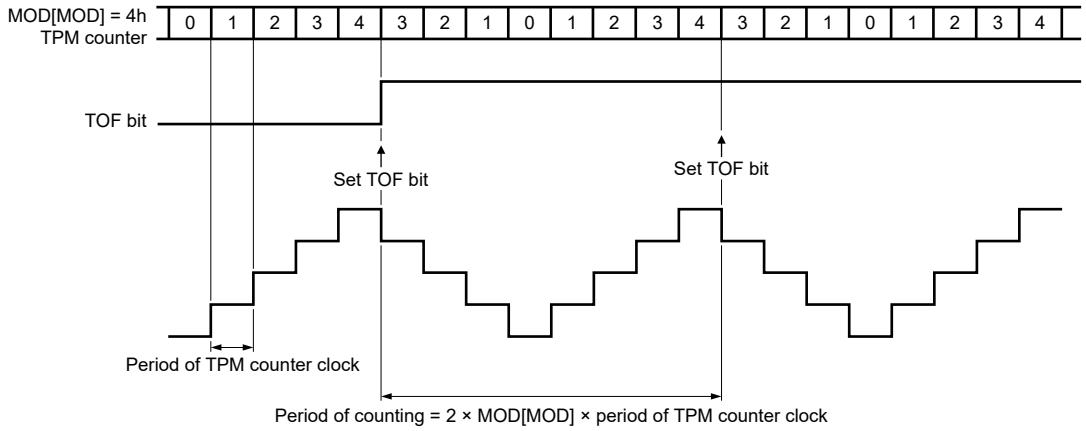


Figure 142. Example of up-down counting

43.3.1.5 Counter reset

Any write to CNT[COUNT] resets the TPM counter and forces the channel outputs to their initial values (except for channels in Output Compare mode).

43.3.1.6 Counter trigger

You can configure the TPM counter to start, stop, or reset in response to a hardware trigger input. The trigger input synchronizes with the asynchronous counter clock, so there is a three-counter-clock delay between the trigger assertion and counter response.

- When CONF[CSOT] = 1, the counter does not start incrementing until the trigger input detects a rising edge.
- When CONF[CSOO] = 1, the counter stops incrementing whenever SC[TOF] = 1. The counter does not increment again unless:
  - It is disabled.
  - CONF[CSOT] = 1 and the trigger input detects a rising edge.
- When CONF[CROT] = 1, the counter resets to 0, as if an overflow occurred, whenever the trigger input detects a rising edge. Any PWM channels are updated to their reload state.
- When CONF[CPOT] = 1, the counter pauses incrementing whenever you assert the trigger input. The counter continues incrementing when the trigger input negates. PWM output channels are forced to their default state.

You can configure the polarity of the external input trigger with CONF[TRGPOL].

When you enable an internal trigger source, the trigger input is selected from one or more channel input capture events. The input capture filters are used with the internal trigger sources. You can use POL[POL*n*] fields to invert the polarity of the input channels.

The following restrictions apply with input capture channel sources:

- When CONF[CSOT] = 1, the counter starts incrementing only on a rising edge on the channel input, if C*n*SC[ELS*n*A] = 1.
- When CONF[CROT] = 1, the counter resets to 0 on either edge of the channel input, as you configure it using C*n*SC[ELS*n*B] and C*n*SC[ELS*n*A].
- When CONF[CPOT] = 1, the counter pauses incrementing whenever you assert the channel input. PWM output channels are forced to their default state.

43.3.2 Registers updated from write buffers

43.3.2.1 MOD register update

If SC[CMOD] = 0, then Modulo (MOD) updates whenever you write to MOD[MOD].

If SC[CMOD] ≠ 0, then the MOD register updates accordingly as below:

- CPWM mode is disabled (SC[CPWMS] = 0), then the MOD register updates whenever you write to MOD[MOD], and the TPM counter value changes from the value defined in MOD[MOD] to 0.
- CPWM mode is enabled (SC[CPWMS] = 1), then the MOD register updates whenever you write to MOD[MOD], and the TPM counter value changes from the value defined in MOD[MOD] to (MOD[MOD] – 1).

43.3.2.2 C*n*V register update

If SC[CMOD] = 0, then the C*n*V register updates whenever you write to C*n*V[VAL].

If SC[CMOD] ≠ 0, then the C*n*V register updates according to the selected mode:

- If you select Output Compare mode, then the C*n*V register updates on the next TPM counter increment (end of the prescaler counting) after you write to C*n*V[VAL].
- If you select EPWM mode, then the C*n*V register updates after you write to C*n*V[VAL], and the TPM counter value changes from the value defined in MOD[MOD] to 0.
- If you select CPWM mode, then the C*n*V register updates after you write to C*n*V[VAL], and the TPM counter value changes from the value defined in MOD[MOD] to (MOD[MOD] – 1).

43.3.3 Peripheral triggers

See the chip-specific TPM information for more details.

43.3.3.1 Output triggers

TPM generates output triggers for the counter and for each channel that you can use to trigger events in other peripherals. The counter trigger asserts whenever SC[TOF] is 1 and remains asserted until the next increment.

Each TPM channel generates both a pre-trigger output and a trigger output.

1. The pre-trigger output asserts whenever C*n*SC[CH*n*F] sets.
2. The trigger output asserts on the first counter increment after the pre-trigger asserts.
3. Both the trigger and pre-trigger negate on the first counter increment after the trigger asserts.

When (COMBINE[COMBINE*n*] = 1) in Output Compare mode, the pre-trigger output for both channel *n* and channel *n* + 1 asserts when the CH*n*F flag is set and negates when the CH(*n* + 1)F flag is set. The trigger continues to assert on the first counter increment, after the pre-trigger asserts and negates at the same time as the pre-trigger negation.

43.3.3.2 Input trigger

You can configure the TPM input trigger to perform the following operations with configurable polarity:

- Increment the counter on trigger rising edge
- Start incrementing the counter on trigger rising edge
- Reset or reload the counter on trigger rising edge
- Pause the counter while trigger high

The TPM input trigger is synchronized and must remain asserted for at least two counter clock cycles, so that the input trigger can be detected.

43.3.4 Modes of operations

43.3.4.1 Input Capture mode

Input Capture mode is enabled when:

- (SC[CPWMS] = 0)
- (MS*n*B:MS*n*A = 0:0)
- (ELS*n*B:ELS*n*A ≠ 0:0)

When a selected edge occurs on the channel input:

- The C*n*V register captures the current value of the TPM counter.
- It also writes 1 to C*n*SC[CH*n*F] and generates a channel interrupt if C*n*SC[CH*n*IE] = 1 (see Figure 143).

When you configure a channel for input capture, the CH*n* pin is an edge-sensitive input. ELS*n*B:ELS*n*A control fields determine which edge, falling or rising, triggers the input-capture event. To detect the input signal correctly and to meet Nyquist criteria for signal sampling, the maximum frequency for the channel input signal is the counter clock divided by 4.

Input Capture mode ignores any writes to the C*n*V register.

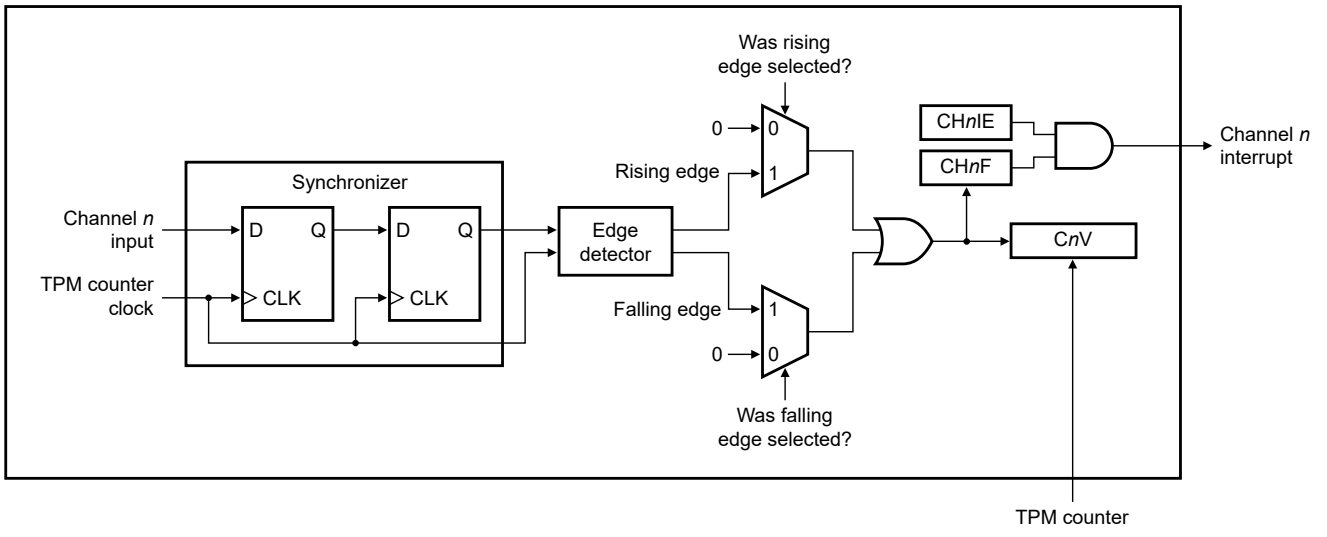


Figure 143. Input Capture mode

The CH*n*F flag is set on the third rising edge of the TPM counter clock after a valid edge occurs on the channel input.

43.3.4.1.1 Input capture filter

The input capture filter function is only available in Input Capture or Software Compare mode when Quadrature Decoder mode is enabled.

First, the TPM counter clock synchronizes the input signal. After synchronization, the input signal enters the filter block (see Figure 144).

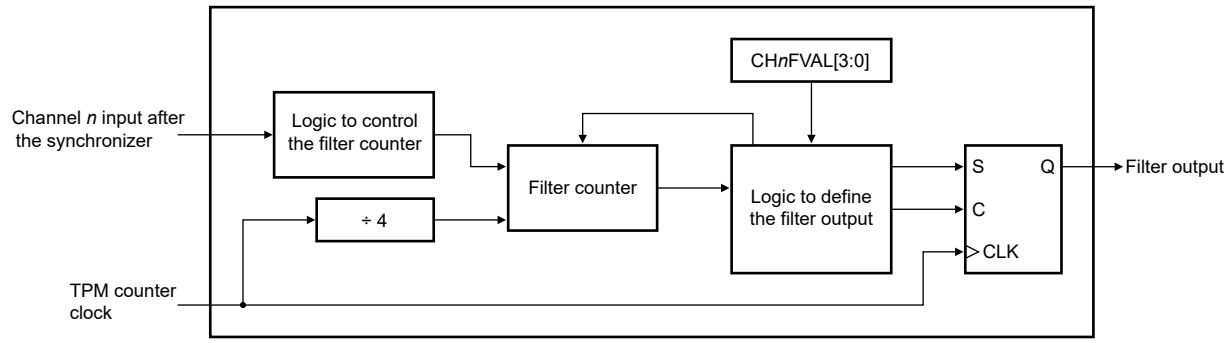


Figure 144. Channel input filter

When there is a state change in the input signal, TPM resets the counter, and it starts counting up. As long as the new state is stable on the input, the counter continues to increment. When the counter is equal to (CH*n*FVAL[3:0] × 4), the state change of the input signal is validated.

TPM resets the counter if the opposite edge appears on the input signal before it is validated. At the next input transition, the counter starts counting again. Any pulse that is less than the minimum value selected by (CH*n*FVAL[3:0] × 4 counter clocks) is considered as a glitch and does not pass through the filter. Figure 145 shows a timing diagram of the input filter.

The filter function is disabled when CH*n*FVAL[3:0] = 0. In this case, the input signal is delayed by 2 rising edges of the counter clock. If CH*n*FVAL[3:0] ≠ 0000, then the input signal is delayed by the minimum pulse width (CH*n*FVAL[3:0] × 4 system clocks) plus a further 3 rising edges of the system clock: two rising edges to the synchronizer, plus one more to the edge detector. In other words, the CH*n*F flag is set for (3 + (4 × CH*n*FVAL[3:0])) counter clock periods after a valid edge occurs on the channel input (see Figure 145).

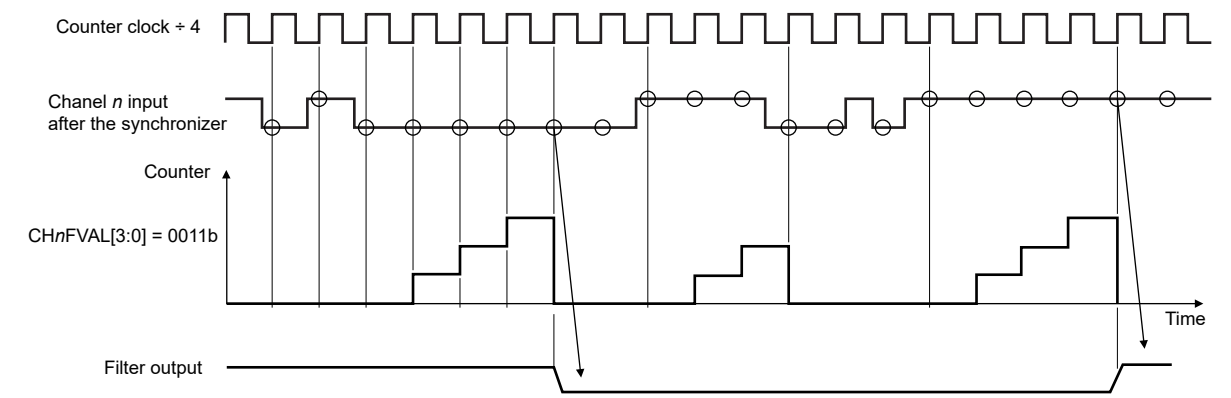


Figure 145. Channel input filter example

43.3.4.2 Output Compare mode

Output Compare mode is enabled when SC[CPWMS] = 0 and MS*n*B:MS*n*A = X:1.

In this mode, TPM can generate timed pulses with programmable:

- Position
- Polarity
- Duration
- Frequency

When the TPM counter matches the value defined in C*n*V[VAL] of an output compare channel, then channel *n* output can be set, cleared, or toggled if MS*n*B = 0. If MS*n*B = 1, then channel *n* output is pulsed high or low (as long as the TPM counter matches the value defined in C*n*V[VAL]).

When you initially configure a channel to Output Compare mode, the channel output is updated with its negated value (logic 0 for set/toggle/pulse high and logic 1 for clear/pulse low).

The channel *n* match (TPM counter = C*n*V[VAL]) writes 1 to C*n*SC[CH*n*F] and generates a channel *n* interrupt (if C*n*SC[CH*n*IE] = 1).

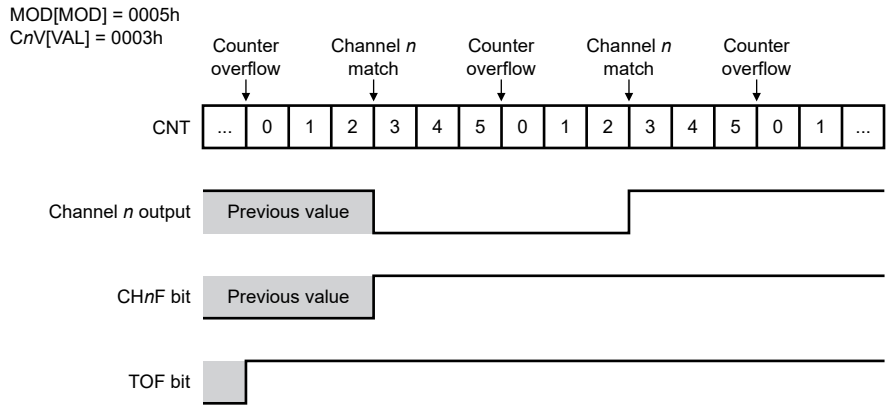


Figure 146. Example of Output Compare mode when a match toggles the channel output

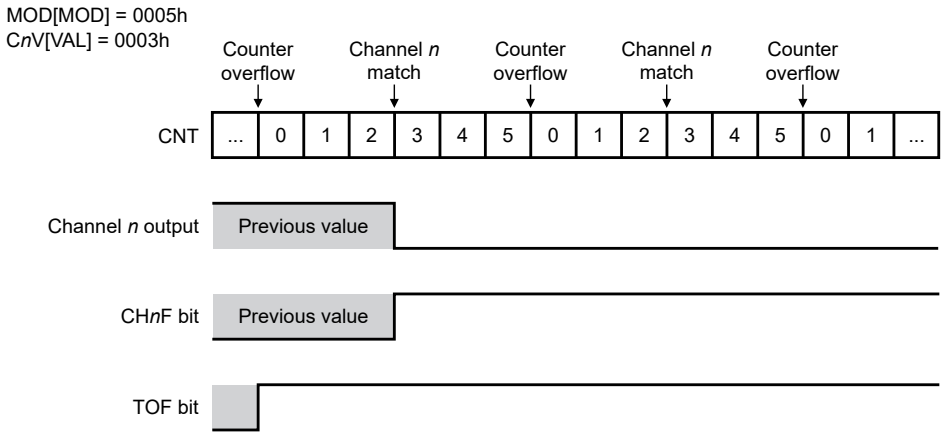


Figure 147. Example of Output Compare mode when a match clears the channel output

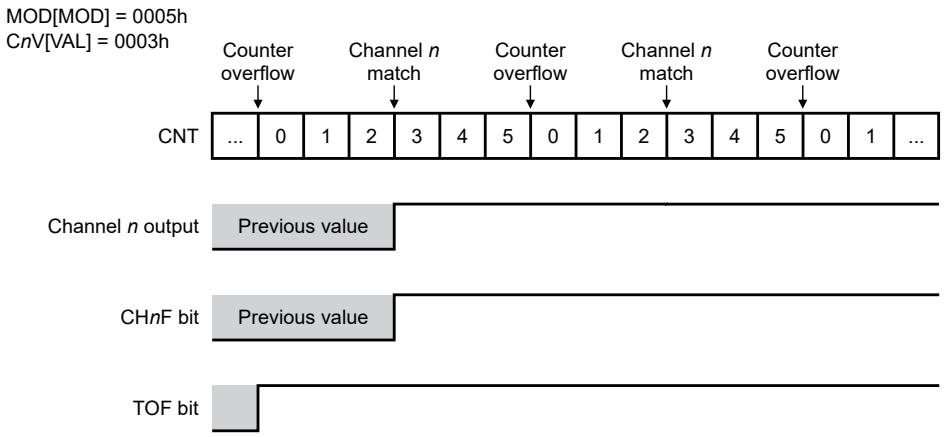


Figure 148. Example of Output Compare mode when a match sets the channel output

You can also use Output Compare mode with:

- SC[CPWMS] = 0 and MS*n*B:MS*n*A = 0:1
- SC[CPWMS] = 0 and ELS*n*B:ELS*n*A = 0:0

This condition is known as Software Compare mode. This mode sets the CH*n*F flag and generates a channel *n* interrupt (if CH*n*IE = 1) when the TPM counter reaches the value defined in the C*n*V register; however, TPM does not modify or control the channel *n* output.

43.3.4.3 Edge-Aligned PWM (EPWM) mode

EPWM mode is enabled when SC[CPWMS] = 0 and MS*n*B:MS*n*A = 1:0. The EPWM period is determined by (MOD[MOD] + 0001h) and the pulse width (duty cycle) is determined by C*n*V[VAL].

The channel *n* match (TPM counter = C*n*V[VAL]) writes 1 to C*n*SC[CH*n*F] and generates a channel *n* interrupt (if C*n*SC[CH*n*IE] = 1) at the end of the pulse width (see Figure 149).

This type of PWM signal is called edge-aligned because the leading edges of all PWM signals are aligned with the beginning of the period, which is the same for all channels within TPM.

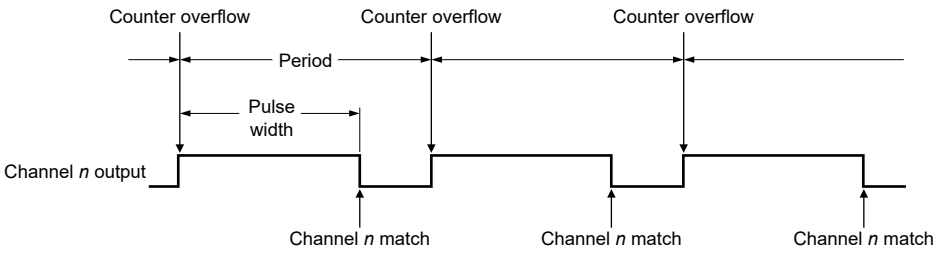


Figure 149. EPWM period and pulse width with ELS*n*B:ELS*n*A = 1:0

If ELS*n*B:ELS*n*A = 1:0, then the channel *n* output is forced high at the counter overflow or reload (when the TPM counter loads with 0), and it is forced low at the channel *n* match (TPM counter = C*n*V[VAL]). The channel *n* output is forced high when you first enable or whenever you pause the TPM counter (see Figure 150).

If ELS*n*B:ELS*n*A = 0:0, then the channel *n* output is forced high at the counter overflow or reload (when the TPM counter loads with 0), and it is forced low at the channel *n* match (TPM counter = C*n*V[VAL]). The channel *n* output is forced low when you first enable or whenever you pause the TPM counter.

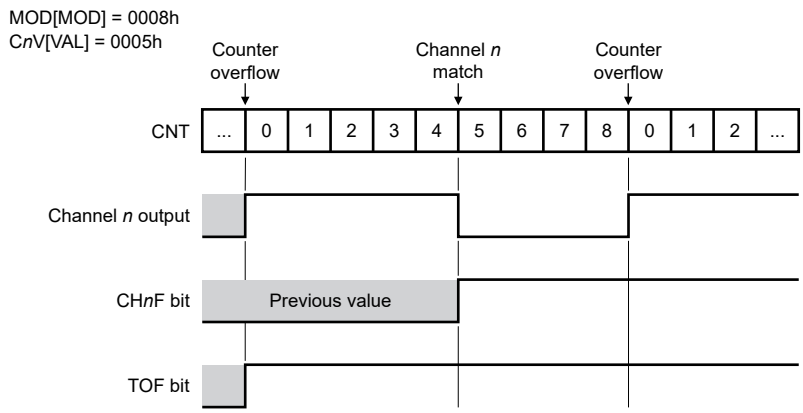


Figure 150. EPWM signal with ELS*n*B:ELS*n*A = 1:0

If ELS*n*B:ELS*n*A = 0:1, then the channel *n* output is forced low at the counter overflow or reload (when the TPM counter loads with 0), and it is forced high at channel *n* match (TPM counter = C*n*V[VAL]). Channel *n* output is forced low when you first enable or whenever you pause the TPM counter (see Figure 151).

If ELS*n*B:ELS*n*A = 1:1, then the channel *n* output is forced low at the counter overflow or reload (when the TPM counter loads with 0), and it is forced high at the channel *n* match (TPM counter = C*n*V[VAL]). Channel *n* output is forced high when you first enable or whenever you pause the TPM counter.

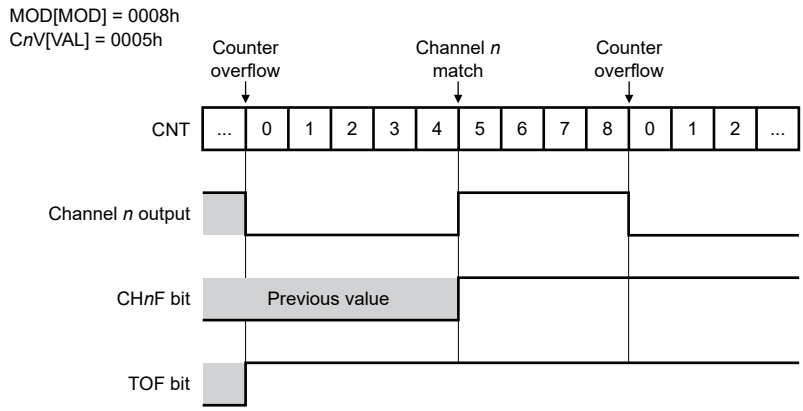


Figure 151. EPWM signal with ELS*n*B:ELS*n*A = 0:1

If C*n*V[VAL] = 0000h, then the channel *n* output is a 0% duty cycle EPWM signal.

If C*n*V[VAL] > MOD[MOD], then the channel *n* output is a 100% duty cycle EPWM signal and the CH*n*F flag is not set because there is never a channel *n* match. Therefore, MOD[MOD] must be less than FFFFFFFFh to get a 100% duty cycle EPWM signal.

43.3.4.4 Center-Aligned PWM (CPWM) mode

CPWM mode is enabled when (SC[CPWMS] = 1) and (MS*n*B:MS*n*A = 1:0).

The CPWM pulse width (duty cycle) is determined by 2 × C*n*V[VAL] and the period is determined by 2 × MOD[MOD] (see Figure 152). You must keep MOD[MOD] in the range of 0001h to 7FFFFFFF because values outside this range can produce ambiguous results.

In CPWM mode, the TPM counter counts up until it reaches the value defined in MOD[MOD], and then counts down until it reaches 0.

The channel *n* match (TPM counter = C*n*V[VAL]) sets C*n*SC[CH*n*F] and generates a channel *n* interrupt (if C*n*SC[CH*n*IE] = 1) when TPM is counting down (at the begin of the pulse width), and when TPM is counting up (at the end of the pulse width).

This type of PWM signal is called center-aligned because the pulse width centers for all channels are at the same place when the TPM counter is 0.

The other channel modes are not designed to be used with the up-down counter when SC[CPWMS] = 1. Therefore, you must use all TPM channels in CPWM mode when SC[CPWMS] = 1.

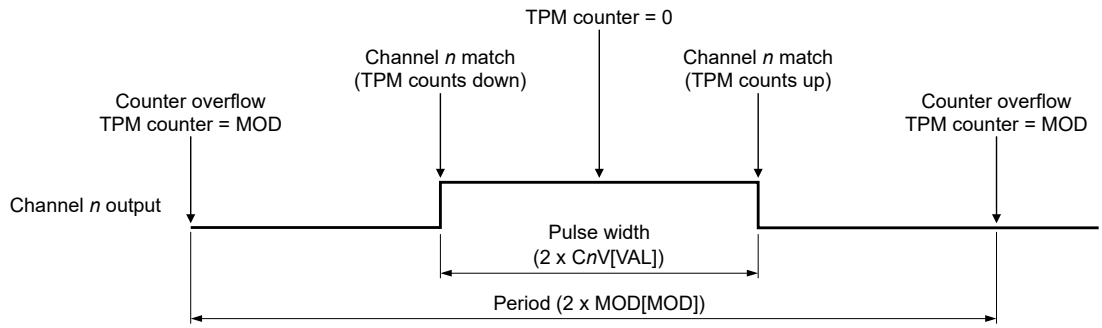


Figure 152. CPWM period and pulse width with ELS*n*B:ELS*n*A = 1:0

If (ELS*n*B:ELS*n*A = 1:0) then the channel *n* output is forced high at the channel *n* match (TPM counter = C*n*V) when counting down, and it is forced low at the channel *n* match when counting up. The channel *n* output is forced high when you first enable or reload the TPM counter, or whenever you pause it (see Figure 153).

If (ELS*n*B:ELS*n*A = 0:0) then the channel *n* output is forced high at the channel *n* match (TPM counter = C*n*V) when counting down, and it is forced low at the channel *n* match when counting up. The channel *n* output is forced low when you first enable or reload the TPM counter, or whenever you pause it.

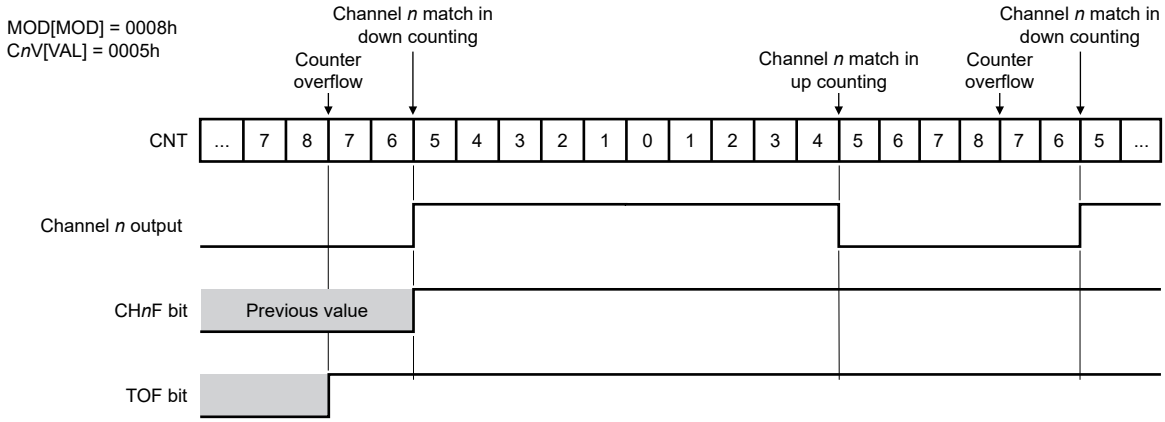


Figure 153. CPWM signal with ELS*n*B:ELS*n*A = 1:0

If (ELS*n*B:ELS*n*A = 0:1) then the channel *n* output is forced low at the channel *n* match (TPM counter = C*n*V) when counting down, and it is forced high at the channel *n* match when counting up. The channel *n* output is forced low when you first enable or reload the TPM counter, or whenever you pause it (see Figure 154).

If (ELS*n*B:ELS*n*A = 1:1) then the channel *n* output is forced low at the channel *n* match (TPM counter = C*n*V) when counting down, and it is forced high at the channel *n* match when counting up. The channel *n* output is forced high when you first enable or reload the TPM counter, or whenever you pause it.

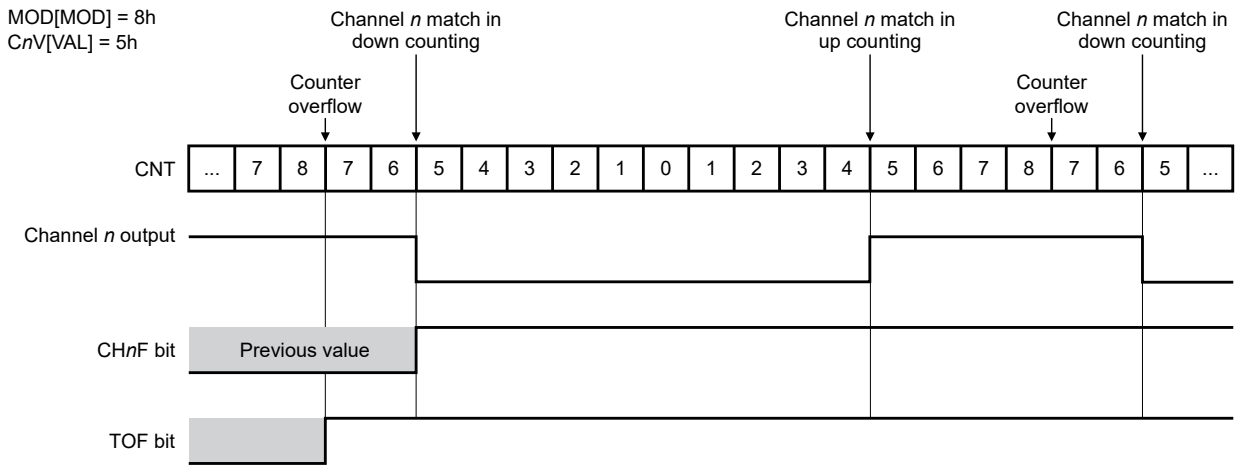


Figure 154. CPWM signal with ELS*n*B:ELS*n*A = 0:1

If (C*n*V[VAL] = 0000h) then the channel *n* output is a 0% duty cycle CPWM signal.

If (C*n*V[VAL] > MOD[MOD]) then the channel *n* output is a 100% duty cycle CPWM signal, although the CH*n*F flag is set when the counter changes from incrementing to decrementing. Therefore, MOD[MOD] must be less than 7FFFFFFF in order to get a 100% duty cycle CPWM signal.

43.3.4.5 Combine PWM mode

Combine PWM mode is enabled when:

- MS*n*B:MS*n*A = 1:0
- COMBINE[COMBINE*n*] = 1
- QDCTRL[QUADEN] = 0
- SC[CPWMS] = 0

In Combine PWM mode, an even channel *n* and adjacent odd channel *n* + 1 are combined to generate a PWM signal in the channel *n* output.

Determine the PWM period and pulse width according to Equation 4.

NOTE

Do not configure the second compare to a value that is lower than the first compare.

```
PWM period = MOD[MOD] + 0001h
PWM pulse width (duty cycle) = |C(n + 1)V[VAL] - CnV[VAL]|
```

Equation 4. PWM period and pulse width

- If (C*n*V[VAL] = C(*n* + 1)V[VAL] = 0000h), then the channel *n* output has a 0% duty cycle.
- If (C*n*V[VAL] = C(*n* + 1)V[VAL] > MOD[MOD]), then the channel *n* output has a 100% duty cycle. CH*n*F flag is not set because there is never a channel *n* match.

Therefore, MOD[MOD] must be less than FFFFh in order to get a 100% duty cycle signal.

The channel *n* match (TPM counter = C*n*V[VAL]) writes 1 to C*n*SC[CH*n*F] and generates a channel *n* interrupt (if C*n*SC[CH*n*IE] = 1). The channel *n* + 1 match (TPM counter = C(*n* + 1)V[VAL]), sets the CH(*n* + 1)F flag and generates a channel *n* + 1 interrupt, if CH(*n* + 1)IE = 1.

If channel *n* (ELS*n*B:ELS*n*A = 0:1), then the channel *n* output is forced low at the beginning of the period (TPM counter = 0) and at the channel *n* + 1 match (TPM counter = C(*n* + 1)V[VAL]). It is forced high at the channel *n* match (TPM counter = C*n*V[VAL]).

If channel *n* (ELS*n*B:ELS*n*A = 1:0), then the channel *n* output is forced high at the beginning of the period (TPM counter = 0) and at the channel *n* + 1 match (TPM counter = C(*n* + 1)V[VAL]). It is forced low at the channel *n* match (TPM counter = C*n*V). See Figure 155 for pictorial representation.

When COMBINE[COMSWAP*n*] = 1, then the channel *n* output is forced low or high at the beginning of the period (TPM counter = 0) and at the channel *n* match (TPM counter = C*n*V[VAL]). It is forced high or low at the channel *n* + 1 match (TPM counter = C(*n* + 1)V[VAL]).

Channel *n* + 1 generates the same output as the channel *n* output, but the channel *n* + 1 (ELS*n*B:ELS*n*A) configuration controls the output polarity.

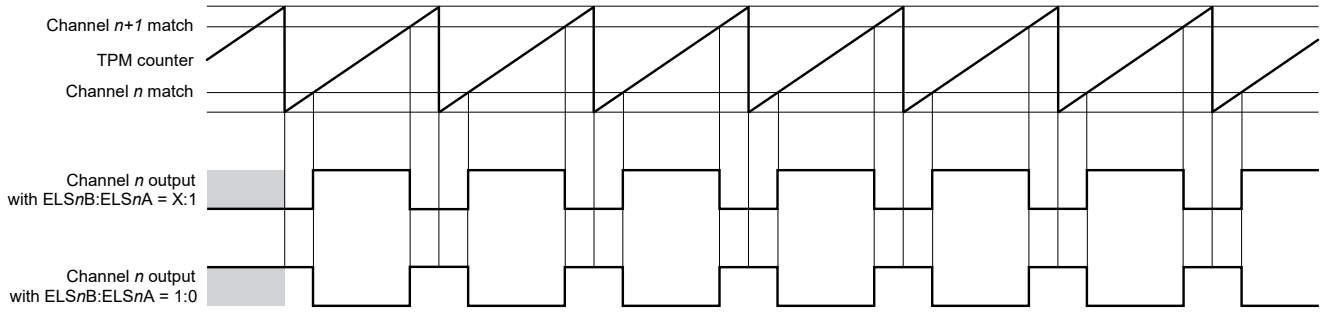


Figure 155. Combine mode

The following figures illustrate generation of PWM signals using the Combine mode.

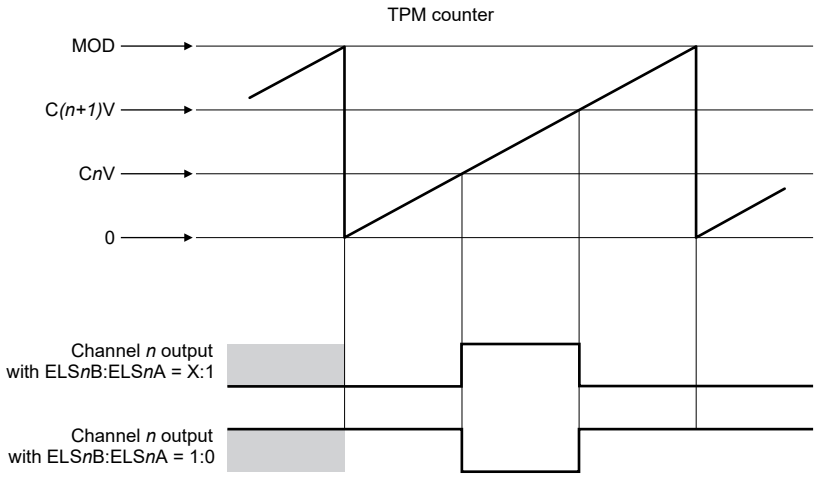


Figure 156. Channel *n* output if (C*n*V < MOD) and (C(*n* + 1)V < MOD) and (C*n*V < C(*n* + 1)V)

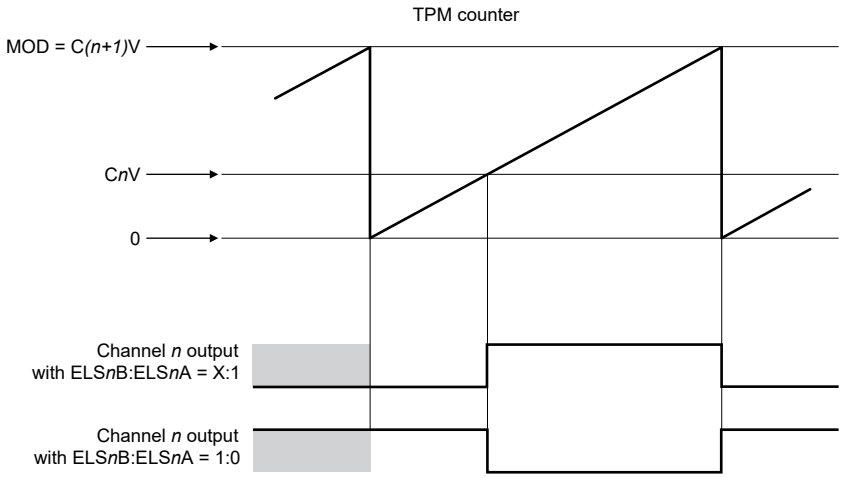


Figure 157. Channel *n* output if (C*n*V < MOD) and (C(*n* + 1)V = MOD)

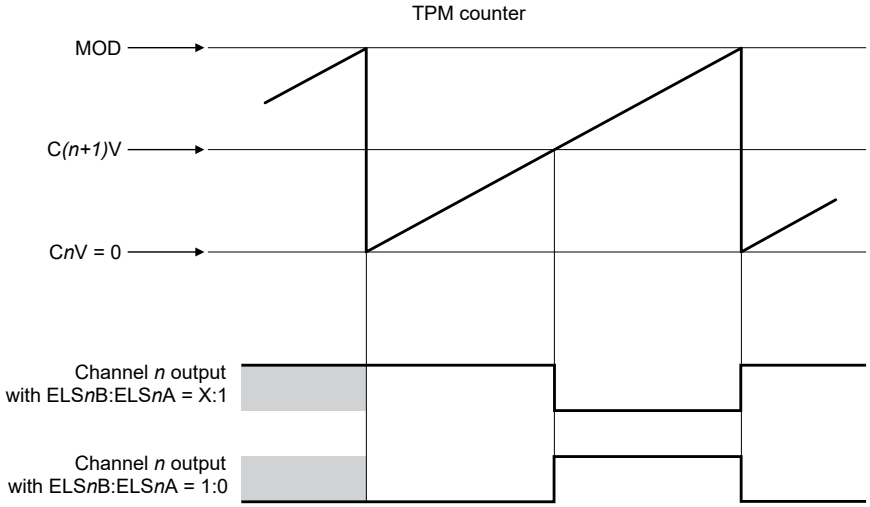


Figure 158. Channel *n* output if (C*n*V = 0) and (C(*n* + 1)V < MOD)

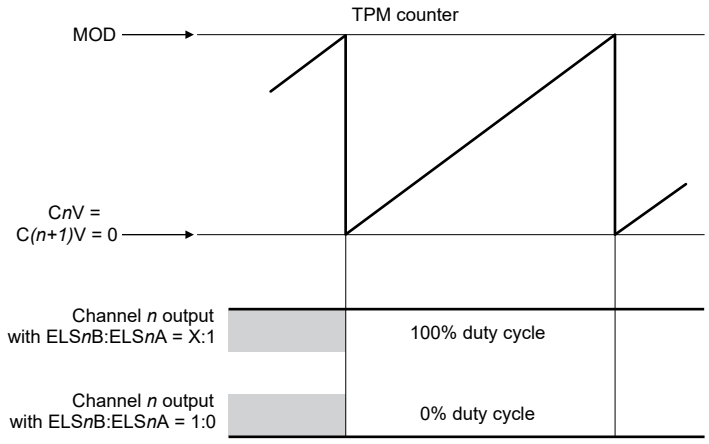


Figure 159. Channel (n) output if (C*n*V = C(*n* + 1)V = 0)

43.3.4.5.1 Dead time insertion

Dead time insertion is enabled in PWM Combine mode for each pair of channels when CH*n*FVAL and CH(*n* + 1)FVAL are non-zero. The dead time delay that is used for each TPM channel is defined as (CH(*n* + 1)FVAL[3:0] × 4) + (CH*n*FVAL[3:0] × 4).

The dead time delay insertion ensures that two complementary signals (even channel *n* and odd channel *n* + 1) do not drive the active state at the same time.

If ELS*n*B:ELS*n*A = 0:1, ELS(*n* + 1)B:ELS(*n* + 1)A = 1:0, COMBINE[COMSWAP*n*] = 0 and dead time is enabled, then:

- When a channel *n* match (TPM counter = C*n*V) occurs, the channel *n* output remains at the low value until the end of the dead time delay, when the channel *n* output is set.
- When a channel *n* + 1 match (TPM counter = C(*n* + 1)V) occurs, the channel *n* + 1 output remains at the low value until the end of the dead time delay, when the channel *n* + 1 output is set (see Figure 160).

If ELS*n*B:ELS*n*A = 1:0, ELS(*n*+1)B:ELS(*n*+1)A = 0:1, COMBINE[COMSWAP*n*] = 1, and dead time is enabled, then:

- When a channel *n* + 1 match (TPM counter = C(*n* + 1)V) occurs, the channel (*n* + 1) output remains at the low value until the end of the dead time delay, when channel *n* + 1 output is set.
- When a channel *n* match (TPM counter = C*n*V) occurs, the channel *n* output remains at the low value until the end of the dead time delay, when channel *n* output is set (see Figure 161).

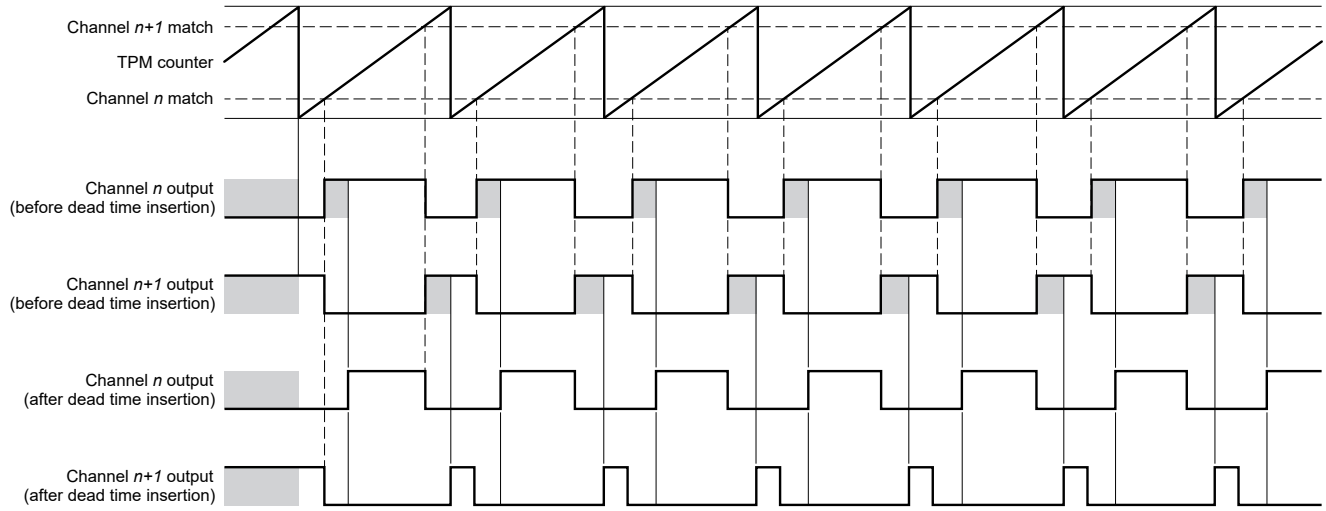


Figure 160. Dead time insertion with ELS*n*B:ELS*n*A = 0:1, ELS(*n* + 1)B:ELS(*n* + 1)A = 1:0, COMBINE[COMSWAP*n*] = 0

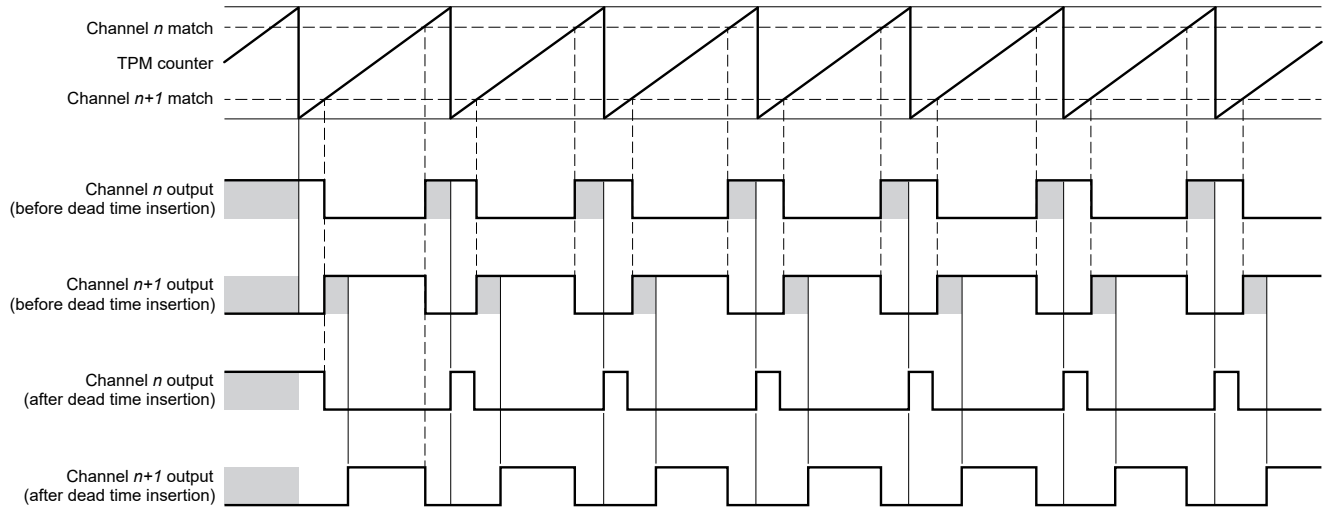


Figure 161. Dead time insertion with ELS*n*B:ELS*n*A = 1:0, ELS(*n* + 1)B:ELS(*n* + 1)A = 0:1, COMBINE[COMSWAP*n*] = 1

43.3.4.6 Combine Input Capture mode

Combine Input Capture mode is enabled if:

- (COMBINE[COMBINE*n*] = 1)
- (MS*n*B:MS*n*A = 0:0)
- (ELS*n*B:ELS*n*A ≠ 0:0)

This mode allows you to measure the pulse width of the signal at the input of channel *n* of a channel pair. The channel *n* filter can be active in this mode.

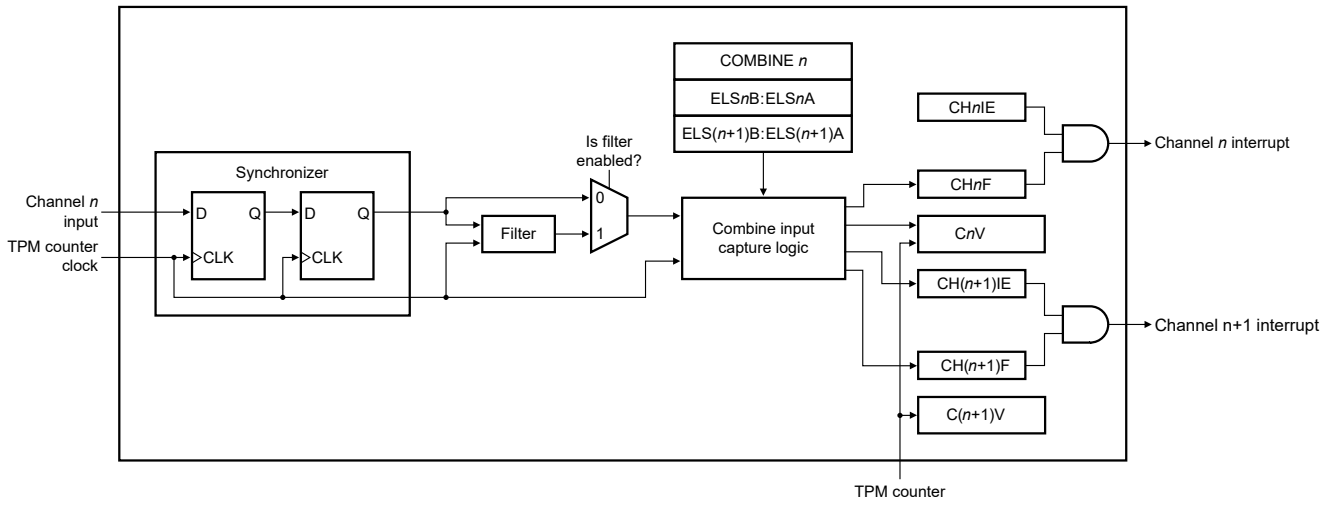


Figure 162. Block diagram

ELS*n*B:ELS*n*A fields select the edge that channel *n* captures. ELS(*n* + 1)B:ELS(*n* + 1)A fields select the edge that channel *n* + 1 captures.

This mode uses only the channel *n* input and ignores the channel *n* + 1 input. If COMBINE[COMSWAP*n*] = 1, then it uses only the channel *n* + 1 input and ignores the channel *n* input.

Detection of the edge selected by channel *n* fields at channel *n* input writes 1 to C*n*SC[CH*n*F] and generates a channel *n* interrupt (if C*n*SC[CH*n*IE] = 1). Detection of the edge selected by channel *n* + 1 fields at channel *n* input sets the CH(*n* + 1)F flag and generates the channel *n* + 1 interrupt (if CH(*n* + 1)IE = 1).

The C*n*V register stores the value of the TPM counter when the channel *n* input detects the edge selected by channel *n*. The C(*n* + 1)V register stores the value of the TPM counter when a channel *n* input detects the edge selected by channel *n* + 1.

NOTE

- Channel *n* fields are:
  - CH*n*F
  - CH*n*IE
  - MS*n*A
  - ELS*n*B
  - ELS*n*A
- Channel *n* + 1 fields are:
  - CH(*n* + 1)F
  - CH(*n* + 1)IE
  - MS(*n* + 1)A
  - ELS(*n* + 1)B
  - ELS(*n* + 1)A
- Use the Combine Input Capture mode with (ELS*n*B:ELS*n*A = 0:1 or 1:0) and (ELS(*n* + 1)B:ELS(*n* + 1)A = 0:1 or 1:0).

43.3.4.7 Quadrature Decoder mode

Quadrature Decoder mode is enabled if (QDCTRL[QUADEN] = 1). This mode uses channel 0 (phase A) and channel 1 (phase B) input signals to control the TPM counter increment and decrement (see Figure 163).

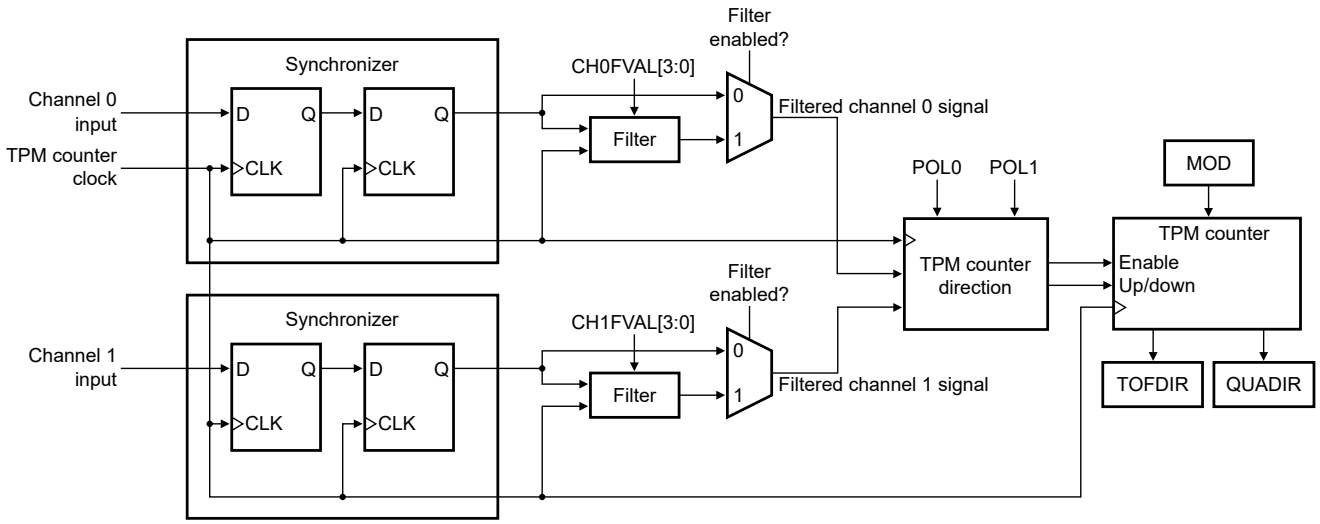


Figure 163. Block diagram

You can configure the input filter and polarity for channel 0 and channel 1 inputs in Quadrature Decode mode using Filter Control (FILTER) and Channel Polarity (POL).

NOTE

When Quadrature Decoder mode is enabled, then channel 0 and channel 1 input signals clock the TPM counter. Therefore, in this mode, you can only use Software Compare mode for channel 0 and channel 1, and you can only use Input Capture or Output Compare mode for other TPM channels.

QDCTRL[QUADMODE] defines the encoding mode that you use in Quadrature Decoder mode.

- If QDCTRL[QUADMODE] = 1, then count and direction encoding mode is enabled.
- If QDCTRL[QUADMODE] = 0, then phase encoding mode is enabled.

In count and direction encoding mode, the channel 1 input value indicates the counting direction, and the channel 0 input value defines the counting rate. A rising edge at the channel 0 input signal updates the TPM counter (see Figure 164).

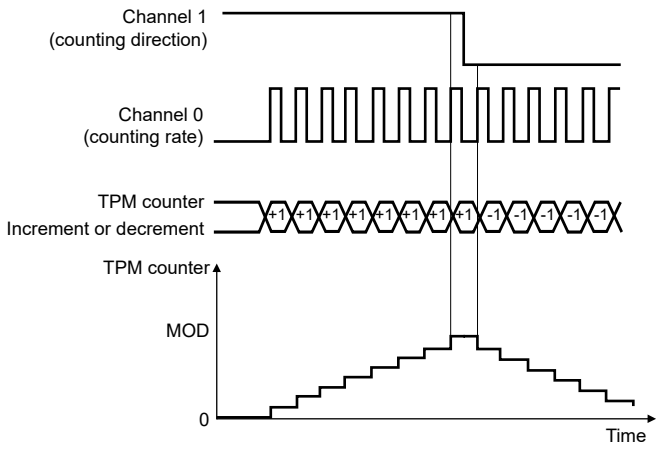


Figure 164. Quadrature Decoder—count and direction encoding mode

In phase encoding mode, the relationship between channel 0 and channel 1 signals indicates the counting direction, and channel 0 and channel 1 signals define the counting rate. An edge at either channel 0 or channel 1 signals updates the TPM counter (see Figure 165).

If POL[POL0] = 0 and POL[POL1] = 0, then:

- The TPM counter increment happens at:
  - A rising edge at channel 0 signal, and channel 1 signal is at logic 0
  - A rising edge at channel 1 signal, and channel 0 signal is at logic 1
  - A falling edge at channel 1 signal, and channel 0 signal is at logic 0
  - A falling edge at channel 0 signal, and channel 1 signal is at logic 1
- The TPM counter decrement happens at:
  - A falling edge at channel 0 signal, and channel 1 signal is at logic 0
  - A falling edge at channel 1 signal, and channel 0 signal is at logic 1
  - A rising edge at channel 1 signal, and channel 0 signal is at logic 0
  - A rising edge at channel 0 signal, and channel 1 signal is at logic 1

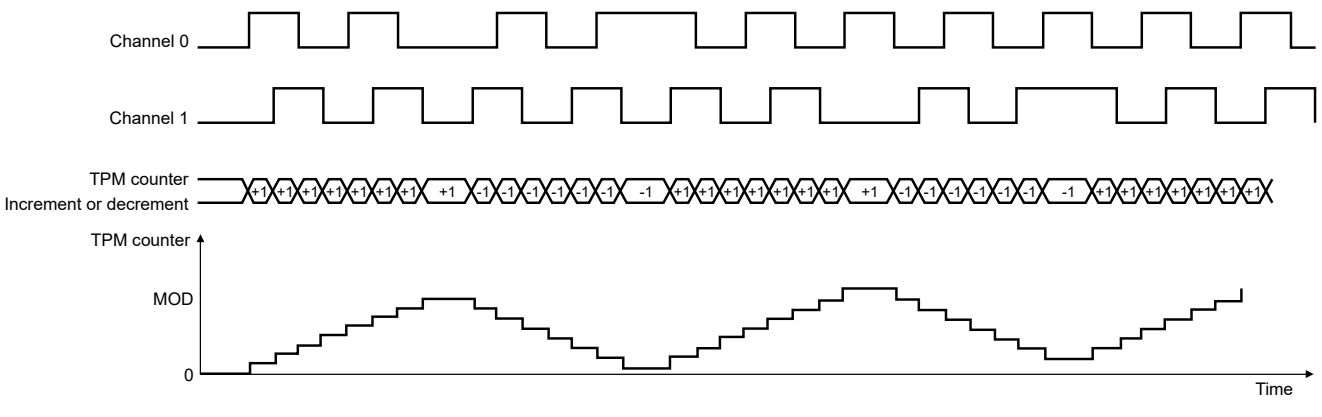


Figure 165. Quadrature Decoder—phase encoding mode

In Figure 166, when the TPM counter changes from the value defined in MOD[MOD] to 0, then SC[TOF] is 1 and QDCTRL[TOFDIR] becomes 1. SC[TOF] indicates that a TPM counter overflow has occurred. QDCTRL[TOFDIR] indicates that TPM was counting up when the TPM counter overflow occurred.

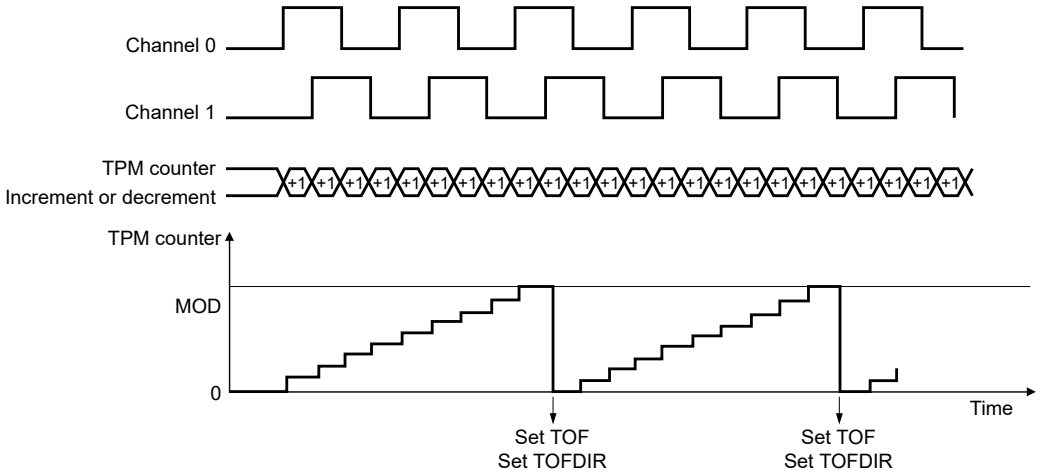


Figure 166. TPM counter overflow in up counting for Quadrature Decoder mode

In Figure 167, when the TPM counter changes from 0 to MOD[MOD], then SC[TOF] is 1 and QDCTRL[TOFDIR] becomes 0. SC[TOF] indicates that a TPM counter overflow has occurred. QDCTRL[TOFDIR] indicates that TPM was counting down when the TPM counter overflow occurred.

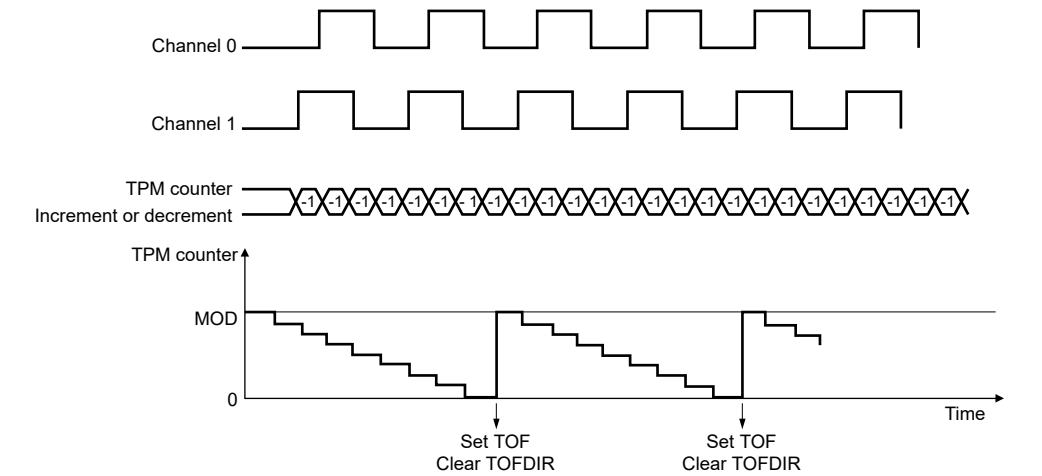


Figure 167. TPM counter overflow in down counting for Quadrature Decoder mode

43.3.5 Low-Power mode

During chip Low-Power mode, you can configure TPM to operate normally or to pause all counting.

Chip mode	TPM operation
Low-Power mode	• When CONF[DOZEEN] = 0, and TPM uses an external or internal clock source that remains functional, then counting continues. TPM can generate an asynchronous interrupt to exit the chip from Low-Power mode. • When CONF[DOZEEN] = 1, then counting pauses during Low-Power mode. Trigger inputs and input capture events are ignored, and PWM outputs are forced to their initial state.

43.3.6 Debug mode

During chip Debug mode, you can configure TPM to operate normally or to pause all counting temporarily.

Chip mode	TPM operation
Debug (core is in Debug or Halted mode)	• When CONF[DBGMODE] = 00b, then counting pauses until the core returns to normal user operating mode. Trigger inputs and input capture events are ignored, and PWM outputs are forced to their initial state. • When CONF[DBGMODE] = 11b, then counting continues.

43.3.7 Clocking

TPM supports two clock domains.

The bus clock domain is used by the register interface and for synchronizing interrupts and DMA requests.

The TPM counter clock domain clocks the counter and prescaler along with the output compare and input capture logic. The TPM counter clock is considered asynchronous to the bus clock. It can be a higher or lower frequency than the bus clock. It can optionally remain operational in low-power modes. When the global timebase feature is enabled, you must clock any TPM instance that is sharing the global timebase by the same TPM counter clock.

43.3.8 Reset

TPM resets whenever any chip reset occurs.

When TPM exits from reset:

- The TPM counter and the prescaler counter are 0 and are stopped (SC[CMOD] = 0).
- The timer overflow interrupt is 0.
- The channel interrupts are 0.
- The channels are in Input Capture mode.
- The channel outputs are 0.
- TPM does not control the channel pins (ELS*n*B:ELS*n*A = 0:0).

43.3.9 Interrupts

43.3.9.1 Timer overflow interrupt

TPM generates the timer overflow interrupt when (SC[TOIE] = 1) and (SC[TOF] = 1).

43.3.9.2 Channel *n* interrupt

TPM generates the channel *n* interrupt when (C*n*SC[CH*n*IE] = 1) and (C*n*SC[CH*n*F] = 1).

43.3.10 DMA

The channel and overflow flags generate a DMA transfer request according to SC[DMA] and C*n*SC[CH*n*IE]/SC[TOIE] fields. See the following table for more information.

Table 300. DMA transfer request

DMA	CH*n*IE/ TOIE	Channel and overflow DMA transfer request	Channel and overflow interrupt
0	0	Not generated	Not generated
0	1	Not generated	Generated if (CH*n*F/TOF = 1)
1	0	Generated if (CH*n*F/TOF = 1)	Not generated
1	1	Generated if (CH*n*F/TOF = 1)	Generated if (CH*n*F/TOF = 1)

If DMA = 1, the CH*n*F/TOF field can be cleared either by completion of the DMA transfer or by writing 1 to CH*n*F/TOF (see Table 301).

Table 301. Clear CH*n*F/TOF field

DMA	How to clear CH*n*F/TOF
0	CH*n*F/TOF field is cleared by writing 1 to it.
1	CH*n*F/TOF field is cleared either when the DMA transfer is completed or by writing 1 to it.

43.4 External signals

Table 302 shows the user-accessible signals for TPM.

Table 302. TPM signal descriptions

Signal	Description	Direction
EXTCLK	External clock If selected in SC[CMOD], EXTCLK increments the TPM counter on every rising edge synchronized to the TPM counter clock. EXTCLK must be less than half of the TPM counter clock frequency. The TPM counter prescaler selection and settings are also used when EXTCLK is selected.	I
CH*n*	Channel *n* I/O pin (where *n* = 5 to 0) You can configure each CH*n* to operate either as input or output. CH*n* is an output when configured in Output Compare or PWM mode and the TPM counter is enabled; otherwise, CH*n* is an input.	I/O

43.5 Initialization

To initialize TPM:

1. Write to the following registers, in any order, to configure the counter mode of operation:
   - Configuration (CONF)
   - Quadrature Decoder Control and Status (QDCTRL)
   - Modulo (MOD)
2. Write to the following registers, in any order, to configure the mode of operation for each channel:
   - Channel n Value (C0V - C5V)
   - Combine Channel (COMBINE)
   - Channel Trigger (TRIG)
   - Channel Polarity (POL)
   - Filter Control (FILTER)
3. Use Channel n Status and Control (C0SC - C5SC) to configure the mode of operation for each channel and to enable the channel.
4. Use Status and Control (SC) to configure the counter mode of operation and to enable the TPM (TPM is enabled and counting when SC[CMOD] ≠ 00).

43.6 Application information

To configure TPM counter to generate an overflow interrupt every 64,000 cycles:

1. Write any data to CNT to reset the counter.
2. Write MOD[MOD] = F9FFh to configure counter overflow.
3. Write SC = 48h to enable the counter and overflow interrupt.
4. Write STATUS = 100h to clear the flag during the interrupt routine.

To configure TPM channel 0 for input capture on either edge generating an interrupt:

1. Write C0SC = 4Ch to configure channel 0.
2. Optionally, write CONF = 840000h to configure counter to reset on each channel 0 input capture. Write CONF = 850000h to delay starting the counter until the first edge.
3. Write any data to CNT to reset the counter.
4. Write MOD[MOD] = FFFFFFFFh to configure the counter overflow to maximum.
5. Write SC = 48h to enable the counter and overflow interrupt.
6. During the interrupt routine, first check the setting for the STATUS flag:
   - If STATUS[TOF] is set, clear flag by writing STATUS = 100h. Note that software is responsible for tracking number of overflows between consecutive input capture events.
   - If STATUS[CH0F] is set, first read C0V to obtain the input capture value and then clear flag by writing STATUS = 0001h.

To configure TPM channel 0 for output compare to toggle the output pin using an array of counter values:

1. Write C0SC = 54h for interrupt or write C0SC = 15h for DMA.
2. Write C0V = array[0] to configure initial compare value.
3. Write any data to CNT to reset the counter.
4. Write MOD[MOD] = FFFFFFFFh to configure the counter overflow to maximum.
5. Write SC = 08h to enable the counter.
6. Write the next compare value C0V = array[N] during the interrupt routine and then write STATUS = 0001h to clear the flag.

7. Write the next compare value C0V = array[N] during the DMA transfer. DMA transfer will automatically clear the channel flag.

The array is an array of counter values where the first output compare occurs at “array[0]” cycles after the counter is enabled and subsequent output compares occur at “array[N] – array[N-1]” cycles after the last compare. If the output waveform repeats, then MOD can be set to an output compare value where the waveform starts to repeat.

An example of using TPM with the asynchronous DMA is described in AN4631:Using the Asynchronous DMA features of the Kinetis L Series.

43.7 Memory map and register definition

This section provides a detailed description of all TPM registers.

An attempt to access a reserved register location in the TPM memory map generates a bus error.

43.7.1 TPM register descriptions

43.7.1.1 TPM memory map

TPM0 base address: 4003_1000h

TPM1 base address: 4003_2000h

TPM2 base address: 4898_4000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	See section
4h	Parameter (PARAM)	32	R	See section
8h	TPM Global (GLOBAL)	32	RW	0000_0000h
10h	Status and Control (SC)	32	RW	0000_0000h
14h	Counter (CNT)	32	RW	0000_0000h
18h	Modulo (MOD)	32	RW	0000_FFFFh
1Ch	Capture and Compare Status (STATUS)	32	RW	0000_0000h
20h	Channel n Status and Control (C0SC)	32	RW	0000_0000h
24h	Channel n Value (C0V)	32	RW	0000_0000h
28h	Channel n Status and Control (C1SC)	32	RW	0000_0000h
2Ch	Channel n Value (C1V)	32	RW	0000_0000h
30h	Channel n Status and Control (C2SC)	32	RW	0000_0000h
34h	Channel n Value (C2V)	32	RW	0000_0000h
38h	Channel n Status and Control (C3SC)	32	RW	0000_0000h
3Ch	Channel n Value (C3V)	32	RW	0000_0000h
40h	Channel n Status and Control (C4SC)	32	RW	0000_0000h
44h	Channel n Value (C4V)	32	RW	0000_0000h

Table continues on the next page...

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Offset	Register	Width (In bits)	Access	Reset value
48h	Channel n Status and Control (C5SC)	32	RW	0000_0000h
4Ch	Channel n Value (C5V)	32	RW	0000_0000h
64h	Combine Channel (COMBINE)	32	RW	0000_0000h
6Ch	Channel Trigger (TRIG)	32	RW	0000_0000h
70h	Channel Polarity (POL)	32	RW	0000_0000h
78h	Filter Control (FILTER)	32	RW	0000_0000h
80h	Quadrature Decoder Control and Status (QDCTRL)	32	RW	0000_0000h
84h	Configuration (CONF)	32	RW	0000_0000h

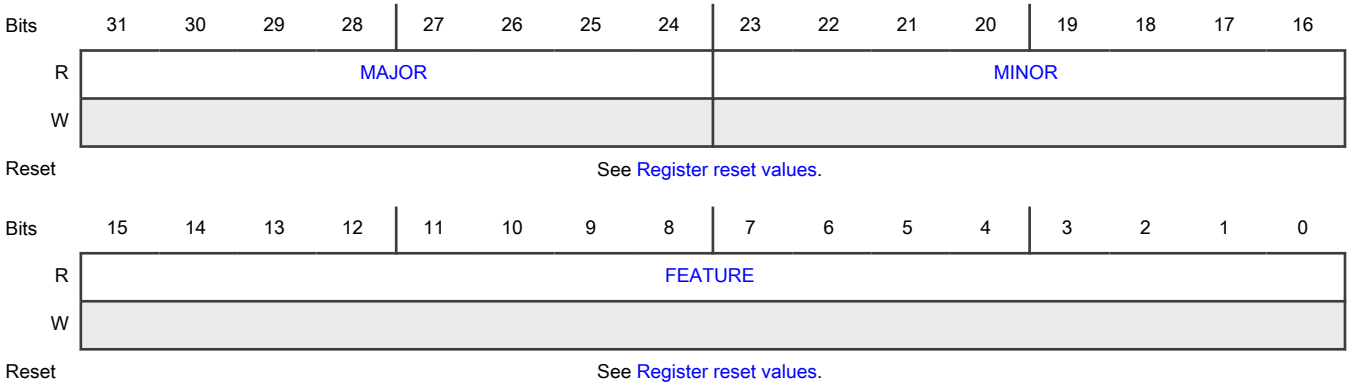
43.7.1.2 Version ID (VERID)

Offset

Register	Offset
VERID	0h

Function
Contains the module version ID and feature information.

Diagram



Register reset values

Register	Reset value
VERID	TPM0,TPM1: 0600_0007h TPM2: 0600_0003h

Fields

Field	Function
31-24 MAJOR	Major Version Number Specifies the major version number for the module specification.
23-16 MINOR	Minor Version Number Specifies the minor version number for the module specification.
15-0 FEATURE	Feature Identification Number Configures different feature sets for TPM that implements a standard feature set with additional registers/functions. 0000_0000_0000_0001b - Standard feature set 0000_0000_0000_0011b - Standard feature set with the filter and combine registers implemented 0000_0000_0000_0101b - Standard feature set with the quadrature register implemented 0000_0000_0000_0111b - Standard feature set with the filter, combine, and quadrature registers implemented

43.7.1.3 Parameter (PARAM)

Offset

Register	Offset
PARAM	4h

Function
Contains values of the module parameters.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0								WIDTH							
W																
Reset	See Register reset values.															

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	TRIG								CHAN							
W																
Reset	See Register reset values.															

Register reset values

Register	Reset value
PARAM	TPM0,TPM1: 0020_0406h TPM2: 0020_0402h

Fields

Field	Function
31-24 —	Reserved
23-16 WIDTH	Counter Width Specifies the width of the counter and timer channels.
15-8 TRIG	Trigger Count Specifies the number of trigger inputs that TPM implements.
7-0 CHAN	Channel Count Specifies the number of timer channels that TPM implements.

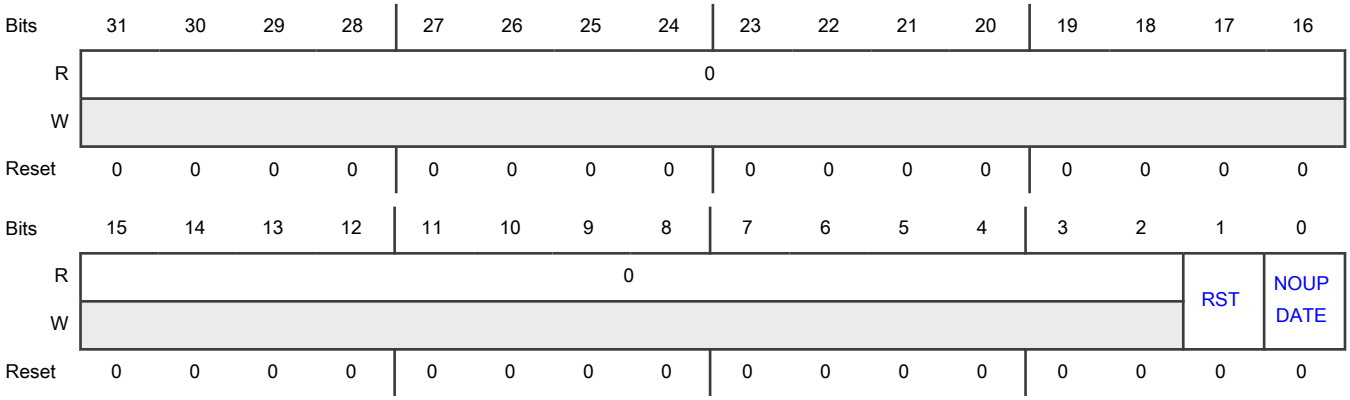
43.7.1.4 TPM Global (GLOBAL)

Offset

Register	Offset
GLOBAL	8h

Function
Includes the software reset control field.

Diagram



Fields

Field	Function
31-2 —	Reserved
1 RST	Software Reset Resets all internal logic and registers, except TPM Global (GLOBAL). This field remains 1 until you write 0 to it. 0b - Module is not reset 1b - Module is reset
0 NOUPDATE	No Update Blocks updates to all internal double-buffered registers while this field remains 1. You can still update the software visible registers, but changes cannot take effect until you write 0 to this field. At that point they update as normal. 0b - Internal double-buffered registers update as normal 1b - Internal double-buffered registers do not update

43.7.1.5 Status and Control (SC)

Offset

Register	Offset
SC	10h

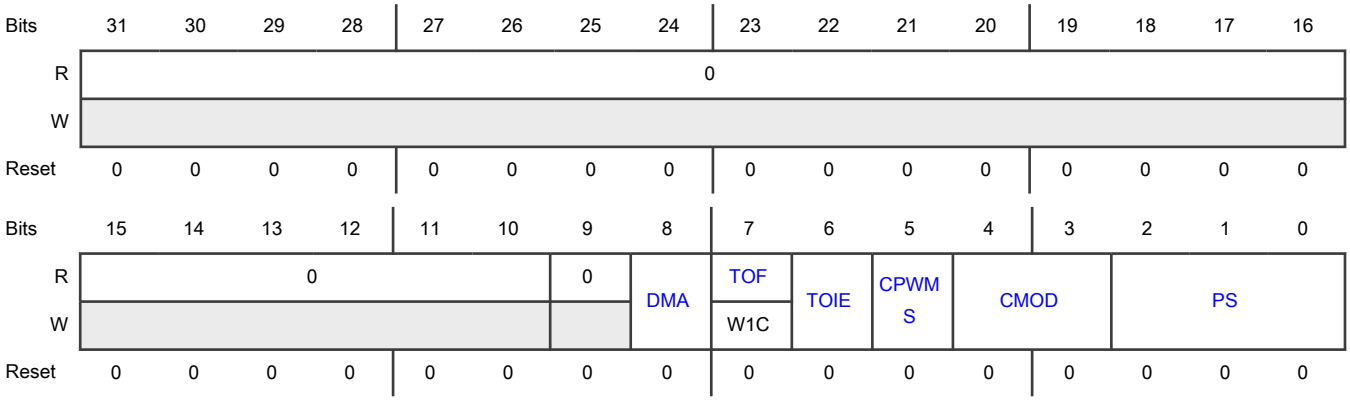
Function

Contains the overflow status flag and control fields that you can use to configure:

- Interrupt enable
- Module configuration
- Prescaler factor

These controls relate to all channels within this module.

Diagram



Fields

Field	Function
31-10 —	Reserved
9 —	Reserved
8 DMA	DMA Enable Enables DMA transfers for the overflow flag. 0b - Disable 1b - Enable
7 TOF	Timer Overflow Flag Indicates whether a TPM overflow has occurred. Hardware sets this flag when the TPM counter value is equal to the value defined in MOD[MOD], and increments after this value. If another TPM overflow occurs between the flag setting and the flag clearing, then the write operation has no effect. Therefore, TOF remains set, which indicates that another overflow has occurred. In this case, a TOF interrupt request is not lost due to a delay in clearing the previous TOF. 0b - No overflow 1b - Overflow
6 TOIE	Timer Overflow Interrupt Enable Enables TPM overflow interrupts. A TOF interrupt is generated when SC[TOF] = 1. If TOIE = 0, use software polling or DMA request. 0b - Disable 1b - Enable
5 CPWMS	Center-Aligned PWM Select Enables CPWM mode. This mode configures TPM to operate in up-down counting mode.

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Field	Function
	This field is write-protected. Disable the TPM counter before you write to this field. 0b - Up counting mode 1b - Up-down counting mode
4-3 CMOD	Clock Mode Selection Selects the TPM counter clock modes. When disabling the counter, this field remains 1 until acknowledged in the TPM clock domain. 00b - TPM counter is disabled 01b - TPM counter increments on every TPM counter clock 10b - TPM counter increments on the rising edge of EXTCLK synchronized to the TPM counter clock 11b - TPM counter increments on the rising edge of the selected external input trigger
2-0 PS	Prescale Factor Selection Selects one of 8 division factors for the clock mode selected by SC[CMOD]. This field is write-protected. Disable the TPM counter before you write to this field. 000b - Divide by 1 001b - Divide by 2 010b - Divide by 4 011b - Divide by 8 100b - Divide by 16 101b - Divide by 32 110b - Divide by 64 111b - Divide by 128

43.7.1.6 Counter (CNT)

Offset

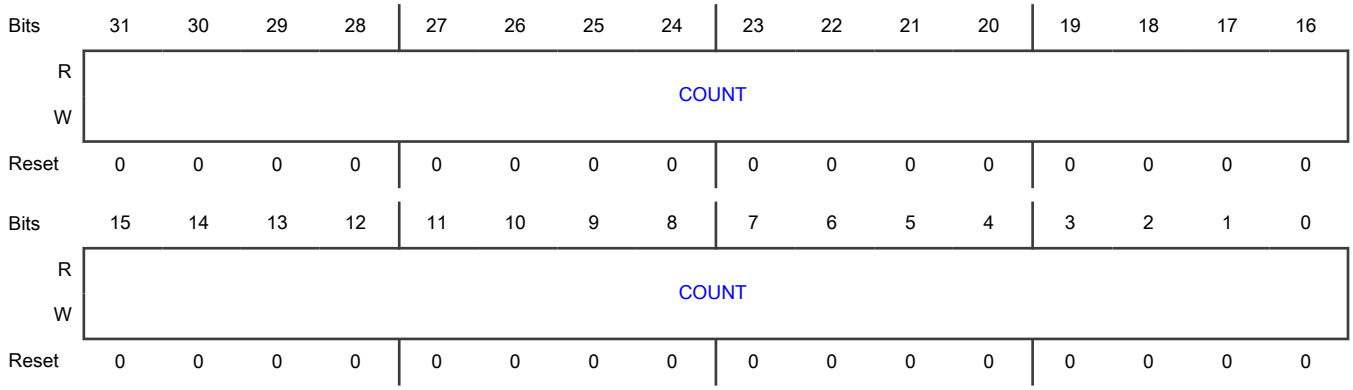
Register	Offset
CNT	14h

Function

Contains the TPM counter value. You can write 0 to this register with reset. Writing any value to CNT[COUNT] triggers a reload of the counter and forces PWM outputs to their reload state.

When debug is active, the TPM counter does not increment unless you configure it otherwise. Reading this register adds two wait states to the register access, because of synchronization delays.

Diagram



Fields

Field	Function
31-0 COUNT	Counter Value Specifies the TPM counter value.

43.7.1.7 Modulo (MOD)

Offset

Register	Offset
MOD	18h

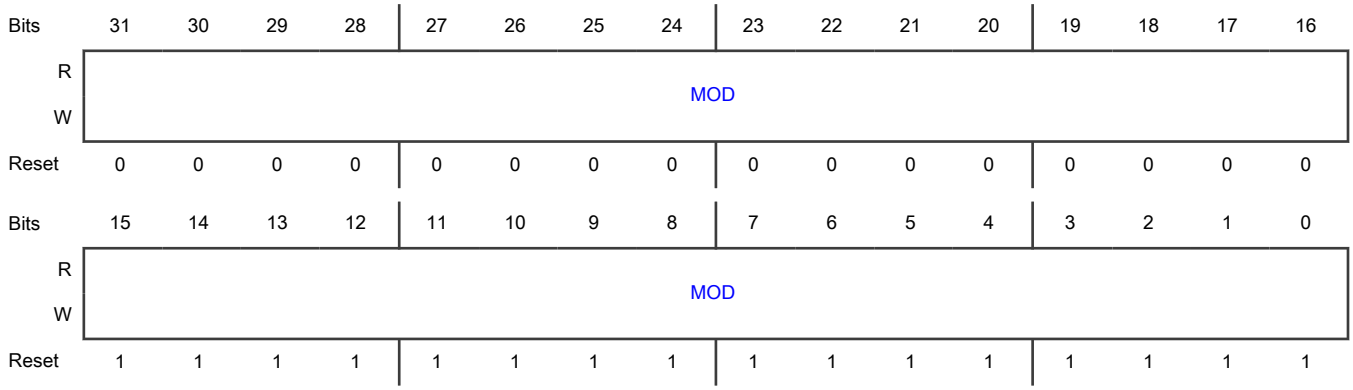
Function

Contains the modulo value for the TPM counter. When the TPM counter reaches the modulo value and increments, SC[TOF] sets and the next value of the TPM counter depends on the selected counting method (see Counter).

Writing to the MOD register latches the value into a buffer. This register updates with the value of its write buffer according to MOD register update. Additional writes to the MOD write buffer are ignored until the register has been updated.

To avoid confusion about occurrence of the first counter overflow, initialize the TPM counter (write to CNT[COUNT]) before writing to the MOD register.

Diagram



Fields

Field	Function
31-0 MOD	Modulo Value Specifies the modulo value for the TPM counter. Write a single 16-bit or 32-bit access value to this field.

43.7.1.8 Capture and Compare Status (STATUS)

Offset

Register	Offset
STATUS	1Ch

Function

Contains a copy of the status flag (C*n*SC[CHF]) for each TPM channel, as well as SC[TOF], for software convenience. Each CH*n*F field in STATUS is a mirror of the corresponding C*n*SC[CHF]. You can check all C*n*SC[CHF] fields using only one read of STATUS. Writing all ones to STATUS writes 0 to all C*n*SC[CHF] fields.

Hardware sets the individual channel flags when an event occurs on the channel. If another event occurs between the flag setting and the write operation, the write operation has no effect; therefore, CHF remains set, which indicates that another event has occurred. In this case, a CHF interrupt request is not lost because of the clearing sequence for a previous CHF.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0							TOF	0		CH5F	CH4F	CH3F	CH2F	CH1F	CH0F
W								W1C			W1C	W1C	W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-9 —	Reserved
8 TOF	Timer Overflow Flag Contains a copy of SC[TOF]. 0b - No overflow 1b - Overflow
7-6 —	Reserved
5 CH5F	Channel 5 Flag Contains a copy of C5SC[CHF]. Sets the flag when an event occurs on the channel (see the register description for more). **NOTE** This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
TPM0	STATUS	—
TPM1	STATUS	—
TPM2	—	STATUS

0b - Event not occurred

1b - Event occurred

4	Channel 4 Flag

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>CH4F</td><td>Contains a copy of C4SC[CHF]. Sets the flag when an event occurs on the channel (see the register description for more).
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>TPM0</td><td>STATUS</td><td>—</td></tr><tr><td>TPM1</td><td>STATUS</td><td>—</td></tr><tr><td>TPM2</td><td>—</td><td>STATUS</td></tr></table>0b - Event not occurred
1b - Event occurred</td></tr>
<tr><td>3
CH3F</td><td>Channel 3 Flag
Contains a copy of C3SC[CHF]. Sets the flag when an event occurs on the channel (see the register description for more).
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>TPM0</td><td>STATUS</td><td>—</td></tr><tr><td>TPM1</td><td>STATUS</td><td>—</td></tr><tr><td>TPM2</td><td>—</td><td>STATUS</td></tr></table>0b - Event not occurred
1b - Event occurred</td></tr>
<tr><td>2
CH2F</td><td>Channel 2 Flag
Contains a copy of C2SC[CHF]. Sets the flag when an event occurs on the channel (see the register description for more).
NOTE
This field is not supported in every instance. The following table includes only supported registers.</td></tr>
</table>

Table continues on the next page...

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Field	Function
	<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>TPM0</td><td>STATUS</td><td>—</td></tr><tr><td>TPM1</td><td>STATUS</td><td>—</td></tr><tr><td>TPM2</td><td>—</td><td>STATUS</td></tr></table> 0b - Event not occurred 1b - Event occurred
1 CH1F	Channel 1 Flag Contains a copy of C1SC[CHF]. Sets the flag when an event occurs on the channel (see the register description for more). 0b - Event not occurred 1b - Event occurred
0 CH0F	Channel 0 Flag Contains a copy of C0SC[CHF]. Sets the flag when an event occurs on the channel (see the register description for more). 0b - Event not occurred 1b - Event occurred

43.7.1.9 Channel n Status and Control (C0SC - C5SC)

Offset

Register	Offset
C0SC	20h
C1SC	28h
C2SC	30h
C3SC	38h
C4SC	40h
C5SC	48h

Function

Contains the channel-interrupt-status flag and control fields used to configure:

- Interrupt enable
- Channel configuration

- Pin function

Table 303. Mode, edge, and level selection

SC[CPWMS]	MS*n*B:MS*n*A	ELS*n*B:ELS*n*A	Mode	Configuration
0	00	00	None	Channel disabled
0	01	00	Software Compare	Pin not used for TPM
0	00	01	Input Capture	Capture on rising edge only
		10		Capture on falling edge only
		11		Capture on rising or falling edge
	01	01	Output Compare	Toggle output on match
		10		Clear output on match
		11		Set output on match
	10	10	Edge-Aligned PWM	High-true pulses (clear output on counter match, set output on counter reload, set output when counter first enabled or paused)
		00		High-true pulses (clear output on counter match, set output on counter reload, clear output when counter first enabled or paused)
		01		Low-true pulses (set output on counter match, clear output on counter reload, clear output when counter first enabled or paused)
		11		Low-true pulses (set output on counter match, clear output on counter reload, set output when counter first enabled or paused)
	11	10	Output Compare	Pulse output low on match
		01		Pulse output high on match
1	10	10	Center-Aligned PWM	High-true pulses (clear output on counter match-up, set output on counter match-down, set output on counter reload, or when counter first enabled or paused)
		00		High-true pulses (clear output on counter match-up, set output on counter match-down, clear output on counter reload, or when counter first enabled or paused)

Table continues on the next page...

Table 303. Mode, edge, and level selection (continued)

SC[CPWMS]	MS*n*B:MS*n*A	ELS*n*B:ELS*n*A	Mode	Configuration
		01		Low-true pulses (set output on match-up, clear output on match-down, clear output on counter reload, or when counter first enabled or paused)
		11		Low-true pulses (set output on match-up, clear output on match-down, set output on counter reload, or when counter first enabled or paused)

NOTE

Each module instance supports a different number of registers.

Instance	Register supported	Register not supported
TPM0	C0SC–C5SC	—
TPM1	C0SC–C5SC	—
TPM2	C0SC–C1SC	C2SC–C5SC

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	See Register reset values.															

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								CHF	CHIE	MSB	MSA	ELSB	ELSA	0	DMA
W									W1C							
Reset	See Register reset values.															

Register reset values

Register	Reset value
C0SC–C1SC	TPM0–TPM2: 0000_0000h
C2SC–C5SC	TPM0,TPM1: 0000_0000h TPM2: Register not supported

Fields

Field	Function
31-8 —	Reserved
7 CHF	Channel Flag Indicates whether an event has occurred on the channel. TPM writes 1 to this field when an event occurs on the channel. If another event occurs between the CHF being set and the write operation, the write operation has no effect; therefore, CHF remains set, which indicates that another event has occurred. In this case, a CHF interrupt request is not lost due to the delay in clearing the previous CHF. 0b - Event not occurred 1b - Event occurred
6 CHIE	Channel Interrupt Enable Enables channel interrupts. 0b - Disable 1b - Enable
5 MSB	Channel Mode Select B Configures further selections in the channel logic. Its functionality depends on the channel mode (see Table 303).
4 MSA	Channel Mode Select A Configures further selections in the channel logic. Its functionality depends on the channel mode (see Table 303).
3 ELSB	Edge or Level Select B Performs the function that depends on the channel mode (see Table 303).
2 ELSA	Edge or Level Select A Performs the function that depends on the channel mode (see Table 303).
1 —	Reserved
0 DMA	DMA Enable Enables DMA transfers for the channel. 0b - Disable 1b - Enable

43.7.1.10 Channel n Value (C0V - C5V)

Offset

Register	Offset
C0V	24h
C1V	2Ch
C2V	34h
C3V	3Ch
C4V	44h
C5V	4Ch

Function

Contains the captured TPM counter value for the input modes or the match value for the output modes.

Input Capture mode ignores any write to a C*n*V register. In compare modes, writing to a C*n*V register latches the value into a buffer. A C*n*V register updates with the value of its write buffer according to C*n*V register update.

NOTE

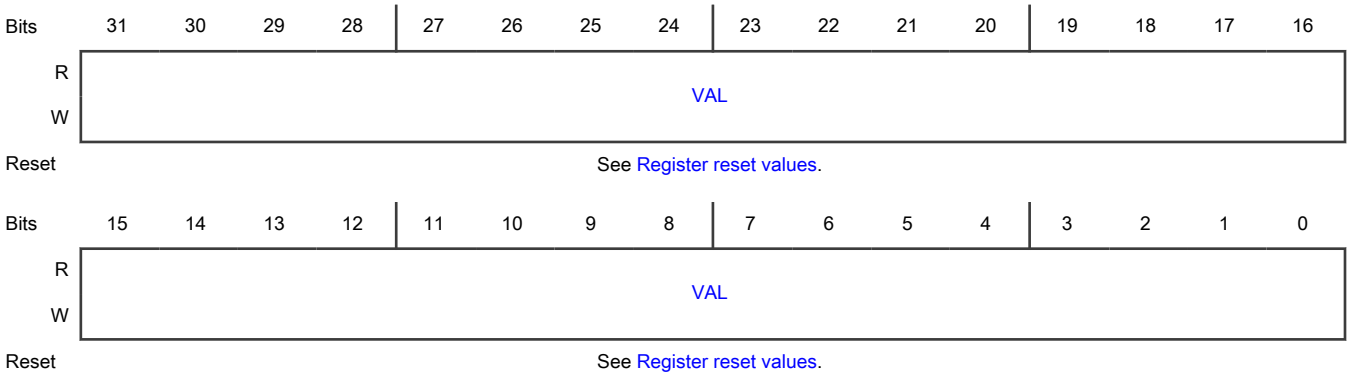
Additional writes to the C*n*V write buffer are ignored until the register has been updated.

NOTE

Each module instance supports a different number of registers.

Instance	Register supported	Register not supported
TPM0	C0V–C5V	—
TPM1	C0V–C5V	—
TPM2	C0V–C1V	C2V–C5V

Diagram



Register reset values

Register	Reset value
C0V–C1V	TPM0–TPM2: 0000_0000h
C2V–C5V	TPM0,TPM1: 0000_0000h TPM2: Register not supported

Fields

Field	Function
31-0 VAL	Channel Value Contains the captured TPM counter value for the input modes, or the match value for the output modes. Write a single 16-bit or 32-bit access value to this field.

43.7.1.11 Combine Channel (COMBINE)

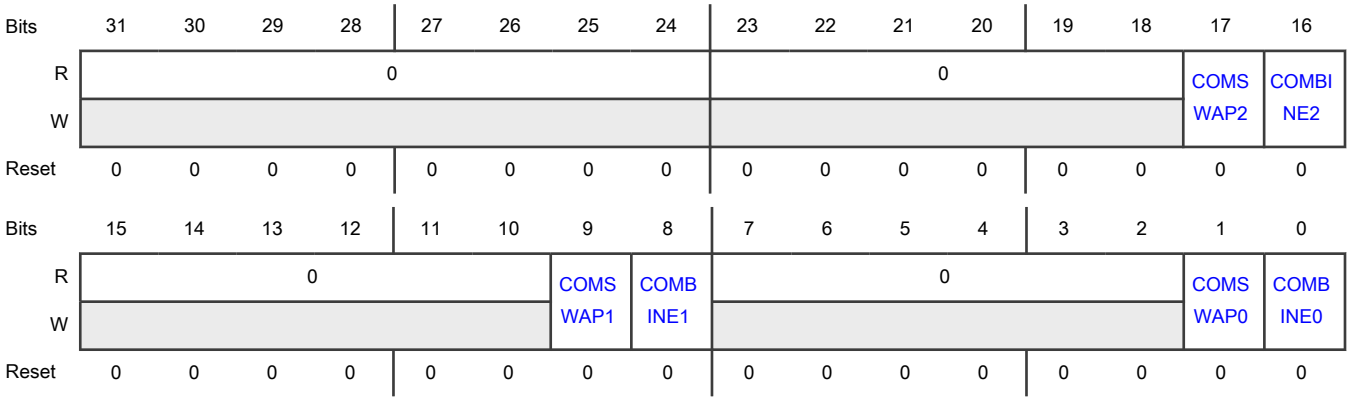
Offset

Register	Offset
COMBINE	64h

Function

Contains the control fields used to configure the combine channel modes for each pair of channels *n* and *n*+1, where n is all the even-numbered channels.

Diagram



Fields

Field	Function
31-24	Reserved

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>—</td><td></td></tr>
<tr><td>23-18
—</td><td>Reserved</td></tr>
<tr><td>17
COMSWAP2</td><td>Combine Channels 4 and 5 Swap
When set in combine mode, the even channel is used for the input capture and first compare, while the odd channel is used for the second compare.
NOTE
The value of the first compare must not be greater than that of the second compare.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>TPM0</td><td>COMBINE</td><td>—</td></tr><tr><td>TPM1</td><td>COMBINE</td><td>—</td></tr><tr><td>TPM2</td><td>—</td><td>COMBINE</td></tr></table>0b - Even channel
1b - Odd channel</td></tr>
<tr><td>16
COMBINE2</td><td>Combine Channels 4 and 5
Enables the combine feature for channels 4 and 5. In Input Capture mode, the combined channels use the even channel input. In Software Compare mode, the even channel match asserts the output trigger and the odd channel match negates the output trigger. In PWM mode, the even channel match is used for the first compare and odd channel match for the second compare.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>TPM0</td><td>COMBINE</td><td>—</td></tr><tr><td>TPM1</td><td>COMBINE</td><td>—</td></tr><tr><td>TPM2</td><td>—</td><td>COMBINE</td></tr></table></td></tr>
</table>

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
</table>
0b - Independent
1b - Combined
</td></tr>
<tr><td>15-10
—</td><td>Reserved</td></tr>
<tr><td>9
COMSWAP1</td><td>
Combine Channels 2 and 3 Swap
When set in combine modes, the odd channel is used for the input capture and first compare, while the even channel is used for the second compare.
NOTE
The value of the first compare must not be greater than that of the second compare.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>TPM0</td><td>COMBINE</td><td>—</td></tr>
<tr><td>TPM1</td><td>COMBINE</td><td>—</td></tr>
<tr><td>TPM2</td><td>—</td><td>COMBINE</td></tr>
</table>
0b - Even channel
1b - Odd channel
</td></tr>
<tr><td>8
COMBINE1</td><td>
Combine Channels 2 and 3
Enables the combine feature for channels 2 and 3.
In Input Capture mode, the combined channels use the even channel input. In Software Compare mode, the even channel match asserts the output trigger, and the odd channel match negates the output trigger. In PWM mode, the even channel match is used for the first compare, and odd channel match for the second compare.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function
	<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>TPM0</td><td>COMBINE</td><td>—</td></tr><tr><td>TPM1</td><td>COMBINE</td><td>—</td></tr><tr><td>TPM2</td><td>—</td><td>COMBINE</td></tr></table> 0b - Independent 1b - Combined
7-2 —	Reserved
1 COMSWAP0	Combine Channel 0 and 1 Swap When set in combine modes, the odd channel is used for the input capture and first compare, while the even channel is used for the second compare. **NOTE** The value of the first compare must not be greater than that of the second compare. 0b - Even channel 1b - Odd channel
0 COMBINE0	Combine Channels 0 and 1 Enables the combine feature for channels 0 and 1. In Input Capture mode, the combined channels use the even channel input. In Software Compare mode, the even channel match asserts the output trigger, and the odd channel match negates the output trigger. In PWM mode, the even channel match is used for the first compare and odd channel match for the second compare. 0b - Independent 1b - Combined

43.7.1.12 Channel Trigger (TRIG)

Offset

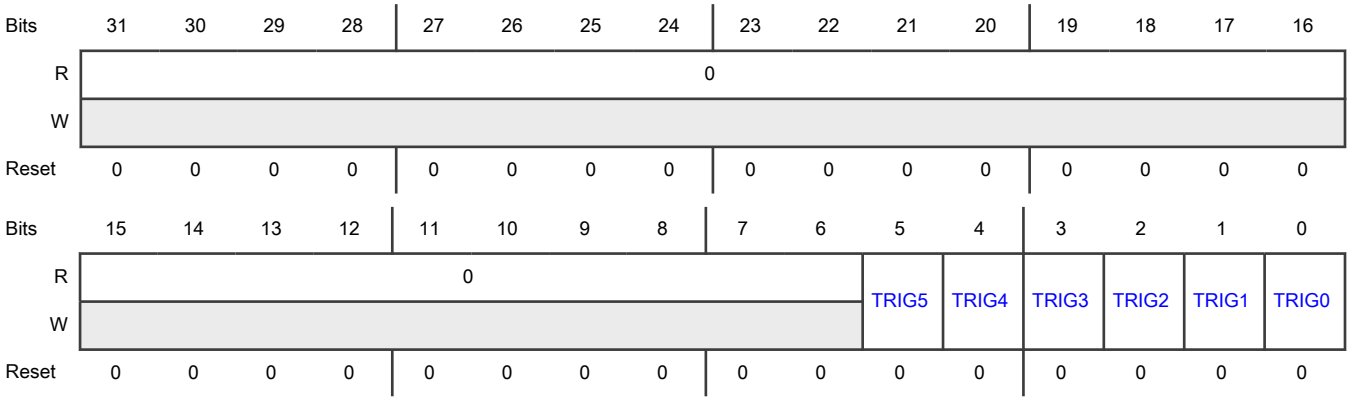
Register	Offset
TRIG	6Ch

Function

Configures the trigger input that is used by the channel to capture the counter value in Input Capture mode. In Output Compare or PWM mode, configures the trigger input used to modulate the channel output. When modulating the output, the

output is forced to the channel initial value whenever the trigger is not asserted. The even-numbered channels share the first input trigger source, and the odd-numbered channels share the second input trigger source.

Diagram



Fields

Field	Function
31-6 —	Reserved
5 TRIG5	Channel 5 Trigger **NOTE** This field is not supported in every instance. The following table includes only supported registers. 0b - No effect 1b - Configures trigger input 1 to be used by channel 5
4 TRIG4	Channel 4 Trigger **NOTE** This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
TPM0	TRIG	—
TPM1	TRIG	—
TPM2	—	TRIG

Instance	Field supported in	Field not supported in
TPM0	TRIG	—

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>TPM1</td><td>TRIG</td><td>—</td></tr>
<tr><td>TPM2</td><td>—</td><td>TRIG</td></tr>
</table>
0b - No effect
1b - Configures trigger input 0 to be used by channel 4</td></tr>
<tr><td>3
TRIG3</td><td>Channel 3 Trigger
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>TPM0</td><td>TRIG</td><td>—</td></tr>
<tr><td>TPM1</td><td>TRIG</td><td>—</td></tr>
<tr><td>TPM2</td><td>—</td><td>TRIG</td></tr>
</table>
0b - No effect
1b - Configures trigger input 1 to be used by channel 3</td></tr>
<tr><td>2
TRIG2</td><td>Channel 2 Trigger
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>TPM0</td><td>TRIG</td><td>—</td></tr>
<tr><td>TPM1</td><td>TRIG</td><td>—</td></tr>
<tr><td>TPM2</td><td>—</td><td>TRIG</td></tr>
</table>
0b - No effect
1b - Configures trigger input 0 to be used by channel 2</td></tr>
<tr><td>1
TRIG1</td><td>Channel 1 Trigger</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - No effect 1b - Configures trigger input 1 to be used by channel 1
0 TRIG0	Channel 0 Trigger 0b - No effect 1b - Configures trigger input 0 to be used by channel 0

43.7.1.13 Channel Polarity (POL)

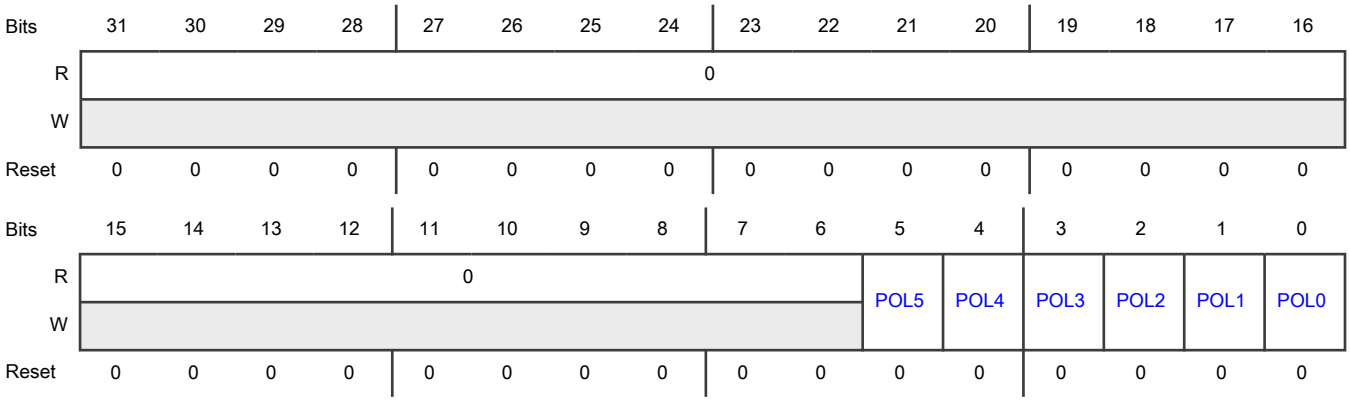
Offset

Register	Offset
POL	70h

Function

Defines the input and output polarity of each of the channels.

Diagram



Fields

Field	Function
31-6 —	Reserved
5 POL5	Channel 5 Polarity **NOTE** This field is not supported in every instance. The following table includes only supported registers.

Table continued from the previous page...

Field	Function

Instance	Field supported in	Field not supported in
TPM0	POL	—
TPM1	POL	—
TPM2	—	POL

0b - Active high

1b - Active low

4

POL4

Channel 4 Polarity

NOTE

This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
TPM0	POL	—
TPM1	POL	—
TPM2	—	POL

0b - Active high

1b - Active low

3

POL3

Channel 3 Polarity

NOTE

This field is not supported in every instance. The following table includes only supported registers.

Instance	Field supported in	Field not supported in
TPM0	POL	—
TPM1	POL	—
TPM2	—	POL

0b - Active high

1b - Active low

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>2
POL2</td><td>Channel 2 Polarity
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table><tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr><tr><td>TPM0</td><td>POL</td><td>—</td></tr><tr><td>TPM1</td><td>POL</td><td>—</td></tr><tr><td>TPM2</td><td>—</td><td>POL</td></tr></table>
0b - Active high
1b - Active low</td></tr>
<tr><td>1
POL1</td><td>Channel 1 Polarity
0b - Active high
1b - Active low</td></tr>
<tr><td>0
POL0</td><td>Channel 0 Polarity
0b - Active high
1b - Active low</td></tr>
</table>

43.7.1.14 Filter Control (FILTER)

Offset

Register	Offset
FILTER	78h

Function

Selects the filter value of the channel inputs, and an additional output delay value for the channel outputs. In PWM Combine mode, you can use this field to implement dead-time insertion.

NOTE

To write values to CH*n*FVAL, ensure that the corresponding channel-interrupt status flag and control (C*n*SC[5:2]) fields are set to 0.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0								CH5FVAL				CH4FVAL			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	CH3FVAL				CH2FVAL				CH1FVAL				CH0FVAL			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 —	Reserved
23-20 CH5FVAL	Channel 5 Filter Value When configured for Input Capture or Software Compare mode, configures the filter value for the channel 5 input. The filter is disabled when the value is zero. Otherwise, the filter is configured as (CH5FVAL × 4) clock cycles. Sets the dead-time insertion time for channel 5 in PWM modes. Dead time insertion is disabled when CH5FVAL is zero. Otherwise, dead time insertion for channel 5 is configured as (CH5FVAL × 4) clock cycles. **NOTE** This field is not supported in every instance. The following table includes only supported registers.
19-16 CH4FVAL	Channel 4 Filter Value When configured for Input Capture or Software Compare mode, configures the filter value for the channel 4 input when configured for input capture or software compare modes. The filter is disabled when the value is zero. Otherwise, the filter is configured as (CH4FVAL × 4) clock cycles. Sets the dead-time insertion time for channel 4 in PWM modes. Dead time insertion is disabled when CH4FVAL is zero. Otherwise, dead time insertion for channel 4 is configured as (CH4FVAL × 4) clock cycles.

Instance	Field supported in	Field not supported in
TPM0	FILTER	—
TPM1	FILTER	—
TPM2	—	FILTER

Table continued from the previous page...

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>TPM0</td><td>FILTER</td><td>—</td></tr>
<tr><td>TPM1</td><td>FILTER</td><td>—</td></tr>
<tr><td>TPM2</td><td>—</td><td>FILTER</td></tr>
</table>
</td></tr>
<tr><td>15-12
CH3FVAL</td><td>
Channel 3 Filter Value
When configured for Input Capture or Software Compare mode, configures the filter value for the channel 3 input. The filter is disabled when the value is zero. Otherwise, the filter is configured as (CH3FVAL×4)clock cycles.
Sets the dead-time insertion time for channel 3 in PWM modes. Dead time insertion is disabled when CH3FVAL is zero. Otherwise, dead time insertion for channel 3 is configured as (CH3FVAL×4)clock cycles.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
<table>
<tr><th>Instance</th><th>Field supported in</th><th>Field not supported in</th></tr>
<tr><td>TPM0</td><td>FILTER</td><td>—</td></tr>
<tr><td>TPM1</td><td>FILTER</td><td>—</td></tr>
<tr><td>TPM2</td><td>—</td><td>FILTER</td></tr>
</table>
</td></tr>
<tr><td>11-8
CH2FVAL</td><td>
Channel 2 Filter Value
When configured for Input Capture or Software Compare mode, configures the filter value for the channel 2 input. The filter is disabled when the value is zero. Otherwise, the filter is configured as (CH2FVAL×4)clock cycles.
Sets the dead-time insertion time for channel 2 in PWM modes. Dead time insertion is disabled when CH2FVAL is zero. Otherwise, dead time insertion for channel 2 is configured as (CH2FVAL×4)clock cycles.
NOTE
This field is not supported in every instance. The following table includes only supported registers.
</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function

Instance	Field supported in	Field not supported in
TPM0	FILTER	—
TPM1	FILTER	—
TPM2	—	FILTER

Field	Function
7-4 CH1FVAL	Channel 1 Filter Value When configured for Input Capture or Software Compare mode, configures the filter value for the channel 1 input. The filter is disabled when the value is zero. Otherwise, the filter is configured as (CH1FVAL×4)clock cycles. Sets the dead-time insertion time for channel 1 in PWM modes. Dead time insertion is disabled when CH1FVAL is zero. Otherwise, dead time insertion for channel 1 is configured as (CH1FVAL×4)clock cycles.
3-0 CH0FVAL	Channel 0 Filter Value When configured for Input Capture or Software Compare mode, configures the filter value for the channel 0 input. The filter is disabled when the value is zero. Otherwise, the filter is configured as (CH0FVAL×4)clock cycles. Sets the dead time insertion time for channel 0 in PWM modes. Dead time insertion is disabled when CH0FVAL is zero. Otherwise, dead time insertion for channel 0 is configured as (CH0FVAL×4)clock cycles.

43.7.1.15 Quadrature Decoder Control and Status (QDCTRL)

Offset

Register	Offset
QDCTRL	80h

Function

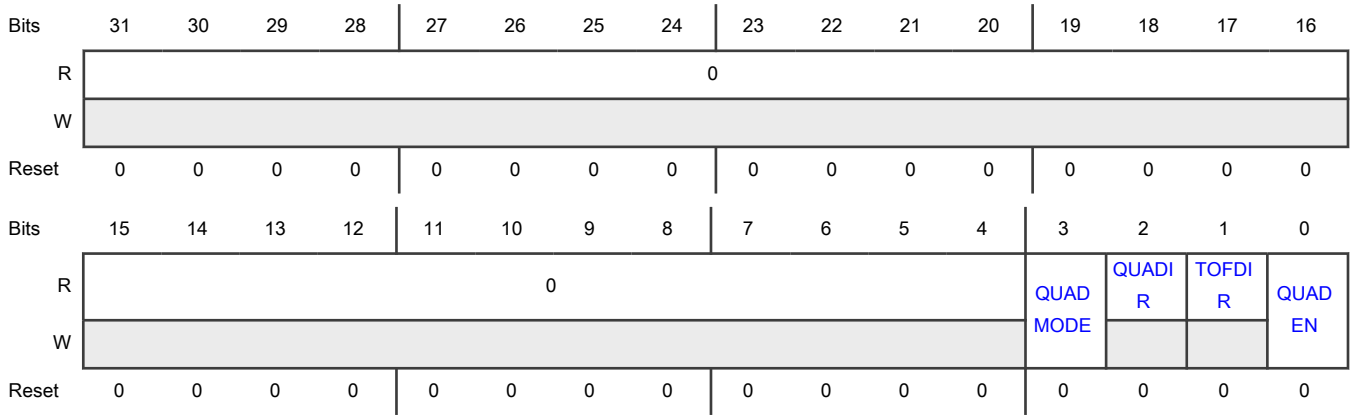
Contains the control and status fields for Quadrature Decoder mode.

NOTE

Each module instance supports a different number of registers.

Instance	Register supported	Register not supported
TPM0	QDCTRL	—
TPM1	QDCTRL	—
TPM2	—	QDCTRL

Diagram



Fields

Field	Function
31-4 —	Reserved
3 QUADMODE	Quadrature Decoder Mode Selects the encoding mode used in Quadrature Decoder mode. 0b - Phase encoding mode 1b - Count and direction encoding mode
2 QUADIR	Counter Direction in Quadrature Decode Mode Indicates whether the counting direction is decreasing or increasing. 0b - Decreasing (counter decrement) 1b - Increasing (counter increment)
1 TOFDIR	Timer Overflow Direction Indicates if SC[TOF] was set on the top or bottom of counting. • Field value 0 indicates that SC[TOF] was set on the bottom of counting. There was a TPM counter decrement and TPM counter changes from its minimum value (0) to its maximum value (MOD[MOD]). • Field value 1 indicates that SC[TOF] was set on the top of counting. There was a TPM counter increment and TPM counter changes from its maximum value (MOD[MOD]) to its minimum value (0). 0b - Bottom of counting 1b - Top of counting
0 QUADEN	Quadrature Decoder Enable

Table continues on the next page...

Table continued from the previous page...

Field	Function
	Enables Quadrature Decoder mode. In this mode, the channel 0 and channel 1 inputs control the TPM counter direction and can only be used for Software Compare mode. Quadrature Decoder mode has precedence over the other modes. 0b - Disable 1b - Enable

43.7.1.16 Configuration (CONF)

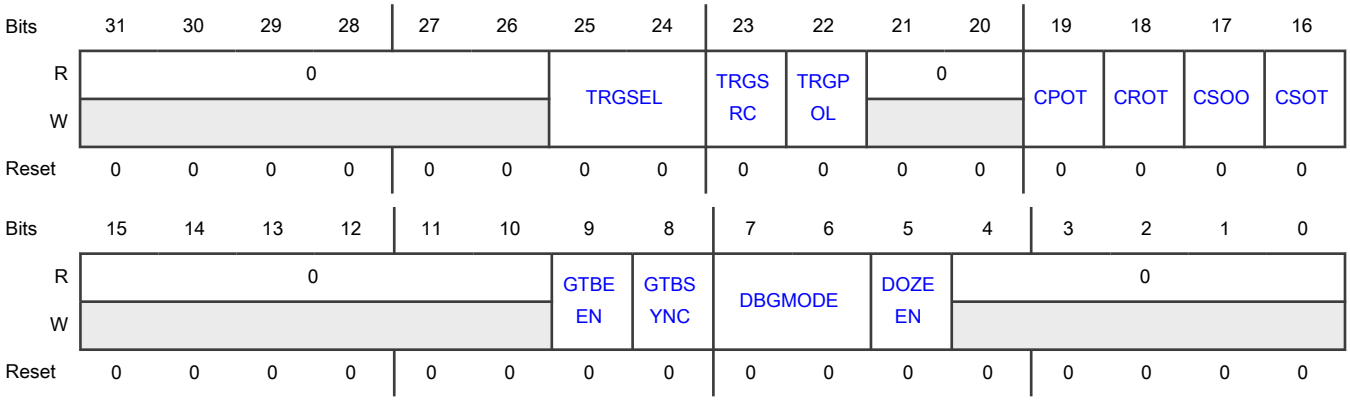
Offset

Register	Offset
CONF	84h

Function

Selects the TPM behavior in Debug mode and Low-Power mode, and the use of an external GTB.

Diagram



Fields

Field	Function
31-26 —	Reserved
25-24 TRGSEL	Trigger Select Selects the input trigger that you use to start, reload, and pause the counter. You can configure the source of the trigger (external or internal to TPM) by CONF[TRGSRC]. Disable the TPM counter before you change this field. See the chip-specific TPM information for available external trigger options.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	The below list shows available internal trigger sources. 01b - Channel 0 pin input capture 10b - Channel 1 pin input capture 11b - Channel 0 or channel 1 pin input capture
23 TRGSRC	Trigger Source Selects between internal (channel pin input capture) or external trigger sources. CONF[TRGSEL] selects this trigger source. When selecting an internal trigger, configure the selected channel for input captures as follows: • CONF[CSOT] enables you to start the counter initially using only a rising edge input capture. • CONF[CROT] enables you to reload the counter using either a rising edge or falling edge input capture. • CONF[CPOT] enables you to pause the counter using the state of the channel input pin. You can use Channel Polarity (POL) to invert the polarity of the channel input pins. Disable the TPM counter before you change this field. 0b - External 1b - Internal (channel pin input capture)
22 TRGPOL	Trigger Polarity Selects the polarity of the external trigger source. Disable the TPM counter before you change this field. 0b - Active high 1b - Active low
21-20 —	Reserved
19 CPOT	Counter Pause on Trigger Specifies that while the trigger remains asserted (level sensitive), and this field is 1, the counter pauses incrementing. While being paused, the counter ignores the input capture events and forces PWM outputs to their default state. If the TPM counter pauses during Debug mode or Low-Power mode, then the counter ignores the trigger input. Disable the TPM counter before you change this field. 0b - TPM counter continues 1b - TPM counter pauses
18 CROT	Counter Reload on Trigger Specifies that when you detect a rising edge on the selected trigger input and this field is 1, then the TPM counter reloads with 0 (and sets PWM outputs to their reload state). If the TPM counter pauses during Debug mode or Low-Power mode, then the counter ignores the trigger input. Disable the TPM counter before you change this field.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - No reload 1b - Reload
17 CSOO	Counter Stop on Overflow Specifies that the TPM counter pauses when SC[TOF] = 1 and this field is 1. Reloading the counter with 0 by writing to Counter (CNT), or by a trigger input, does not cause the counter to stop incrementing. When stopped, the counter does not start incrementing unless you first disable and then enable it, or if you detect a rising edge on the selected trigger input when CONF[CSOT] is 1. While the counter is paused, it ignores the input capture events and forces PWM outputs to their default state. Disable the TPM counter before you change this field. 0b - TPM counter continues 1b - TPM counter stops
16 CSOT	Counter Start on Trigger Specifies that until you detect a rising edge on the selected trigger input, and this field is 1, the TPM counter pauses incrementing when it is enabled. If the TPM counter pauses due to an overflow, a rising edge on the selected trigger input also causes the TPM counter to start incrementing again. While being paused, the counter ignores the input capture events, and forces PWM outputs to their default state. If the TPM counter pauses during Debug mode or Low-Power mode, then the counter ignores the trigger input. Disable the TPM counter before you change this field. 0b - Counter starts immediately 1b - Counter starts after detection of a rising edge on the selected input trigger
15-10 —	Reserved
9 GTBEEN	GTB Enable Configures TPM to use an externally generated GTB counter. When you use an externally generated timebase, the channels do not use the internal TPM counter, but you can use the internal TPM counter to generate a periodic interrupt or DMA request using Modulo (MOD) and SC[TOF]. 0b - Internally generated TPM counter 1b - Externally generated GTB counter
8 GTBSYNC	GTB Synchronization Enables the TPM counter to synchronize with GTB. It uses the GTB enable, trigger, paused state and overflow to ensure that the TPM counter starts incrementing, stops incrementing, and resets at the same time as GTB. Disable the TPM counter before you change this field. 0b - Disable 1b - Enable
7-6	Debug Mode

Table continues on the next page...

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Field	Function
DBGMODE	Configures the TPM behavior in Debug mode (see Debug mode). All other configurations are reserved. 00b - TPM counter pauses 11b - TPM counter continues
5 DOZEEN	Doze Enable Configures the TPM behavior in Low-Power mode (see Low-Power mode). 0b - TPM counter continues 1b - TPM counter pauses
4-0 —	Reserved

Chapter 44
Low Power Inter-Integrated Circuit (LPI2C)

44.1 Chip-specific LPI2C information

Table 304. Reference links to related information

Topic	Related module	Reference
Full description	LPI2C	LPI2C
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

44.1.1 Module instances

This device has two instances of the LPI2C module, LPI2C0, and LPI2C1.

44.1.2 Host request configuration

Both of the LPI2C0 and LPI2C1 support host request feature.

The input trigger that can be used as host request input is from TRGMUX, refer to Trigger multiplexer (TRGMUX) for more details.

44.2 Overview

LPI2C supports an efficient interface to an I2C bus as a controller and target:

- Implements logic support for Standard, Fast, Fast+, Ultra Fast, and High-Speed (HS) modes of operation
- Uses little CPU overhead, with DMA offloading of FIFO register accesses
- Continues operating in Sleep modes if an appropriate clock is available

LPI2C also complies with the System Management Bus (SMBus) Specification, version 3. The SMBus is a single-ended simple two-wire bus, which is typically used for low-bandwidth communications.

The Inter-Integrated Circuit (I^2C) serial bus is multi-controller, multi-target, packet-switched, and single-ended, and is often used to attach microcontroller ICs to lower-speed peripheral ICs.

NOTE

Terminology in this chapter has been updated to align with I^2C-bus specification, Rev. 7.0, as shown in Table 305.

Table 305. Updated terms

Updated term	Deprecated term
Controller	Master
Target	Slave

44.2.1 Block diagram

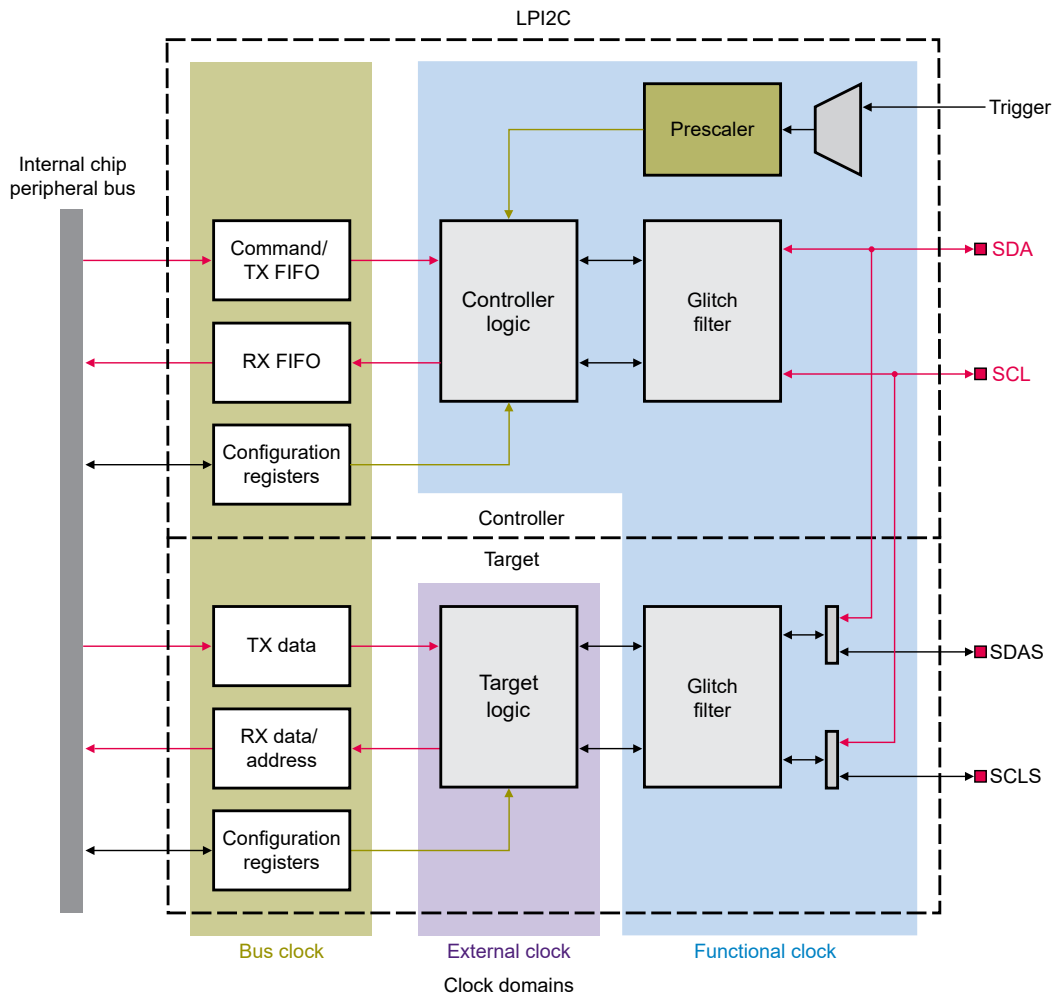


Figure 168. Block diagram

44.2.2 Features

LPI2C supports:

- Standard, Fast, Fast+ and Ultra Fast modes
- HS mode in target mode and controller mode
- Multicontroller, including synchronization and arbitration, means that any number of controller nodes can be present. Also, controller and target roles can be changed between messages (after a Stop signal is sent).
- Clock stretching. Used on the SCL line, as an I2C flow control mechanism.
- Arbitration for when the system has more than one controller. When used on the SDA line, ensures that there is only one I2C transmitter at a time.
- General call, seven-bit addressing, and ten-bit addressing
- Software reset, Start byte, and device ID (also require software support)

The LPI2C controller supports:

- Command and transmit FIFO of 4 words (8-bit transmit data + 3-bit command)

- Receive FIFO of 4 words (8-bit receive data).
- Command FIFO waiting for an I2C idle bus before initiating a transfer
- Initiation of repeated Start and Stop conditions and one or more controller-receiver transfers by command FIFO
- Stop condition generation from command FIFO, or automatic generation of Stop condition when the transmit FIFO is empty
- Interrupt generation on data match and unwanted data rejection, via flexible receive data match
- Flags and optional interrupt signals at repeated Start condition, Stop condition, loss of arbitration, unexpected NACK, and command word errors
- Configurable bus idle timeout and pin-stuck-low timeout

The LPI2C target supports:

- Separate I2C target registers to minimize software overhead because of controller or target switching
- 7-bit or 10-bit addressing, address range, SMBus alert, and general call address.
- Transmit data register that supports interrupt or DMA requests
- Receive data register that supports interrupt or DMA requests
- Software-controllable ACK or NACK, with optional clock stretching on ACK or NACK field
- Configurable clock stretching, to avoid transmit-FIFO-underrun and receive-FIFO-overrun errors
- Flags and optional interrupt at end of packet, Stop condition, or bit error detection

44.3 Functional description

44.3.1 Controller mode

The LPI2C controller logic operates independently from the target logic to perform all controller-mode transfers on the I2C bus.

44.3.1.1 Transmit and Command FIFO commands

The transmit FIFO stores command data to initiate various I2C operations. The following operations can be initiated through commands in the transmit FIFO:

- Start or repeated Start condition with address byte, expecting ACK or NACK.
- Transmit data. This operation is the default for zero-extended-byte writes to the transmit FIFO.
- Receive 1-256 bytes of data. You can configure this operation to discard received data and not to store it in the receive FIFO.
- Stop condition. You can configure this operation to send a Stop condition when the transmit FIFO is empty.

Multiple transmit and receive commands can be inserted between the Start and Stop conditions. To comply with the I2C specification, transmit and receive commands must not be interleaved. The receive data command and the receive data and discard commands can be interleaved. This interleaving ensures that only the desired received data is stored in the receive FIFO (or compared with the data match logic).

The LPI2C controller automatically transmits a NACK on the last byte of a receive data command. It transmits the NACK unless the next command in the FIFO is also a receive data command. If the transmit FIFO is empty when a receive data command completes, a NACK is also automatically transmitted.

The LPI2C controller supports 10-bit addressing via a (repeated) Start condition, followed by a transmit data byte containing the second address byte, followed by any number of data bytes with the controller transmit data.

A Start or repeated Start condition expecting a NACK (for example, HS mode controller code) must be followed by a Stop or (repeated) Start condition.

44.3.1.2 Controller operations

When LPI2C is enabled, it monitors the I2C bus to detect when the I2C is idle (MSR[BBF]). If either SCL or SDA are low, the I2C bus is no longer considered idle. The bus becomes idle if a Stop condition is detected or if a bus idle timeout is detected (as configured by MCFGR2[BUSIDLE]). After the bus is idle, if the transmit FIFO is not empty and the host request is asserted or disabled, the LPI2C controller initiates a transfer on the bus. This transfer involves the following steps:

1. Wait the bus idle time equal to (MCCR0[CLKLO] + 1) multiplied by the prescaler (MCFGR1[PRESCALE]).
2. Transmit a Start condition and address byte using the timing configuration in Controller Clock Configuration 0 (MCCR0). If an HS mode transfer is configured, the timing configuration from Controller Clock Configuration 1 (MCCR1) is used instead.
3. Perform controller transmit or controller receive transfers, as configured by the transmit FIFO.
4. Transmit NACK on the last byte of a controller receive transfer. This action is performed unless the next command in the transmit FIFO is also a receive data command and the transmit FIFO is not empty.
5. Transmit a repeated Start or Stop condition as configured by the transmit FIFO or MCFGR1[AUTOSTOP]. A repeated Start can change which timing configuration register is used.

When MCFGR0[RELAX] is 1, the LPI2C controller does not wait for the I2C bus to be idle before starting a transfer. It also relaxes some restrictions on the order of FIFO commands. For example, it allows a Stop command when it is idle to generate a Start condition, followed by one SCL clock pulse, and then a Stop condition.

When the LPI2C controller is disabled, LPI2C continues emptying the transmit FIFO until a Stop condition is transmitted. (The controller could be disabled due to MCR[MEN] being 0, or automatically due to mode entry.) However, LPI2C no longer stalls the I2C bus by waiting for the transmit or receive FIFO. After the transmit FIFO is empty, LPI2C generates a Stop condition automatically.

The LPI2C controller can stall the I2C bus under certain conditions. This stalling results in SCL pulled low continuously on the first bit of a byte, until these conditions change:

- The LPI2C controller is enabled and busy, the transmit FIFO is empty, and MCFGR1[AUTOSTOP] is 0. The LPI2C controller continues to stall the bus until the transmit FIFO is loaded with more data.
- The LPI2C controller is enabled and receiving data, receive data is not being discarded (due to command or receive data match), and the receive FIFO is full. The LPI2C controller continues to stall the I2C bus until the receive FIFO is emptied.

The LPI2C controller aborts the existing transfer when MCFGR0[ABORT] becomes 1. This action causes the LPI2C controller to complete the existing word and then transmit a Stop condition. If the receive FIFO is full when the receive operation is aborted, the last received data is discarded. A new transfer does not start while MCFGR0[ABORT] is 1.

44.3.1.3 Receive FIFO and data matching

The receive FIFO stores receive data during controller-receiver transfers. You can configure the LPI2C controller to discard received data instead of storing it in the receive FIFO. This option is configured via the command word in the transmit FIFO.

Received data supports a receive data match function that can match received data against one of two bytes, or against a masked data byte. You can configure the data match function to compare only the first one or two data words received since the last (repeated) Start condition. Received data that is already discarded due to the command word cannot cause a data match. It delays the match on the first data word received until after the discarded data is received.

You can configure the receiver match function to discard all received data until a data match is detected, using MCFGR0[RDMO]. Following a data match, write 0 to MCFGR0[RDMO] before writing 0 to MSR[DMF] to allow all subsequent data to be received.

44.3.1.4 Timing parameters

The LPI2C controller can configure the following timing parameters. Parameters are configured separately for HS mode (Controller Clock Configuration 1 (MCCR1)) and other modes (Controller Clock Configuration 0 (MCCR0)). This separation allows the HS mode controller code to be sent using regular timing parameters. Then it allows a switch to HS mode timing (following a repeated Start) until the next STOP condition.

Configure the LPI2C controller timing parameters, measured in LPI2C functional clock cycles, as shown in Table 306. You must configure these parameters to meet the I2C timing specification for the required mode.

Table 306. Timing parameters

I2C specification timing parameter	I2C specification timing symbol	LPI2C timing parameter (in LPI2C functional clock cycles)
SCL clock period	tSCL	(CLKHI + CLKLO + 2 + SCL_LATENCY) × (2 ^ PRESCALE)
Hold time (repeated) Start condition	tHD:STA	(SETHOLD +1) × (2 ^ PRESCALE)
Low period of the SCL clock	tLOW	(CLKLO + 1) × (2 ^ PRESCALE)
High period of the SCL clock	tHIGH	(CLKHI + 1 + SCL_LATENCY) × (2 ^ PRESCALE)
Setup time for a repeated Start condition or Stop condition	tSU:STA, tSU:STO	(SETHOLD + 1 + SCL_LATENCY) × (2 ^ PRESCALE)
Data hold time	tHD:DAT	(DATAVD + 1) × (2 ^ PRESCALE)
Data setup time	tSU:DAT	(SDA_LATENCY + 1) × (2 ^ PRESCALE)
Bus free time between a Stop and Start condition	tBUF	(CLKLO + 1 + SDA_LATENCY) × (2 ^ PRESCALE)
Data valid time, data valid acknowledge time	tVD:DAT, tVD:ACK	(DATAVD + 1) × (2 ^ PRESCALE)

Table 307 defines the latency parameters. These parameters assume that the risetime is less than one LPI2C functional clock cycle. The risetime depends on a number of factors, including the I/O propagation delay, the I2C bus loading, and the external pullup resistor sizing. A larger risetime increases the number of cycles that the signal takes to propagate through the synchronizer (and glitch filter), which increases the latency.

Table 307. Synchronization latency

Timing parameter	Timing definition
SCL_LATENCY	ROUNDDOWN ((2 + FILTSCL + SCL_RISETIME) ÷ (2 ^ PRESCALE))
SDA_LATENCY	ROUNDDOWN ((2 + FILTSDA + SDA_RISETIME) ÷ (2 ^ PRESCALE))

The following timing restrictions must be enforced to avoid unexpected Start or Stop conditions on the I2C bus. These restrictions also avoid unexpected Start or Stop conditions detected by the LPI2C controller. The timing restrictions can be summarized as "SDA cannot change when SCL is high outside a transmitted (repeated) Start or Stop condition."

Table 308. LPI2C timing parameter restrictions

Timing parameter	Minimum	Maximum	Comment
CLKLO	03h	—	CLKLO x (2 ^ PRESCALE) > SCL_LATENCY
CLKHI	01h	—	Configure CLKHI to meet the duty cycle requirements in the I2C specification
SETHOLD	02h	—	SETHOLD × (2 ^ PRESCALE) > SDA_LATENCY

Table continues on the next page...

Table 308. LPI2C timing parameter restrictions (continued)

Timing parameter	Minimum	Maximum	Comment
DATAVD	01h	CLKLO – SDA_LATENCY – 1	Configure DATAVD to meet the data hold requirement in the I2C specification
FILTSCL	00h	[CLKLO × (2 ^ PRESCALE)] – 3	FILTSCL and FILTSDA are the only parameters not multiplied by (2 ^ PRESCALE)
FILTSDA	FILTSCL	[CLKLO × (2 ^ PRESCALE)] – 3	Configuring FILTSDA greater than FILTSCL can delay the SDA input to compensate for board level skew
BUSIDLE	(CLKLO + SETHOLD + 2) × 2	—	Must also be greater than (CLKHI + 1)

See the UM10204, *I2C-bus specification and user manual*.

See Application information for example LPI2C timing configurations.

44.3.1.5 Error conditions

The LPI2C controller monitors errors while it is active. The following conditions generate an error flag and block a new Start condition from being sent, until the flag is cleared by software:

- A Start or Stop condition is detected and is not generated by the LPI2C controller (MSR[ALF] becomes 1).
- Transmitting data on SDA and different values are received (MSR[ALF] becomes 1). LPI2C controller stops driving SDA immediately, but continues to drive SCL for the remainder of the byte.
- NACK is detected when transmitting data, and MCFGR1[IGNACK] is 0 (MSR[NDF] becomes 1).
- NACK is detected and is expecting ACK for the address byte, and MCFGR1[IGNACK] is 0 (MSR[NDF] becomes 1).
- ACK is detected and is expecting NACK for the address byte, and MCFGR1[IGNACK] is 0 (MSR[NDF] becomes 1).
- Transmit FIFO is requesting to transmit or receive data without a Start condition (MSR[FEF] becomes 1). This restriction is ignored when MCFGR0[RELAX] is 1.
- SCL (or SDA if MCFGR1[TIMECFG] is 1) is low for (MCFGR2[TIMELOW] × 256) prescaler cycles without a pin transition (MSR[PLTF] becomes 1).

You must respond to MSR[PLTF] to terminate the existing command. You can terminate the command cleanly by writing 0 to MCR[MEN], or you can terminate it abruptly by writing 1 to MCR[RST].

You can use MCFGR0[RELAX] to attempt to recover a target with SDA stuck low. If MCFGR0[RELAX] is 1, the LPI2C controller does not wait for the I2C bus to be idle before starting a transfer. Initiating a Start command with address FFh, then the Stop condition, should generate sufficient SCL clock edges to cause the target to release SDA.

You can use MCFGR2[BUSIDLE] to force the I2C bus to be considered idle when SCL and SDA remain high for (BUSIDLE + 1) prescaler cycles. The bus is considered idle when the LPI2C controller is first enabled. When BUSIDLE is configured greater than zero, then SCL or SDA must be high for (BUSIDLE + 1) prescaler cycles before the I2C bus is considered idle.

44.3.1.6 Pin configuration

Configuration	Description
Open-drain support	The LPI2C controller defaults to open-drain configuration of the SDA and SCL pins. Support for true open drain depends on the specific device, and requires the pins where LPI2C pins are muxed to support true open drain.
HS mode support	Support for HS mode depends on the specific device. This mode requires the SCL pin to support the current source pullup required in the I2C specification.
Ultra-Fast mode support	The LPI2C controller supports the output-only push-pull function required for I2C Ultra-Fast mode using the SDA and SCL pins. Support for Ultra-Fast mode also requires MCFGR1[IGNACK] to be 1.
Push-pull two-wire support	A push-pull two-wire configuration is available to the LPI2C controller. If LPI2C is the only controller and all I2C pins on the bus are at the same voltage, this configuration may support a partial HS mode. A partial HS mode, not a full HS mode, because this configuration actively drives high rather than enabling a current service pull-up. This configuration sets the SCL pin as push-pull for every clock except the first clock pulse, to allow HS-mode-compatible targets to perform clock stretching. In this mode, the SDA pin is tristated for controller-receive data bits and controller-transmit ACK/NACK bits, and is configured as push-pull at other times. To avoid the risk of contention when SDA is push-pull, configure the pin for open-drain operation, as part of the device-specific configuration.
Push-pull four-wire support	The push-pull four-wire configuration separates the SCL input data and output data into separate pins. It also separates the SDA input data and output data into separate pins. The SCL/SDA pins are used for input data; the SCLS/SDAS pins are used for output data, with configurable polarity. This configuration simplifies external connections when connecting the LPI2C to the I2C bus through external level shifters or discrete components. When using this four-wire configuration, the LPI2C controller logic and LPI2C target logic cannot connect to separate I2C buses.

44.3.2 Target mode

To perform all target mode transfers on the I2C bus, the LPI2C target logic operates independently from the LPI2C controller logic.

44.3.2.1 Address matching

You can configure the LPI2C target:

- To match one of two addresses, using either 7-bit or 10-bit addressing modes for each address.
- To match a range of addresses in either 7-bit or 10-bit addressing modes.
- To match the general call address and generate appropriate flags.
- To match the SMBus alert address and generate appropriate flags.
- To detect the HS mode controller code address, and to disable the digital filters and output valid delay time until the next Stop condition is detected.

After a valid address is matched, the LPI2C target automatically performs target-transmit or target-receive transfers until:

- A NACK is detected (unless SCFGR1[IGNACK] becomes 1).
- A bit error is detected (the LPI2C target is driving SDA, but a different value is sampled).
- A (repeated) Start or Stop condition is detected.

When SCFGR1[RXALL] is 1, the LPI2C target receives all addresses and data on the I2C bus. Unless the address is matched, it never drives the SDA pin. Configure the LPI2C target to match only on 7-bit address mode when this feature is enabled. Software can support 10-bit address mode. This option is intended for debugging the contents of an I2C transfer between another controller

and target. Likewise, SCFGR1[SDCFG] and SCFGR1[RSCFG] configure the Stop or repeated Start flags to assert on all Stop or repeated Start conditions, even when there is no address match.

44.3.2.2 Transmit and receive data

Target Transmit Data (STDR) and Target Receive Data (SRDR) are double-buffered and only update during a target-transmit and target-receive transfer, respectively.

You can configure the target address that was received to be read from SRDR (for example, when using DMA to transfer data) or from Target Address Status (SASR).

You can configure STDR to request data only after a target-transmit transfer is detected. You can also configure it to request new data whenever STDR is empty.

Write to STDR only when SSR[TDF] is set.

Read SRDR only when SSR[RDF] is set, or when SSR[AVF] is set and SCFGR1[RXCFG] = 1.

Read SASR only when SSR[AVF] is set.

44.3.2.3 Read request

The LPI2C target generates a read request when the I2C bus is idle and you write 1 to SCFGR0[RDREQ]. This occurrence causes the LPI2C target to pull the SDA pin low until either the first SCL falling edge or SCFGR0[RDREQ] becomes 0. Following the next Stop condition or a software timeout, you can proceed as follows:

- If the LPI2C target is accessed at the correct address, the read request is acknowledged, and you must write 0 to SCFGR0[RDREQ].
- If SCFGR0[RDACK] is 1, the read request is acknowledged by a Start followed by one SCL pulse followed by a STOP condition. You must write 0 to SCFGR0[RDREQ].
- If neither of the first two cases occurred, the read request is not acknowledged. You must write 0 and then 1 to SCFGR0[RDREQ] after an appropriate delay, provided the I2C bus is idle.
- If a software timeout occurs, the read request is not acknowledged, and you should write 0 to SCFGR0[RDREQ]. Another request can be generated after an appropriate delay.

Writing to SCFGR0[RDREQ] when the I2C bus is busy results in a logic 0 being written. Write 1 to SCFGR0[RDREQ], then confirm that the register is written to correctly. If the register does not update correctly, the I2C bus is no longer idle and the read request must be attempted later.

44.3.2.4 Clock stretching

The LPI2C target supports many configurable options for clock stretching. You can configure these conditions to perform clock stretching:

- SSR[AVF] is set during the ninth clock pulse of the address byte.
- SSR[TDF] is set during the ninth clock pulse of a target-transmit transfer.
- SSR[RDF] is set during the ninth clock pulse of a target-receive transfer.
- SSR[TAF] is set during the eighth clock pulse of an address byte or a target-receive transfer. In HS mode, this option is disabled.
- Clock stretching can be extended for a number of cycles equal to the value of SCFGR2[CLKHOLD] cycles. This stretching allows additional setup time to sample the SDA pin externally. In HS mode, this option is disabled.

When clock stretching is enabled, clock stretching extends for one peripheral bus clock cycle after SDA updates, unless extended by the SCFGR2[CLKHOLD] configuration.

44.3.2.5 Timing parameters

The LPI2C target can configure the following timing parameters:

- SDA data valid time from SCL negation to SDA update
- SCL hold time when clock stretching is enabled to increase setup time when sampling SDA externally
- SCL glitch filter time
- SDA glitch filter time

These parameters are disabled when SCR[FILTEN] is 0, when SCR[FILTDZ] is 1 in Doze mode, and when LPI2C target detects HS mode. When disabled, the LPI2C target is clocked directly from the I2C bus. In this case, the target may not satisfy all timing requirements of the I2C specification (such as SDA minimum hold time in Standard/Fast mode).

The LPI2C target places the following restrictions on the timing parameters:

- You must configure SCFGR2[FILTSDA] to be greater than or equal to SCFGR2[FILTSCL] (unless compensating for board level skew between SDA and SCL).
- You must configure SCFGR2[DATAVD] to be less than the minimum SCL low period.

44.3.2.6 Error conditions

The LPI2C target can flag the following error conditions:

- SSR[BEF] is set when the LPI2C target is driving SDA but it samples a different value than what is expected.
- SSR[FEF] is set due to a transmit data underrun or a receive data overrun. To eliminate the possibility of underrun and overrun, enable clock stretching. When SCFGR1[RXNACK] is 1, the LPI2C target generates a NACK on a receive data overrun.
- SSR[FEF] is also set due to an address overrun, but only when SCFGR1[RXCFG] is 1. To eliminate the possibility of overrun, enable clock stretching. When SCFGR1[RXNACK] is 1, the LPI2C target generates a NACK on an address overrun regardless of the value of SCFGR1[RXCFG].

The LPI2C target does not implement a timeout due to SCL or SDA being stuck low. If this detection is required, use the LPI2C controller logic so you can reset the LPI2C target when this condition is detected.

44.3.3 Low-power modes

LPI2C remains functional during low-power modes, if MCR[DOZEN] = 0 and LPI2C uses an external or internal clock source that remains enabled. LPI2C can generate an interrupt or DMA request to cause a wake-up from low-power modes.

You can configure LPI2C to be disabled in low-power modes when MCR[DOZEN] = 1. In this case, LPI2C waits for the current transfer to complete any pending operation.

NOTE

See the chip-specific information for low-power modes available on your chip.

44.3.4 Debug mode

Table 309. Debug mode

Mode	LPI2C operation
Debug	If MCR[DBGEN] = 1, can continue operating in Debug mode.

44.3.5 Peripheral triggers

The connection of the LPI2C peripheral triggers to other peripherals depends upon the specific device being used.

Table 310. LPI2C triggers

Trigger	Description
Controller output trigger	Generates an output trigger that can be connected to other peripherals on the device. The controller output trigger asserts on either a repeated Start or a Stop condition. The trigger remains asserted for one cycle of the LPI2C functional clock divided by MCFGR1[PRESCALE].
Target output trigger	Generates an output trigger that can be connected to other peripherals on the device. The target output trigger asserts on either a repeated Start or a Stop condition that occurs after a target address match. The target output trigger remains asserted until the next target SCL pin negation.
Input trigger	Controls the start of a LPI2C bus transfer. The input trigger is synchronized. To be detected, the input trigger must assert for at least two cycles of the LPI2C functional clock divided by the value of MCFGR1[PRESCALE].

44.3.6 Clocking

Table 311. LPI2C clocks

Clock	Description
LPI2C functional clock	The LPI2C functional clock is asynchronous to the bus clock. It can remain enabled in low-power modes to support I2C bus transfers by the LPI2C controller. The functional clock is also used by the LPI2C target to support digital filter and data hold time configurations. The LPI2C controller divides the functional clock by a prescaler (MCFGR1[PRESCALE]) and the resulting frequency must be at least eight times faster than the I2C bus bandwidth.
External clock	The LPI2C target logic is clocked directly from the external pins. These pins are SCL and SDA, or SCLS and SDAS if the controller and target are implemented on separate pins). This clocking allows the LPI2C target to remain operational, even when the LPI2C functional clock is disabled. **NOTE** If the LPI2C functional clock is disabled, the LPI2C target digital filter must be disabled. This condition can affect compliance with some timing parameters of the I2C specification, such as data hold time.
Bus clock	The bus clock is only used for bus accesses to the control and configuration registers. The bus clock frequency must be sufficient to support the data bandwidth requirements of the LPI2C controller and target registers.

For chip-specific clocking information, see the Clocking chapter.

44.3.7 Reset

Table 312. LPI2C resets

Reset	Description
Chip reset	The logic and registers for the LPI2C controller and target are reset to their default states after a chip reset.
Software reset	The LPI2C controller implements a software reset field in its control register. MCR[RST] resets all controller logic and registers to their default states, except for Controller Control (MCR) itself. The LPI2C target implements a software reset field in its control register. SCR[RST] resets all target logic and registers to their default states, except for Target Control (SCR) itself.

Table continues on the next page...

Table 312. LPI2C resets (continued)

Reset	Description
FIFO reset	The LPI2C controller implements write-only control fields that reset the transmit FIFO (MCR[RTF]) and receive FIFO (MCR[RRF]). After a FIFO is reset, that FIFO is empty. The LPI2C target implements write-only control fields that reset the transmit data register (SCR[RTF]) and receive data register (SCR[RRF]). After a data register is reset, that data register is empty.

44.3.8 Interrupts and DMA requests

Depending on the configuration, interrupts and DMA requests can be combined:

- LPI2C controller and target interrupts
- LPI2C controller and target transmit DMA requests
- LPI2C controller and target receive DMA requests

44.3.8.1 Controller mode

Table 313 lists the Controller mode sources that can generate LPI2C controller interrupts and LPI2C controller transmit and receive DMA requests.

Table 313. Controller interrupts and DMA requests

Status flag	Description	Can generate		
		Interrupt?	DMA request?	Low-power wake-up?
Transmit Data Flag (MSR[TDF])	Data can be written to transmit FIFO, as configured by MFCR[TXWATER].	Y	TX	Y
Receive Data Flag (MSR[RDF])	Data can be read from the receive FIFO, as configured by MFCR[RXWATER].	Y	RX	Y
End Packet Flag (MSR[EPF])	Controller has transmitted a repeated Start or Stop condition.	Y	N	Y
Stop Detect Flag (MSR[SDF])	Controller has transmitted a Stop condition (and the LPI2C controller is idle, if MCFGR1[STOPCFG] = 1) .	Y	N	Y
NACK Detect Flag (MSR[NDF])	During an address byte, the controller expects an ACK but detects a NACK. During an address byte, the controller expects a NACK but detects an ACK. During a controller-transmitter data byte, the controller detects a NACK.	Y	N	Y
Arbitration Lost Flag (MSR[ALF])	The controller lost arbitration due to a Start or Stop condition detected at the wrong time, or the controller was transmitting data but received data different from the data that was transmitted.	Y	N	Y

Table continues on the next page...

Table 313. Controller interrupts and DMA requests (continued)

Status flag	Description	Can generate		
		Interrupt?	DMA request?	Low-power wake-up?
FIFO Error Flag (MSR[FEF])	The controller expects a Start condition in the command FIFO, but the next entry in the command FIFO is not a Start condition.	Y	N	Y
Pin Low Timeout Flag (MSR[PLTF])	Pin low timeout is enabled and SCL (or SDA, if configured) is low for longer than the configured timeout.	Y	N	Y
Data Match Flag (MSR[DMF])	The received data matches the configured data match, but the received data is not discarded due to a command FIFO entry.	Y	N	Y
Start Detect Flag (MSR[STF])	A Start condition is detected on the I2C bus (and the LPI2C controller is idle, if MCFGR1[STARTCFG] = 1).	Y	N	Y
Controller Busy Flag (MSR[MBF])	LPI2C controller is busy transmitting or receiving data.	N	N	N
Bus Busy Flag (MSR[BBF])	LPI2C controller is enabled and activity is detected on the I2C bus, but no Stop condition is detected and no bus idle timeout (if enabled) occurred.	N	N	N

44.3.8.2 Target mode

Table 314 lists the target mode sources that can generate LPI2C target interrupts and LPI2C target transmit and receive DMA requests.

Table 314. Target interrupts and DMA requests

Status flag	Description	Can generate		
		Interrupt?	DMA request?	Low-power wake-up?
Transmit Data Flag (SSR[TDF])	Data can be written to Target Transmit Data (STDR).	Y	TX	Y
Receive Data Flag (SSR[RDF])	Data can be read from Target Receive Data (SRDR).	Y	RX	Y
Address Valid Flag (SSR[AVF])	Address can be read from Target Address Status (SASR).	Y	RX	Y
Transmit ACK Flag (SSR[TAF])	ACK or NACK can be written to Target Transmit ACK (STAR).	Y	N	Y
Repeated Start Flag (SSR[RSF])	Target has detected an address match followed by a repeated Start condition.	Y	RX	Y
Stop Detect Flag (SSR[SDF])	Target has detected an address match followed by a Stop condition.	Y	RX	Y

Table continues on the next page...

Table 314. Target interrupts and DMA requests (continued)

Status flag	Description	Can generate		
		Interrupt?	DMA request?	Low-power wake-up?
Bit Error Flag (SSR[BEF])	Target was transmitting data, but received data is different from what was transmitted.	Y	N	Y
FIFO Error Flag (SSR[FEF])	This flag is set by: • Transmit data underrun • Receive data overrun • Address status overrun when SCFGR1[RXCFG] = 1 This flag can only be set when clock stretching is disabled.	Y	N	Y
Address Match 0 Flag (SSR[AM0F])	Target detected an address match SAMR[ADDR0].	Y	N	N
Address Match 1 Flag (SSR[AM1F])	Target detected an address match with SAMR[ADDR1] or using an address range.	Y	N	N
General Call Flag (SSR[GCF])	Target detected an address match with the general call address.	Y	N	N
SMBus Alert Response Flag (SSR[SARF])	Target detected an address match with the SMBus alert address.	Y	N	N
Target Busy Flag (SSR[SBF])	LPI2C target is busy receiving an address byte or is transmitting or receiving data.	N	N	N
Bus Busy Flag (SSR[BBF])	LPI2C target is enabled and a Start condition is detected on I2C bus, but no Stop condition detected.	N	N	N

44.3.8.3 End-of-packet DMA transfer

End-of-packet functionality serves serial interfaces where the transfer size may not be known in advance and the data is pushed by an external device. Examples include UART receive, I2C Target mode, and SPI Target mode. End-of-packet processing is intended to ensure that data does not become stranded in either the receive FIFO or DMA receive buffer. Support for end-of-packet processing must be implemented in both the serial interfaces and DMA controller.

The condition that signals the end of packet differs for each serial interface but is processed by the serial peripheral and DMA in the same way. For example:

- UART end of packet is signaled by an idle line condition.
- I2C end of packet is signaled by Stop or repeated Start condition.
- SPI end of packet is signaled by PCS negation.

When the serial peripheral is configured to signal an end-of-packet condition to the DMA and the serial interface detects an end-of-packet condition, it asserts the DMA request for the receive FIFO regardless of the watermark configuration. For larger watermark configurations, this behavior ensures that the last few words of the transfer are first flushed from the receive FIFO.

The DMA then reads the contents of the receive FIFO, depending on the first word in the FIFO:

- If the receive FIFO is empty, the serial interface signals an end-of-packet condition to the DMA controller.

- If the receive FIFO is not empty, but the first word in the FIFO starts a new packet, data is not pulled from the receive FIFO. Also, the serial interface signals an end-of-packet condition to the DMA controller.
- If the receive FIFO is not empty, and the first word in the FIFO does not start a new packet, the DMA transfers data as normal.

Because the DMA may transfer multiple words per request, the end-of-packet condition persists until the DMA minor loop finishes and no additional data is pulled from the FIFO. The status flag that triggered the end-of-packet condition is cleared when the minor loop completes after the end of packet is signaled to the DMA controller.

When the DMA detects the end-of-packet condition, it writes all received words up to the end of packet into system memory. It also saves the destination address for the word after the last valid data. The DMA then terminates the channel as if the major loop completed, including final offsets and optional interrupts, channel linking, and scatter-gather. The final destination address can be saved to system memory or is available in the destination address register.

Because the DMA terminates the major loop, the receive FIFO is not serviced until the DMA is reconfigured. You can perform this reconfiguration through software or hardware (for example, channel linking or scatter-gather). Minimize this delay to avoid receiver FIFO overrun. Automatic DMA end-of-packet processing is not recommended when there are only a few words transferred between end-of-packet conditions. In this case, the DMA spends more time processing the end of packet than transferring the data. For example, to avoid an excessive number of idle conditions, increase the UART idle line length as needed.

44.4 External signals

Table 315. External signals

Signal	Name	Two-wire scheme	Four-wire scheme	Direction
SCL	LPI2C clock line	SCL	In Four-Wire mode, this pin is the SCL input pin.	Input or output
SDA	LPI2C data line	SDA	In Four-Wire mode, this pin is the SDA input pin.	Input or output
SCLS	Secondary I2C clock line	Not used	In Four-Wire mode, this pin is the SCLS output pin. If LPI2C controller/target are configured to use separate pins, then this pin is the LPI2C target SCL pin.	Input or output
SDAS	Secondary I2C data line	Not used	In Four-Wire mode, this pin is the SDAS output pin. If LPI2C controller/target are configured to use separate pins, then this pin is the LPI2C target SDA pin.	Input or output

Figure 169 shows the two-signal connection.

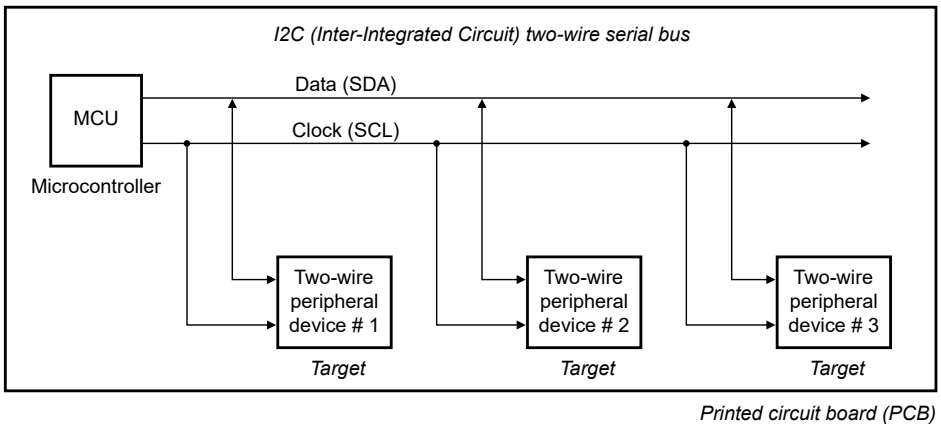


Figure 169. I²C two-wire serial bus

Figure 170 shows a possible four-signal connection.

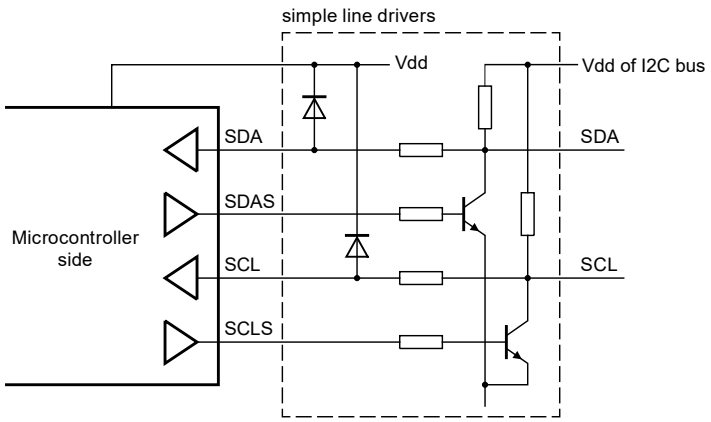


Figure 170. I²C four-wire serial bus

44.5 Initialization

To initialize the LPI2C controller:

1. Configure Controller Configuration 0 (MCFGR0)–Controller Configuration 3 (MCFGR3) as required by the application.
2. Configure Controller Clock Configuration 0 (MCCR0) and Controller Clock Configuration 1 (MCCR1) to satisfy the timing requirements of the I2C mode supported by the application.
3. Enable controller interrupts and DMA requests as required by the application.
4. Enable the LPI2C controller by writing 1 to MCR[MEN].

To initialize the LPI2C target:

1. Configure Target Address Match (SAMR) with the I2C address of the target location on the I2C bus.
2. Configure Target Configuration 0 (SCFGR0) and Target Configuration 1 (SCFGR1) as required by the application.
3. Configure Target Configuration 2 (SCFGR2) to satisfy the timing requirements of the I2C mode supported by the application.
4. Enable target interrupts and DMA requests as required by the application.
5. Enable the LPI2C target by writing 1 to SCR[SEN].

44.6 Application information

Configure the I2C timing parameters to meet the requirements of the I2C specification. This configuration depends on the supported mode and LPI2C functional clock frequency. When switching between two modes using different clock configuration registers (for example, Fast mode and HS mode), MCFGR1[PRESCALE] must remain constant between the modes.

Table 316. Example timing configurations

I2C mode	Clock frequency	Baud rate	PRESCALE	FILTSCL / FILTSDA	SETHOLD	CLKLO	CLKHI	DATAVD
Standard	8 MHz	100 kbit/s	0h	0h/0h	24h	28h	24h	02h
Standard	48 MHz	100 kbit/s	2h	1h/1h	37h	3Fh	37h	03h
Standard	60 MHz	100 kbit/s	2h	1h/1h	45h	50h	44h	04h
Fast	8 MHz	400 kbit/s	0h	0h/0h	04h	0Bh	05h	02h
Fast+	8 MHz	1 Mbit/s	0h	0h/0h	02h	03h	01h	01h
Fast	48 MHz	400 kbit/s	0h	1h/1h	1Dh	3Eh	35h	0Fh
Fast	48 MHz	400 kbit/s	2h	1h/1h	07h	11h	0Bh	03h
Fast+	48 MHz	1 Mbit/s	2h	1h/1h	03h	06h	04h	04h
HS	48 MHz	3.2 Mbit/s	0h	0h/0h	07h	08h	03h	01h
Fast	60 MHz	400 kbit/s	1h	2h/2h	11h	28h	1Fh	08h
Fast+	60 MHz	1 Mbit/s	1h	2h/2h	07h	0Fh	0Bh	01h
HS	60 MHz	3.33 Mbit/s	1h	0h/0h	04h	04h	02h	01h

44.7 Memory map and registers

44.7.1 LPI2C register descriptions

Writing to a read-only register or reading from a write-only register can cause bus errors. This module does not check whether programmed values in the registers are correct; you must ensure that valid programmed values are written to the registers.

44.7.1.1 LPI2C memory map

LPI2C0 base address: 4003_3000h

LPI2C1 base address: 4003_4000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	0103_0003h
4h	Parameter (PARAM)	32	R	0000_0202h
10h	Controller Control (MCR)	32	RW	0000_0000h
14h	Controller Status (MSR)	32	RW	0000_0001h
18h	Controller Interrupt Enable (MIER)	32	RW	0000_0000h
1Ch	Controller DMA Enable (MDER)	32	RW	0000_0000h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
20h	Controller Configuration 0 (MCFGR0)	32	RW	0000_0000h
24h	Controller Configuration 1 (MCFGR1)	32	RW	0000_0000h
28h	Controller Configuration 2 (MCFGR2)	32	RW	0000_0000h
2Ch	Controller Configuration 3 (MCFGR3)	32	RW	0000_0000h
40h	Controller Data Match (MDMR)	32	RW	0000_0000h
48h	Controller Clock Configuration 0 (MCCR0)	32	RW	0000_0000h
50h	Controller Clock Configuration 1 (MCCR1)	32	RW	0000_0000h
58h	Controller FIFO Control (MFCR)	32	RW	0000_0000h
5Ch	Controller FIFO Status (MFSR)	32	R	0000_0000h
60h	Controller Transmit Data (MTDR)	32	W	0000_0000h
70h	Controller Receive Data (MRDR)	32	R	0000_4000h
78h	Controller Receive Data Read Only (MRDROR)	32	R	0000_4000h
110h	Target Control (SCR)	32	RW	0000_0000h
114h	Target Status (SSR)	32	RW	0000_0000h
118h	Target Interrupt Enable (SIER)	32	RW	0000_0000h
11Ch	Target DMA Enable (SDER)	32	RW	0000_0000h
120h	Target Configuration 0 (SCFGR0)	32	RW	0000_0000h
124h	Target Configuration 1 (SCFGR1)	32	RW	0000_0000h
128h	Target Configuration 2 (SCFGR2)	32	RW	0000_0000h
140h	Target Address Match (SAMR)	32	RW	0000_0000h
150h	Target Address Status (SASR)	32	R	0000_4000h
154h	Target Transmit ACK (STAR)	32	RW	0000_0000h
160h	Target Transmit Data (STDR)	32	W	0000_0000h
170h	Target Receive Data (SRDR)	32	R	0000_4000h
178h	Target Receive Data Read Only (SRDROR)	32	R	0000_4000h

44.7.1.2 Version ID (VERID)

Offset

Register	Offset
VERID	0h

Function

Contains version numbers for the module design and feature set.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	MAJOR								MINOR							
W																
Reset	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	FEATURE															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

Fields

Field	Function
31-24 MAJOR	Major Version Number Returns the major version number for the module design specification.
23-16 MINOR	Minor Version Number Returns the minor version number for the module design specification.
15-0 FEATURE	Feature Specification Number Returns the feature set number. 0000_0000_0000_0010b - Controller only, with standard feature set 0000_0000_0000_0011b - Controller and target, with standard feature set

44.7.1.3 Parameter (PARAM)

Offset

Register	Offset
PARAM	4h

Function

Contains parameter values implemented in the module.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				MRXFIFO				0				MTXFIFO			
W																
Reset	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0

Fields

Field	Function
31-16 —	Reserved
15-12 —	Reserved
11-8 MRXFIFO	Controller Receive FIFO Size Configures the number of words in the controller receive FIFO to $2^{MRXFIFO}$.
7-4 —	Reserved
3-0 MTXFIFO	Controller Transmit FIFO Size Configures the number of words in the controller transmit FIFO to $2^{MTXFIFO}$.

44.7.1.4 Controller Control (MCR)

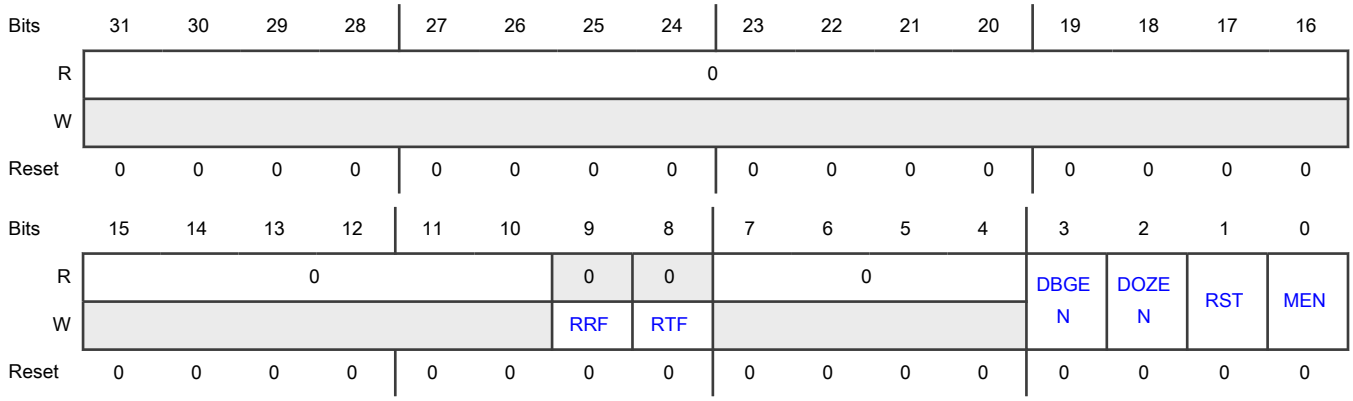
Offset

Register	Offset
MCR	10h

Function

Contains resets, debug enable, and other controller control settings.

Diagram



Fields

Field	Function
31-10 —	Reserved
9 RRF	Reset Receive FIFO Resets the receive FIFO in Controller Receive Data (MRDR). 0b - No effect 1b - Reset receive FIFO
8 RTF	Reset Transmit FIFO Resets the transmit FIFO in Controller Transmit Data (MTDR). 0b - No effect 1b - Reset transmit FIFO
7-4 —	Reserved
3 DBGEN	Debug Enable Enables the controller in Debug mode. 0b - Disable 1b - Enable
2 DOZEN	Doze Mode Enable Enables the controller in Doze mode. 0b - Enable 1b - Disable
1	Software Reset

Table continues on the next page...

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Field	Function
RST	Resets all internal controller logic and registers except Controller Control (MCR). This field remains 1 (enabled) until you write 0 to it. The reset takes effect immediately and remains asserted until negated by software. There is no minimum delay required before clearing the software reset. 0b - No effect 1b - Reset
0 MEN	Controller Enable Enables the controller logic. 0b - Disable 1b - Enable

44.7.1.5 Controller Status (MSR)

Offset

Register	Offset
MSR	14h

Function

Contains status flags for transmit and receive data, for start and stop conditions, and for bus and controller busy or idle status.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0						BBF	MBF	0							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	STF	DMF	PLTF	FEF	ALF	NDF	SDF	EPF	0						RDF	TDF
W	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C								
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Fields

Field	Function
31-26 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
25 BBF	Bus Busy Flag Specifies whether the I2C bus is busy. 0b - Idle 1b - Busy
24 MBF	Controller Busy Flag Specifies whether the I2C controller is busy. 0b - Idle 1b - Busy
23-16 —	Reserved
15 STF	Start Flag Specifies whether a Start condition is detected on the bus when the bus is idle. When MCFGR1[STARTCFG] is 0, this field becomes 1 only if the LPI2C controller is also idle. When MCFGR1[STARTCFG] is 1, STF becomes 1 for any Start condition when the I2C bus is idle. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Start condition not detected 1b - Start condition detected When writing 0b - No effect 1b - Clear the flag
14 DMF	Data Match Flag Indicates whether the received data matches MDMR[MATCH0] or MDMR[MATCH1] (as configured by MCFGR1[MATCFG]). Received data discarded due to MTDR[CMD] does not cause this flag to set. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Matching data not received 1b - Matching data received When writing 0b - No effect 1b - Clear the flag

Table continues on the next page...

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Field	Function
13 PLTF	Pin Low Timeout Flag Indicates whether pin low timeout has occurred. Sets when the SCL or SDA input is low for more than the number of PINLOW cycles defined by MCFGR3[PINLOW], even when the LPI2C controller is idle. You must resolve the pin low condition via software. PLTF cannot be cleared as long as the pin low timeout continues. Before LPI2C can initiate a Start condition, you must clear this flag. See MCFGR1[TIMECFG] for the SCL and/or SDA timeout settings. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Pin low timeout did not occur 1b - Pin low timeout occurred When writing 0b - No effect 1b - Clear the flag
12 FEF	FIFO Error Flag Detects the LPI2C controller's attempt to send or receive data without first generating a (repeated) Start condition. This error can occur when the transmit FIFO underflows when MCFGR1[AUTOSTOP] = 1. When this flag is set, the LPI2C controller sends a Stop condition (if busy). The controller does not initiate a new Start condition until the flag is cleared. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No FIFO error 1b - FIFO error When writing 0b - No effect 1b - Clear the flag
11 ALF	Arbitration Lost Flag Indicates whether arbitration is lost. Either of these conditions sets this flag: • The LPI2C controller transmits a logic 1 and detects a logic 0 on the I2C bus. • The LPI2C controller detects a Start or Stop condition when the LPI2C controller is transmitting data. When ALF is set, the LPI2C controller releases the I2C bus (goes idle), and the LPI2C controller does not initiate a new Start condition until the ALF is cleared.

Table continues on the next page...

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Field	Function
	NOTE This field behaves differently for register reads and writes. When reading 0b - Controller did not lose arbitration 1b - Controller lost arbitration When writing 0b - No effect 1b - Clear the flag
10 NDF	NACK Detect Flag Indicates whether an unexpected NACK has been detected. This flag is set when the LPI2C controller detects a NACK it was not expecting when transmitting an address or data. When set, the controller does not initiate a new Start condition until this flag is cleared. If a NACK is expected for a given address (as configured by the command word), this flag is set if a NACK is not generated. When this flag is set, the LPI2C controller automatically transmits a Stop condition if MCFGR1[AUTOSTOP] = 1, or if the transmit FIFO is not empty. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No unexpected NACK detected 1b - Unexpected NACK detected When writing 0b - No effect 1b - Clear the flag
9 SDF	Stop Detect Flag Indicates whether the LPI2C controller has generated a Stop condition. When MCFGR1[STOPCFG] = 0, this flag is set for any Stop condition. When MCFGR1[STOPCFG] = 1, this flag is set only when the LPI2C controller is also idle (transmit FIFO is empty). **NOTE** This field behaves differently for register reads and writes. When reading 0b - No Stop condition generated 1b - Stop condition generated When writing 0b - No effect

Table continues on the next page...

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Field	Function
	1b - Clear the flag
8 EPF	End Packet Flag Indicates whether the LPI2C controller has generated a repeated Start condition or a Stop condition. When the controller first generates a Start condition, this flag is not set. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No Stop or repeated Start generated 1b - Stop or repeated Start generated When writing 0b - No effect 1b - Clear the flag
7-2 —	Reserved
1 RDF	Receive Data Flag Indicates whether the receive data is ready. This flag is set when the number of words in the receive FIFO is greater than MFCR[RXWATER]. 0b - Receive data not ready 1b - Receive data ready
0 TDF	Transmit Data Flag Indicates whether transmit data is requested. This flag is set when the number of words in the transmit FIFO is equal or less than MFCR[TXWATER]. 0b - Transmit data not requested 1b - Transmit data requested

44.7.1.6 Controller Interrupt Enable (MIER)

Offset

Register	Offset
MIER	18h

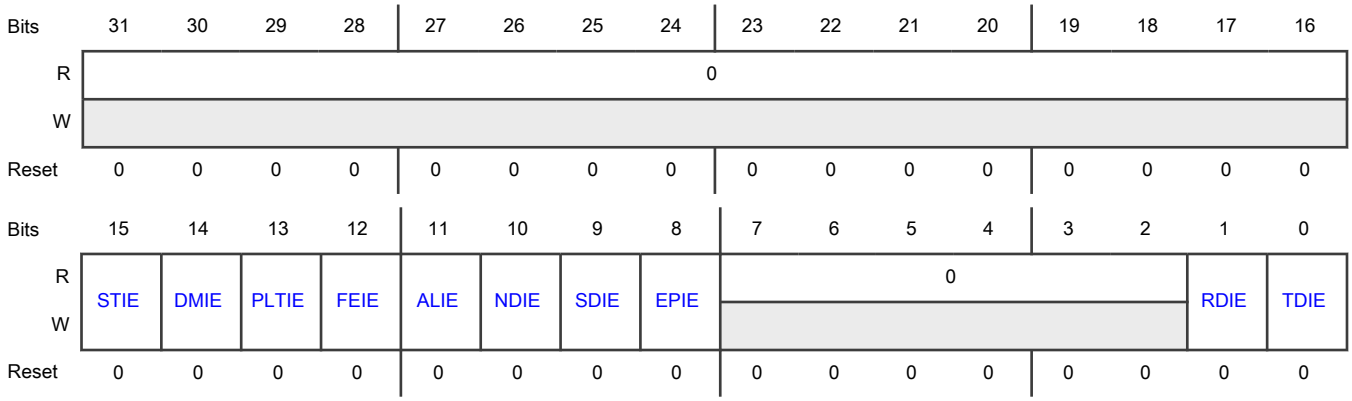
Function

Contains enables for:

- Transmit and receive data interrupts

- Start, Stop, and NACK detection interrupts
- DMA interrupts

Diagram



Fields

Field	Function
31-16 —	Reserved
15 STIE	Start Interrupt Enable Enables interrupt for Start condition. 0b - Disable 1b - Enable
14 DMIE	Data Match Interrupt Enable Enables interrupt for data match. 0b - Disable 1b - Enable
13 PLTIE	Pin Low Timeout Interrupt Enable Enables interrupt for pin-low timeout. 0b - Disable 1b - Enable
12 FEIE	FIFO Error Interrupt Enable Enables interrupt for FIFO error. 0b - Disable 1b - Enable
11	Arbitration Lost Interrupt Enable

Table continues on the next page...

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Field	Function
ALIE	Enables interrupt for arbitration lost. 0b - Disable 1b - Enable
10 NDIE	NACK Detect Interrupt Enable Enables interrupt for NACK detection. 0b - Disable 1b - Enable
9 SDIE	Stop Detect Interrupt Enable Enables interrupt for Stop detection. 0b - Disable 1b - Enable
8 EPIE	End Packet Interrupt Enable Enables interrupt for end packet. 0b - Disable 1b - Enable
7-2 —	Reserved
1 RDIE	Receive Data Interrupt Enable Enables interrupt for receive data. 0b - Disable 1b - Enable
0 TDIE	Transmit Data Interrupt Enable Enables interrupt for transmit data. 0b - Disable 1b - Enable

44.7.1.7 Controller DMA Enable (MDER)

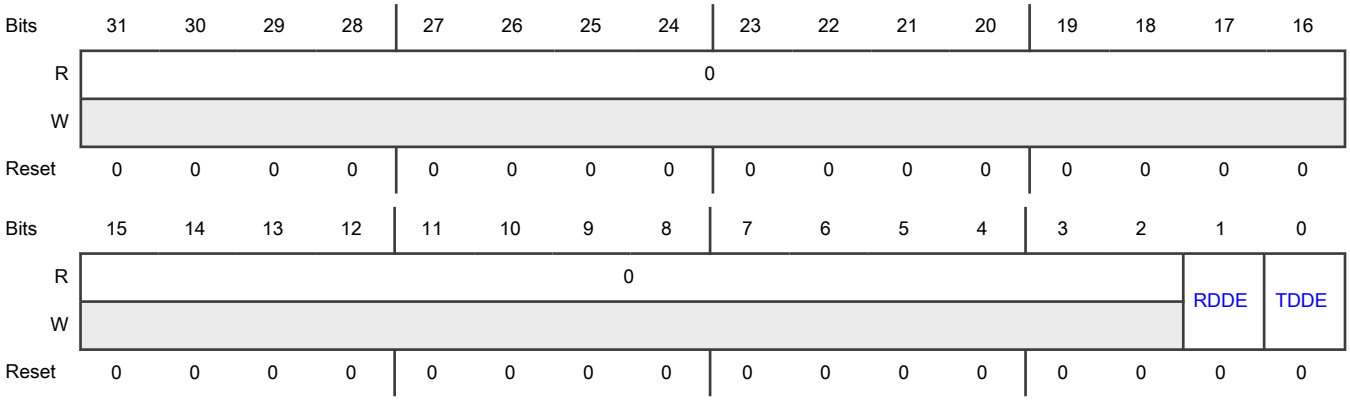
Offset

Register	Offset
MDER	1Ch

Function

Contains DMA transmit, request, and receive enables.

Diagram



Fields

Field	Function
31-2 —	Reserved
1 RDDE	Receive Data DMA Enable Enables DMA receive data. 0b - Disable 1b - Enable
0 TDDE	Transmit Data DMA Enable Enables DMA transmit data. 0b - Disable 1b - Enable

44.7.1.8 Controller Configuration 0 (MCFGR0)

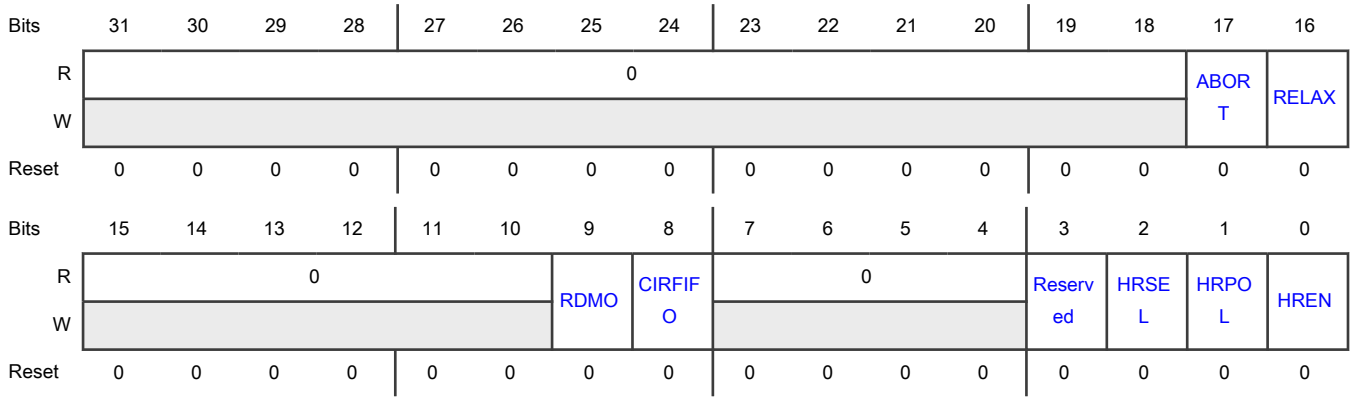
Offset

Register	Offset
MCFGR0	20h

Function

Contains host settings and other receive and transfer settings.

Diagram



Fields

Field	Function
31-18 —	Reserved
17 ABORT	Abort Transfer Determines whether the LPI2C controller completes the existing byte and then sends a Stop condition. A new transfer does not start while this field is 1. 0b - Normal transfer 1b - Abort existing transfer and do not start a new one
16 RELAX	Relaxed Mode Specifies the type of transfer. If this field is 1, the LPI2C controller relaxes several transfer restrictions. Transfers start when the bus is busy and FIFO commands are not checked for errors. You can use this mode to attempt recovery of a stuck I2C target by toggling the SCL pin. 0b - Normal transfer 1b - Relaxed transfer
15-10 —	Reserved
9 RDMO	Receive Data Match Only Determines whether all received data that does not set MSR[DMF] is discarded. After MSR[DMF] is set, the RDMO configuration is ignored. When disabling RDMO, write 0 to this field before writing 0 to MSR[DMF] to ensure that no receive data is lost. 0b - Received data is stored in the receive FIFO 1b - Received data is discarded unless MSR[DMF] is set
8 CIRFIFO	Circular FIFO Enable Enables the transmit FIFO read pointer to be saved to a temporary register. The transmit FIFO empties as normal. After the LPI2C controller is idle and the transmit FIFO is empty, the read pointer value is

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Field	Function
	restored from the temporary register. This setting causes the contents of the transmit FIFO to be cycled through repeatedly. If MCFGR1[AUTOSTOP] is 1, then a Stop condition is sent whenever the transmit FIFO is empty and the read pointer is restored. 0b - Disable 1b - Enable
7-4 —	Reserved
3 —	Reserved
2 HRSEL	Host Request Select Selects the source of the host request input. When host request is enabled, this field must not change. 0b - Reserved 1b - Host request input is input trigger
1 HRPOL	Host Request Polarity Configures the polarity of the host request input. When host request is enabled, this field must not change. HRPOL sets the polarity for both the HREQ pin and the input trigger. • When HRPOL=0, the polarity is configured for active low, so host request is asserted if the HREQ pin or input trigger are logic 0. • When HRPOL=1, the polarity is configured for active high, so host request is asserted if the HREQ pin or input trigger are logic 1. 0b - Active low 1b - Active high
0 HREN	Host Request Enable Enables host request. When enabled, the LPI2C controller only initiates a Start condition if the host request input is asserted and the bus is idle. A repeated Start condition is not affected by the host request. 0b - Disable 1b - Enable

44.7.1.9 Controller Configuration 1 (MCFGR1)

Offset

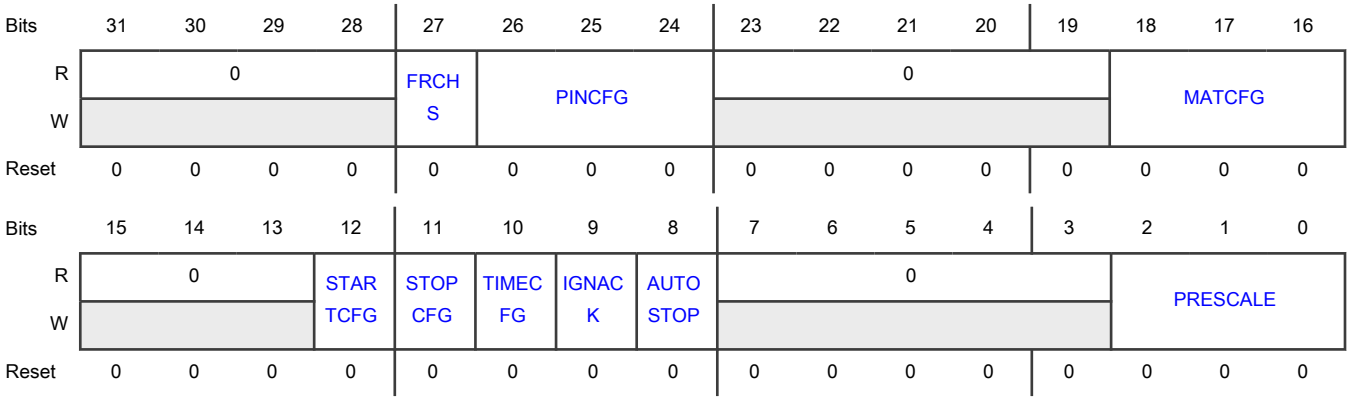
Register	Offset
MCFGR1	24h

Function

Contains controls for pin configuration, clock prescaler, and various other control settings.

Write to this register only when the I2C controller is disabled.

Diagram



Fields

Field	Function
31-28 —	Reserved
27 FRCHS	Force HS Mode Forces the LPI2C pin state into HS mode. Writing 1 to this field does not impact the digital filter configuration or digital timing parameters. 0b - No effect 1b - LPI2C pin state forced into HS mode
26-24 PINCFG	Pin Configuration Configures the pin mode for LPI2C. 000b - Two-pin open drain mode. SCL/SDA pins: Bidirectional open drain for controller and target. SCLS/SDAS pins: Not used. 001b - Two-pin output only mode (Ultra-Fast mode). SCL/SDA pins: Output-only (Ultra-Fast mode) open drain for controller and target. SCLS/SDAS pins: Not used. 010b - Two-pin push-pull mode. SCL/SDA pins: Bidirectional push-pull for controller and target. SCLS/SDAS pins: Not used. 011b - Four-pin push-pull mode. SCL/SDA pins: Input only for controller and target. SCLS/SDAS pins: Output-only push-pull for controller and target. 100b - Two-pin open-drain mode with separate LPI2C target. SCL/SDA pins: Bidirectional open drain for controller. SCLS/SDAS pins: Bidirectional open drain for target.

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Field	Function
	101b - Two-pin output only mode (Ultra-Fast mode) with separate LPI2C target. SCL/SDA pins: Output-only (Ultra-Fast mode) open drain for controller. SCLS/SDAS pins: Output-only open drain for target. 110b - Two-pin push-pull mode with separate LPI2C target. SCL/SDA pins: Bidirectional push-pull for controller. SCLS/SDAS pins: Bidirectional push-pull for target. 111b - Four-pin push-pull mode (inverted outputs). SCL/SDA pins: Input only for controller and target. SCLS/SDAS pins: Inverted output-only push-pull for controller and target.
23-19 —	Reserved
18-16 MATCFG	Match Configuration Configures the condition that sets MSR[DMF]. See Controller Data Match (MDMR). 000b - Match is disabled 001b - Reserved 010b - Match is enabled: first data word equals MDMR[MATCH0] OR MDMR[MATCH1] 011b - Match is enabled: any data word equals MDMR[MATCH0] OR MDMR[MATCH1] 100b - Match is enabled: (first data word equals MDMR[MATCH0]) AND (second data word equals MDMR[MATCH1) 101b - Match is enabled: (any data word equals MDMR[MATCH0]) AND (next data word equals MDMR[MATCH1) 110b - Match is enabled: (first data word AND MDMR[MATCH1]) equals (MDMR[MATCH0] AND MDMR[MATCH1]) 111b - Match is enabled: (any data word AND MDMR[MATCH1]) equals (MDMR[MATCH0] AND MDMR[MATCH1])
15-13 —	Reserved
12 STARTCFG	Start Configuration Configures the conditions that set MSR[STF] when a Start condition occurs. When this field is 0, MSR[STF] is set on a Start condition when both the I2C bus and LPI2C are idle. In other words, any nonrepeated Start condition is initiated by any controller on the bus except the LPI2C controller. When this field is 1, MSR[STF] is set on a Start condition when the I2C bus is idle. In other words, any nonrepeated Start condition is initiated by any controller on the bus including the LPI2C controller. 0b - Sets when both I2C bus and LPI2C controller are idle 1b - Sets when I2C bus is idle
11 STOPCFG	Stop Configuration Configures the conditions that set MSR[SDF].

Table continues on the next page...

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Field	Function
	When this field is 0, any Stop condition generated by the LPI2C controller sets SDF. When this field is 1, the last Stop condition before the LPI2C controller is idle sets SDF. In this case, the transmit FIFO is empty at the time of the Stop condition. 0b - Any Stop condition 1b - Last Stop condition
10 TIMECFG	Timeout Configuration Configures which signals must be low for longer than the configured timeout to set MSR[PLTF]. When this field is 0, MSR[PLTF] is set when SCL is low for longer than the configured timeout. 0b - SCL 1b - SCL or SDA
9 IGNACK	Ignore NACK Determines whether the LPI2C controller ignores a received NACK and treats it as an ACK. In this case, MSR[NDF] is never set. This field must be 1 in Ultra-Fast mode. 0b - No effect 1b - Treat a received NACK as an ACK
8 AUTOSTOP	Automatic Stop Generation Determines whether a Stop condition is generated when the LPI2C controller is busy and the transmit FIFO is empty. A Stop condition can also be generated using a transmit FIFO command. When this field is 1, a Stop condition is automatically generated when the transmit FIFO is empty and the LPI2C controller is busy. 0b - No effect 1b - Stop automatically generated
7-3 —	Reserved
2-0 PRESCALE	Prescaler Configures the clock prescaler used for all LPI2C controller logic except the digital glitch filters. 000b - Divide by 1 001b - Divide by 2 010b - Divide by 4 011b - Divide by 8 100b - Divide by 16 101b - Divide by 32 110b - Divide by 64

Table continues on the next page...

Table continued from the previous page...

Field	Function
	111b - Divide by 128

44.7.1.10 Controller Configuration 2 (MCFGR2)

Offset

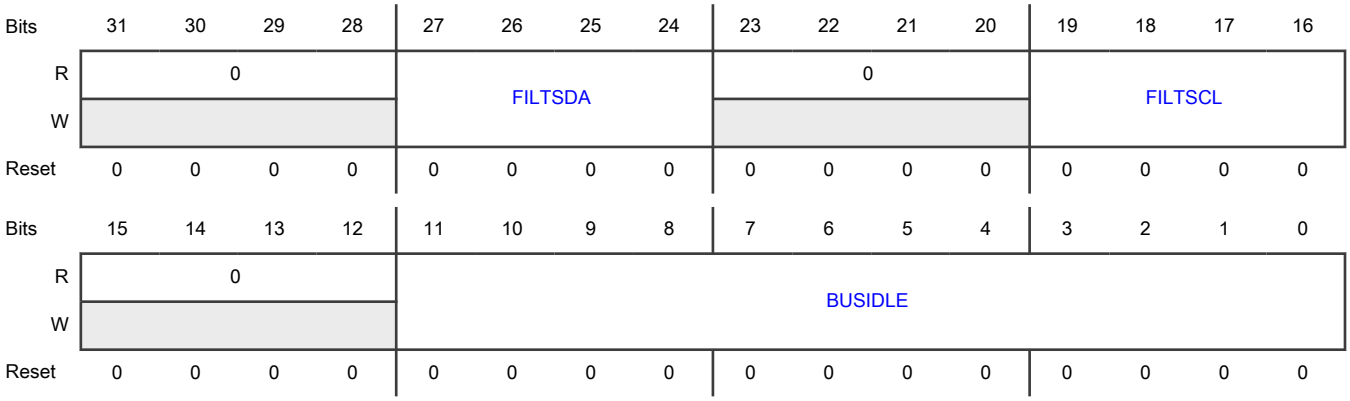
Register	Offset
MCFGR2	28h

Function

Contains the configuration for the bus idle timeout and glitch filters for SDA and SCL.

Write to this register only when the I2C controller is disabled.

Diagram



Fields

Field	Function
31-28 —	Reserved
27-24 FILTSDA	Glitch Filter SDA Configures the I2C controller digital glitch filters for the SDA input. The latency through the glitch filter is equal to the number of cycles defined by this field. The value of this field must be less than the minimum SCL low or high period. Glitches equal to or less than the number of cycles defined by this field are filtered out and ignored. Writing 0 to this field disables the glitch filter. MCFGR1[PRESCALE] does not affect the glitch filter cycle count. It is automatically bypassed in HS mode.

Table continues on the next page...

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Field	Function
23-20 —	Reserved
19-16 FILTSCL	Glitch Filter SCL Configures the I2C controller digital glitch filters for SCL input. The latency through the glitch filter is equal to the number of cycles defined by this field. The value of this field must be less than the minimum SCL low or high period. Glitches equal to or less than the number of cycles defined by this field are filtered out and ignored. These cycles are based on the functional clock. Writing 0 to this field disables the glitch filter. MCFGR1[PRESCALE] does not affect the glitch filter cycle count. It is automatically bypassed in HS mode.
15-12 —	Reserved
11-0 BUSIDLE	Bus Idle Timeout Configures the bus idle timeout period, in clock cycles. If both SCL and SDA are high for longer than the number of cycles defined by this field, the I2C bus is assumed to be idle and the controller can generate a Start condition. Writing 0 to this field disables the bus idle timeout.

44.7.1.11 Controller Configuration 3 (MCFGR3)

Offset

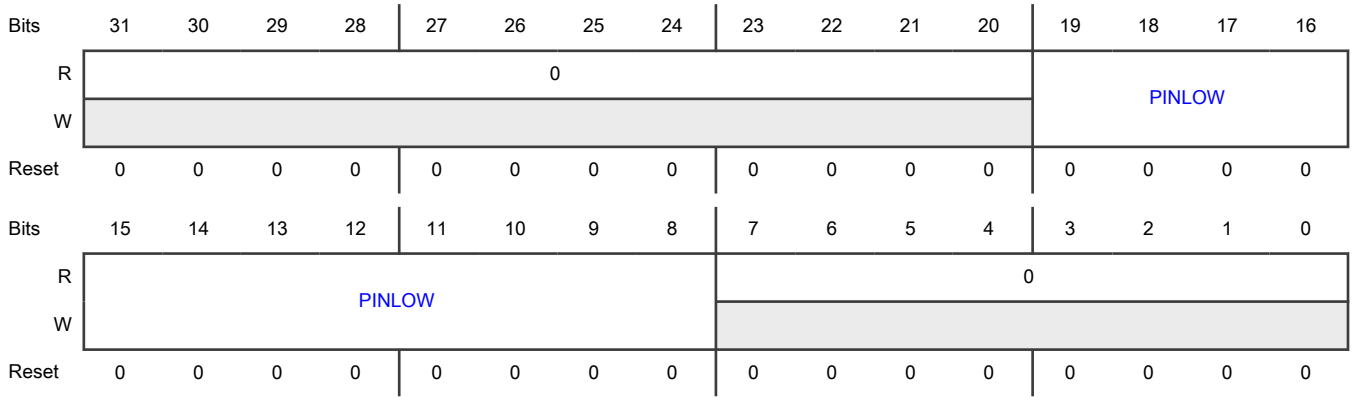
Register	Offset
MCFGR3	2Ch

Function

Configures the threshold value for the pin low timeout flag.

Write to this register only when the I2C controller is disabled.

Diagram



Fields

Field	Function
31-20 —	Reserved
19-8 PINLOW	Pin Low Timeout Configures the threshold value, in clock cycles, that sets MSR[PLTF]. If SCL or SDA (selected by MCFGR1[TIMECFG]) is low for longer than (PINLOW × 256) cycles, MSR[PLTF] is set. When this field is 0, the pin low timeout feature is disabled.
7-0 —	Reserved

44.7.1.12 Controller Data Match (MDMR)

Offset

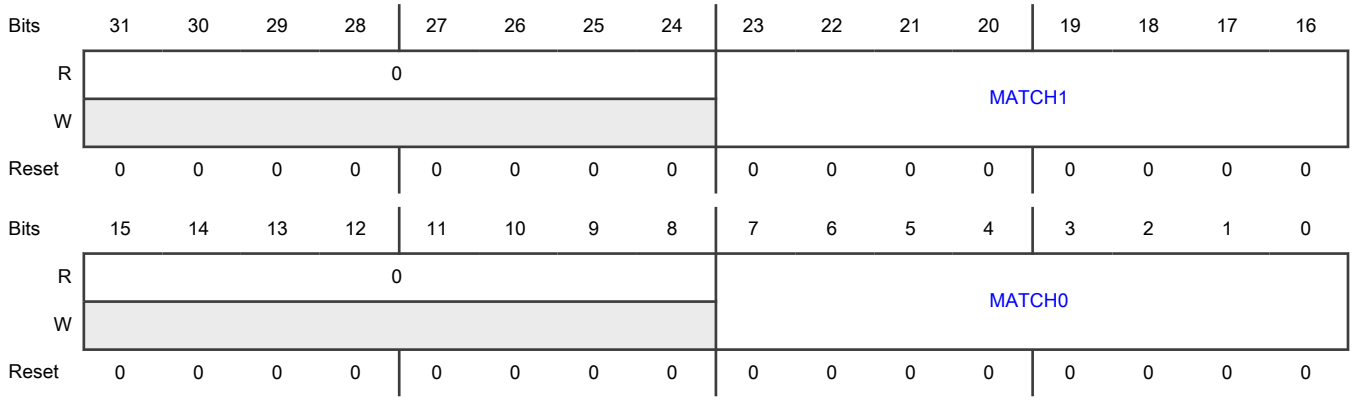
Register	Offset
MDMR	40h

Function

Contains data match values.

Write to this register only when the I2C controller is disabled or idle.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 MATCH1	Match 1 Value Specifies match 1 value that is compared to the received data when receive data match is enabled.
15-8 —	Reserved
7-0 MATCH0	Match 0 Value Specifies match 0 value that is compared to the received data when receive data match is enabled.

44.7.1.13 Controller Clock Configuration 0 (MCCR0)

Offset

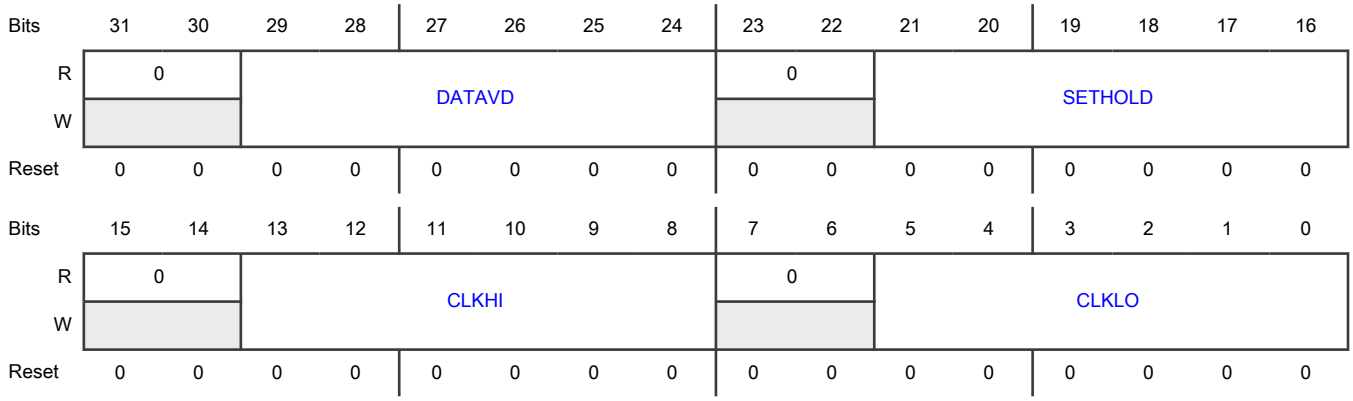
Register	Offset
MCCR0	48h

Function

Configures various clock controls.

You cannot make changes to this register when the I2C controller is enabled and is used for standard, fast, fast-mode plus, and ultra-fast transfers.

Diagram



Fields

Field	Function
31-30 —	Reserved
29-24 DATAVD	Data Valid Delay Specifies the minimum number of cycles (minus one) used as the data hold time for SDA. This value must be less than the minimum SCL low period.
23-22 —	Reserved
21-16 SETHOLD	Setup Hold Delay Specifies the minimum number of cycles (minus one) used by the controller for these conditions: • Hold time for a Start • Setup and hold time for a repeated Start • Setup time for a Stop The setup time is extended by the time it takes to detect a rising edge on the external SCL pin. Ignoring any additional board delay due to external loading, this time is equal to (2 + FILTSCL) ÷ 2^PRESCALE cycles.
15-14 —	Reserved
13-8 CLKHI	Clock High Period Specifies the minimum number of cycles (minus one) that the controller drives the SCL clock high. The SCL high time is extended by the time needed to detect a rising edge on the external SCL pin. Ignoring any additional board delay due to external loading, this time is equal to (2 + FILTSCL) ÷ 2^PRESCALE cycles.
7-6 —	Reserved

Table continues on the next page...

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Field	Function
5-0 CLKLO	Clock Low Period Specifies the minimum number of cycles (minus one) that the controller drives the SCL clock low. This value is also used for the minimum bus free time between a Stop and a Start condition. This period is extended by the time needed to detect a rising edge on the external SCL pin. Ignoring any additional board delay due to external loading, this time is equal to (2 + FILTSCL) ÷ 2^PRESCALE cycles.

44.7.1.14 Controller Clock Configuration 1 (MCCR1)

Offset

Register	Offset
MCCR1	50h

Function

Configures various clock controls.

You cannot makes changes to this register when the I2C controller is enabled and is used for HS mode transfers. The separate clock configuration for HS mode allows arbitration to take place in Fast mode (with timing configured by Controller Clock Configuration 0 (MCCR0)), before switching to HS mode (with timing configured by MCCR1).

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		DATAVD						0		SETHOLD					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		CLKHI						0		CLKLO					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 DATAVD	Data Valid Delay

Table continues on the next page...

Table continued from the previous page...

Field	Function
	Specifies the minimum number of cycles (minus one) used as the data hold time for SDA. This value must be less than the minimum SCL low period.
23-22 —	Reserved
21-16 SETHOLD	Setup Hold Delay Specifies the minimum number of cycles (minus one) used by the controller for these conditions: • Hold time for a Start condition • Setup and hold time for a repeated Start condition • Setup time for a Stop condition The setup time is extended by the time needed to detect a rising edge on the external SCL pin. Ignoring any additional board delay due to external loading, this time is equal to (2 + FILTSCL) ÷ 2^PRESCALE cycles.
15-14 —	Reserved
13-8 CLKHI	Clock High Period Specifies the minimum number of cycles (minus one) that the controller drives the SCL clock high. The SCL high time is extended by the time needed to detect a rising edge on the external SCL pin. Ignoring any additional board delay due to external loading, this time is equal to (2 + FILTSCL) ÷ 2^PRESCALE cycles.
7-6 —	Reserved
5-0 CLKLO	Clock Low Period Specifies the minimum number of cycles (minus one) that the controller drives the SCL clock low. This value is also used for the minimum bus free time between a Stop and a Start condition. This period is extended by the time needed to detect a rising edge on the external SCL pin. Ignoring any additional board delay due to external loading, this time is equal to (2 + FILTSCL) ÷ 2^PRESCALE cycles.

44.7.1.15 Controller FIFO Control (MFCR)

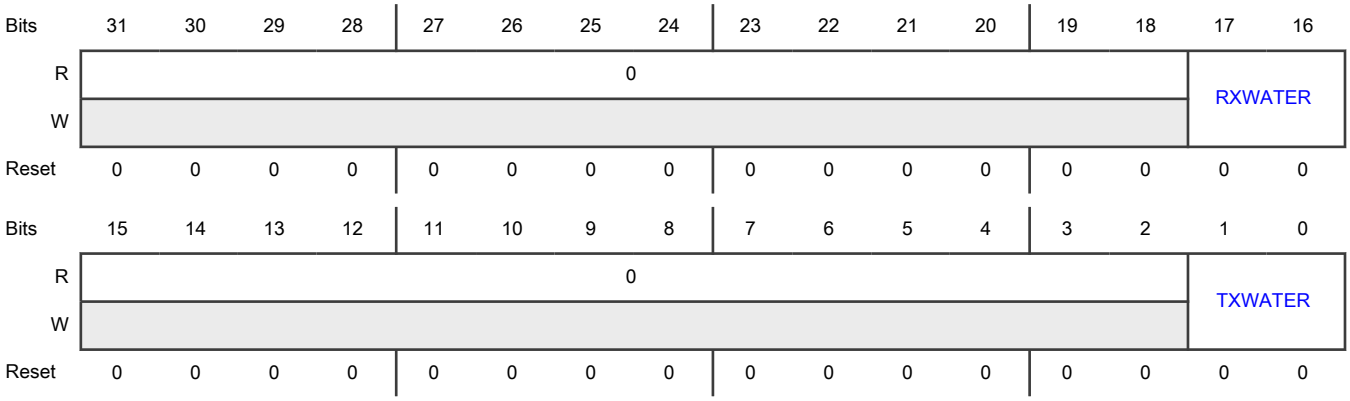
Offset

Register	Offset
MFCR	58h

Function

Controls the receive and transmit FIFO watermark values.

Diagram



Fields

Field	Function
31-18 —	Reserved
17-16 RXWATER	Receive FIFO Watermark Determines the watermark for setting SSR[RDF]. That flag is set when the number of words in the receive FIFO is greater than the value of this field. Writing a value equal to or greater than the FIFO size truncates the value.
15-2 —	Reserved
1-0 TXWATER	Transmit FIFO Watermark Determines the watermark for setting SSR[TDF]. That flag is set when the number of words in the transmit FIFO is equal or less than the value of this field. Writing a value equal to or greater than the FIFO size truncates the value.

44.7.1.16 Controller FIFO Status (MFSR)

Offset

Register	Offset
MFSR	5Ch

Function

Specifies the number of words in the transmit and receive FIFOs.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0													RXCOUNT		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0													TXCOUNT		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-19 —	Reserved
18-16 RXCOUNT	Receive FIFO Count Specifies the number of words in the receive FIFO.
15-3 —	Reserved
2-0 TXCOUNT	Transmit FIFO Count Specifies the number of words in the transmit FIFO.

44.7.1.17 Controller Transmit Data (MTDR)

Offset

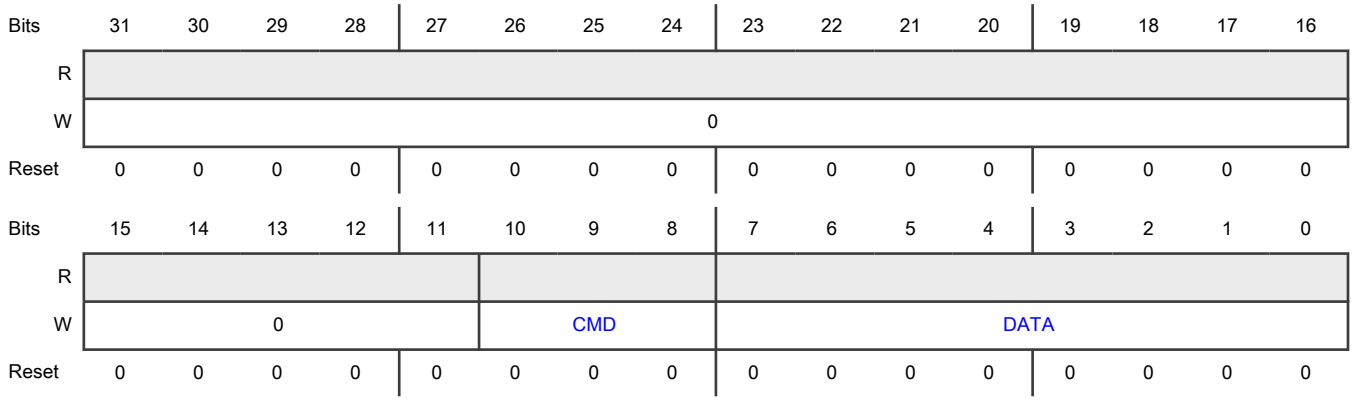
Register	Offset
MTDR	60h

Function

Configures transmit data:

- An 8-bit write to MTDR[CMD] is ignored and does not increment the FIFO write pointer.
- An 8-bit write to MTDR[DATA] zero-extends the value of MTDR[CMD] and increments the FIFO write pointer.
- A 16-bit or 32-bit write operation writes to both MTDR[CMD] and MTDR[DATA] and increments the FIFO write pointer.

Diagram



Fields

Field	Function
31-11 —	Reserved
10-8 CMD	Command Data Selects command transmitted by controller. 000b - Transmit the value in DATA[7:0] 001b - Receive (DATA[7:0] + 1) bytes. DATA[7:0] is used as a byte counter. Receive that many bytes and check each for a data match (if configured) before storing the received data in the receive FIFO. 010b - Generate Stop condition on I2C bus 011b - Receive and discard (DATA[7:0] + 1) bytes. DATA[7:0] is used as a byte counter. Receive that many bytes but do not check for a data match or store those bytes in the receive FIFO. 100b - Generate (repeated) Start on the I2C bus and transmit the address in DATA[7:0] 101b - Generate (repeated) Start on the I2C bus and transmit the address in DATA[7:0] (this transfer expects a NACK to be returned) 110b - Generate (repeated) Start on the I2C bus and transmit the address in DATA[7:0] using HS mode 111b - Generate (repeated) Start on the I2C bus and transmit the address in DATA[7:0] using HS mode (this transfer expects a NACK to be returned)
7-0 DATA	Transmit Data Contains data used by the commands listed in MTDR[CMD]. Performing an 8-bit write to this field zero-extends the value of MTDR[CMD].

44.7.1.18 Controller Receive Data (MRDR)

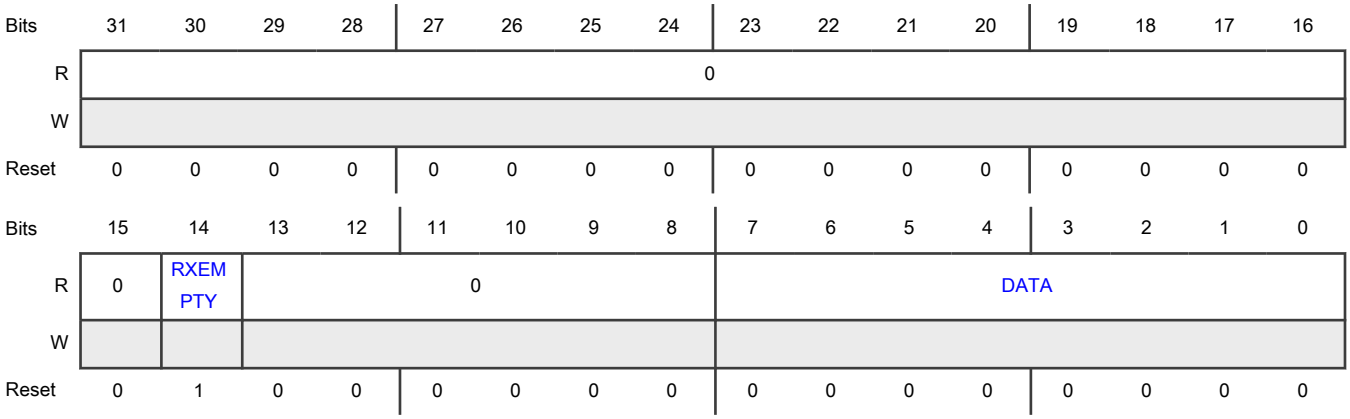
Offset

Register	Offset
MRDR	70h

Function

Contains the status of the receive FIFO and the data received by the I2C controller that has not been discarded.

Diagram



Fields

Field	Function
31-15 —	Reserved
14 RXEMPTY	Receive Empty Indicates whether the controller receive data FIFO is empty. 0b - Not empty 1b - Empty
13-8 —	Reserved
7-0 DATA	Receive Data Contains data received by the I2C controller that has not been discarded. Received data can be discarded due to the command in MTDR[CMD], or the controller can be configured to discard nonmatching data.

44.7.1.19 Controller Receive Data Read Only (MRDROR)

Offset

Register	Offset
MRDROR	78h

Function

Contains the status of the receive FIFO and returns the data received by the I2C controller, but does not pull the data from the FIFO.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	RXEMPTY	0						DATA							
W																
Reset	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-15 —	Reserved
14 RXEMPTY	RX Empty Indicates whether the receive data FIFO is empty. 0b - Not empty 1b - Empty
13-8 —	Reserved
7-0 DATA	Receive Data

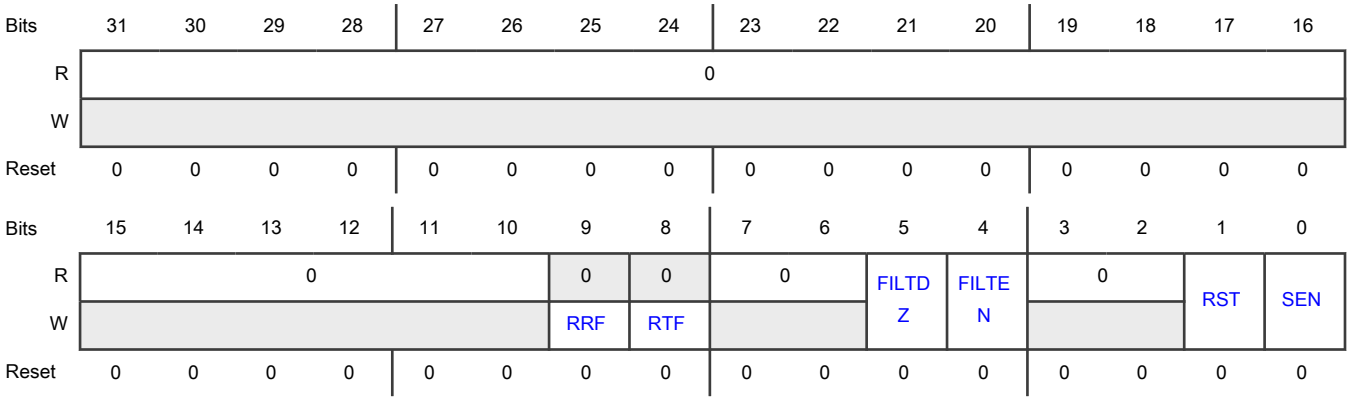
44.7.1.20 Target Control (SCR)

Offset

Register	Offset
SCR	110h

Function
Contains resets and other target control settings.

Diagram



Fields

Field	Function
31-10 —	Reserved
9 RRF	Reset Receive FIFO Empties the receive FIFO in Target Receive Data (SRDR). 0b - No effect 1b - SRDR is now empty
8 RTF	Reset Transmit FIFO Empties the transmit FIFO in Target Transmit Data (STDR). 0b - No effect 1b - STDR is now empty
7-6 —	Reserved
5	Filter Doze Enable

Table continues on the next page...

Table continued from the previous page...

Field	Function
FILTDZ	Enables filter in Doze mode. Update this field only when the I2C target is disabled. 0b - Enable 1b - Disable
4 FILTEN	Filter Enable Enables digital filter and output delay counter for target mode. Update this field only when the I2C target is disabled. 0b - Disable 1b - Enable
3-2 —	Reserved
1 RST	Software Reset Resets target mode logic. The reset takes effect immediately. The value of this field remains 1 until you write 0 to it. There is no minimum delay required before clearing the software reset. 0b - Not reset 1b - Reset
0 SEN	Target Enable Enables I2C Target mode. 0b - Disable 1b - Enable

44.7.1.21 Target Status (SSR)

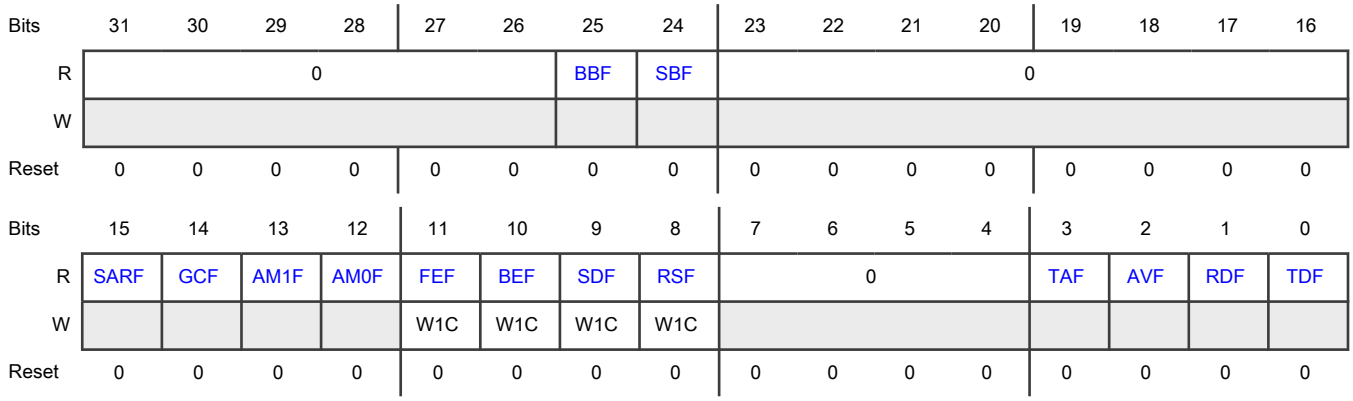
Offset

Register	Offset
SSR	114h

Function

Contains status flags for transmit and receive data, for error conditions, and for bus and target busy or idle status.

Diagram



Fields

Field	Function
31-26 —	Reserved
25 BBF	Bus Busy Flag Indicates whether an I2C bus is idle or busy. 0b - Idle 1b - Busy
24 SBF	Target Busy Flag Indicates whether an I2C target is idle or busy. 0b - Idle 1b - Busy
23-16 —	Reserved
15 SARF	SMBus Alert Response Flag Indicates whether an SMBus alert response has been detected. You can clear this flag by reading Target Address Status (SASR). This flag cannot generate an asynchronous wakeup. 0b - Disabled or not detected 1b - Enabled and detected
14 GCF	General Call Flag Indicates whether a target has detected the general call address. You can clear this flag by reading Target Address Status (SASR). This flag cannot generate an asynchronous wakeup.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - General call address disabled or not detected 1b - General call address detected
13 AM1F	Address Match 1 Flag Indicates whether the received address matches the value in ADDR1, or it falls within the ADDR0 to ADDR1 range as configured by SCFGR1[ADDRCFG]. This flag is cleared by reading Target Address Status (SASR). This flag cannot generate an asynchronous wakeup. 0b - Matching address not received 1b - Matching address received
12 AM0F	Address Match 0 Flag Indicates whether the received address matches the ADDR0 field, as configured by SCFGR1[ADDRCFG]. This flag is cleared by reading Target Address Status (SASR). This flag cannot generate an asynchronous wakeup. 0b - ADDR0 matching address not received 1b - ADDR0 matching address received
11 FEF	FIFO Error Flag Indicates whether there is a FIFO error. This flag can only be set when clock stretching is disabled. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No FIFO error 1b - FIFO error When writing 0b - No effect 1b - Clear the flag
10 BEF	Bit Error Flag Indicates whether the LPI2C target has transmitted a logic 1 and detects a logic 0 on the I2C bus. The target ignores the rest of the transfer until the next (repeated) Start condition. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No bit error occurred

Table continues on the next page...

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Field	Function
	1b - Bit error occurred When writing 0b - No effect 1b - Clear the flag
9 SDF	Stop Detect Flag Indicates whether the LPI2C target detects a Stop condition, and if the LPI2C target matched the last address byte. When SCFGR1[SDCFG] = 1, this flag is set on any Stop condition. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No Stop detected 1b - Stop detected When writing 0b - No effect 1b - Clear the flag
8 RSF	Repeated Start Flag Indicates whether the LPI2C target detects a repeated Start condition and if the LPI2C target matched the last address byte. When SCFGR1[RSCFG] = 1, this flag is set on any repeated Start condition. This flag is not set when the target first detects a Start condition. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No repeated Start detected 1b - Repeated Start detected When writing 0b - No effect 1b - Clear the flag
7-4 —	Reserved
3 TAF	Transmit ACK Flag Indicates whether a transmit ACK or NACK is required. You can clear this flag by writing to Target Transmit ACK (STAR). 0b - Not required

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Required
2 AVF	Address Valid Flag Indicates whether the contents of Target Address Status (SASR) are valid. You can clear this flag by reading SASR. When SCFGR1[RXCFG] = 1, this flag is also cleared by reading Target Receive Data (SRDR). 0b - Not valid 1b - Valid
1 RDF	Receive Data Flag Indicates whether receive data is ready. You can clear this flag by reading Target Receive Data (SRDR). When SCFGR1[RXCFG] = 1, this flag is not cleared when reading Target Receive Data (SRDR) if SSR[AVF] = 1. 0b - Not ready 1b - Ready
0 TDF	Transmit Data Flag Indicates whether transmit data has been requested. This flag is cleared by writing to Target Transmit Data (STDR). When SCFGR1[TXCFG] = 0, if a NACK, repeated Start, or Stop condition is detected, this flag is also cleared. 0b - Transmit data not requested 1b - Transmit data is requested

44.7.1.22 Target Interrupt Enable (SIER)

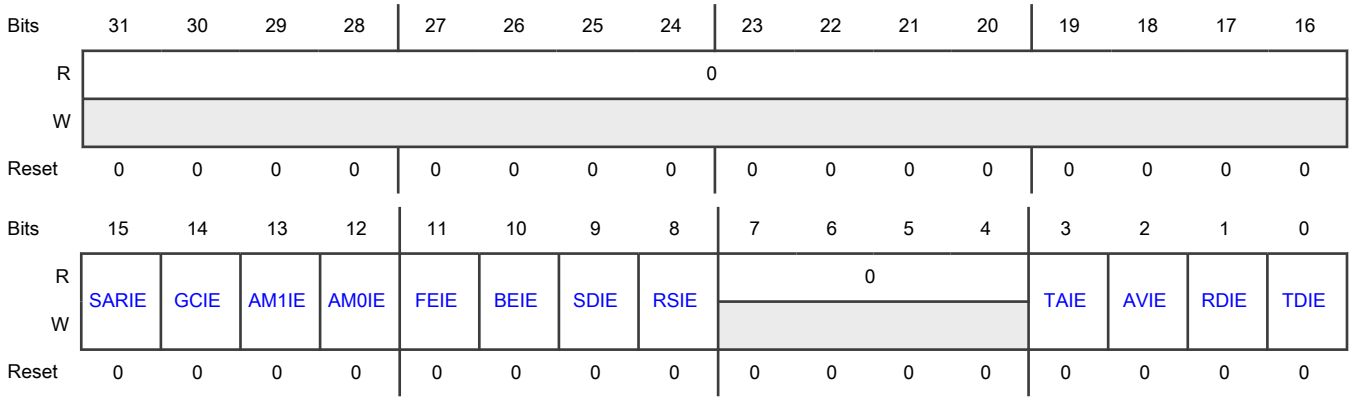
Offset

Register	Offset
SIER	118h

Function

Contains transmit and receive data interrupt enables, start and stop detect interrupt enables, and other target interrupt enables.

Diagram



Fields

Field	Function
31-16 —	Reserved
15 SARIE	SMBus Alert Response Interrupt Enable Enables interrupt for SMBus alert response. 0b - Disable 1b - Enable
14 GCIE	General Call Interrupt Enable Enables interrupt for general call. 0b - Disabled 1b - Enabled
13 AM1IE	Address Match 1 Interrupt Enable Enables interrupt for address match 1. 0b - Disable 1b - Enable
12 AM0IE	Address Match 0 Interrupt Enable Enables interrupt for address match 0. 0b - Disable 1b - Enable
11 FEIE	FIFO Error Interrupt Enable Enables interrupt for FIFO error. 0b - Disable 1b - Enable

Table continues on the next page...

Table continued from the previous page...

Field	Function
10 BEIE	Bit Error Interrupt Enable Enables interrupt for bit error. 0b - Disable 1b - Enable
9 SDIE	Stop Detect Interrupt Enable Enables interrupt for Stop detection. 0b - Disable 1b - Enable
8 RSIE	Repeated Start Interrupt Enable Enables interrupt for repeated start. 0b - Disable 1b - Enable
7-4 —	Reserved
3 TAIE	Transmit ACK Interrupt Enable Enables interrupt for transmit ACK. 0b - Disable 1b - Enable
2 AVIE	Address Valid Interrupt Enable Enables interrupt for valid address. 0b - Disable 1b - Enable
1 RDIE	Receive Data Interrupt Enable Enables interrupt for receive data. 0b - Disable 1b - Enable
0 TDIE	Transmit Data Interrupt Enable Enables interrupt for transmit data. 0b - Disable 1b - Enable

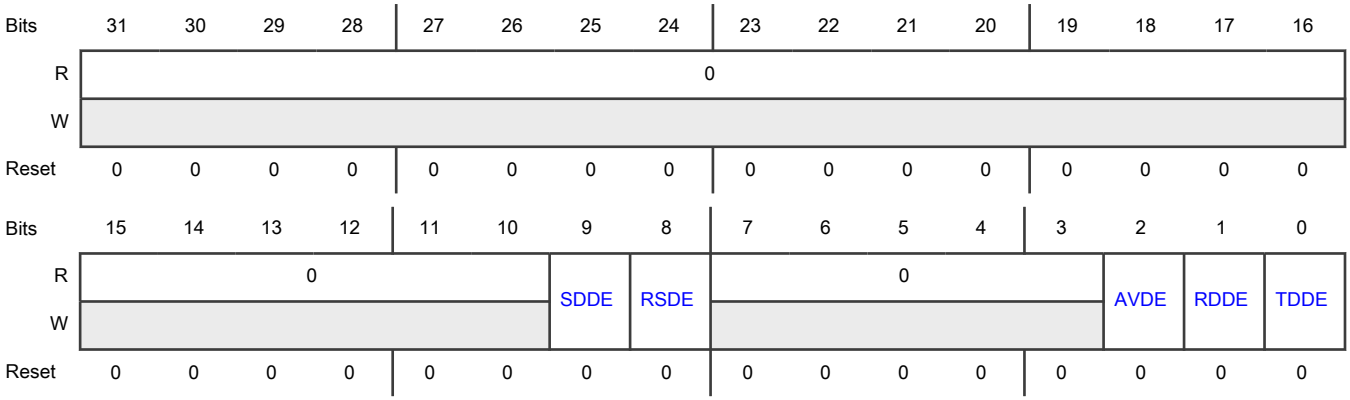
44.7.1.23 Target DMA Enable (SDER)

Offset

Register	Offset
SDER	11Ch

Function
Contains the transmit, request, and receive enables for DMA.

Diagram



Fields

Field	Function
31-10 —	Reserved
9 SDDE	Stop Detect DMA Enable Enables DMA end-of-packet processing on stop detection. Reading Target Receive Data (SRDR) when it is empty: • Generates a DMA end-of-packet response. • Returns 0000_40FFh. • Writes 0 to SSR[SDF]. 0b - Disable 1b - Enable
8 RSDE	Repeated Start DMA Enable Enables DMA end-of-packet processing on repeated start. Reading Target Receive Data (SRDR) when it is empty: • Generates a DMA end-of-packet response.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	• Returns 0000_40FFh. • Writes 0 to SSR[RDF]. 0b - Disable 1b - Enable
7-3 —	Reserved
2 AVDE	Address Valid DMA Enable Enables address valid DMA request. The address valid DMA request is shared with the receive data DMA request. If both are enabled, write 1 to SCFGR1[RXCFG] to allow the DMA to read the address from Target Receive Data (SRDR). 0b - Disable 1b - Enable
1 RDDE	Receive Data DMA Enable Enables receive data for DMA. 0b - Disable DMA request 1b - Enable DMA request
0 TDDE	Transmit Data DMA Enable Enables transmit data for DMA. 0b - Disable 1b - Enable

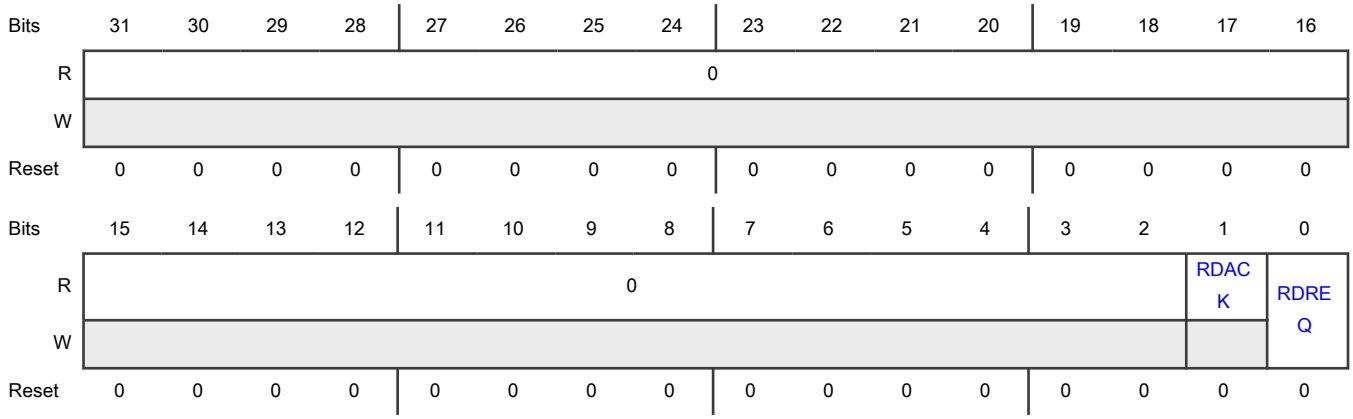
44.7.1.24 Target Configuration 0 (SCFGR0)

Offset

Register	Offset
SCFGR0	120h

Function
Configures the read request feature.

Diagram



Fields

Field	Function
31-2 —	Reserved
1 RDACK	Read Acknowledge Flag Indicates whether a Start then Stop sequence with one SCL pulse between them acknowledged the read request while SCFGR0[RDREQ] = 1. You can clear this flag by writing 0 to SCFGR0[RDREQ]. 0b - Read Request not acknowledged 1b - Read Request acknowledged
0 RDREQ	Read Request Enables read request. When the I2C bus is idle, writing 1 to this field causes the LPI2C target to drive SDA low, triggering a Start condition. The LPI2C target releases SDA on the next falling edge of SCL or when you write 0 to this field. To initiate a second read request (for example, following I2C bus activity that did not acknowledge the request), write 0 then 1 to this field. When the I2C bus is busy, writing to this register always writes 0 to this field. 0b - Disable 1b - Enable

44.7.1.25 Target Configuration 1 (SCFGR1)

Offset

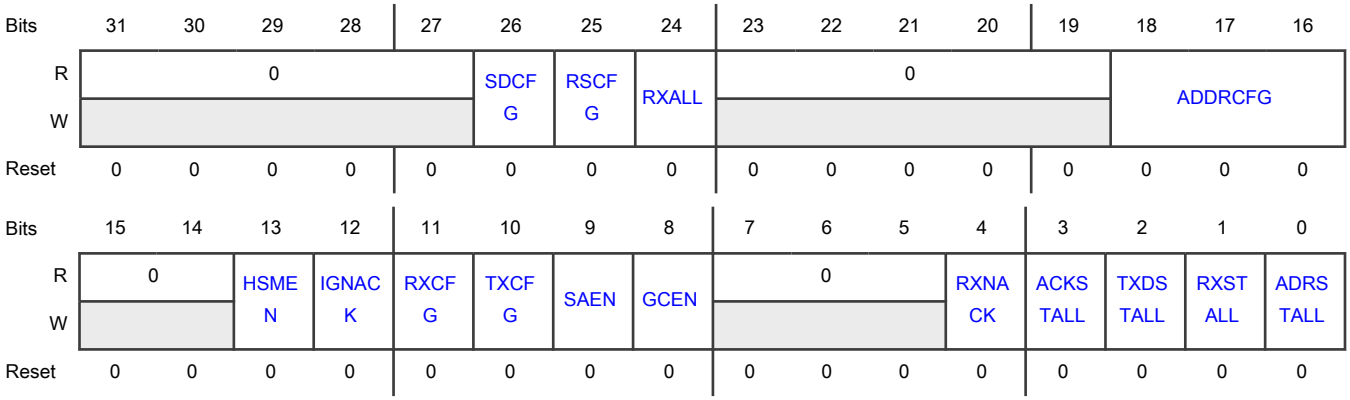
Register	Offset
SCFGR1	124h

Function

Configures various aspects of the target.

Write to this register only when the I2C target is disabled.

Diagram



Fields

Field	Function
31-27 —	Reserved
26 SDCFG	Stop Detect Configuration Configures the conditions that set SSR[SDF]. 0b - Any Stop condition following an address match 1b - Any Stop condition
25 RSCFG	Repeated Start Configuration Configures the conditions that set SSR[RSF]. 0b - Any repeated Start condition following an address match 1b - Any repeated Start condition
24 RXALL	Receive All Enables receive-all functionality. When enabled, the LPI2C target stores all addresses on the I2C bus in Target Address Status (SASR) and all data on the I2C bus in Target Receive Data (SRDR). However, the LPI2C target does not drive SDA (for ACK or target-transmit transfer) unless there is an address match. The LPI2C target can drive SCL if clock stretching is enabled. When this field is 1, the LPI2C target only supports 7-bit addressing modes (you must configure SCFGR1[ADDRCFG] for 7-bit address match). Software can support 10-bit addresses, however. The first byte of a 10-bit address is saved to Target Address Match (SAMR). The second byte is saved as the first data byte in Target Receive Data (SRDR).

Table continues on the next page...

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Field	Function
	Use this field to aid debugging of the I2C bus by saving all data on the bus without altering the state of the bus. When this field is 1, it is recommended to also write 1 to SCFGR1[RSCFG] and SCFGR1[SDCFG] so you can track the full state of the I2C bus. 0b - Disable 1b - Enable
23-19 —	Reserved
18-16 ADDRCFG	Address Configuration Configures the condition that causes an address to match. 000b - Address match 0 (7-bit) 001b - Address match 0 (10-bit) 010b - Address match 0 (7-bit) or address match 1 (7-bit) 011b - Address match 0 (10-bit) or address match 1 (10-bit) 100b - Address match 0 (7-bit) or address match 1 (10-bit) 101b - Address match 0 (10-bit) or address match 1 (7-bit) 110b - From address match 0 (7-bit) to address match 1 (7-bit) 111b - From address match 0 (10-bit) to address match 1 (10-bit)
15-14 —	Reserved
13 HSMEN	HS Mode Enable Enables detection of the HS mode controller code of target address 0000_1XX, but does not cause an address match on this code. When this field is 1 and any HS mode controller code is detected, SCR[FILTEN] and SCFGR1[ACKSTALL] are ignored until the next Stop condition is detected. 0b - Disable 1b - Enable
12 IGNACK	Ignore NACK Determines whether the target ends transfer when a NACK condition is detected. When this field is 1, the LPI2C target continues transfers after a NACK is detected. This field is required to be 1 in Ultra-Fast mode. 0b - End transfer on NACK 1b - Do not end transfer on NACK
11 RXCFG	Receive Data Configuration Configures which data is returned and which flags are cleared when reading Target Receive Data (SRDR).

Table continues on the next page...

Table continued from the previous page...

Field	Function
	When this field is 0, reading SRDR returns received data and clears SSR[RDF]. When this field is 1, reading SRDR: • Returns the value of Target Address Status (SASR) and clears SSR[AVF] when SSR[AVF] is set. • Returns received data and clears SSR[RDF] when SSR[AVF] is not set. 0b - Return received data, clear SSR[RDF] 1b - Return SASR and clear SSR[AVF] when SSR[AVF] is set, return received data and clear SSR[RDF] when SSR[AFV] is not set
10 TXCFG	Transmit Flag Configuration Determines which conditions set SSR[TDF]. This field always becomes 1 before a NACK is detected at the end of a target-transmit transfer. This change can cause an extra word to be written to the transmit data FIFO. When this field is 0, Target Transmit Data (STDR) is automatically emptied when a target-transmit transfer is detected. SSR[TDF] is set when a target-transmit transfer is detected, and SSR[TDF] is cleared at the end of the target-transmit transfer. When this field is 1, SSR[TDF] is set when STDR is empty, and SSR[TDF] is cleared when STDR is full. This setting allows STDR to be filled before a target-transmit transfer is detected. However, it can cause STDR to be written before a NACK is detected on the last byte of a target-transmit transfer. 0b - SSR[TDF] is set only during a target-transmit transfer when STDR is empty 1b - SSR[TDF] is set whenever STDR is empty
9 SAEN	SMBus Alert Enable Enables a match on an SMBus alert. 0b - Disable 1b - Enable
8 GCEN	General Call Enable Enables a general call address. 0b - Disable 1b - Enable
7-5 —	Reserved
4 RXNACK	Receive NACK Determines whether to override the setting of STAR[TXNACK] when the LPI2C receives a matching address during an overrun. When this field is 1, the LPI2C target responds with a NACK under the following conditions:

Table continues on the next page...

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Field	Function
	• SSR[AVF] would be set due to matching an address, but that flag is already 1 (address overrun). • SSR[RDF] would be set due to receiving data, but that flag is already 1 (receive data overrun). 0b - ACK or NACK always determined by STAR[TXNACK] 1b - NACK always generated on address overrun or receive data overrun, otherwise ACK or NACK is determined by STAR[TXNACK]
3 ACKSTALL	ACK SCL Stall Enables SCL clock stretching during target-transmit address bytes and target-receiver address and data bytes, so you can write to Target Transmit ACK (STAR) before the ACK or NACK is transmitted. Clock stretching occurs when transmitting the ninth bit, and is therefore not compatible with HS mode. If this field is 1: • You do not need to write 1 to SCFGR1[RXSTALL] or SCFGR1[ADRSTALL]. • When there is an address match on the first byte of a 10-bit address, SSR[AVF] is set, allowing you to read the received address before writing to Target Transmit ACK (STAR). 0b - Disable 1b - Enable
2 TXDSTALL	Transmit Data SCL Stall Enables SCL clock stretching when SSR[TDF] = 1 during a target-transmit transfer. Clock stretching occurs following the ninth bit, and is therefore compatible with HS mode. 0b - Disable 1b - Enable
1 RXSTALL	RX SCL Stall Enables SCL clock stretching when SSR[RDF] = 1 during a target-receive transfer. Clock stretching occurs following the ninth bit, and is therefore compatible with HS mode. 0b - Disable 1b - Enable
0 ADRSTALL	Address SCL Stall Enables SCL clock stretching when SSR[AVF] = 1. Clock stretching only occurs following the ninth bit, and is therefore compatible with HS mode. 0b - Disable 1b - Enable

44.7.1.26 Target Configuration 2 (SCFGR2)

Offset

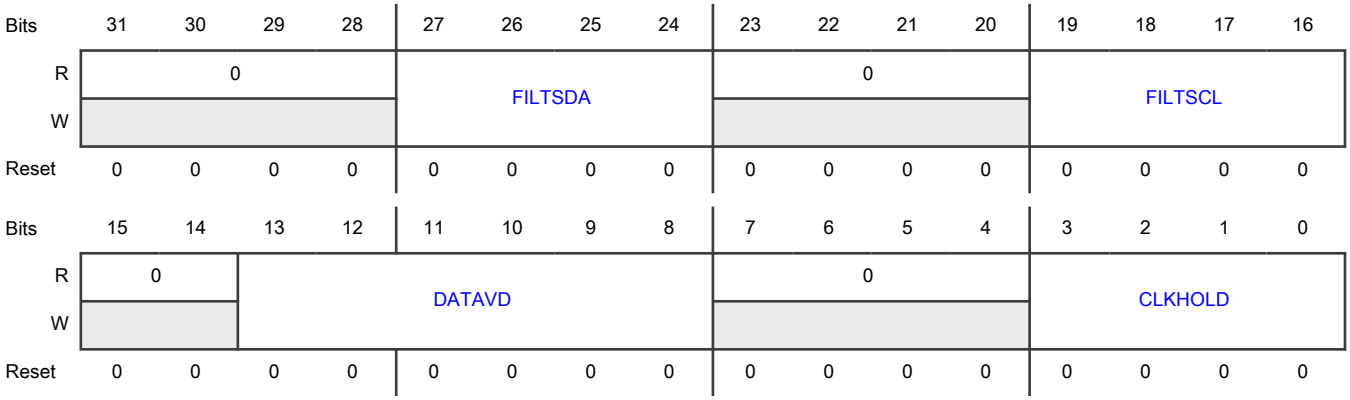
Register	Offset
SCFGR2	128h

Function

Configures data valid delay, clock hold time, and glitch filters for SDA and SCL.

Write to this register only when the I2C target is disabled.

Diagram



Fields

Field	Function
31-28 —	Reserved
27-24 FILTSDA	Glitch Filter SDA Configures the I2C target digital glitch filters for SDA input. Writing 0 to this field disables the glitch filter. Glitches equal to or less than the number of cycles defined by this field are filtered out and ignored. The latency through the glitch filter is equal to the number of cycles defined by this field + 3. The latency must be configured to be less than the minimum SCL low or high period. MCFGR1[PRESCALE] does not affect the glitch filter cycle count, and the glitch filter cycle count is disabled in HS mode.
23-20 —	Reserved
19-16	Glitch Filter SCL

Table continues on the next page...

Table continued from the previous page...

Field	Function
FILTSCL	Configures the I2C target digital glitch filters for SCL input. Writing 0 to this field disables the glitch filter. Glitches equal to or less than the number of cycles defined by this field are filtered out and ignored. The latency through the glitch filter is equal to the number of cycles defined by this field + 3. The latency must be configured to be less than the minimum SCL low or high period. MCFGR1[PRESCALE] does not affect the glitch filter cycle count, and the glitch filter cycle count is disabled in HS mode.
15-14 —	Reserved
13-8 DATAVD	Data Valid Delay Configures the SDA data valid delay time for the I2C target, which is equal to FILTSCL + DATAVD + 3 cycles. The data valid delay must be configured to be less than the minimum SCL low period. MCFGR1[PRESCALE] does not affect the I2C target data valid delay time, and the I2C target data valid delay time is disabled in HS mode.
7-4 —	Reserved
3-0 CLKHOLD	Clock Hold Time Configures the minimum clock hold time for the I2C target, when clock stretching is enabled. The minimum hold time is equal to the number of cycles defined by this field + 3. MCFGR1[PRESCALE] does not affect the I2C target clock hold time, and the I2C target clock hold time is disabled in HS mode.

44.7.1.27 Target Address Match (SAMR)

Offset

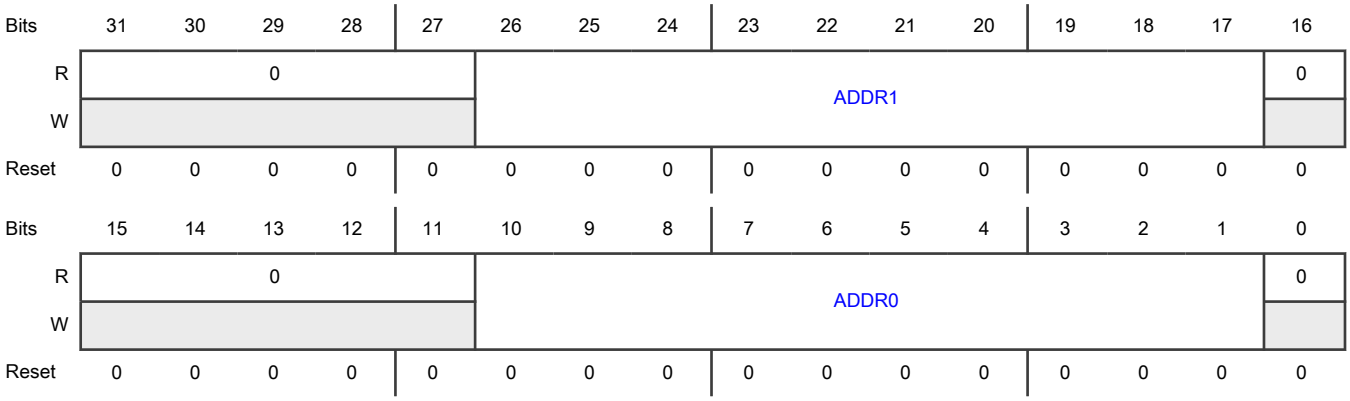
Register	Offset
SAMR	140h

Function

Contains address values for received target match comparison.

Write to this register only when the I2C target is disabled.

Diagram



Fields

Field	Function
31-27 —	Reserved
26-17 ADDR1	Address 1 Value Contains the value of address 1, which is compared to the received address to detect the target address. In 10-bit mode, the first address byte is compared to {11110, ADDR1[26:25]} and the second address byte is compared to ADDR1[24:17]. In 7-bit mode, the address is compared to ADDR1[23:17].
16-11 —	Reserved
10-1 ADDR0	Address 0 Value Contains the value of address 0, which is compared to the received address to detect the target address. In 10-bit mode, the first address byte is compared to {11110, ADDR0[10:9]} and the second address byte is compared to ADDR0[8:1]. In 7-bit mode, the address is compared to ADDR0[7:1].
0 —	Reserved

44.7.1.28 Target Address Status (SASR)

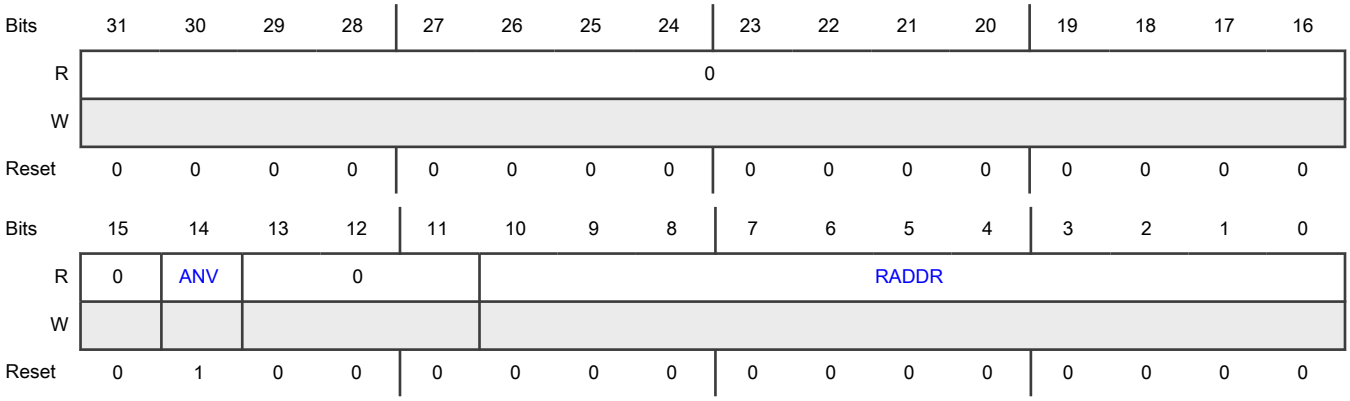
Offset

Register	Offset
SASR	150h

Function

Contains the received address and its validity.

Diagram



Fields

Field	Function
31-15 —	Reserved
14 ANV	Address Not Valid Indicates whether SASR[RADDR] is valid. 0b - Valid 1b - Not valid
13-11 —	Reserved
10-0 RADDR	Received Address Contains the received address. Updates whenever SSR[AM0F] or SSR[AM1F] is set. Reading Target Address Status (SASR) clears SSR[AM0F] and SSR[AM1F]. In 7-bit mode, the address byte is stored in RADDR[7:0]. In 10-bit mode, the first address byte is {11110, RADDR[10:9], RADDR[0]} and the second address byte is RADDR[8:1]. The Read-or-Write bit is therefore always stored in RADDR[0]. When SCFGR1[ACKSTALL] = 1, if the first address byte matches in 10-bit mode, the first address byte is stored in RADDR[7:0] so you can read this field before writing the Transmit ACK. If the second address byte matches, this field is then updated with the full 10-bit address.

44.7.1.29 Target Transmit ACK (STAR)

Offset

Register	Offset
STAR	154h

Function

Configures choice of ACK or NACK on each received word.

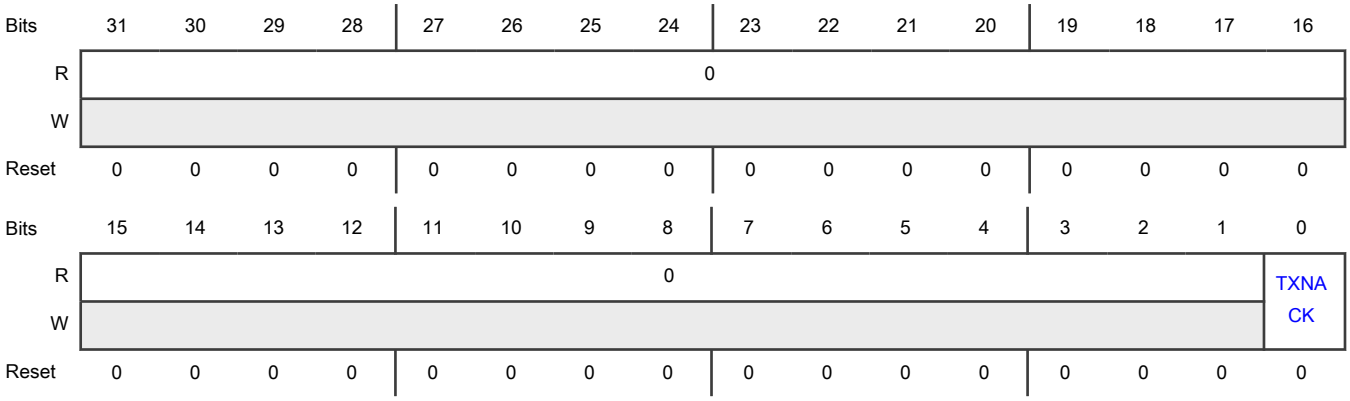
You can write to this register only when SCFGR1[ACKSTALL] = 1.

SCFGR1[ACKSTALL] enables clock stretching during the ACK-or-NACK bit slot. During this time, you can write to this register.

The logic ensures that the clock stretching continues for at least one bus clock cycle after this register is updated.

This clock stretching time can be extended via SCFGR2[CLKHOLD].

Diagram



Fields

Field	Function
31-1 —	Reserved
0 TXNACK	Transmit NACK Selects whether transmit ACK (logic 0) or NACK (logic 1) is returned on the bus by the I2C target after receiving each word. • When SCFGR1[ACKSTALL] = 1, a transmit NACK signal must be written once for each matching address byte and each received word. SCFGR1[ACKSTALL] must be 1, because that setting stalls the data transfer until software reads the received word (and determines whether to respond with an ACK or NACK). • To configure the default (ACK or NACK), you can write to this field when LPI2C target is disabled or idle. 0b - Transmit ACK 1b - Transmit NACK

44.7.1.30 Target Transmit Data (STDR)

Offset

Register	Offset
STDR	160h

Function

Contains the I2C target data to transmit.

Clock stretching (enabled or disabled) affects when the transmit data is transferred. SCFGR1[TXDSTALL] enables clock stretching during the first data bit of a target-transmit transfer.

If clock stretching is enabled (SCFGR1[TXDSTALL] = 1), the transmit data transfer is stalled until this register is updated. Clock stretching is extended by at least 1 bus clock cycle after this register is updated. Clock stretching can be delayed further by using SCFGR2[CLKHOLD].

If clock stretching is disabled (SCFGR1[TXDSTALL] = 0), the transmit data must be written before the start of the target-transmit transfer, otherwise SSR[FEF] is set.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R																
W	0															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R																
W	0								DATA							
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-8 —	Reserved
7-0 DATA	Transmit Data Contains the I2C target data to transmit. Writing data to this register stores I2C target transmit data in this register.

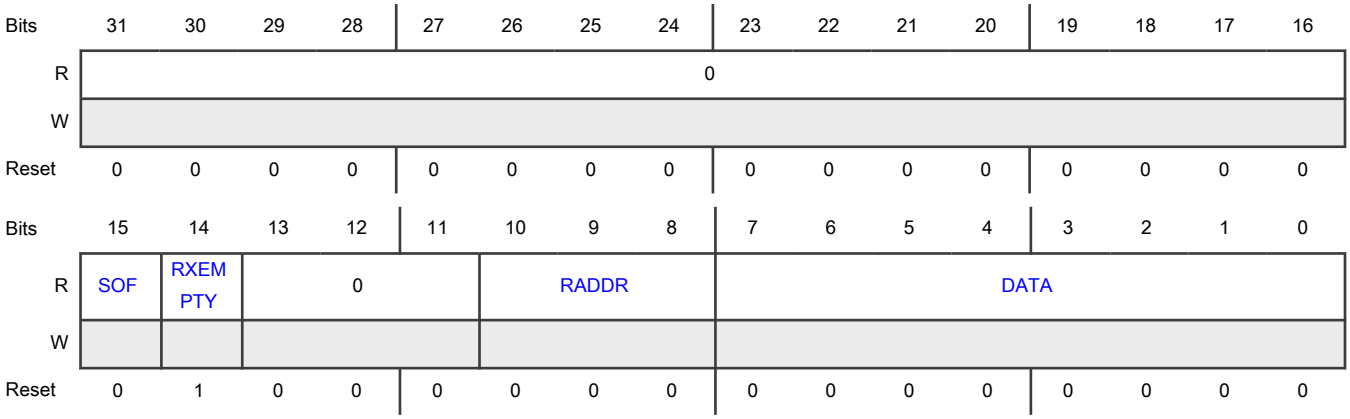
44.7.1.31 Target Receive Data (SRDR)

Offset

Register	Offset
SRDR	170h

Function
Contains status of target receive data transfer.

Diagram



Fields

Field	Function
31-16 —	Reserved
15 SOF	Start of Frame Indicates whether this data word is the first data word since a (repeated) Start or Stop condition. 0b - Not first 1b - First
14 RXEMPTY	Receive Empty Indicates whether this register is empty. 0b - Not empty 1b - Empty
13-11 —	Reserved
10-8	Received Address

Table continues on the next page...

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Field	Function
RADDR	Contains the address received by the IC2 target. When both SCFGR1[RXCFG] and SSR[AVF] are 1, bits [10:8] of SASR[RADDR] are returned. Otherwise, this field returns zero.
7-0 DATA	Received Data Contains the data received by the I2C target. When both SCFGR1[RXCFG] and SSR[AVF] are 1, bits [7:0] of SASR[RADDR] are returned.

44.7.1.32 Target Receive Data Read Only (SRDROR)

Offset

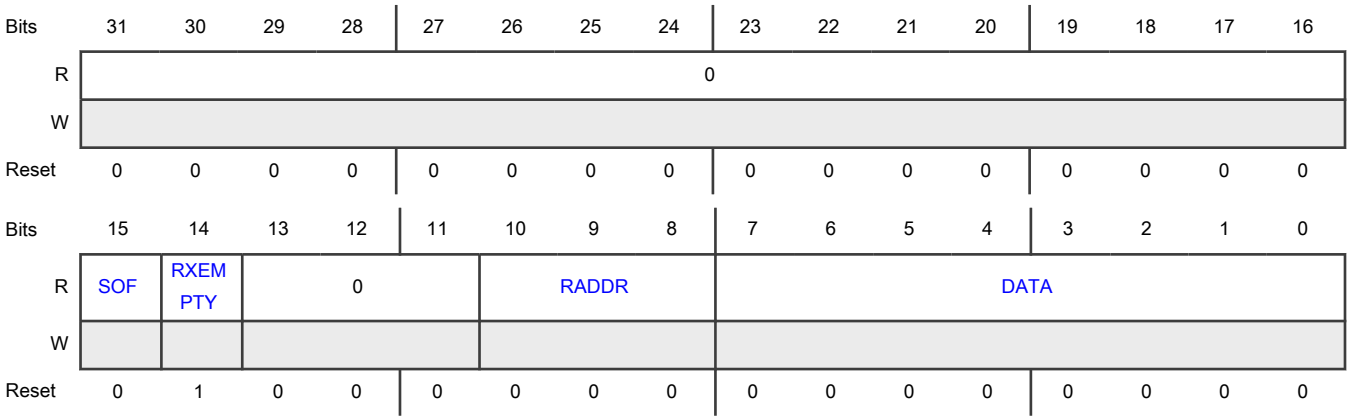
Register	Offset
SRDROR	178h

Function

Contains the data received by the I2C target.

Reading this register returns the data received by the I2C target, but does not pull the data from the register.

Diagram



Fields

Field	Function
31-16 —	Reserved
15 SOF	Start of Frame Indicates whether this data word is the first data word since a (repeated) Start or Stop condition.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Not the first 1b - First
14 RXEMPTY	Receive Empty Indicates whether Target Receive Data (SRDR) is empty. 0b - Not empty 1b - Empty
13-11 —	Reserved
10-8 RADDR	Received Address Contains address received by the LPI2C target. When both SCFGR1[RXCFG] and SSR[AVF] are 1, bits [10:8] of SASR[RADDR] are returned. Otherwise, this field returns zero.
7-0 DATA	Receive Data Contains data received by the LPI2C target. When both SCFGR1[RXCFG] and SSR[AVF] are 1, bits [7:0] of SASR[RADDR] are returned.

Chapter 45
Improved Inter-Integrated Circuit (I3C)

45.1 Chip-specific I3C information

Table 317. Reference links to related information

Topic	Related module	Reference
Full description	I3C	I3C
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

45.1.1 Module instances

This device has one instance of the I3C module, I3C0.

45.1.2 PORT module configuration for I3C mode pull-up resistor control

In order to work in the I3C mode, the PV (pull value), PE (pull enable) and PS (pull select) values in the corresponding PORT_PCR registers should be correctly configured in advance.

The following table lists the required PORT_PCR register bit fields configuration of corresponding I3C pins to support I3C pull-up resistor control.

Table 318. PORT module configuration to support different I3C pull-up resistor control

I3C pins	Weak pull-up resistor enable	Strong pull-up resistor enable
I3C0_SDA	Corresponding PCRx[PE] = 1, PCRx[PV] = 0, PCRx[PS] = 1	Corresponding PCRx[PE] = 1, PCRx[PV] = 1, PCRx[PS] = 1
I3C0_SCL	Corresponding PCRx[PE] = 1, PCRx[PS] = 1	–

45.1.3 DMA wake-up support in I3C mode

In order to support I3C mode DMA wake-up, the CMC_CKCTRL[CKMODE] should be configured as 0x0 (No clock gating), 0x1 (Core clock is gated), or 0x3 (Core and platform clocks are gated).

45.2 Overview

I3C is a communications processor that improves upon the use and power of I2C, and provides an alternative to SPI for mid-speed applications.

The I3C bus protocol supports:

- In-band interrupts (IBI): these interrupts move from target to controller without extra wires, and the controller knows which target sent the interrupt
- Common command codes (CCC)
- Dynamic addressing
- Multi-controller and multi-drop
- Hot-Join (HJ)
- I2C compatibility

I3C supports all required and many optional features of the MIPI Alliance Specification for I3C, v1.0 and v1.1, except for ternary data rates (HDR-TSP and HDR-TSL). See Features, Target Capabilities (SCAPABILITIES), and Target Capabilities 2 (SCAPABILITIES2) for more information.

45.2.1 Block diagram

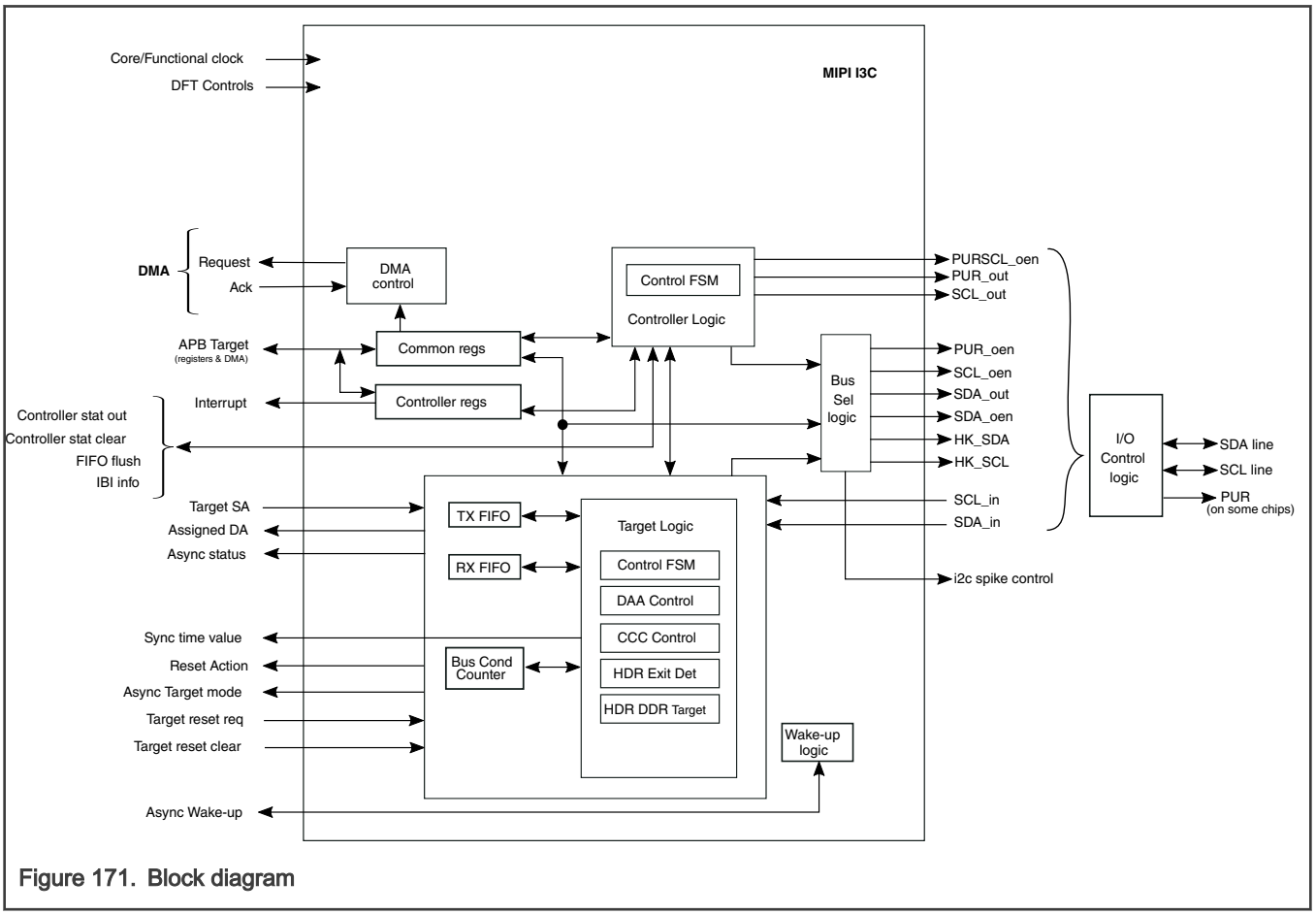


Figure 171. Block diagram

45.2.2 Features

- Two-wire multidrop bus that is capable of up to 12.5 MHz clock speeds with up to 11 devices:
  - Uses standard pads with 4 mA drive.
  - Dynamically assigns target addresses, and targets do not require static addresses (SAs). However, targets can have an I2C static address assigned at startup, so the target can operate on an I2C bus. By default, I3C supports 7-bit I2C-style addresses.
  - Allows targets to use the inbound SCL clock as the peripheral clock (instead of the clock from the controller) so that devices can have slow or inaccurate clocks internally.
  - Allows simple targets, such as temperature sensors, to have no internal clock.
  - I3C controller supports handoff from Open-Drain to Push-Pull mode for ACK to data transfer.
  - Generally, the controller terminates the read, but for I3C, the target can also end the read.
- IBIs that allow targets to send notifications to a controller:
  - Can be equivalent to a separate GPIO, but can also be directly data-bearing.

  - Can be prioritized. When multiple targets send interrupts to a controller at the same time, the order is resolved. Dynamic addresses (DAs) establish the priority of the targets, so the controller controls the priority of the targets.

    Targets with lower-value DAs are higher-priority level IBIs.
  - Can start interrupts even when the controller is not active on the bus. A free-running clock is not required, but starting an interrupt requires a Bus Available condition.
  - Can resolve an initial event via a time-stamping option, not requiring an interrupt.
- Built-in commands for applications created in software or firmware by using the register interface maintained in a separate space. These commands do not collide with normal controller-to-target messages and:
  - Control bus behavior, modes and states, low-power state, inquiries, and more.
  - Have an extra room for new built-in commands for other groups.
- Organized forms of multicontroller modes that are secondary controllers using clean handoffs between different controllers.
- Hot-Join onto I3C bus allows devices to connect to the bus later than when the bus starts. This:
  - Enables a device or module to access the I3C bus after power up or when physically inserted onto the I3C bus.
  - Provides a clean method for notification when new devices or modules access the I3C bus.
- I3C can use both I2C and I3C buses:
  - I3C supports specific legacy I2C devices on the bus.
  - I3C target devices can operate on I2C buses.
  - In I2C controller mode, it supports only Push-Pull mode on the SCL line.
  - A reset output is available for I2C mode SW reset for application usage. Asserted when the module is an I2C target and gets a I2C software General command from a controller. See the chip-specific section, for usage if this is available.
- Higher data rate modes are available:
  - I3C has a high data rate: double data rate (HDR-DDR) mode, which is double the data rate of SDR .
  - Only the controller and the specific targets, which are capable and configured to work with HDR-DDR, support the higher data rate (the other targets can ignore it).

I3C supports most of the I3C features (see Target Capabilities (SCAPABILITIES) and Target Capabilities 2 (SCAPABILITIES2)), except for the ternary data rates (HDR-TSP and HDR-TSL), HDR-BT modes, and peer-to-peer messaging.

45.3 Functional description

45.3.1 Operating modes

This section describes all functional operation modes of the I3C module.

45.3.1.1 Target and controller roles for I3C

The I3C protocol defines these roles for devices on the I3C bus:

- Main controller: initially configures the I3C bus and serves as the first active controller
- Secondary controller: accepts the controller role from any active controller to become the new active controller (the secondary controller may then pass the controller role along: either back to the previous active controller, or on to any other controller-capable device)
- Target: responds to commands from any I3C controller
- I2C target: responds to compatible commands from any I3C controller

The I3C peripheral contains both controller and target components and can be configured to be either controller or target, or as target with secondary controller capability. However, if I3C is chosen to be a controller, then the I3C peripheral supports Target mode to facilitate handoffs to multiple controllers.

In general, any I3C controller can be a controller or a target because a controller becomes a target when giving over control to another controller. The only exceptions to this rule occur when using point-to-point communication or when using a controller that never shares controllership.

45.3.1.1.1 Controller requirements

Controller mode uses software that supports the requirements of the controller (including as a secondary controller):

- Managing the enter dynamic address assignment (ENTDAA) assigning dynamic addresses (DAs) to each target. The I3C peripheral supports this process but requires you to make choices.
- Driving the serial data (SDA) signal in both Open-Drain and Push-Pull modes. After START command, SDA is in Open-Drain mode and after Repeated START command, it is in Push-Pull mode:
  - SDA is subject to arbitration because both controller and target can drive the SDA line (arbitration is also useful for handoff from controller to target).
  - The ninth bit of SDA controller write data is an odd parity bit.
- Building a table of targets and their capabilities to control which actions and commands may be sent to the targets.
- Managing requests such as IBI and controller requests (handoff).
- Adjusting clock speed or write-to-read timing to match the limitations of the target. This adjustment can be done in hardware using dividers and uneven duty cycles, but you must decide how.
- Adjusting the maximum data length.
- Being a target after the controller role handoff to another controller-capable device.

The controller needs an accurate clock capable of running at a frequency that is the multiple of a frequency between 11 MHz and 12.5 MHz. For example:

- 24 MHz (multiple of 12 MHz)

If required to use a lower I3C SCL value, for example as small as 5 MHz (although the lower value does not support a mixed bus system):

- The controller clock can be a multiplier of that value.
- A lower SCL can also be achieved using a higher PPBAUD value.

45.3.1.1.2 I3C target acts like I2C target on I3C buses

If the target is assigned an I2C static address, the I3C target acts like an I2C device when it first powers on. If the I3C target is placed on an I2C bus with an I2C controller, then the I3C target stays in I2C mode and operates normally. The software is aware that the I3C target is in I2C mode because:

- There has not been an interrupt (see SSTATUS[DACHG]) indicating that a dynamic address was assigned.

For full I2C support of Fast mode (Fm) and Fast-mode Plus (Fm+), the pads must support a 50-ns spike filter. This filter must be turned off when the I3C 7Eh broadcast address is received (indicating an I3C controller). You can turn off the spike filters via hardware using the raw net indicating that the address was received, or via software. I3C does not need a 50-ns spike filter to operate on an I2C bus. Therefore, the spike filter is not a requirement for the I3C peripheral.

Depending on the configuration, the module supports most I2C features. See Target Capabilities (SCAPABILITIES) and Target Capabilities 2 (SCAPABILITIES2) for more information.

45.3.1.1.3 How a target rejoins the I3C bus

When a target tries to rejoin the I3C bus following a power-up or hard reset, the target needs a new dynamic address (DA). The target can rejoin the I3C bus in these ways:

- If the DA is lost, Hot-Join is used.
- If the DA is retained in the peripheral (for example, with state retention flip-flops), SCONFIG[OFFLINE] is used.

When SCONFIG[SLVENA] is 1, SCONFIG[OFFLINE] may become 1. This setting causes the peripheral to rejoin the bus safely. It does so by ensuring that the I3C bus is not in HDR mode, using the same approach as TE0 or TE1 exit. The peripheral waits for the HDR exit pattern from the controller, or for 60 µs of SCL and SDA lines not changing, whichever occurs first.

After using SCONFIG[OFFLINE], the I3C peripheral cannot safely use IBI until SSTATUS[STOP] becomes 1. This status ensures that the next START is safe to use for IBI.

If the application has to perform an IBI, it must wait for SSTATUS[STOP] to become 1, or for SCL and SDA lines to remain high for 200 µs. You can perform this process using the SSTATUS and SINTSET controls:

- If Target Status (SSTATUS) indicates that the bus is not busy and the peripheral interrupts on START or STOP, use a timer to measure 200 µs. If the timer finishes with no START or STOP, it is safe to use IBI.
- If a START causes an interrupt, then the timer must be turned off and the application must wait for a STOP.
- If a STOP causes an interrupt, it is safe to use IBI.

45.3.1.2 Using the I3C controller for I2C and I3C

The I3C controller operates with the following set of built-in capabilities with the application flow:

- Built-in enter dynamic address assignment (ENTDAA) mechanism to simplify the assignment of dynamic addresses to targets. This feature is used when set dynamic address from static address (SETDASA) is not available.

  NOTE

  When SETDASA CCC is available, use SETDASA CCC before using ENTDAA CCC; all targets without assigned dynamic addresses respond to ENTDAA CCC.

- Request for START + address with IBI support, including both I2C and I3C modes.
- SDR write flow via FIFO, with automatic parity in I3C and ACK or NACK detection in I2C.
- SDR read flow via the FIFO, with an automatic NACK generator for I2C, and optional use of a terminate generator for I3C.
- Request for Repeated START + address or STOP when finished with the previous request, including both I2C and I3C.
- Auto-IBI mode, which responds immediately to a target-initiated IBI and can be used when in Sleep or Deep Sleep mode.
- Special message mode for SDR and DDR to simplify DMA use.
- Automated SCL, SDA, pullup, and High-Keeper controls.
- I2C and I3C frequency and duty cycle configurations from functional clock.

  NOTE

  You must configure Controller Configuration (MCONFIG) and Controller In-band Interrupt Registry and Rules (MIBIRULES) before using the controller.

45.3.1.3 Protocol modes and states

The following modes are activated in I3C:

- I2C mode is the default mode on startup:
  - If no I2C static address is used, this mode has no effect other than to track frames looking for I3C transitional frames.
  - If an I2C static address is used, the device can interact with the I2C bus controller using the address.
- When in I2C mode, I3C Transitory Frame mode occurs whenever the I3C broadcast address is received (7Eh). In particular:

- This mode occurs when 7Eh is broadcast followed by SETDASA from the controller. If there is a static address match, the target is assigned a dynamic address and it enters I3C SDR mode.
- This mode occurs when 7Eh is broadcast followed by ENTDAA from the controller. If the target can send a 48-bit provisioned ID (48b ID), a dynamic address is assigned, and the target enters I3C SDR mode.
- If a Hot-Join arbitrated event occurs (sending 02h when the controller generates another address such as 7Eh), there is a conceptual Hot-Join mode. ENTDAA or SETDASA sets a dynamic address to resolve the event, and the target enters I3C SDR mode.

NOTE

An I3C target can operate as a normal I2C target only when it has a static address. Otherwise, it matches nothing in I2C and waits for the aforementioned events.

- I3C SDR mode is the standard mode after I3C activates, which is defined by a dynamic address being assigned. This mode is the resting mode of I3C, and all devices are normally in SDR mode:
  - RSTDAA CCC causes an exit from SDR mode and a return to I2C mode. This transition is not normally used.

    RSTDAA can be issued to ensure that all I3C targets participate in an upcoming dynamic address assignment process, before the I3C controller starts assigning the target address.
  - SETNEWDA does not affect the SDR mode; it only changes the dynamic address of an I3C device that already had a dynamic address assigned.
  - When in SDR mode, the device ignores messages to or from its original I2C static address.
- The I3C CCC command submode of type Direct or Broadcast. Following are the options to exit the CCC:
  - Exit the Broadcast CCC submode by a Repeated START or by a STOP.
  - Exit the Direct CCC submode by a 7Eh broadcast address after a Repeated START or by a STOP.
  - I3C dynamic address assignment (DAA) CCC command enters DAA mode. This mode is a special mode for dynamic addressing. Use STOP to exit. If a target has a dynamic address, the command is ignored.
- I3C SETDASA CCC command enters Static Address Match submode, which allows matching the static address of the device (if any). The command is ignored when a target has a dynamic address, or when the target in I2C mode has no static address.

NOTE

The special point-to-point address is also matched.

- I3C HDR modes are activated by ENTHDR*n* CCC commands, where *n* represents the type of HDR (0 to 7). This mode is valid until an HDR exit pattern is detected, irrespective of whether HDR mode for a target is supported.

  Exit-pattern detection must always be on to prevent errors. Alternatively, you could set it to be activated only on ENTHDR.
- A special HDR-DDR syntax is used for transmitting CCC in the HDR-DDR protocol.
- Internal states such as IBI or no-IBI and Low-Power mode are flagged internally (see SSTATUS[EVDET] for more information). These states are exported to the application and affect the engine to restrain it from performing a prohibited operation.

45.3.1.4 Address match

For an address match to occur, the target matches the I3C broadcast address and either the I2C-style static address or I3C dynamic address (see Table 319).

The address match is inactive (just listening) for all Repeated START commands and also for the START command, unless an IBI, CR, or Hot-Join has been activated. If inactive, it simply tries to match. If not matched, it waits for a Repeated START or STOP command. If an IBI, CR, or Hot-Join has been activated, the arbitration mechanism is used for START (but never for a Repeated START).

When matching the 7Eh broadcast address, it looks for a CCC until the next Repeated START or STOP command.

Table 319. Address match conditions

For	Match condition occurs when	Notes
I3C broadcast address	The address is 111 1110b (written as 7Eh).	
I2C-style static address	• The device has a static address. • The device is not in I3C mode.	When in I3C mode, the address matches only until the ENTDAA, SETDASA, or SETAASA command has a dynamic address assigned. SETDASA matches the static address or the special one-controller-to-one-target point-to-point address.
I3C dynamic address	ENTDAA or SETDASA assigns it, or SETNEWDA modifies it.	

45.3.1.5 I3C from low power mode and wake-up

A wake-up interrupt is available to bring the I3C module out of low power mode.

This interrupt works in both Controller and Target mode of operation as described below.

45.3.1.5.1 Controller mode

In Controller mode, I3C works with 2 clocks.

- Host interface clock for accessing registers and DMA
- Functional clock (FCLK) for controller logic operation and generating SCL

The Functional clock can be switched off to keep the I3C controller in low power mode if there is no data to be sent by the host and the i3C bus is in idle state (SDA = 1).

Before switching off the clock, take the below steps.

- Ensure that you enable the Controller mode MCONFIG[MSTENA] = 01b.
- Ensure that the bus is in the idle state.
- Switch off the Functional Clock.

If any agent on the bus pulls the SDA line low and at the SoC level the ENABLE bit of the I3C SDA interrupt is set to 1, then the interrupt goes high to inform the SoC logic to switch on the FCLK again.

45.3.1.5.2 Target mode

In Target mode, I3C works with only the Host interface clock (for accessing registers and DMA)

The main target control logic works on the external SCL clock.

The Host interface clock can be switched off to keep the I3C Target in low-power mode.

Before switching off the clock, take these steps.

- Ensure that you configure the Target mode, MCONFIG[MSTENA] = 00b along with all other normal target configuration as required.
- Clear the interrupts in Target Status (SSTATUS) after handling them.
- Enable DA matched interrupt in SINTSET[MATCHED].

- The host can now stop the Host interface clock to enter low power mode.

The interrupt asserts when any address match happens, either DA or SA or group address with this target.

The host then resumes the Host interface clock to serve and clear the interrupt.

45.3.2 Operations

This section describes the operations of the module.

45.3.2.1 Reading and writing I2C messages using the normal method

1. Set up interrupts using the following fields of Controller Interrupt Set (MINTSET):
   - MCTRLDONE: Indicates when the module completes an MCTRL request.
   - COMPLETE: Indicates when data is finished sending or being received.
   - RXPEND: Used for read operations. Works with Controller Data Control (MDATACTRL) to set the FIFO trigger. You can also use this field to allow DMA to read out data.
   - TXNOTFULL: Used for write operations. Works with Controller Data Control (MDATACTRL) to set the FIFO trigger. You can also use this field to allow DMA to supply data.
   - IBIWON: Indicates that an IBI, CR, or HJ has won the arbitration on a header address.
   - Additionally, Controller Errors and Warnings (MERRWARN) indicates the causes of errors and warnings.
2. Configure the following fields in Controller Control (MCTRL) simultaneously:
   a. Write 1 to REQUEST (EmitStartAddr).
   b. Write 1 to TYPE (I2C).
   c. Configure IBIRESP to respond to IBIs in your chosen manner.
   d. Write 1 to DIR for read, or write 0 for write.
   e. Write the static address of the I2C target to ADDR.
   f. Configure RDTERM to the maximum length for read operations, to auto-terminate, or set it to STOP as the data is read out. For example, write 1 (with MCTRL[REQUEST] = 0) to stop after the next character.
3. Write or read the data.
   - For write operations, write to Controller Write Data Byte (MWDATAB) for each byte before the last byte, and then write to Controller Write Data Byte End (MWDATABE) for the last byte:
     — You can perform or start this operation before setting up interrupts.
     — If there is more data than the FIFO can hold, use the TXNOTFULL interrupt based on the trigger level. This interrupt allows the application to provide more data or to use DMA.
   - For read operations, wait for RXPEND, and then read out data via Controller Read Data Byte (MRDATAB). DMA may also be used.
4. After message transfer is complete (MSTATUS[COMPLETE] = 1), the message may end with a STOP condition, or a new message may start with a Repeated START condition:
   a. Write 2 to MCTRL[REQUEST] (EmitStop to STOP). Then wait for the MCTRLDONE status to be asserted for its completion. (When sending STOP in I2C mode, MCONFIG[ODSTOP] and MCTRL[TYPE] must be 1.)
   b. Write 1 to MCTRL[REQUEST] (EmitStartAddr to restart). IBI is not possible in this case.

NOTE

I2C Fm and I2C Fm+ modes are supported for legacy I2C devices as per the I3C standard specifications. See I2C configuration to meet timing requirements for Fm and Fm+ modes for more information.

45.3.2.2 Reading and writing I3C messages using the normal methods (SDR and HDR-DDR)

The normal method for I3C is the same as the method for I2C with a few differences:

1. Set up interrupts using the following fields of Controller Interrupt Set (MINTSET):
   - MCTRLDONE: Indicates when the I3C module completes an MCTRL request.
   - COMPLETE: Indicates when data is finished sending or being received.
   - RXPEND: Used for read operations. Works with Controller Data Control (MDATACTRL) to set the FIFO trigger. You can also use it to allow DMA to read out bytes.
   - TXNOTFULL: Used for write operations. Works with Controller Data Control (MDATACTRL) to set the FIFO trigger. You can also use it to allow DMA to supply bytes.
   - IBIWON: Indicates that an IBI, CR, or HJ has won the arbitration on a header address.
   - Additionally, Controller Errors and Warnings (MERRWARN) indicates the causes of errors and warnings.
2. Set up Controller Control (MCTRL).
   - Option 1: Configure the following fields of Controller Control (MCTRL) simultaneously in this way:
     a. Write 1 to REQUEST (EmitStartAddr).
     b. Write 0 to TYPE for I3C Single Data Rate (SDR) mode or write 2 for Double Data Rate (DDR) mode.
     c. Configure IBIRESP to respond to IBIs in your chosen manner.
     d. Write 1 to DIR for read, or write 0 for write.
     e. Write the dynamic address of the I3C target to ADDR.
     f. For read operations, you can configure RDTERM to the maximum length to terminate automatically.
     g. For write operations, prewriting the data (MWDATAB or MWDATAH) is preferred to ensure that there are no time delays waiting for the data.

        For DMA with MCTRL, use either Controller Write Byte Data 1 (to Bus) (MWDATAB1) or Controller Write Halfword Data (to Bus) (MWDATAH1).

     NOTE

     HDR-DDR mode requires writing an 8-bit command value for read or write. This value must be written into the TX FIFO via Controller Write Data Byte (MWDATAB). The END field is not used for this byte.

   - Option 2: This option is preferred when stopped (bus free condition) in SDR mode, and not in HDR-DDR mode. It allows any target to issue an IBI and avoids collisions with an IBI address. Also, it is faster (when the MSB of the dynamic address is always 0).

     Configure the following fields of Controller Control (MCTRL) in this way:
     a. Write 1 to REQUEST (EmitStartAddr). No prewritten transmit data can be in the FIFO.
     b. Write 0 to TYPE (I3C).
     c. Configure IBIRESP to respond to IBIs in your chosen manner.
     d. Write 0 to DIR.
     e. Write 7Eh to ADDR.
     f. Wait for MCTRLDONE (via interrupt, for example), then proceed as in option 1. The option 2 method has advantages for IBIs when 7Eh is sent on START (but not on Repeated START conditions).
3. Write or read the data.
   - For write operations, write to MWDATAB for each byte before the last byte, and then write to Controller Write Data Byte End (MWDATABE) for the last byte. For HDR-DDR, the byte with END must be even (second, fourth, sixth, and so on) because DDR uses byte pairs:

— You can perform or start this operation before step 1 (REQUEST = 1) of the option 1 method, but not before the option 2 method.

— If there is more data than the FIFO can hold, use the TXNOTFULL interrupt based on the trigger level. This interrupt allows the application to provide more data or to use DMA.

- For read operations, wait for RXPEND, and then read out data via Controller Read Data Byte (MRDATAB) or Controller Read Data Halfword (MRDATAH). DMA may also be used. When using DMA, read using the same registers.

4. After message transfer is complete (MSTATUS[COMPLETE] = 1), the message may be ended with STOP (or EXIT in HDR mode). Alternatively, a new message may be started with a Repeated START (or HDR-Restart in HDR mode):
   - In SDR mode, write 2 to MCTRL[REQUEST] (EmitStop to STOP). Then wait for the MCTRLDONE status to be asserted for its completion.
   - For HDR mode, write 6 to MCTRL[REQUEST] (ForceExit) to end HDR mode. Then wait for the MCTRLDONE status to be asserted for its completion. When sending the HDR exit pattern, MCONFIG[ODSTOP] must be 0.
   - Write 1 to MCTRL[REQUEST] (EmitStartAddr to start another message). IBI is not possible in this case.

45.3.2.3 Determining bus types and modes

The settings of MCTRL[TYPE] and MCTRL[REQUEST] determine bus types and modes.

Table 320. Determining bus types and modes

Value of MCTRL[TYPE]	Meaning when MCTRL[REQUEST] = 1 (EmitStartAddr)	Meaning when MCTRL[REQUEST] = 2 (EmitStop)	Meaning when MCTRL[REQUEST] = 6 (ForceExit)
0	SDR mode of I3C	SDR mode of I3C	Exit pattern
1	Standard I2C protocol	Standard I2C protocol	Reserved
2	The bus enters DDR mode (7E and then ENTHDR0), if the module is not in DDR mode already. The first byte written to the transmit FIFO must be a command and already in the FIFO. To end DDR mode, use ForceExit.	Reserved	Target reset
3	If not already in HDR-BT, the bus automatically enters BT mode (7E and then ENTHDR3). You must also configure the MHDRBTCFG register for multilane and CMD rules.	Reserved	Reserved

Table 321. Deriving the dynamic address

Value of MCTRL[TYPE]	Meaning when MCTRL[REQUEST] = 4 (ProcessDAA)
0	The dynamic address is derived from MWDATAB[VALUE]; in case of a NACK, ProcessDAA continues to the next 7E/R request.
1	Reserved
2	The dynamic address is derived from MWDATAB[VALUE]; in case of a NACK, a STOP condition is sent after the assignment.
3	Reserved

45.3.2.4 Sending a CCC to I3C targets

The normal common command code (CCC) method uses an I3C write operation with an address of 7Eh (the CCC is the first byte):

- For broadcast type, any remaining bytes are sent with the CCC. This operation ends with a STOP or a Repeated START and 7Eh.
- For direct type, only the CCC byte is sent (or by a CCC and a defining byte, if required by the CCC).

  These bytes are followed by a Repeated START and the address of the I3C target (for SETDASA, this address is its I2C static address). This sequence may be repeated with more Repeated START conditions and addresses until done. It may end in STOP or a Repeated START and 7Eh. After the Repeated START and target address, the values are read or written depending on the CCC.
- I3C provides interrupts (by hardware) for unhandled and handled CCC when received by the target. Its state is reflected in Target Status (SSTATUS).

I3C controllers require to emit a single START, 7E/W sequence with both SCL high and SCL low half periods at full open-drain timing (for example, 200 ns). This sequence allows I3C targets acting as I2C legacy devices to turn off their I2C 50-ns spike filters, if they have them.

NOTE

START, 7E/W is a notation indicating a START command, followed by the 7Eh broadcast address and then by a write command.

After that sequence, addresses following START may be sent with Open-Drain Low (for example, 200 ns) but high of Push-Pull timing (for example, 40 ns). The I3C controller must emit this START, 7E/W sequence with MCONFIG[ODHPP] = 0. ODHPP is Open-Drain High period at Push-Pull speeds, and MCONFIG[ODHPP] is usually 1.

NOTE

- MCONFIG[ODHPP] is ignored when sending a message to an I2C legacy device on an I3C bus.
- Each Repeated START is a new EmitStart request. This request can be chained by an interrupt or pushed by a message model using DMA.

45.3.2.5 IBI handling

An IBI occurs when a target sends its address after a START, and that address is numerically the lowest. That is, it is lower than the address sent by the controller and addresses sent by any other targets. When the controller sends 7Eh, the controller always loses the arbitration.

The IBI can occur unexpectedly when any new START (not a Repeated START) is sent. The IBI can also occur in response to a target pulling SDA low. This condition can occur in one of these ways:

- The controller has set the request to AutoIBI mode, so the IBI occurs automatically. The controller sends 7Eh to allow the target to win the arbitration.
- The application receives the SLVSTART (target START request) interrupt, so it sends 7Eh.

The IBI response is configured by MCTRL[IBIRESP], which can be set to:

- NACK (always reject the IBI).
- ACK (always accept the IBI):
  - You must configure Controller In-band Interrupt Registry and Rules (MIBIRULES) so that the engine knows whether IBI bytes follow.
  - If IBI bytes follow (also known as IBI mandatory byte), then the COMPLETE field does not become 1 when IBIWON becomes 1. RXPEND becomes 1 for one or more bytes in the receive FIFO. When the last byte is received, then the COMPLETE field becomes 1. The controller automatically stops IBI data after 9 bytes (including the mandatory data byte). MCTRL[RDTERM] can be used with MCTRL[REQUEST] = 0 to end the process of receiving data sooner. I3C

supports address ACK to mandatory byte transition during IBI from Open_Drain (controller acknowledges the target address) to Push Pull (target sends SDR data).

— I3C target supports up to 7 bytes (maximum limit is defined by IBIEXT1[MAX]) of extended IBI data following a mandatory data byte. Extended data to send, if any, is present in Extended IBI Data 1 (IBIEXT1) and Extended IBI Data 2 (IBIEXT2).

- Manual (allow the decision to be made by the application on a case-by-case basis):
  — The application rewrites it when stopped, pending an IBI.
  — The application can ACK or NACK the IBI based on the IBI address defined in MSTATUS.
  — This mode selects whether there is an IBI byte when accepting the IBI request from targets.

Accurate timestamping of I3C target data is supported in I3C though Async mode 0. In I3C Asynchronous Timing Control mode, a target device timestamp event occurs within that target. The target notifies the controller about the event by generating an IBI.

45.3.2.6 Assigning dynamic addresses to I3C devices

If dynamic addresses (DAs) are all assigned below 40h (7-bit values from 3Fh down to 03h, except where not allowed), then MIBIRULES[MSB0] can be 1. This setting optimizes the START timing. When dynamic addresses are assigned, you must program Controller In-band Interrupt Registry and Rules (MIBIRULES) based on which I3C target uses IBI bytes (present in SIDEXT[BCR]).

Any SETDASA assignments can be performed via the normal CCC model. These assignments cannot be performed when using the static address for the directed part.

There is a built-in mechanism to process ENTDAA mode:

1. Set up interrupts using the following fields of Controller Interrupt Set (MINTSET):
   - MCTRLDONE: Indicates when a target has sent its ID and BCR or DCR, and a new DA is needed.
   - COMPLETE: Indicates when DAA is done (NACKed by all targets).
   - RXPEND: Indicates the reading of the IDs of the targets. You can also use this field to allow DMA to read out bytes.
   - IBIWON: Indicates when an IBI has occurred (normally there are no IBI conditions when assigning dynamic addresses to the I3C device).
   - Additionally, Controller Errors and Warnings (MERRWARN) indicates the causes of errors and warnings.
2. Configure Controller Control (MCTRL):
   a. Write 4 to MCTRL[REQUEST] (ProcessDAA).
   b. Set MCTRL[IBIRESP] to IBI response, if possible. If not possible, set to the first target assignment.
3. Wait for the MCTRLDONE interrupt when reading ID using the RXPEND interrupt. If MSTATUS[STATE] = 5 (DAA mode) and MSTATUS[BETWEEN] = 1, it is waiting to write a dynamic address:
   a. Write the dynamic address into Controller Write Data Byte (MWDATAB) using bits 6:0, such as 14h for DA = 7'h14.
   b. Write 4 to MSTATUS[STATE] (ProcessDAA again). This option writes the DA, then moves to the next DA.
   c. If MSTATUS[COMPLETE] = 1 and MSTATUS[STATE] = 0, then all targets are assigned.
   d. If MSTATUS indicates NACK after writing a new DA, the DA is not accepted by the target. The next step is to write 2 to MCTRL[REQUEST] (EmitStop) and start over. It is also acceptable to write 4 to MCTRL[REQUEST] (ProcessDAA again).

45.3.2.7 Using Controller Message mode

Controller Message mode is intended for use with DMA although Message mode can also be used by the processor. In Message mode, all writes are to the same location, including control and data. Reads occur from an associated location.

NOTE

The data writes for Message mode work in the same way as the halfword access registers, Controller Write Data Halfword (MWDATAH) and Controller Read Data Halfword (MRDATAH).

To send a message via Single Data Rate (SDR), follow these steps (from DMA or processor):

1. Write the control request to Controller Write Message Control in SDR mode (MWMSG_SDR_CONTROL). This request includes the following items:
   - The address.
   - I2C or I3C.
   - Read or write.
   - The count of bytes to process.
   - How to end (on STOP or ready for Repeated START).
2. Process the data:
   - For write operations, write the rest of the data to Controller Write Message Data in SDR mode (MWMSG_SDR_DATA). Use the DMA trigger (or interrupt) to keep the transmit FIFO full, and the controller stops using the data when it has already consumed the number of bytes configured in the LEN field.
   - For read operations, a DMA trigger (or interrupt) indicates when the RX FIFO is ready to be read out via Controller Read Message in SDR mode (MRMSG_SDR).
3. Select the in-band interrupt (IBI) behavior in MCTRL[IBIRESP].
4. Use END type STOP (MCTRL[REQUEST] = 2) with a zero-length message or by using Controller Control (MCTRL). To exit Message mode with the original message, use END type STOP (MCTRL[REQUEST] = 2) with a zero-length message or by using the MCTRL register.

To send a message via Double Data Rate (DDR), follow these steps (from DMA or processor):

1. Write the control request to Controller Write Message in DDR mode: First Control Word (MWMSG_DDR_CONTROL). This request includes:
   - The count of byte pairs.
   - How to end the message (through HDR exit or to wait for HDR restart).
2. Write the second control data to MWMSG_DDR_CONTROL. This second write includes:
   - The address.
   - Read or write.
   - The 7-bit command value.
3. Process the data:
   - For write operations, write the rest of the data to MWMSG_DDR_DATA. Use the DMA trigger (or interrupt) to keep the transmit FIFO full, and the controller stops using the data when the program count MWMSG_DDR_CONTROL register reaches 0.
   - For read operations, a DMA trigger (or interrupt) indicates when the receive FIFO is ready to be read out.
4. Select in-band interrupt (IBI) behavior in MCTRL[IBIRESP].
5. Use END type exit (MCTRL[REQUEST] = 6) with a zero-length message or by using the MCTRL register to exit DDR Message mode with the original message.

45.3.2.8 Handing off controllership to another target and getting it back

To hand off controllership, the controller can perform either of the following actions:

- Wait for a controller request (CR) (that is, MSTATUS[IBIWON] = 1 interrupt), indicating that the CR is using MSTATUS[IBITYPE].
- Push the request manually.

In either case, the controller sends a GETACCMST request, which is a directed GET informing the target that it is being assigned controllership. If the target accepts this request, it returns its dynamic address in bits 7:1 and the negative parity of its dynamic address in bit 0. A STOP must be issued, and MCONFIG[MSTENA] must be set to 2 (switching to Target mode).

To gain controllership, the target sends a CR using Target Control (SCTRL):

- If MCONFIG[MSTENA] is 2, the GETACCCR CCC is ACKed.
- If MCONFIG[MSTENA] is not 2, the GETACCCR CCC is NACKed.

After controllership is granted, MSTATUS[NOWMASTER] becomes 1. The application must enable MINTSET[NOWMASTER], so the application is interrupted when a controllership transfer occurs.

45.3.2.9 Controller engine flow diagram

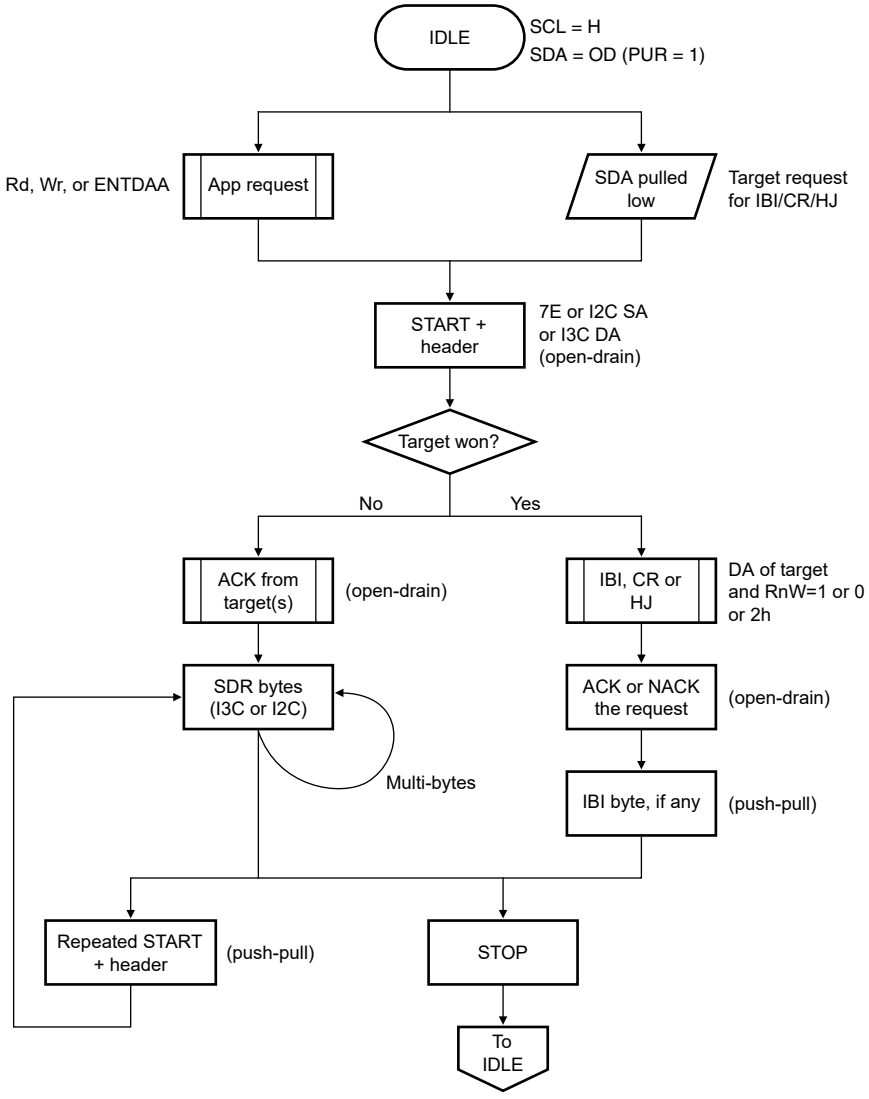


Figure 172. Controller engine flow diagram for SDR (HDR flow progresses from SDR bytes)

45.3.2.10 Target receives data from controller

When the address match is valid for the target dynamic address and the type is W (write from controller), the target ACKs the address. It does so unless some condition prevents it, such as a full buffer. On ACK, the Write state is entered. Once ACKed, it waits for each complete data byte. This process occurs in two steps:

1. Eight bits are clocked in and stored in the next buffer location when in the Write state.
2. On the ninth bit:
   - In I3C mode, the W9TH state (in I3C, the ninth data bit written by the controller is the parity of the preceding eight data bits) is used and the parity is checked. The buffer is marked as complete with or without a parity error.
   - In I2C mode, the W9TH state (in I2C, the ninth data bit written by the controller is an ACK by the target) is used and the data is ACKed and stored.

When the address match is valid for the 7Eh broadcast address, the target acknowledges it. After first data completion, it sets the in_ccc broadcast or direct flag (based on bit 7 of the command). If recognized, it parses the command, setting that bit as well. The recognized commands are for dynamic address work and modes. The CCC and DAA blocks handle the workload afterward. If not supported, then the commands are passed up to the system.

45.3.2.11 Target sends data to controller

When the address match is valid for the target dynamic address, and the type is R (read by controller), the target ACKs the address. The target does so unless there is no data waiting for the read. On ACK, the Read state is entered.

After being ACKed, it emits the data byte at a time, with the ninth bit using the R9TH state. In I2C, the ninth data bit from target to controller is an ACK by the controller. In I3C, this bit allows the target to end a read, and allows the controller to abort a read:

- In I3C mode, the T bit is emitted to allow the device to indicate whether this byte is the last. If it is not the last byte, the controller may terminate the read via the T bit.
- In I2C mode, the ninth bit allows the controller to terminate via NACK, or else it allows the read to continue via ACK. On completion of each byte read, the "done" signal is pulsed to get the next byte.

If the read is terminated by the controller unexpectedly (abort in I3C, NACK before END marked), the application is notified.

45.3.3 Clocking

The controller works on the following primary clocks:

- The system clock, which controls access to the memory-mapped registers.
- A functional clock (FCLK), which is used to generate the SCL clock rate on the I2C or I3C bus.

I3C supports adjusting clock frequency and accuracy via Target Time Control Clock (STCCLOCK).

FCLK is used to check conditions such as bus availability, bus free for IBI, or HJ:

- To determine the Bus Available condition for IBI, the target needs a clock to generate the ~1 µs timing. To support this requirement, a slow clock (CLK_SLOW) is provided to save on power.
- I3C supports a counter field, SCONFIG[BAMATCH], to calculate the Bus Available condition. BAMATCH provides the count of the slow clock . This field counts 1 µs or more to allow an IBI to drive SDA low when the controller is free. The I3C module controls the maximum width and maximum values.

I3C supports a timeout when stalled for too long in a frame. This timeout occurs when:

- The transmit FIFO or receive FIFO is not handled and the bus is stuck in the middle of a message.
- No STOP is issued and the bus is between messages.
- IBI manual is used and no decision is made.

45.3.4 Reset

- Global or system reset fed into the module: Everything is reset by this global or system reset. Release is assumed to be synchronized with the system clock. It is not synchronized with SCL or SDA. These signals must not be active when the reset is released; otherwise, I3C enters Hot-Join mode and remains inactive.
- Software reset

45.3.5 Interrupts

This section describes all the interrupts (IRQs) that this module generates. All status interrupts are updated in Controller Status (MSTATUS) and Target Status (SSTATUS).

Supported interrupts occur:

- For pending IBI, CR, or Hot-Join that have been sent by a target.
- When a CCC is received and is handled by the module (SSTATUS[CHANDLED]).
- When an error or warning has occurred, such as data underrun, data overrun, parity error, HDR-DDR, or CRC error.

A wake-up interrupt is also available to bring the I3C module out of low power mode. See I3C from low power mode and wake-up .

45.4 External signals

Table 322. External signals

Signal	Description	Direction
SCL	Serial clock	Input or output
SDA	Serial data	Input or output
PUR	Pull up resistance. There is an internal pullup resistance on SDA, which the I3C controls. If the internal pullup is not enough, PUR can control an external pullup resistance on SDA actively. See the chip-specific I3C information on whether this external pullup is available on your chip.	Output

45.5 Initialization

45.5.1 Controller configuration

Certain configuration is performed when initializing this module. Controller Configuration (MCONFIG) controls the frequencies, duty cycle, optimizations for performance, and other parameters.

Table 323. Configuration for module initialization

Configuration parameter		Description
MSTENA	Controller enable	Determines whether the peripheral starts in Controller mode (main controller in I3C terms) or starts in Target mode (and switches to Controller mode later).
HKEEP	High-Keeper	Determines how the high-keeper (weak pullup) is implemented, depending on the device capabilities.
PPBAUD	Push-Pull baud	Sets the push-pull frequency as a divider from the FCLK (alternative clock fed to the peripheral). This frequency sets the SCL half-clock period baseline (used at least for the high time of SCL).

Table continues on the next page...

Table 323. Configuration for module initialization (continued)

Configuration parameter		Description
		The formula for SCL in Push-Pull mode using PPBAUD and PPLOW is: SCL frequency (in MHz) = FCLK ÷ ((2 + 2 × PPBAUD) + PPLOW) If PPLOW is 0, then SCL high = SCL low (in ns) = (1 + PPBAUD) × 1000 ÷ FCLK (in MHz) Examples: • If FCLK = 24 MHz, then PPBAUD = 0 yields 12 MHz (42.67 ns per half period) • If FCLK = 50 MHz, then PPBAUD = 1 yields 12.5 MHz (20 + 20 = 40 ns per half period)
PPLOW	Push-Pull low	Changes the duty cycle for Push-Pull. It indicates how many more FCLK cycles to use for low. The formula for SCL in Push-Pull mode using PPBAUD and PPLOW is: SCL frequency (in MHz) = FCLK ÷ ((2 + 2 × PPBAUD) + PPLOW) If PPLOW is a nonzero value, then: • SCL high (in ns) = (1 + PPBAUD) × 1000 ÷ FCLK (in MHz) • SCL low (in ns) = (1 + PPBAUD + PPLOW) × 1000 ÷ FCLK (in MHz) For example, when FCLK is 50 MHz, PPBAUD is 1, and PPLOW is 1, then the periods are: • (1 + 1) × 1000 ÷ 50 = 20 + 20 = 40 ns high • (1 + 1 + 1) × 1000 ÷ 50 = 20 + 20 + 20 = 60 ns low This timing is equivalent to 10 MHz SCL, but this timing maintains the 40 ns high needed; therefore, I2C devices do not see the high periods. **NOTE** The PPLOW value does not have any impact on Open-Drain mode and I2C mode SCL rate calculations.
ODBAUD	Open-Drain baud	Determines the number of PPBAUD periods to make up one I3C Open-Drain half-clock baseline. If ODHPP is 0, the ODBAUD half-clock time period = (ODBAUD + 1) × PPBAUD high period. If ODHPP is 0, the formula for SCL in Open-Drain mode is: SCL (in MHz) = FCLK ÷ (2 + 2 × PPBAUD) × (ODBAUD + 1) Target to get open-drain half-clock period is 200 ns. For example: • If PPBAUD yields 12.5 MHz (40 ns per PPBAUD period), then ODBAUD = 4 can be used to get 200 ns. See ODHPP for details on short high and long low. • If PPBAUD = 1, FCLK = 50 MHz, and ODBAUD = 4, then open-drain SCL = 50 ÷ (2 + 2 × 1) × 5 = 2.5 MHz.
ODHPP	Open-Drain High Push-Pull	Optional field that allows the I3C open drain to be long low and short high. The high period of SCL is the PPBAUD period. This period leaves enough time for the pullup resistor to pull the SDA high when SCL is low. It is also quick when SCL is high and there are no changes happening. ODBAUD low half-clock time period = (ODBAUD + 1) × PPBAUD high period.

Table continues on the next page...

Table 323. Configuration for module initialization (continued)

Configuration parameter		Description
		ODBAUD high half-clock time period = PPBAUD high period If ODHPP is 1, the formula for SCL in Open-Drain mode is: SCL (in MHz) = FCLK ÷ (1 + PPBAUD) × (ODBAUD + 1) + (1 + PBAUD) For example: • If PPBAUD produces 12.5 MHz (40 ns per PPBAUD period), then ODBAUD = 4 and ODHPP = 1. These settings provide a high period of 40 ns and a low period of 200 ns. • If PPBAUD = 1, FCLK = 50 MHz, and ODBAUD = 4, then open-drain SCL = 50 ÷ (1 + 1) × 5 + (1 + 1) = 4.16 MHz.
I2CBAUD	I2C Baud	Indicates the number of ODBAUD periods that are required to communicate with I2C devices (MCTRL[TYPE] = 2 or MWMSG_SDR_CONTROL[I2C] = 1). For example, if ODBAUD gives 200 ns, and the goal is Fm+ (Fast Mode, 1 MHz), then the sum must be 1 µs. I2CBAUD acts differently for odd and even values. For example: • If I2CBAUD = 3, it gives three ODBAUD periods low and two ODBAUD periods high. • If I2CBAUD = 4, it gives three ODBAUD periods for low and three ODBAUD periods for high. • Also, if I2CBAUD = 3, this yields 200 × 3 = 600 ns and 200 × 2 = 400 ns, with the sum 600 + 400 = 1000 ns = 1 µs.
SKEW	Skew	The normal SDA skew from SCL is handled by using the time for the SCL to reach its pad and return. This time is normally 2 ns to 5 ns (or sometimes more). If the skew is too fast, then add more delay. The skew allows specifying the number of FCLK to insert.

Additional optimizations:

- Use MIBIRULES[MSB0] to obtain faster start header times. If the controller application assigns all I3C dynamic addresses to be less than 40h (it does not have MSB set), you can write 1 to MIBIRULES[MSB0]. When the controller emits 7Eh (broadcast) and a target does not drive the first bit low, the rest of the header can be at push-pull speeds. This speed is two times faster or more, depending on optimizations.
- Auto-emit 7Eh speeds up the frame when used with MIBIRULES[MSB0]. It allows the processor to sleep when the frame starts automatically (in response to a target).

45.5.2 Interrupt service flow

Set up interrupts for Controller Status (MSTATUS) in Controller Interrupt Set (MINTSET).

Set up interrupts for Target Status (SSTATUS) in Target Interrupt Set (SINTSET).

45.6 Application information

45.6.1 I2C configuration to meet timing requirements for Fm and Fm+ modes

I2C Fm and I2C Fm+ modes are supported according to the I3C standard specifications.

Table 324 shows the configuration for Fm mode, where frequency is close to 400 kHz but timing requirement is not met (T_{SU_STA} is not met) because the actual value is 600 ns. Rest of the requirements are met per the I2C specifications in the chip data sheet.

Table 325 shows the configuration for Fm mode, where all timing requirements are met.

Table 324. Configuration for Fm mode with not all timing requirements met

FCLK	PPBAUD	ODBAUD	I2CBAUD	SCL frequency	Timing requirement status
24 MHz	0	4	11	370 kHz	T_{SU_STA} - 353 ns

Table 325. Configuration for Fm mode with all timing requirements met

FCLK	PPBAUD	ODBAUD	I2CBAUD	SCL frequency	Timing requirement status
24 MHz	1	2	9	363 kHz	All requirements met per the I2C specifications in the chip data sheet

Table 326 shows the configuration for Fm+ mode, where the frequency is close to 1 MHz. In this case, the T_{SU_STA} timing requirement is not met because the actual value is 260 ns. Rest of the requirements are met per the I2C specifications in the chip data sheet.

Table 327 shows the configuration for Fm+ mode, where all timing requirements are met. To meet all the timing specifications, frequency may differ from 1 MHz. Use the configurations listed in Table 327.

Table 326. Configuration for Fm+ mode with not all timing requirements met

FCLK	PPBAUD	ODBAUD	I2CBAUD	SCL frequency	Timing requirement status
24 MHz	0	4	3	960 kHz	T_{SU_STA} - 228 ns

Table 327. Configuration for Fm+ mode with all timing requirements met

FCLK	PPBAUD	ODBAUD	I2CBAUD	SCL frequency	Timing requirement status
24 MHz	0	3	6	749 kHz	All requirements met per the I2C specifications in the chip data sheet

NOTE

The controller module provides an option to slow down the clock for standard speed mode to support legacy I2C standard targets as well (although this option may not necessarily meet the exact timing requirement of the standard mode according to the standard I2C timing specification).

For the timing requirements under consideration, see the "I3C timing requirements when communicating with I2C legacy devices" table in the MIPI I3C v1.1.1 specification available on www.mipi.org.

45.7 I3C register descriptions

Writing to a read-only (RO) register, except to Controller Interrupt Mask (MINTMASKED), causes bus errors. This module does not verify whether programmed values in the registers are correct. You must ensure that valid programmed values are written.

However, the peripheral ignores writes to RO registers and returns 0 for reads from WO or nonexistent registers. It requires all 32-bit registers to be read and written as 32-bit and aligned to 32 bits. The peripheral uses the advanced peripheral bus (APB: AMBA 3 APB Protocol Specification v1.0); therefore, the peripheral does not know whether partial read or write operations (less than 32 bits) are used.

45.7.1 I3C memory map

I3C0 base address: 4003_5000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Controller Configuration (MCONFIG)	32	RW	0000_0000h
4h	Target Configuration (SCONFIG)	32	RW	0017_0000h
8h	Target Status (SSTATUS)	32	RW	0000_1400h
Ch	Target Control (SCTRL)	32	RW	0000_0000h
10h	Target Interrupt Set (SINTSET)	32	RW	0000_0000h
14h	Target Interrupt Clear (SINTCLR)	32	RW	See section
18h	Target Interrupt Mask (SINTMASKED)	32	R	0000_0000h
1Ch	Target Errors and Warnings (SERRWARN)	32	RW	0000_0000h
20h	Target DMA Control (SDMACTRL)	32	RW	0000_0010h
2Ch	Target Data Control (SDATACTRL)	32	RW	8000_0030h
30h	Target Write Data Byte (SWDATAB)	32	W	See section
34h	Target Write Data Byte End (SWDATABE)	32	W	See section
38h	Target Write Data Halfword (SWDATAH)	32	W	See section
3Ch	Target Write Data Halfword End (SWDATAHE)	32	W	See section
40h	Target Read Data Byte (SRDATAB)	32	R	0000_0000h
48h	Target Read Data Halfword (SRDATAH)	32	R	See section
54h	Target Write Data Byte (SWDATAB1)	32	W	0000_0000h
54h	Target Write Data Halfword (SWDATAH1)	32	W	0000_0000h
5Ch	Target Capabilities 2 (SCAPABILITIES2)	32	R	0000_0300h
60h	Target Capabilities (SCAPABILITIES)	32	R	E83F_FE70h
64h	Target Dynamic Address (SDYNADDR)	32	RW	0000_0000h
68h	Target Maximum Limits (SMAXLIMITS)	32	RW	0000_0000h
6Ch	Target ID Part Number (SIDPARTNO)	32	RW	3000_0000h
70h	Target ID Extension (SIDEXT)	32	RW	0066_EF00h
74h	Target Vendor ID (SVENDORID)	32	RW	0000_011Bh
78h	Target Time Control Clock (STCCLOCK)	32	RW	0000_3014h
7Ch	Target Message Map Address (SMSGMAPADDR)	32	R	0000_0000h
80h	Controller Extended Configuration (MCONFIG_EXT)	32	RW	0000_0000h
84h	Controller Control (MCTRL)	32	RW	0000_0000h
88h	Controller Status (MSTATUS)	32	RW	0000_1000h
8Ch	Controller In-band Interrupt Registry and Rules (MIBIRULES)	32	RW	0000_0000h
90h	Controller Interrupt Set (MINTSET)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
94h	Controller Interrupt Clear (MINTCLR)	32	RW	See section
98h	Controller Interrupt Mask (MINTMASKED)	32	R	0000_0000h
9Ch	Controller Errors and Warnings (MERRWARN)	32	RW	0000_0000h
A0h	Controller DMA Control (MDMACTRL)	32	RW	0000_0010h
ACh	Controller Data Control (MDATACTRL)	32	RW	8000_0030h
B0h	Controller Write Data Byte (MWDATAB)	32	W	See section
B4h	Controller Write Data Byte End (MWDATABE)	32	W	See section
B8h	Controller Write Data Halfword (MWDATAH)	32	W	See section
BCh	Controller Write Data Halfword End (MWDATAHE)	32	W	See section
C0h	Controller Read Data Byte (MRDATAB)	32	R	0000_0000h
C8h	Controller Read Data Halfword (MRDATAH)	32	R	0000_0000h
CCh	Controller Write Byte Data 1 (to Bus) (MWDATAB1)	32	W	0000_0000h
CCh	Controller Write Halfword Data (to Bus) (MWDATAH1)	32	W	0000_0000h
D0h	Controller Write Message Control in SDR mode (MWMSG_SDR_CONTROL)	32	W	See section
D0h	Controller Write Message Data in SDR mode (MWMSG_SDR_DATA)	32	W	0000_0000h
D4h	Controller Read Message in SDR mode (MRMSG_SDR)	32	R	0000_0000h
D8h	Controller Write Message in DDR mode: First Control Word (MWMSG_DDR_CONTROL)	32	W	See section
D8h	Controller Write Message in DDR Mode Control 2 (MWMSG_DDR_CONTROL2)	32	W	See section
D8h	Controller Write Message Data in DDR mode (MWMSG_DDR_DATA)	32	W	0000_0000h
DCh	Controller Read Message in DDR mode (MRMSG_DDR)	32	R	0000_0000h
E4h	Controller Dynamic Address (MDYNADDR)	32	RW	0000_0000h
11Ch	Map Feature Control 0 (SMAPCTRL0)	32	R	0000_0000h
140h	Extended IBI Data 1 (IBIEXT1)	32	RW	0000_0070h
144h	Extended IBI Data 2 (IBIEXT2)	32	RW	0000_0000h
FFCh	Target Module ID (SID)	32	R	EDCB_0100h

45.7.2 Controller Configuration (MCONFIG)

Offset

Register	Offset
MCONFIG	0h

Function

Controls all controller states when the controller operation is enabled. You must not change this register during an active transaction.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	I2CBAUD				SKEW			ODHPP	ODBAUD							
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	PPLOW				PPBAUD				Reserved	ODSTOP	HKEEP		DISTO	0	MSTENA	
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 I2CBAUD	I2C Baud Rate Specifies the I2C low and high times in ODBAUD counts. See I2CBAUD in Controller configuration.
27-25 SKEW	Skew Specifies the number of FCLK counts for an SDA change after SCL for I3C push-pull. This skew is in addition to the roundtrip of the SCL line from the pad back to the module (6 ns or more): • SKEW is normally not needed, so assign SKEW = 0. • SKEW is only used if SDA is not naturally skewing from an SCL change. • I2C automatically skews SDA (but not PUR) to match I2C rules. Use the following values: • In I2C Controller mode (MCONFIG[MSTENA] = 11b) — SKEW > 0 when clock stretching feature is not required. — SKEW = 0 when clock stretching feature is required. • In I3C Controller mode, use SKEW = 0.

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Field	Function
24 ODHPP	Open-drain High Push-Pull Enables ODHPP. If you write 0 to this field, open-drain SCL high half-clock period is the same as the open-drain low SCL half period. If you write 1 to this field, open-drain high SCL half-lock period is one PPBAUD count for I3C messages. This setting is faster and works for I3C devices. Any legacy I2C devices on the bus do not see the SCL high level at all (less than the spike filter period). For open-drain timing, check upon the first 7Eh broadcast allowing I3C peripherals acting as I2C legacy devices to turn off their I2C 50-ns spike filters. See Sending a CCC to I3C targets for more information. 0b - Disable 1b - Enable
23-16 ODBAUD	Open-drain Baud Rate Specifies the open-drain baud rate. ODBAUD is configured in terms of number of PPBAUD counts - 1. This field must not be 0; this setting is not the same as push-pull. See Controller configuration for more information. The open-drain baud rate is usually 200 ns (see I2CBAUD for I2C counts). When used with MCONFIG[ODHPP], this setting produces 250 ns per clock in I3C. In this case, if MCONFIG[PPBAUD] provides 12 MHz, then one PPBAUD count is half of 12 MHz, or 41.67 ns. To obtain a rate around 200 ns, use a value of 5 - 1 = 4 for ODBAUD.
15-12 PPLOW	Push-Pull Low Acts as an adder for push-pull low to create a duty cycle with a longer low period, with up to 15 more FCLK cycles low than high. PPLOW = 0 produces a 50/50 duty cycle.
11-8 PPBAUD	Push-Pull Baud Rate Specifies the push-pull baud rate. The number of FCLK counts makes each push-pull low and normally high period. PPBAUD = 0 when run at 1/2 input FCLK speed. For example, a 24 MHz FCLK produces a 12 MHz SCL because each FCLK is SCL low or SCL high. MCONFIG[PPLOW] has an effect on the duty cycle. For example, 24 MHz with 50/50 duty cycle is 12 MHz. However, when PPLOW adds three more low beats, the push-pull baud rate becomes 4.8 MHz (from 24 MHz or 5 beats).
7 —	Reserved
6 ODSTOP	Open-drain Stop Enables open-drain stop. If you write 0 to this field, open-drain stop is disabled. ODSTOP must be disabled when sending an HDR exit pattern. If you write 1 to this field, open-drain stop is enabled. STOP condition is emitted at open-drain speeds even for I3C messages. In legacy devices, this feature can ensure that the legacy devices see the STOP condition. 0b - Disable

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Field	Function
	1b - Enable
5-4 HKEEP	High-Keeper Indicates how High-Keeper is supported. If this field is 00b, use pull-up resistor (PUR). No separate pin_HK_SDA or pin_HK_SCL is used. Only pin_PUR_oena is used for SDA. The pin_SCL_oena pin is held high in this mode, SCL clock is push-pull, and pin_SCL_out toggles, which is the actual clock. If this field is 01b, High-Keeper controls are in place; pin_HK_SDA or pin_HK_SCL (High-Keeper) controls are used. SCL may use an HK or that signal (pin_HK_SCL) may only OR into pin_SCL_oena. The pin_HK_SDA pin is used as well for SDA high keeper, along with pin_PUR_oena. Use HKEEP = 10b or 11b for I2C modes. Use HKEEP = 00b or 01b for I3C modes. **NOTE** Your chip may not support any or all High-Keeper methods. You must check the availability of High-Keeper methods. 00b - None 01b - WIRED_IN 10b - PASSIVE_SDA (I2C mode, no clock stretches mode). SDA is open drain, and will be Hi-Z (high-impedance) for Bus Free (IDLE) and hold. The pin pin_HK_SDA is not used in this option, only a combination of SDA_oena and pin_PUR_oena are used. SCL is push-pull. The pin pin_HK_SCL is not used in this option, only pin_SCL_oena is used. Since the controller does not support multi-controller mode, there is no need to have open-drain SCL for I2C. For a single controller application, the controller's SCL output can be a push-pull driver design if there are no devices on the bus which would stretch the clock. 11b - PASSIVE_ON_SDA_SCL. For I2C clock stretching mode, where both SCL and SDA are open-drain. Open-Drain on both SDA and SCL, can Hi-Z (high-impedance) both for Bus Free (IDLE), and can Hi-Z SDA for hold. Does not support multi-controller mode, SCL open-drain is only to support clock stretching.
3 DISTO	Disable Timeout Disables the timeout that produces application errors. If the controller is left in a state other than Stopped for more than 100 µs (because 10 kHz is the slowest allowed I3C speed), the timeout sends a MERRWARN interrupt. To prevent the MERRWARN interrupt during development or testing, write 1 to DISTO to disable the timeout. In systems that support timeouts, timeout is disabled automatically during debug. To obtain a clock configuration with 100 µs timeout, see SCONFIG[BAMATCH]. 0b - Enabled 1b - Disabled
2	Reserved

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Field	Function
—	
1-0 MSTENA	Controller Enable Indicates whether the controller is enabled and the states it can use. If this field is 0b, the controller is disabled. The module can only use Target mode. If this field is 1b, the controller is enabled. When used upon start-up, this module is the main controller by default. I3C controls the bus unless the controller is handed off. When this happens, MSTENA must become 2 so that it has the capability to become the controller again. Performing the handoff means emitting the GETACCMST CCC command. If the command is accepted, I3C emits a STOP condition and sets this field to 2 (or 0). If this field is 10b, I3C is controller-capable, but is operating as a target now. When used from the start, I3C starts as a target, but is prepared to switch to Controller mode. To switch to this mode, the target emits a controller request (CR) or receives a GETACCMST CCC command and accepts it (to switch on the STOP condition). Legacy I2C—if this field is 11b, I2C Controller mode uses an open-drain clock (to allow clock stretching) and relies on passive pull-up resistors (PURs) on both SCL and SDA. This mode uses only I2CBAUD. START requests can only be made for I2C type, and I3C requests are not accepted. If there are only I2C targets on the bus and no clock stretching, use type 1 instead. Type 1 has a push-pull SCL clock, which is faster and uses less power. 00b - CONTROLLER_OFF 01b - CONTROLLER_ON 10b - CONTROLLER_CAPABLE 11b - I2C_CONTROLLER_MODE

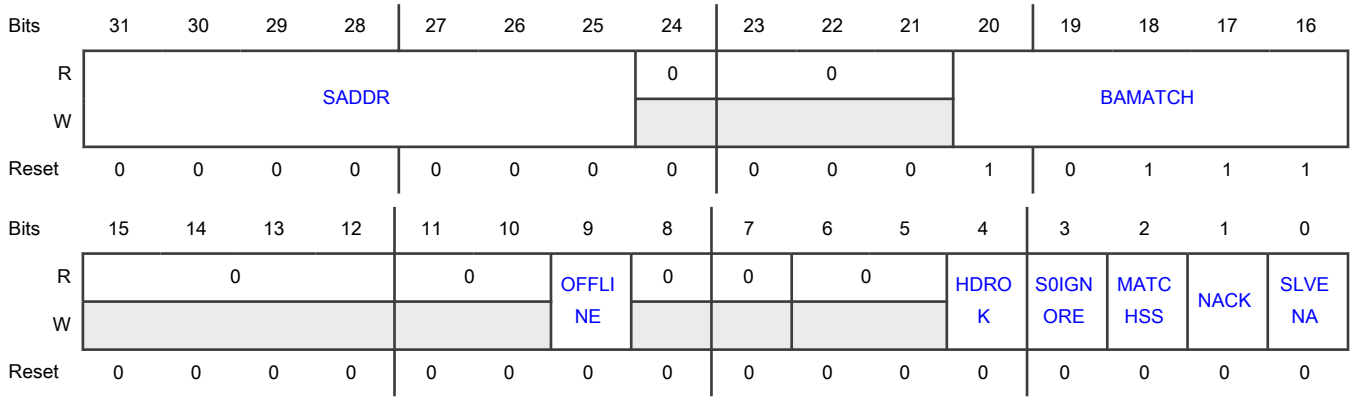
45.7.3 Target Configuration (SCONFIG)

Offset

Register	Offset
SCONFIG	4h

Function
Contains fields that must be configured before the module is activated.

Diagram



Fields

Field	Function
31-25 SADDR	Static Address Sets the I2C 7-bit static address, which otherwise must be 0.
24 —	Reserved
23-21 —	Reserved
20-16 BAMATCH	Bus Available Match Specifies the bus available condition match value for the current slow clock. BAMATCH provides the count of the slow clock to count out 1 µs (or more). The BAMATCH should be set as (slowClk(MHz) - 1) to generate a 1 µs clock cycle. Use BAMATCH = 1 to generate 1 µs clock cycle if slow clock is 1 MHz. A value of 0 would not give a correct match indication. The default value applies to the default slow clock setting of the chip. If the I3C slow clock is updated to a new value, BAMATCH must be updated, too. When I3C operates in Controller mode, BAMATCH is used to generate a 1 µs clock cycle basic time to count 100 µs timeout. When I3C operates in Target mode, BAMATCH allows the IBI to drive SDA low when the controller is not doing so.
15-12 —	Reserved
11-10 —	Reserved
9	Offline

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Field	Function
OFFLINE	Enables wait to ensure that the bus is not in HDR mode. If this field is 1 when SCONFIG[SLVENA] is 1, then I3C waits for either 60 µs of bus quiet or an HDR exit pattern. This waiting ensures that the bus is not in HDR mode, and so can safely monitor the next activity in Single Data Rate (SDR) mode. 0b - Disable 1b - Enable
8 —	Reserved
7 —	Reserved
6-5 —	Reserved
4 HDROK	HDR OK Enables HDR OK. If you write 1 to this field, it allows HDR-DDR and/or HDR-BT messaging, if available, by writing 1 to the corresponding SIDEXT[BCR] field to indicate HDR is available, and the corresponding GETCAPS field for DDR and/or BT bit permitting use. This is a deprecated field; use the SIDEXT[BCR] field instead. 0b - Disable HDR OK 1b - Enable HDR OK
3 S0IGNORE	Ignore TE0 or TE1 Errors Ignores TE0 or TE1 errors. If you write 1 to this field, the target does not detect TE0 or TE1 errors, so it does not lock up waiting on an exit pattern. You must not use this setting when the bus does not use HDR mode. 0b - Do not ignore TE0 or TE1 errors 1b - Ignore TE0 or TE1 errors
2 MATCHSS	Match Start or Stop Enables matched START, that is Repeated START, or STOP condition. If you write 1 to this field, SINTSET[START] and SINTSET[STOP] become 1 only when SSTATUS[MATCHED] is 1. This setting allows the START and STOP fields to be used to detect the end of a message to or from this target. **NOTE** SSTATUS[START] does not assert for START of transaction if SCONFIG[MATCHSS] = 1. SSTATUS[START] only asserts for Repeated Start within that transaction, because SSTATUS[START] only asserts after SSTATUS[MATCHED] occurs, which is after START of transaction.

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Field	Function
	0b - Disable 1b - Enable
1 NACK	Not Acknowledge Controls the ACK or NACK capability. If you write 1 to this field, the target rejects all requests, except for a CCC broadcast. NACK = 1 must be used with caution because the controller may decide that the target is missing, if NACK is overused. 0b - Always disable NACK mode 1b - Always enable NACK mode (works normally)
0 SLVENA	Target Enable Enables the target. If you write 0 to this field, the target ignores the I2C or I3C bus. If you write 1 to this field, the target can operate on the I2C or I3C bus. You must not write 1 to this field before registers such as Target Configuration (SCONFIG), Target ID Part Number (SIDPARTNO), Target ID Extension (SIDEXT), and others are configured because these registers affect the data to and from the controller. Target enable is configured just once before the bus comes up. If target enable is used at other times, SCAPABILITIES[IBI_MR_HJ] must be 1 before writing 1 to SLVENA so that the device does not see a START or STOP condition incorrectly. 0b - Disable 1b - Enable

45.7.4 Target Status (SSTATUS)

Offset

Register	Offset
SSTATUS	8h

Function

Indicates the sticky status for interrupts, states, and modes related to the I3C bus. Not all fields of the register are used if the module only acts as a target. The fields are divided into current activity, interrupt maskable actions, and then states and modes on the bus.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	TIMECTRL		ACTSTATE		HJDIS	0	MRDIS	IBIDIS	0		EVDET		0	EVENT	CHANDLED	HDRMATCH
W														W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	ERRWARN	CCC	DACHG	TXNOTFU...	RX_PEND	STOP	MATCHED	START	0	STHDR	STDAA	STREQWR	STREQRD	STCCCH	STMSG	STNOTST...
W		W1C	W1C			W1C	W1C	W1C								
Reset	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 TIMECTRL	Time Control Indicates whether time control is enabled, and in which mode. 00b - NO_TIME_CONTROL (no time control is enabled) 01b - SYNC_MODE (Synchronous mode is enabled) 10b - ASYNC_MODE (Asynchronous standard mode (0 or 1) is enabled) 11b - BOTHSYNCASYNC (both Synchronous and Asynchronous modes are enabled)
29-28 ACTSTATE	Activity State from Common Command Codes (CCC) Indicates the activity state from CCC. 00b - NO_LATENCY (normal bus operations) 01b - LATENCY_1MS (1 ms of latency) 10b - LATENCY_100MS (100 ms of latency) 11b - LATENCY_10S (10 seconds of latency)
27 HJDIS	Hot-Join Disabled Indicates whether hot-join is disabled. When hot-join is disabled, CTRL requests are not responded to. 0b - Enabled 1b - Disabled
26 —	Reserved
25 MRDIS	Controller Requests Disable Indicates whether controller requests are disabled. When controller requests are disabled, CTRL requests are not responded to.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Enabled 1b - Disabled
24 IBIDIS	In-Band Interrupts Disable Indicates whether in-band interrupts are disabled. When in-band interrupts are disabled, CTRL requests are not responded to. 0b - Enabled 1b - Disabled
23-22 —	Reserved
21-20 EVDET	Event Details Indicates current details of the last (EVENT = 1) or pending event. 00b - NONE (no event or no pending event) 01b - NO_REQUEST (request is not sent yet; either there is no START condition yet, or is waiting for Bus-Available or Bus-Idle (HJ)) 10b - NACKed (not acknowledged, request sent and rejected); I3C tries again 11b - ACKed (acknowledged; request sent and accepted), so done (unless the time control data is still being sent)
19 —	Reserved
18 EVENT	Event Flag Indicates, for a target, whether a pending in-band interrupt (IBI), controller request (CR), or hot-join (HJ) has been sent as requested. See the upper status register fields for details. This field becomes 1 only when acknowledged by a controller. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No event occurred 1b - IBI, CR, or HJ occurred When writing 0b - No effect 1b - Clear the flag
17 CHANDLED	Common Command Code Handled Flag

Table continues on the next page...

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Field	Function
	Indicates whether an HDRMATCH CCC is being handled by I3C. This field is for notification only, but it may result in updates to this register. **NOTE** This field behaves differently for register reads and writes. When reading 0b - CCC handling not in progress 1b - CCC handling in progress When writing 0b - No effect 1b - Clear the flag
16 HDRMATCH	High Data Rate Command Match Flag Indicates whether the HDR command matched the I3C dynamic address of this device. The HDR command is available as the first byte, with RXPEND = 1. The MSB of the command byte indicates whether it is a read or a write command. If the HDR command is a read, and there are to-bus bytes waiting, then the command is ACKed and the data is sent back. Otherwise, the HDR command is NACKed. **NOTE** When this field is 1, you must check SSTATUS[ERRWARN] because the HPAR error may occur after signaling this HDR command. The parity occurs after the destination address and command. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Did not match 1b - Matched the I3C dynamic address When writing 0b - No effect 1b - Clear the flag
15 ERRWARN	Error Warning Indicates that an error or warning has occurred, such as data underrun, data overrun, parity error, HDR-DDR CRC error, or other error or warning condition (see Target Errors and Warnings (SERRWARN) for more information).
14 CCC	Common Command Code Flag Indicates whether a CCC has been received, and is not handled by I3C. There are two types of common command codes: • Broadcast CCC, which corresponds with RXPEND, and the first byte is the CCC (command).

Table continues on the next page...

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Field	Function
	• Direct CCC, which may never be directed to this device. If the direct CCC is directed to this device, then TXSEND or RXPEND are triggered, and RXPEND contains the command. **NOTE** This field behaves differently for register reads and writes. When reading 0b - CCC not received 1b - CCC received When writing 0b - No effect 1b - Clear the flag
13 DACHG	Dynamic Address Change Flag Indicates an occurrence of dynamic address (DA) change. Actual DA can be seen in the DYNADDR register. If this field is 1, DA change is detected. The target DA has been assigned, reassigned, or reset (lost) and is now in the state of being valid or none. This field is also used when the MAP auto feature is configured, changing one or more MAP items. See DYNADDR and MAPCTRL*n* for more information. DYNAADDR for the main DA (0) indicates whether the last change was because of Auto-MAP. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No DA change detected 1b - DA change detected When writing 0b - No effect 1b - Clear the flag
12 TXNOTFULL	Transmit Buffer Not Full Indicates that the transmit buffer is not full. If DMA is enabled for transmitting, then it is also signaled to provide more data. To-bus buffer or FIFO can accept more data to be transmitted. For all but external FIFOs, this process uses SDATACTRL[TXTRIG], which defaults to "not full". 0b - Transmit buffer full 1b - Transmit buffer not full
11 RX_PEND	Received Message Pending Indicates whether a received message is pending. The field indicates when a message from the controller that is not being handled by I3C (not a CCC message) is received. I3C processes such messages internally. For all but external FIFOs, this process uses SDATACTRL[RXTRIG], which

Table continues on the next page...

Table continued from the previous page...

Field	Function
	defaults to "not empty". If DMA is enabled for receiving, then DMA is signaled as well. This field automatically becomes 0 if data is read (from FIFO and non-FIFO sources). 0b - No received message pending 1b - Received message pending
10 STOP	Stop Flag Indicates whether the Stopped state is detected. The STNOTSTOP state also indicates when the module is in Stop mode. A fast STOP and START combination may not trigger the Stop status. In that case, the Start status is always set. If this field is 1, it indicates that the Stop state was present on the bus since the bus was last cleared. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No Stopped state detected 1b - Stopped state detected When writing 0b - No effect 1b - Clear the flag
9 MATCHED	Matched Flag Indicates whether an incoming header matched the I3C dynamic or I2C static address (if any) of this device since the bus was last cleared. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Header not matched 1b - Header matched When writing 0b - No effect 1b - Clear the flag
8 START	Start Flag Indicates whether a START or Repeated START was detected after this flag was last cleared. This flag is not usually needed, but can be used for wake events.

Table continues on the next page...

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Field	Function
	NOTE This field behaves differently for register reads and writes. When reading 0b - Not detected 1b - Detected When writing 0b - No effect 1b - Clear the flag
7 —	Reserved
6 STHDR	Status High Data Rate Indicates whether the I3C bus is in HDR-DDR mode, regardless of whether HDR mode is supported by this module, and regardless of whether the message is intended for this module or some other module. 0b - I3C bus not in HDR-DDR mode 1b - I3C bus in HDR-DDR mode
5 STDAA	Status Dynamic Address Assignment Indicates whether the I3C bus is in Enter Dynamic Address Assignment (ENTDAA) mode, regardless of whether this bus target has a dynamic address. 0b - Not in ENTDAA mode 1b - In ENTDAA mode
4 STREQWR	Status Request Write Indicates whether the REQ in process is SDR write data from the controller to this bus target (or all targets), but not in ENTDAA mode. See status high data rate (STHDR) for double data rate (DDR) handling. 0b - Not an SDR write 1b - SDR write data from the controller, but not in ENTDAA mode
3 STREQRD	Status Request Read Indicates whether the REQ in process is an SDR read from this target. See status high data rate (STHDR) for double data rate (DDR) handling. 0b - Not an SDR read 1b - SDR read from this target or an IBI is being pushed out
2	Status Common Command Code Handler

Table continues on the next page...

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Field	Function
STCCCH	Indicates whether a CCC message is being handled automatically. 0b - No CCC message handled 1b - Handled automatically
1 STMSG	Status Message Indicates whether the bus target is busy (listening to the bus traffic or responding). If STNOSTOP = 1, STMSG is 0 when a nonmatching address is seen, until the next Repeated START or STOP condition occurs. 0b - Idle 1b - Busy
0 STNOTSTOP	Status not Stop Indicates the status of the bus. If this field is 0, I3C is in a STOP condition. If this field is 1, the bus is busy (has activity). Other fields of this register may also be set when busy. STNOTSTOP can also become 1 after a TE0 or TE1 error, when I3C is waiting for an exit pattern. 0b - In STOP condition 1b - Busy

45.7.5 Target Control (SCTRL)

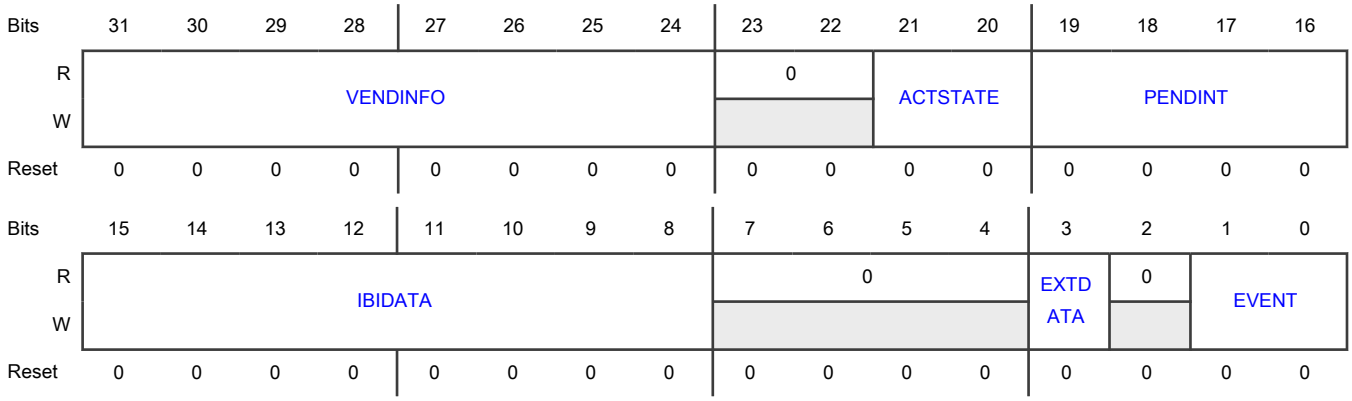
Offset

Register	Offset
SCTRL	Ch

Function

Contains controls for the active use of the I3C bus (for example, event generation such as interrupts to the controller). Only if I3C is configured to support various special operations for the target, this register is used to activate those operations. These events include IBI and GETSTATUS fields (except the protocol error, which is automatically set).

Diagram



Fields

Field	Function
31-24 VENDINFO	Vendor Information Controls vendor information that the GETSTATUS CCC returns. You must set this field to the Vendor Reserved field that the GETSTATUS CCC returns. The application must maintain the vendor information because the controller reads this field. If this field is not configured, then the GETSTATUS field always returns 0.
23-22 —	Reserved
21-20 ACTSTATE	Activity State of Target Controls the activity state of the target. You must set this field to the activity state of the target that the GETSTATUS CCC command returns as activity mode. The application must maintain the activity state because the controller reads this field. If you do not configure the activity state, then the GETSTATUS command always returns 0.
19-16 PENDINT	Pending Interrupt Specifies whether an IBI interrupt is pending. You must set this field to the pending interrupt that the GETSTATUS CCC command returns. The application must maintain the pending interrupt because the controller reads this field. If PENDINT = 0: • The GETSTATUS command returns 1 if an IBI interrupt is pending. • The GETSTATUS field returns 0 if an IBI interrupt is not pending.
15-8 IBIDATA	In-Band Interrupt Data Controls the data byte accompanying the IBI, if the module is enabled for IBI. If SCTRL[IBIDATA] is enabled, then IBI is required.
7-4 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
3 EXTDATA	Extended Data Enables extended data. After IBIDATA is emitted, extended data is acquired from IBIEXT1 and IBIEXT2, if configured. If extended data is used with time control, the data follows the time information. See IBIEXT1[MAX] for more information. 0b - Disable 1b - Enable
2 —	Reserved
1-0 EVENT	Event Requests an event. If this field is 0b, it indicates Normal mode, in which if this field becomes 0 from a nonzero value and event processing has not yet started, the event processing is canceled. However, event processing is not canceled if it has already started. If this field is 1b, an IBI is pushed onto the I3C bus. If there is data associated with the IBI, the data is read from SCTRL[IBIDATA]. If time control is enabled, this data includes any time-control-related bytes. Additionally, SCTRL[IBIDATA][7] becomes 1 automatically (as is required for time control). The IBI interrupt occurs after the first (mandatory) IBIDATA, if any. If this field is 10b, a controller request is started; the meaning depends on SIDEXT[BCR] configured in I3C. If this field is 11b, a hot-join (HJ) request is started, which is used when the device is powered on after the I3C bus is already powered up. It is also used when the device is connected using hot-insertion methods (the device is powered up when it is physically inserted in the powered-up I3C bus). The HJ waits for Bus Idle, and SCTRL[EVENT] = HOT_JOIN_REQUEST must be set before the target enable (SCONFIG[SLVENA]). If this field is a nonzero value, it requests an event. After the request, SSTATUS[EVENT] and SSTATUS[EVDET] show the status as it progresses. After completion, this field automatically returns to 0. After this field becomes a nonzero value, you can write only 0 it (to cancel) until the event processing is finished. 00b - NORMAL_MODE 01b - IBI 10b - CONTROLLER_REQUEST 11b - HOT_JOIN_REQUEST

45.7.6 Target Interrupt Set (SINTSET)

Offset

Register	Offset
SINTSET	10h

Function

Sets interrupt enables for select Target Status (SSTATUS) fields. Reading this register (SINTSET) returns the status of the interrupt enable:

- To activate an interrupt enable, write 1 to its corresponding field in this register (SINTSET).
- To disable an interrupt, write 1 to its corresponding field in Target Interrupt Clear (SINTCLR). Writing 0 to the interrupt enable in this register (SINTSET) does not disable the interrupt.

The Interrupt registers allow the masking of interrupt sources. They also allow the checking of which interrupts are activated. The normal method is to enable an interrupt, and then after the interrupt occurs, clear the interrupt either by writing to Target Status (SSTATUS) or by performing an action on the corresponding data register. The interrupt is level-held, meaning the interrupt stays set until the cause is cleared by some method. The module prevents races; if a new event occurs, that new event is not lost:

- SINTSET sets interrupt enables for Target Status (SSTATUS) fields. Reading the SINTSET register returns the status of the interrupt enables.
- SINTCLR clears interrupt enables for the SSTATUS fields.
- SINTMASKED returns the value of the SSTATUS fields ANDed with their interrupt enables.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0												0	EVENT	CHANDLED	DDRMATC...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	ERRWARN	CCC	DACHG	TXSEND	RXPEND	STOP	MATCHED	START	0							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-20 —	Reserved
19 —	Reserved
18 EVENT	Event Interrupt Enable Enables event interrupts. This field indicates, for a target, whether a pending in-band interrupt (IBI), controller request (CR), or hot-join (HJ) has been sent as requested. The field is configured to support events. See SSTATUS[EVDET] for more information.

Table continues on the next page...

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Field	Function
	0b - Disable 1b - Enable
17 CHANDLED	Common Command Code (CCC) Interrupt Enable Enables CCC interrupts. This field specifies whether CCC is being handled by I3C. Target Status (SSTATUS) shows new results. You can use this field to track when activity states and masks on events (for example, IBIs) occur. The field is used for CCCs that are enabled. 0b - Disable 1b - Enable
16 DDRMATCHED	Double Data Rate Interrupt Enable Enables DDR match for read or write command. This field indicates when DDR matches for read or write command, and the field is used only if HDR is enabled. 0b - Disable 1b - Enable
15 ERRWARN	Error or Warning Interrupt Enable Enables error or warning interrupts. This field indicates whether an error or warning has occurred, such as data underrun, data overrun, parity error, or HDR-DDR CRC error, or any other error or warning condition. See Target Errors and Warnings (SERRWARN) for cause of error. Only available for errors related to configured features. 0b - Disable 1b - Enable
14 CCC	Common Command Code (CCC) Interrupt Enable Enables CCC interrupts. This field indicates whether a CCC has been received, and is not handled by I3C. For CCCs that the block does not handle, RXPEND also interrupts, and SSTATUS[STREQRD] indicates that it is a CCC sending a read request. 0b - Disable 1b - Enable
13 DACHG	Dynamic Address Change Interrupt Enable Enables dynamic address change interrupts: interrupt on dynamic address defined (SETDASA or ENTDAA) or lost (RSTDAA). See Controller Dynamic Address (MDYNADDR) for more information.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Disable 1b - Enable
12 TXSEND	Transmit Interrupt Enable Enables transmit interrupts. This field indicates whether to-bus buffer or FIFO can accept more data to be transmitted. The corresponding interrupt occurs when the controller requests data to read from this target. This interrupt occurs on the first request (header) as well as when it is ready for more data. The corresponding interrupt occurs when the controller requests data to be read from this target. If this interrupt is for a FIFO, it triggers on the transmit emptiness trigger. If this interrupt is for DMA, then it indicates message end (DMA end or termination). 0b - Disable 1b - Enable
11 RXPEND	Receive Interrupt Enable Enables receive interrupts. This field specifies when a message from the controller that is not being handled by the module is received. For example, where data is consumed by hardware directly when it goes into the FIFO (excludes CCCs being handled automatically). If this interrupt is for a FIFO, it indicates a receive fullness trigger. If this interrupt is for DMA, then it indicates message end. 0b - Disable 1b - Enable
10 STOP	Stop Interrupt Enable Enables stop interrupts. This field detects the Stopped state present on the bus since the bus was last cleared. Use SINTSET[START] as the preferred interrupt when needed. This interrupt may not trigger for a quick STOP and START combination because it relates to the state of being stopped. 0b - Disable 1b - Enable
9 MATCHED	Match Interrupt Enable Enables match interrupts. Incoming header matched the I3C dynamic or I2C static address of this device since the bus was last cleared. If configured and if no dynamic address is set, this interrupt is also for matching a header on an I2C static address. See Controller Dynamic Address (MDYNADDR) for related information. 0b - Disable 1b - Enable
8	Start Interrupt Enable

Table continues on the next page...

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Field	Function
START	Enables start interrupts. A START or Repeated START (such as wakeup) is seen after this field last became 0. See SINTSET[STOP] for related information. 0b - Disable 1b - Enable
7-0 —	Reserved

45.7.7 Target Interrupt Clear (SINTCLR)

Offset

Register	Offset
SINTCLR	14h

Function

Clears interrupt enables for select Target Status (SSTATUS) fields. To clear an interrupt enable, write 1 to the corresponding field in this register (SINTCLR). Writing 0 has no effect.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0												0	EVENT	CHANDLED	DDRMATC...
W														W1C	W1C	W1C
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	ERRWARN	CCC	DACHG	TXSEND	RXPEND	STOP	MATCHED	START	0							
W	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C								
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Fields

Field	Function
31-20 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
19 —	Reserved
18 EVENT	EVENT Interrupt Enable Clear Flag
17 CHANDLED	CHANDLED Interrupt Enable Clear Flag
16 DDRMATCHED	DDRMATCHED Interrupt Enable Clear Flag
15 ERRWARN	ERRWARN Interrupt Enable Clear Flag
14 CCC	CCC Interrupt Enable Clear Flag
13 DACHG	DACHG Interrupt Enable Clear Flag
12 TXSEND	TXSEND Interrupt Enable Clear Flag
11 RXPEND	RXPEND Interrupt Enable Clear Flag
10 STOP	STOP Interrupt Enable Clear Flag
9 MATCHED	Matched Interrupt Enable Clear Flag
8 START	START Interrupt Enable Clear Flag
7-0 —	Reserved

45.7.8 Target Interrupt Mask (SINTMASKED)

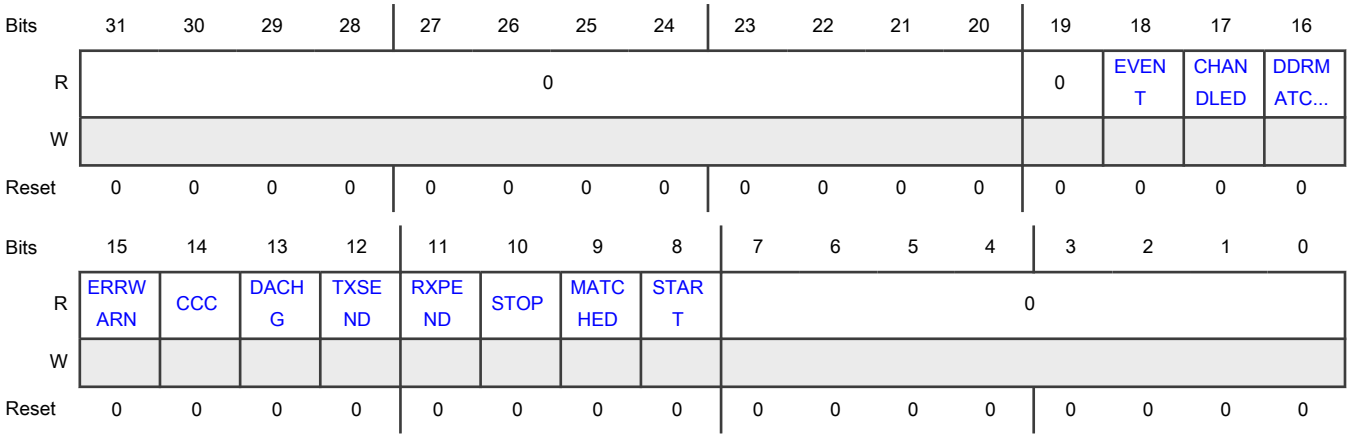
Offset

Register	Offset
SINTMASKED	18h

Function

Returns the status of enabled interrupts (the value of Target Status (SSTATUS) ANDed with the value of Target Interrupt Set (SINTSET)).

Diagram



Fields

Field	Function
31-20 —	Reserved
19 —	Reserved
18 EVENT	EVENT Interrupt Mask
17 CHANDLED	CHANDLED Interrupt Mask
16 DDRMATCHED	DDRMATCHED Interrupt Mask
15	ERRWARN Interrupt Mask

Table continues on the next page...

Table continued from the previous page...

Field	Function
ERRWARN	
14 CCC	CCC Interrupt Mask
13 DACHG	DACHG Interrupt Mask
12 TXSEND	TXSEND Interrupt Mask
11 RXPEND	RXPEND Interrupt Mask
10 STOP	STOP Interrupt Mask
9 MATCHED	MATCHED Interrupt Mask
8 START	START Interrupt Mask
7-0 —	Reserved

45.7.9 Target Errors and Warnings (SERRWARN)

Offset

Register	Offset
SERRWARN	1Ch

Function

Contains errors and warnings from I3C and I2C protocols. This includes internal issues such as overrun and underrun, detected errors and conditions like parity errors, CRC errors, and read terminations by the controller. See SSTATUS[ERRWARN] and SINTSET[ERRWARN] for related information.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0										0		0		OWRITE	OREAD
W															W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		0	0	S0S1	HCRC	HPAR	SPAR	0			INVSTART	TERM	URUNNACK	URUN	ORUN
W					W1C	W1C	W1C	W1C				W1C	W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-22 —	Reserved
21 —	Reserved
20-18 —	Reserved
17 OWRITE	Over-Write Error Flag Indicates that Target Write Data Byte (SWDATAB) or Target Write Data Byte End (SWDATABE) was written to when full. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No overwrite error 1b - Overwrite error When writing 0b - No effect 1b - Clear the flag
16 OREAD	Over-Read Error Flag Indicates that Target Read Data Byte (SRDATAB) was read for more bytes than were available, by the application. This field also indicates over-read errors for Target Read Data Halfword (SRDATAH), if it is enabled.

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Field	Function
	NOTE This field behaves differently for register reads and writes. When reading 0b - No over-read error 1b - Over-read error When writing 0b - No effect 1b - Clear the flag
15-14 —	Reserved
13 —	Reserved
12 —	Reserved
11 S0S1	TE0 or TE1 Error Flag Indicates whether a TE0 or TE1 error occurred and the target is locked and waiting for an HDR exit pattern. Writing 1 to S0S1 causes I3C to release the lock, but this method must be used with great care. S0S1 becomes 0 automatically when an exit pattern is detected, so writing 1 to S0S1 must be used under controlled circumstances to avoid problems. Before starting to operate normally after this error, I3C waits for a START (or Repeated START) or STOP state. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No TE0 or TE1 error occurred 1b - TE0 or TE1 error occurred When writing 0b - No effect 1b - Clear the flag
10 HCRC	HDR-DDR CRC Error Flag Indicates whether an HDR-DDR CRC error occurred on a message from the controller. Error reasons include an HDR restart and an exit being issued before an HDR-DDR message from the controller has finished. This error calls into question the data from the entire DDR command frame.

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Field	Function
	NOTE This field behaves differently for register reads and writes. When reading 0b - No HDR-DDR CRC error occurred 1b - HDR-DDR CRC error occurred When writing 0b - No effect 1b - Clear the flag
9 HPAR	HDR Parity Error Flag Indicates when an HDR parity error or framing error on a message from the controller occurs. The corresponding command or data that has the error is usually in the RX buffer, which can be read using Target Read Data Byte (SRDATAB). **NOTE** This field behaves differently for register reads and writes. When reading 0b - No HDR parity error 1b - HDR parity error When writing 0b - No effect 1b - Clear the flag
8 SPAR	SDR Parity Error Flag Indicates when an SDR parity error on a message from the controller occurs. This error also sets the GETSTATUS protocol error field (which becomes 0 after a GETSTATUS read). For read operations, this field becomes 1 when a read abort (timeout) occurs because of the controller not driving clock for more than 100 µs during an SDR read. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No SDR parity error 1b - SDR parity error When writing 0b - No effect 1b - Clear the flag

Table continues on the next page...

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Field	Function
7-5 —	Reserved
4 INVSTART	Invalid Start Error Flag Indicates an invalid condition with SCL falling before SDA falls, so there is no start. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No invalid start error 1b - Invalid start error When writing 0b - No effect 1b - Clear the flag
3 TERM	Terminated Error Flag Indicates when the controller terminates a read from a target, if an END is not set by the target (on the same read or the previous read). **NOTE** This field behaves differently for register reads and writes. When reading 0b - No terminated error 1b - Terminated error When writing 0b - No effect 1b - Clear the flag
2 URUNNACK	Underrun and Not Acknowledged (NACKed) Error Flag Indicates when the internal to-bus buffer or FIFO is underrun in the read header and so the module NACKed the header. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No underrun; not acknowledged error 1b - Underrun; not acknowledged error When writing

Table continues on the next page...

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Field	Function
	0b - No effect 1b - Clear the flag
1 URUN	Underrun Error Flag Indicates when the internal to-bus buffer or FIFO is underrun during data read (the application is not providing the data fast enough). The END field or register must be used if the read was the last one. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No underrun error 1b - Underrun error When writing 0b - No effect 1b - Clear the flag
0 ORUN	Overrun Error Flag Indicates when the internal from-bus buffer or FIFO has overrun (arrival of too many characters that you cannot process fast enough). **NOTE** This field behaves differently for register reads and writes. When reading 0b - No overrun error 1b - Overrun error When writing 0b - No effect 1b - Clear the flag

45.7.10 Target DMA Control (SDMACTRL)

Offset

Register	Offset
SDMACTRL	20h

Function

Allows DMA to be used for inbound and outbound messages. This register is limited in value for target use because the target must be reactive. These are the two common use case models:

- To avoid an overrun in from-bus collection: if SCONFIG[MATCHSS] becomes 1, then the processor enables the interrupts for START and STOP and enables the DMA to collect the data. The START or STOP interrupt only occurs after a message is directed to the target (MATCHED is 1). The DMA copied data can then be examined.
- To perform larger reads from the to-bus: I3C and I2C reads are preceded by a write that indicates what will be read (or in response to an IBI from the target). Because of this process, the DMA can be used to push through the data:
  - For I3C, the processor must manage the last value, unless the DMA moves wider words and is able to write 1 to the END field. These values are 16-bit values when in Byte mode or 32-bit values when in Halfword mode.
  - For I2C, the controller determines the last value, so the DMA may end early or run out when the controller expects more values.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								0		DMAWIDTH		DMATB		DMAFB	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Fields

Field	Function
31-8 —	Reserved
7-6 —	Reserved
5-4 DMAWIDTH	Width of DMA Operations Indicates the width of DMA operations, if configured to allow halfword data accesses. 00b,01b - Byte 10b - Halfword (16 bits) (this value ensures that two bytes are available in the FIFO) 11b - Reserved
3-2 DMATB	DMA Write (To-Bus) Trigger Enables DMA writes. If this field is enabled, it starts a request DMA on a transmit trigger (see Target Data Control (SDATACTRL)). DMATB requests until full, unless the DMA is set up as a trigger. DMATB becomes 0 when MSTATUS[ERRWARN] becomes 1.

Table continues on the next page...

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Field	Function
	If you write 1b to this field, DMA is enabled for one frame (ended by DMA or terminated). DMATB automatically becomes 0 after a STOP or repeated START. See SCONFIG[MATCHSS] for more information. If you write 10b to this field, DMA is enabled until turned off. The value must only be used with Controller Message mode. 00b - DMA not used 01b - DMA enabled for one frame 10b - DMA enabled until turned off. Recommended mode, instead of 01b, to enable DMA. This setting provides better software control. 11b - Reserved
1-0 DMAFB	DMA Read (From-Bus) Trigger Enables DMA reads. If this field is enabled, DMAFB requests DMA on receive trigger (see SDATACTRL). It requests until empty, unless the DMA is set up as a trigger. This field becomes 0 when SSTATUS[ERRWARN] becomes 1. If this field is 1b (DMA is enabled for one frame), it automatically becomes 0 on STOP or repeated START. See SCONFIG[MATCHSS] for more information. **NOTE** Do not enable DMA after a transaction starts. It must be enabled only when enabling the target and interrupts to avoid any kind of RX FIFO overrun. 00b - DMA not used 01b - DMA enabled for one frame 10b - DMA enabled until turned off. Recommended mode, instead of 01b, to enable DMA. This setting provides better software control. 11b - Reserved

45.7.11 Target Data Control (SDATACTRL)

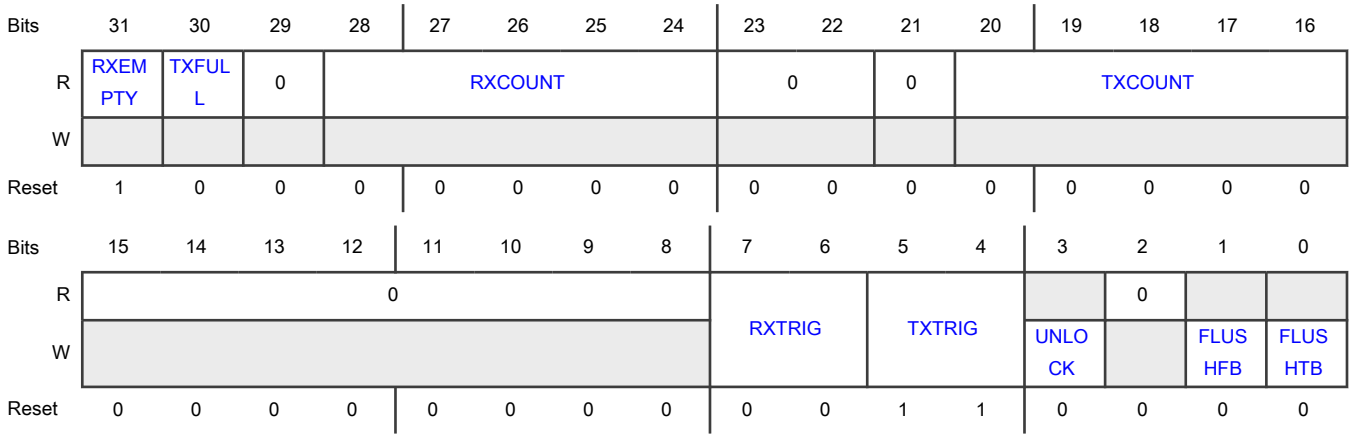
Offset

Register	Offset
SDATACTRL	2Ch

Function

Assists in data control when no FIFO is used. Also assists in data control of FIFO when the FIFO is available (regardless of size) allowing some control over the FIFO behavior. This register controls when to interrupt based on fullness or emptiness of a buffer or FIFO. It also controls behavior related to width, when the buffer or FIFO is not 1 byte wide.

Diagram



Fields

Field	Function
31 RXEMPTY	Receive is Empty Indicates whether the receive FIFO or buffer is empty. 0b - Not empty 1b - Empty
30 TXFULL	Transmit is Full Indicates whether the transmit FIFO or buffer is full. 0b - Not full 1b - Full
29 —	Reserved
28-24 RXCOUNT	Count of Entries in Receive Contains the count of entries in the receive FIFO or buffer. Entry size for SDR and HDR-DDR is in bytes.
23-22 —	Reserved
21 —	Reserved
20-16 TXCOUNT	Count of Entries in Transmit Contains the count of entries waiting in the TXFIFO. This count is the number of entries that the application has written to the transmit FIFO that have not yet gone onto the bus. Entry size for SDR and HDR-DDR is in bytes.

Table continues on the next page...

Table continued from the previous page...

Field	Function
15-8 —	Reserved
7-6 RXTRIG	Receive Trigger Level Indicates the trigger level for receive fullness when using a FIFO. The field affects the RXPEND interrupt. 00b - Trigger when not empty (default) 01b - Trigger when 1/4 or more full 10b - Trigger when 1/2 or more full 11b - Trigger when 3/4 or more full
5-4 TXTRIG	Transmit Trigger Level Indicates the trigger level for transmit emptiness when using a FIFO. The field affects the TXNOTFULL interrupt. 00b - Trigger when empty 01b - Trigger when 1/4 full or less 10b - Trigger when 1/2 full or less 11b - Default (trigger when 1 less than full or less)
3 UNLOCK	Unlock Indicates whether the RXTRIG and TXTRIG fields can be changed on a write. This field must be 1 in the same cycle while writing to TXTRIG or RXTRIG. 0b - Cannot be changed 1b - Can be changed
2 —	Reserved
1 FLUSHFB	Flush From-Bus Buffer or FIFO Not normally used. **NOTE** Before using FLUSHFB, disable the DMA (SDMACTRL[DMAFB] = 0). Then use FLUSHFB to flush the FIFO and then re-enable the DMA. 0b - No action 1b - Flush the buffer
0 FLUSHTB	Flush To-Bus Buffer or FIFO Indicates when the controller terminates a to-bus (read) message prematurely.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	NOTE Before using FLUSHTB, disable the DMA (SDMACTRL[DMATB] = 0). Then use FLUSHTB to flush the FIFO and then re-enable the DMA. 0b - No action 1b - Flush the buffer

45.7.12 Target Write Data Byte (SWDATAB)

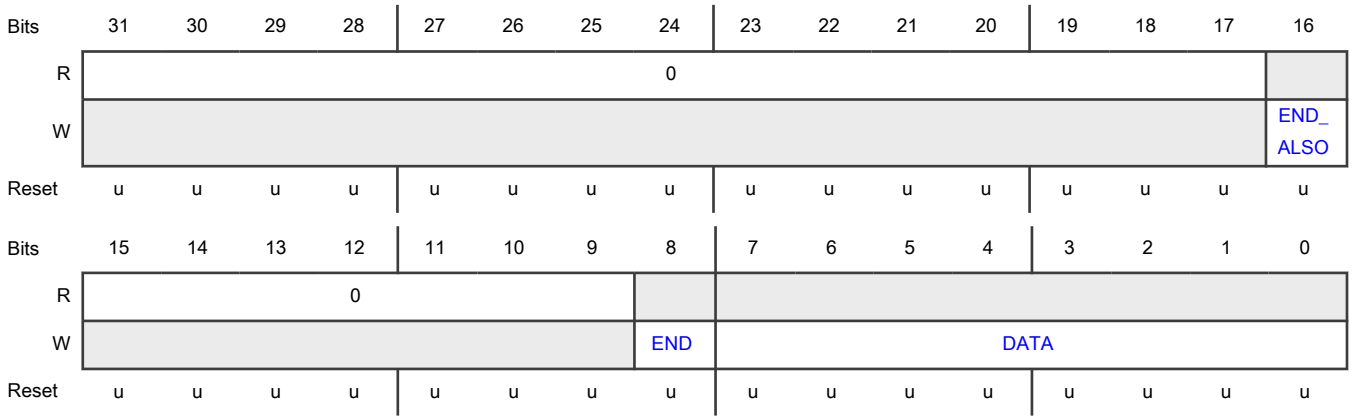
Offset

Register	Offset
SWDATAB	30h

Function

Allows writing a byte to the bus (to the controller) unless an external FIFO is used. Writing a byte requires a byte plus an end-of-data (last) marker bit. A byte must not be written unless there is room, indicated by SSTATUS[TXNOTFULL] = 1.

Diagram



Fields

Field	Function
31-17 —	Reserved
16 END_ALSO	End Also Marks the last byte of the message. This field is required for I3C, but is optional for I2C. If this field is 0, it indicates that there are more bytes in the message.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	For HDR-DDR, the byte with END_ALSO must be an even byte (second, fourth, sixth, and so on) because DDR uses byte pairs. 0b - Not the end 1b - End
15-9 —	Reserved
8 END	End Marks the last byte of the message. If this field is 0, it indicates that there are more bytes in the message. This field is required for I3C, but is optional for I2C. For HDR-DDR, the byte with END must be an even byte (second, fourth, sixth, and so on) because DDR uses byte pairs. 0b - Not the end 1b - End
7-0 DATA	Data Indicates the data byte to be sent to the controller.

45.7.13 Target Write Data Byte End (SWDATABE)

Offset

Register	Offset
SWDATABE	34h

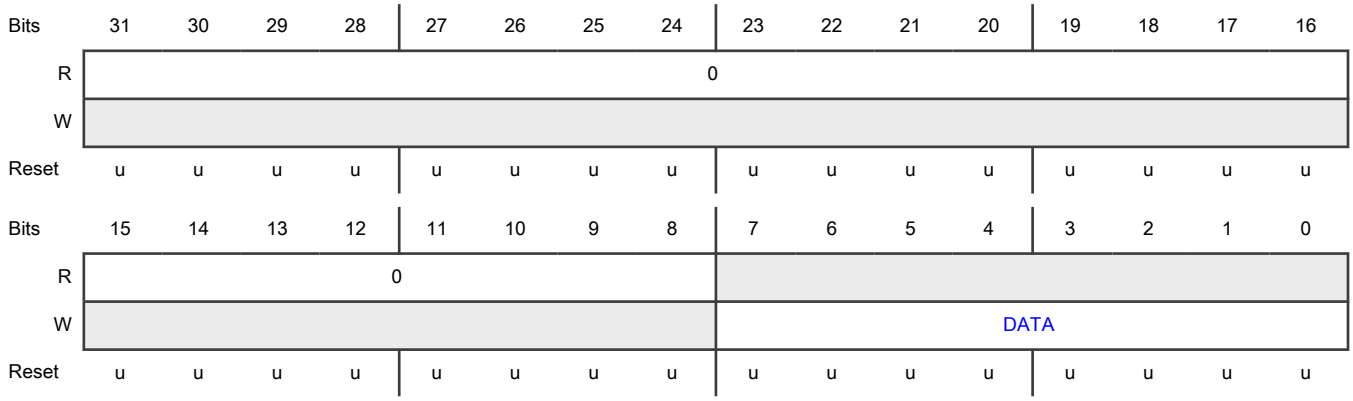
Function

Allows writing a byte to the bus (to the controller) unless an external FIFO is used.

Unlike Target Write Data Byte (SWDATAB), writing a byte only requires the byte itself, and is marked as end-of-data (last byte). A byte must not be written unless there is room, indicated by SSTATUS[TXNOTFULL] = 1.

For HDR-DDR, the byte with the END must be an even byte (second, fourth, sixth, and so on) because DDR uses byte pairs.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 DATA	Data Indicates the data byte to be sent to the controller.

45.7.14 Target Write Data Halfword (SWDATAH)

Offset

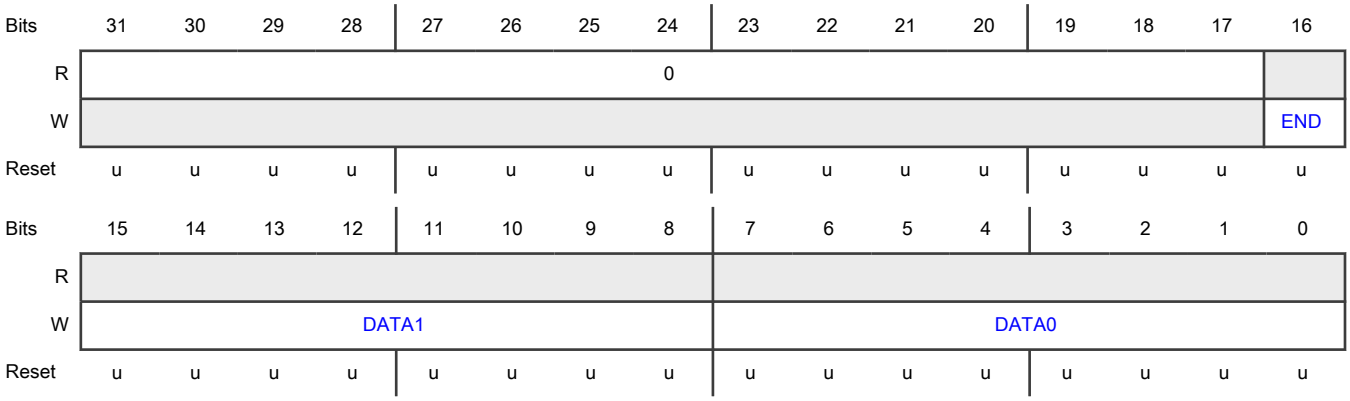
Register	Offset
SWDATAH	38h

Function

Allows writing a halfword (pair of bytes) to the bus unless an external FIFO is used. The low byte is followed by the high byte. The 16th bit marks the end; that is, the last byte of the halfword is the end.

An end-of-data (last) marker bit is allowed (or must be 0). A halfword must not be written unless there is room for both, as indicated by the use of transmit FIFO level trigger or SDATACTRL[TXCOUNT].

Diagram



Fields

Field	Function
31-17 —	Reserved
16 END	End of Message Marks the last byte of the message. This field always marks DATA1 as the end. The field is required for I3C, but is optional for I2C. If this field is 0, it indicates that there are more bytes in the message. For HDR-DDR, the byte with the END must be an even byte (second, fourth, sixth, and so on) because DDR uses byte pairs. 0b - Not the end 1b - End
15-8 DATA1	Data 1 Indicates the second byte to be sent to the controller.
7-0 DATA0	Data 0 Indicates the first byte to be sent to the controller.

45.7.15 Target Write Data Halfword End (SWDATAHE)

Offset

Register	Offset
SWDATAHE	3Ch

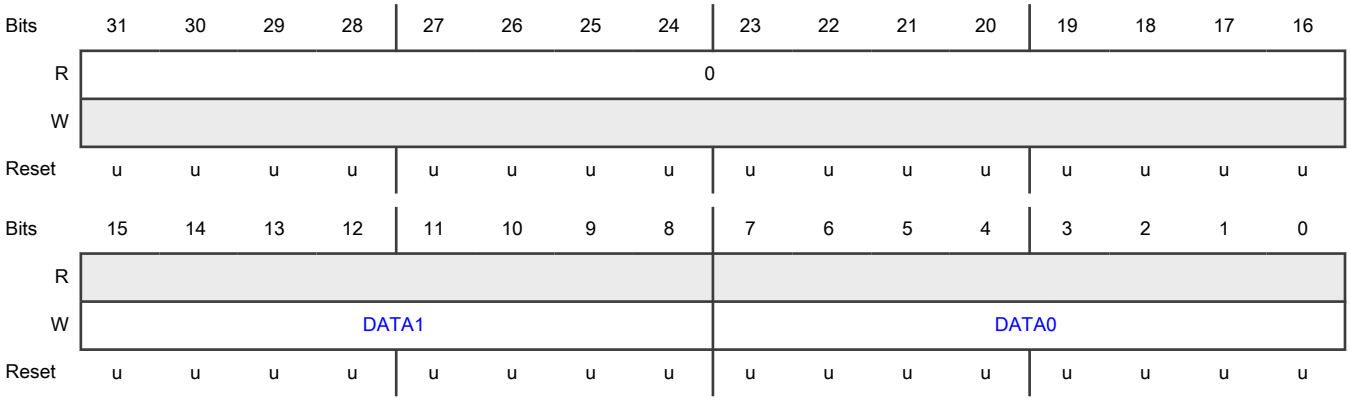
Function

Allows writing a halfword of data, which is the end (the last byte of the halfword is the end). The target writes the halfword (byte pair) in the same way it writes to Target Write Data Halfword (SWDATAH), but marks the second byte as end-of-data (last byte).

For HDR-DDR, the byte with the END must be even (second, fourth, sixth, and so on) because DDR uses byte pairs.

A halfword must not be written unless there is room for both, as indicated by the use of transmit FIFO level trigger or SDATACTRL[TXCOUNT].

Diagram



Fields

Field	Function
31-16 —	Reserved
15-8 DATA1	Data 1 Indicates the second byte to be sent to the controller.
7-0 DATA0	Data 0 Indicates the first byte to be sent to the controller.

45.7.16 Target Read Data Byte (SRDATAB)

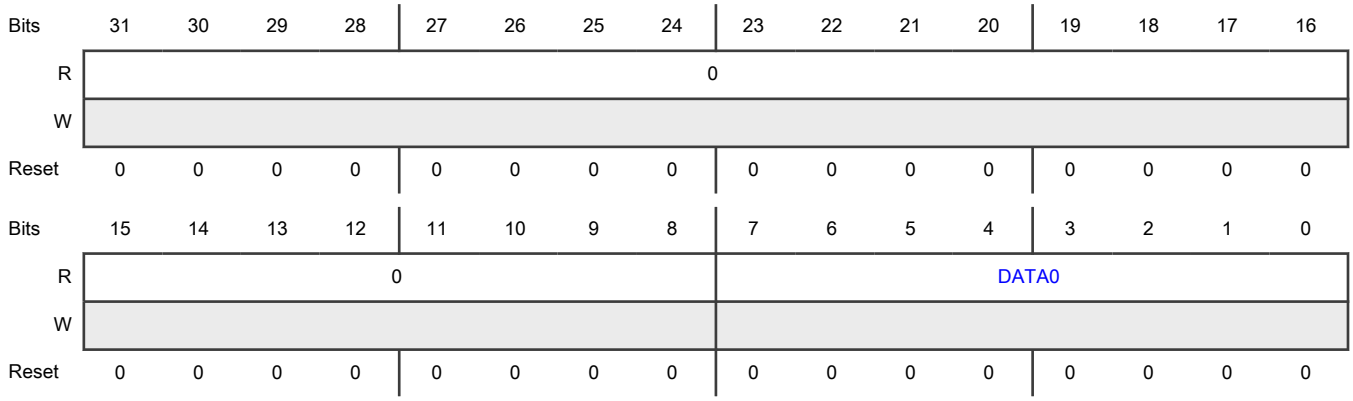
Offset

Register	Offset
SRDATAB	40h

Function

Allows reading a byte from the bus (controller). A byte must not be read unless there is data waiting, as indicated by SSTATUS[RX_PEND] = 1.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 DATA0	Data 0 Indicates the byte read from the controller.

45.7.17 Target Read Data Halfword (SRDATAH)

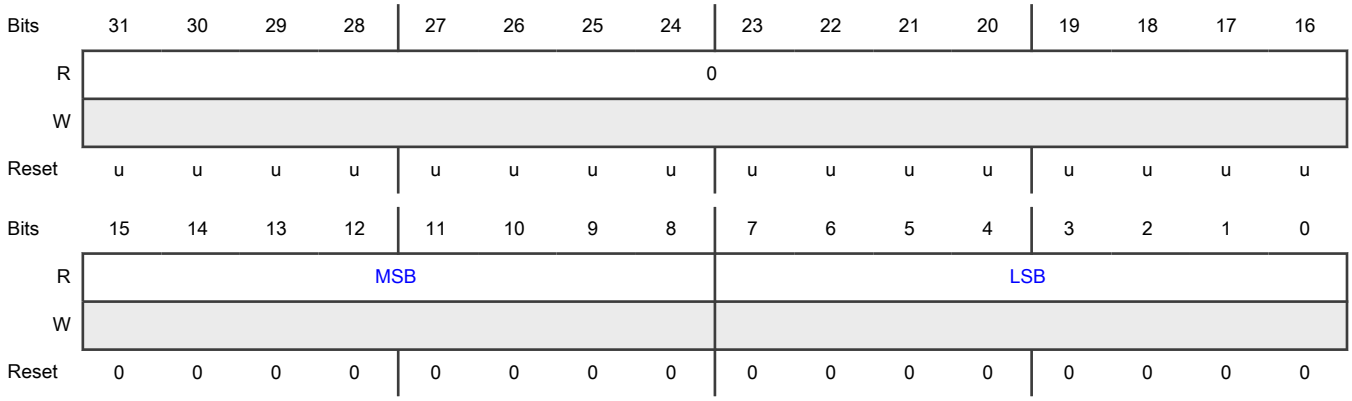
Offset

Register	Offset
SRDATAH	48h

Function

Allows reading a halfword (byte pair) written by the target after an SDR read or DAA or DDR. This register is used only when using Controller Control (MCTRL) to start the message. If MWMSG_SDR or MWMSG_DDR is used to start a message, that interface must be used exclusively. A halfword must not be read unless there are at least two bytes of data waiting, as indicated by the use of receive FIFO level trigger or SDATACTRL[RXCOUNT].

Diagram



Fields

Field	Function
31-16 —	Reserved
15-8 MSB	High Byte Indicates the second byte read from the target.
7-0 LSB	Low Byte Indicates the first byte read from the target.

45.7.18 Target Write Data Byte (SWDATAB1)

Offset

Register	Offset
SWDATAB1	54h

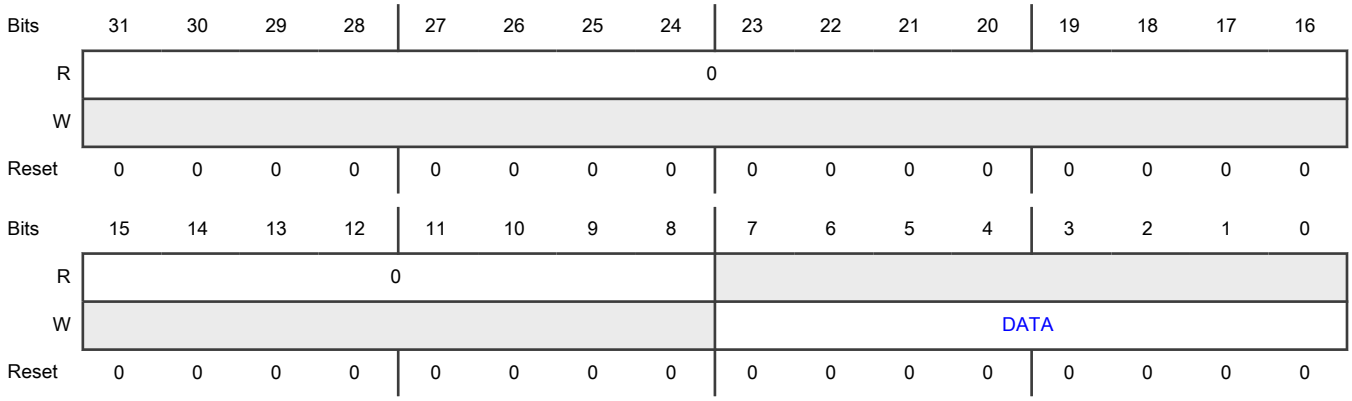
Function

Allows writing a single byte to the bus (to the controller) in a way that only bits 7:0 are used.

This register is intended to be used by DMAs (the upper bytes of the APB word are ignored).

A byte must not be written unless there is room, as indicated by SSTATUS[TXNOTFULL] = 1.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 DATA	Data Indicates the byte to be sent to the controller.

45.7.19 Target Write Data Halfword (SWDATAH1)

Offset

Register	Offset
SWDATAH1	54h

Function

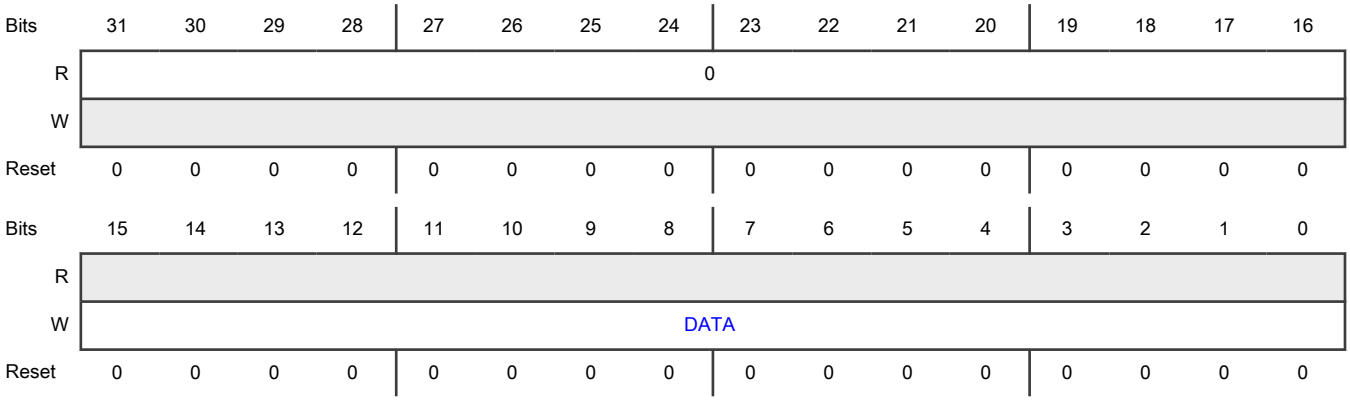
Shares the same address as Target Write Data Byte (SWDATAB1), and SDMACTRL[DMAWIDTH] determines which one is set.

This register allows writing a single-byte pair (halfword) to the bus (to the controller) in a way that only bits 15:0 are used.

This register is intended for use by DMAs, which do not format the upper part of the APB word.

A halfword must not be written unless there is room, as indicated by SSTATUS[TXNOTFULL] = 1.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 DATA	Data Indicates the byte pair (halfword) to be sent to the controller.

45.7.20 Target Capabilities 2 (SCAPABILITIES2)

Offset

Register	Offset
SCAPABILITIES2	5Ch

Function

Indicates which features are available and supported in this module, including controller and target capabilities, HDR modes, and others.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0								SSTWR	SSTSUB	AASA	0	GROUP		SLVRST	0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0						IBIXREG	IBIEXT	0	I2CDEVID	Reserved	I2C10B	MAPCNT			
W																
Reset	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 —	Reserved
23 SSTWR	Target-Target(s)-Tunnel Write Capable Indicates whether target-target(s)-tunnel is write capable. 0b - Not write capable 1b - Write capable
22 SSTSUB	Target-Target(s)-Tunnel Subscriber Capable Indicates whether target-target(s)-tunnel is subscriber capable. 0b - Not subscriber capable 1b - Subscriber capable
21 AASA	SETAASA Supports the set static address as dynamic address CCC (SETAASA) feature. 0b - SETAASA not supported 1b - SETAASA supported
20 —	Reserved
19-18 GROUP	Group Indicates whether v1.1 group addressing is supported. Groups use mapping, so MAPCNT must be the same or greater than GROUP. 00b - v1.1 group addressing not supported 01b - One group supported

Table continues on the next page...

Table continued from the previous page...

Field	Function
	10b - Two groups supported 11b - Three groups supported
17 SLVRST	Target Reset Indicates whether v1.1 target reset is supported. 0b - Not supported 1b - Supported
16 —	Reserved
15-10 —	Reserved
9 IBIXREG	In-Band Interrupt Extended Register Supports extended registers for IBIs. This field indicates whether Extended IBI Data 1 (IBIEXT1) is available. Extended IBI Data 2 (IBIEXT2) is available if IBIEXT1[MAX] > 3. 0b - Not supported 1b - Supported
8 IBIEXT	In-Band Interrupt EXTDATA Supports SCTRL[EXTDATA] to allow data beyond the mandatory data byte (MDB) for IBIs. 0b - Not supported 1b - Supported
7 —	Reserved
6 I2CDEVID	I2C Device ID Indicates whether I2C device ID is supported. 0b - Not supported 1b - Supported
5 —	Reserved
4 I2C10B	I2C 10-bit Address Supports 10-bit I2C address in MAP 1. If this field is 1, MAPCNT must be 1 or greater.

Table continues on the next page...

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Field	Function
	0b - Not supported 1b - Supported
3-0 MAPCNT	Map Count Indicates the number of maps that are allowed. If there is no mapping, this field is 0. (DYNADDR is used to add more static and/or dynamic addresses to act as virtual targets.)

45.7.21 Target Capabilities (SCAPABILITIES)

Offset

Register	Offset
SCAPABILITIES	60h

Function

Indicates which features are available and supported in this module, including controller and/or target capabilities, HDR modes, and others.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	DMA	INT	FIFORX		FIFOTX		EXTFIFO			0	TIMECTRL		IBI_MR_HJ			
W																
Reset	1	1	1	0	1	0	0	0	0	0	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	CCCHANDLE				SADDR		MASTER	0	HDRSUPP		IDREG				IDENA	
W																
Reset	1	1	1	1	1	1	1	0	0	1	1	1	0	0	0	0

Fields

Field	Function
31 DMA	Direct Memory Access Indicates whether DMA is supported. 0b - Not supported 1b - Supported

Table continues on the next page...

Table continued from the previous page...

Field	Function
30 INT	Interrupts Indicates whether interrupts are supported. 0b - Not supported 1b - Supported
29-28 FIFORX	FIFO Receive Indicates the size of receive (from-bus) FIFO. **NOTE** Controller and target use the same receive FIFO, so size is the same for the controller receive FIFO as well. FIFO size of SDR and HDR-DDR is in bytes. 00b - Two or three 01b - Four 10b - Eight 11b - 16 or larger
27-26 FIFOTX	FIFO Transmit Indicates the size of transmit (to-bus) FIFO. **NOTE** Controller and target use the same transmit FIFO, so size is the same for the controller transmit FIFO as well. FIFO size of SDR and HDR-DDR is in bytes. 00b - Two 01b - Four 10b - Eight 11b - 16 or larger
25-23 EXTFIFO	External FIFO Indicates whether external FIFOs are enabled. If they are not enabled, then check FIFOTX and FIFORX for the internal FIFO. 000b - No external FIFO available 001b - Standard available or free external FIFO 010b - Request track external FIFO All other values are reserved.
22 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
21 TIMECTRL	Time Control Specifies whether any time-control type is supported. 0b - No time control supported 1b - At least one time-control type supported
20-16 IBI_MR_HJ	In-Band Interrupts, Controller Requests, Hot-Join Events Indicates which events (IBI, CR, and HJ) are allowed. For example, if this field is 00011b, IBI (bit 0) and IBI_HAS_DATA (bit 1) functionality are both enabled. 0_0000b - Application cannot generate IBI, CR, or HJ 1_xxxxb - Application can use SCONFIG[BAMATCH] for bus-available timing x_1xxxb - Application can generate a Hot-Join event x_x1xxb - Application can generate a controller request for a secondary controller x_xx1xb - When bit 0 = 1, the IBI has data from the SCTRL register x_xxx1b - Application can generate an IBI
15-12 CCCHANDLE	Common Command Codes Handling Indicates what manages CCC between I3C and the application. 0000b - All handling features disabled 1xxxb - GETSTATUS CCC returns the value of SCTRL[VENDINFO] x1xxb - GETSTATUS CCC returns the values of SCTRL[PENDINT] and SCTRL[ACTSTATE] xx1xb - The I3C module manages maximum read and write lengths, and max data speed xxx1b - The I3C module manages events, activities, status, HDR, and if enabled for it, ID and static-address-related items
11-10 SADDR	Static Address Indicates how the static address is managed. 00b - No static address 01b - Static address is fixed in hardware 10b - Hardware controls the static address dynamically (for example, from the pin strap) 11b - SCONFIG register supplies the static address
9 MASTER	Controller Specifies whether controller capability is supported. 0b - Not supported 1b - Supported
8	Reserved

Table continues on the next page...

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Field	Function
—	
7-6 HDRSUPP	High Data Rate Support Indicates which HDR modes are supported. 00b - No HDR modes supported 01b - DDR mode supported All other values are reserved.
5-2 IDREG	ID Register Indicates which ID features are available in the configurable registers. 0000b - All ID register features disabled 1xxxb - A Bus Characteristics Register (BCR) is available x1xxb - A Device Characteristic Register (DCR) is available xx1xb - An ID Random field is available xxx1b - ID Instance is a register; used if there is no PARTNO register
1-0 IDENA	ID 48b Handler Indicates what handles the 48-bit ID value. 00b - Application 01b - Hardware 10b - Hardware, but the I3C module instance handles ID 48b 11b - A part number register (PARTNO)

45.7.22 Target Dynamic Address (SDYNADDR)

Offset

Register	Offset
SDYNADDR	64h

Function

Fills with the assigned address after the controller has assigned it via SETDASA or ENTDAA CCC commands. It clears if the RESETDAA CCC is used. The current validity state is also indicated through SSTATUS[DAVALID], which can be used to interrupt the processor. The DCAUSE field can be used to determine the changes, if enabled.

NOTE

If mapped addresses are enabled, you can access them through the SMAPCTRL*n* registers.

The first dynamic address (DA[0]) may be written irrespective of whether the mapping is enabled, if configured to allow writes used to restore the DA after a power-down (an ultra-low power state that loses power to peripherals but retains the DA somewhere else). This is not required if state-retention flops are used for the DA. This mechanism only allows writes when target is disabled

(and is ignored otherwise). If the controller uses RSTDAA or SETNEWDA, then it overrides this mechanism and yields to the controller-assigned DA. When enabling the target, SCONFIG[OFFLINE] must be 1. This waits for evidence that the bus is not in I3C HDR mode and exits when an HDR exit pattern is seen or when 60 µs has expired. This makes it safe to monitor START and STOP. If the application needs to do an IBI, then the application must either wait for a STOP (see STATUS) or make sure that 200 µs have gone by with no activity (no START or STOP) before the application emits the IBI.

The MAPIDX or MAPSA model allows writing additional DAs (and SAs) into a list (the number in the list is preconfigured); any DA or SA with DAVALID = 0 are never matched. The additional DAs may be based on the bridge target CCC or done by a move (read current DA and then copy into the upper map, and then invalidate the 0 map) when matching ENTDAA over and over. Any mapped location can be invalidated by writing MAPIDX and DAVALID = 0. The mapped ones are not reset by the RSTDA CCC (see Target Message Map Address (SMSGMAPADDR)).

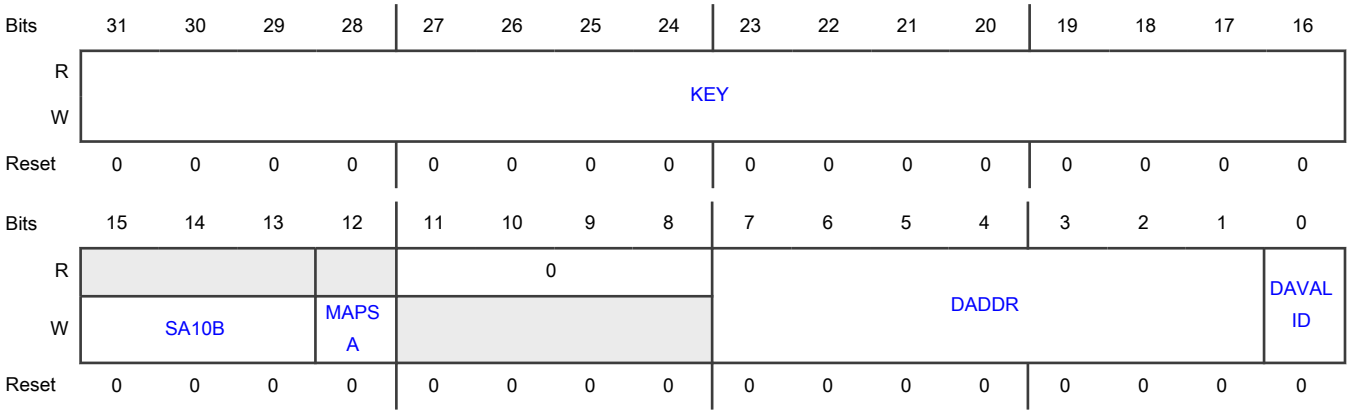
To copy the base DA to the mapped set, you must perform the configuration to allow it; otherwise it leads to distinct mechanisms:

- If used in I3C mode, a base DA is required, so the last one must not be cleared (or writing a dynamic address with DAVALID = 1 is necessary).

NACK/ACK of mapped DAs/SAs: The register also permits specific DAs (above the base) to NACK or ACK writes or reads, such as for bridges when the endpoint is busy. The NACK must not be set for too long, or the controller may consider the target in an error state. The model is to write with KEY = A731h and the MAPIDX and DAVALID to select ACK or NACK.

Mapping: If MAPIDX ≠ 0 and KEY = 0, then the next read returns details on the static or dynamic address at that location. If the read does not have MAPIDX ≠ 0, then it is not an acceptable location.

Diagram



Fields

Field	Function
31-16 KEY	Key Specifies the value of KEY. Must be set to A4D9h to write to the DADDR field (and 1 to the DAVALID field). Write only when a target is not enabled (for restoring after power-down sleep with auto-restore). The mapped locations and base may be written when a target is enabled, but do not write when there are transactions on the I3C bus. KEY reads back 1 if overwritten, else KEY is 0 if assigned by the controller including when the controller changes it. If address mapping is allowed, then writing with KEY = CB19h is used to clear the base DA.

Table continues on the next page...

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Field	Function
	If mapping is allowed, then writing with the key of A731h means that MAPIDX indicates which mapped address to set to ACK or NACK, such that DAVALID = 1 if ACK, DAVALID = 0 if NACK. This allows having the address refuse write and read requests when NACK. When using read back from map index (write with MAPIDX ≠ 0, KEY = 0, read) bit [16] = 1 if NACK, else 0.
15-13 SA10B	10-Bit Static Address Stores a 10-bit static address composed of {SA10B,DADDR}, if not 0 when MAPSA is set. Only one static address may be stored this way, and it must be MAPIDX == 1.
12 MAPSA	Map a Static Address Sets a static address into the list if MAPSA = 1 on a write with MAPIDX ≠ 0; otherwise, a dynamic address is used.
11-8 —	Reserved
7-1 DADDR	Dynamic Address Specifies the dynamic address (DA). This is the assigned dynamic address when DAVALID is 1 and is a static address if the MAPSA field is 1.
0 DAVALID	Dynamic Address Valid Determines whether a dynamic address is assigned. This field is 1 for ACK and 0 for NACK when using the A731h KEY. 0b - DANOTASSIGNED: a dynamic address is not assigned 1b - DAASSIGNED: a dynamic address is assigned

45.7.23 Target Maximum Limits (SMAXLIMITS)

Offset

Register	Offset
SMAXLIMITS	68h

Function

Indicates the limits set by the controller (or the originally requested limits). The maximum limits are not enabled in the hardware design, including maximum read and write lengths. If the maximum read and write lengths are enabled, then the current setting (including the default request) shows up in this register (SMAXLIMITS).

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				MAXWR											
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				MAXRD											
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 —	Reserved
27-16 MAXWR	Maximum Write Length Indicates the maximum write length, which must be between 8 to 4095 (saturation). The application must not set the maximum write length to a higher value than the maximum write length set by the controller.
15-12 —	Reserved
11-0 MAXRD	Maximum Read Length Indicates the maximum read length, which must be between 16 to 4095 (saturation). The application must not set the maximum read length to a higher value than the maximum read length set by the controller.

45.7.24 Target ID Part Number (SIDPARTNO)

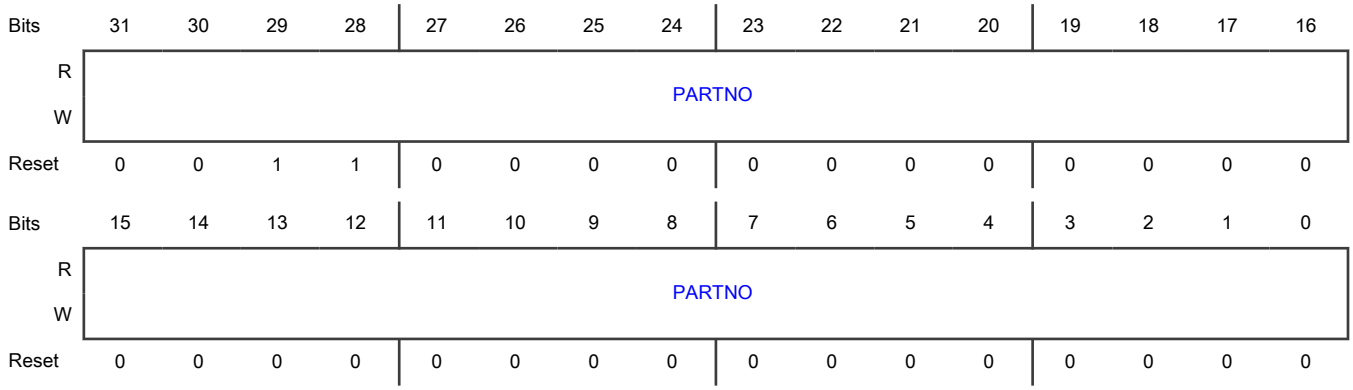
Offset

Register	Offset
SIDPARTNO	6Ch

Function

Allows you to write the ID part number. You must write a nonzero value into the PARTNO field because 0 is not valid.

Diagram



Fields

Field	Function
31-0 PARTNO	Part Number

45.7.25 Target ID Extension (SIDEXT)

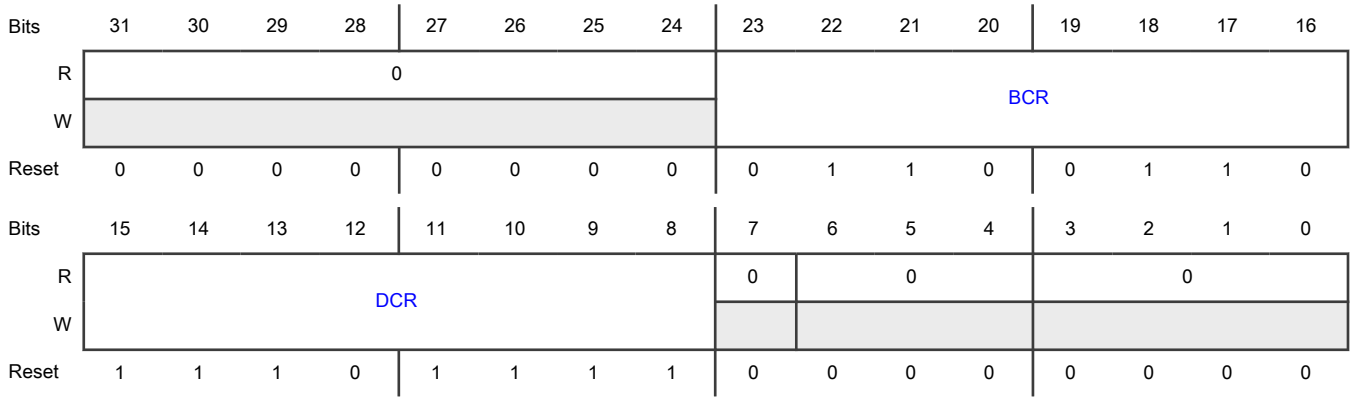
Offset

Register	Offset
SIDEXT	70h

Function

Allows you to write the ID extension of DCR and/or BCR.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 BCR	Bus Characteristics Register Sets the value for BCR, if this field is configured. Otherwise, the default value is considered. This field controls features such as secondary controller and slow-speed requirements.
15-8 DCR	Device Characteristic Register Sets the value for DCR, if this field is configured. Otherwise, the default value is considered.
7 —	Reserved
6-4 —	Reserved
3-0 —	Reserved

45.7.26 Target Vendor ID (SVENDORID)

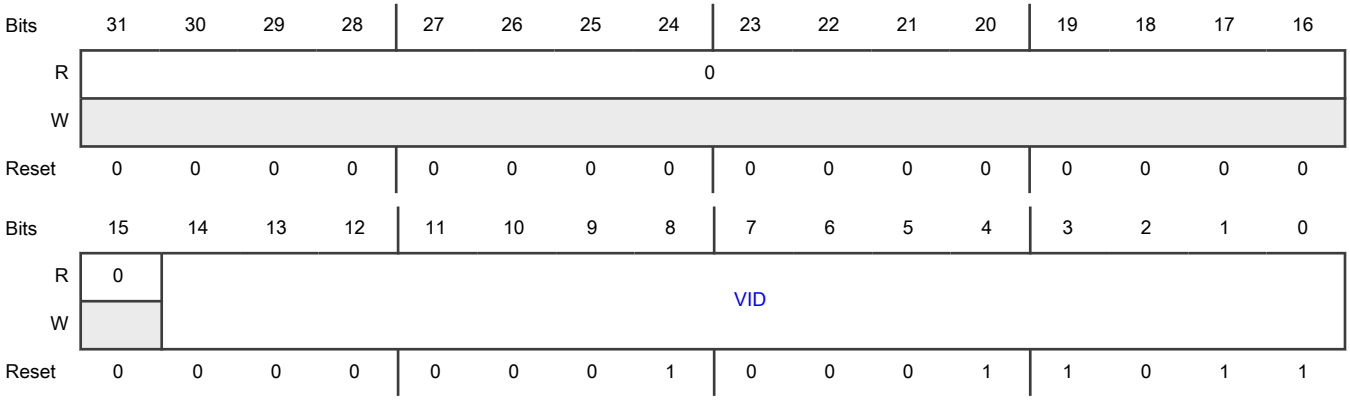
Offset

Register	Offset
SVENDORID	74h

Function

Allows you to write the vendor ID. The default value is the chip vendor ID, and is set from the constant field. When using the chip vendor ID, the part number (PARTNO) does not collide with other uses. The MIPI vendor ID is available to all companies (MIPI membership is not required). To get a vendor ID, make a request at the mipi.org website.

Diagram



Fields

Field	Function
31-15 —	Reserved
14-0 VID	Vendor ID Configures the 15-bit MIPI vendor ID. If not configured, the default value is considered.

45.7.27 Target Time Control Clock (STCCLOCK)

Offset

Register	Offset
STCCLOCK	78h

Function

Allows you to dynamically set the time control clock and accuracy information. The clock frequency and accuracy are constants set by the hardware. If the clock can be adjusted (that is, divided) or if the accuracy could vary with knowable information, then the clock may be set via this register, which must be updated whenever the clock source is changed.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	FREQ								ACCURACY							
W																
Reset	0	0	1	1	0	0	0	0	0	0	0	1	0	1	0	0

Fields

Field	Function
31-16 —	Reserved
15-8 FREQ	Clock Frequency Indicates the clock frequency in 0.5 MHz steps. For example, a value of 20 in this field indicates a frequency of 10 MHz. Default set by parameters if configured.

Table continues on the next page...

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Field	Function
7-0 ACCURACY	Clock Accuracy Indicates the clock accuracy in 1/10ths of %. For example, a value of 15 indicates an accuracy of 1.5%. Default set by parameters if configured.

45.7.28 Target Message Map Address (SMSGMAPADDR)

Offset

Register	Offset
SMSGMAPADDR	7Ch

Function

Allows you to determine which address is matched when STATUS[MATCHED] = 1. This register is used when the DYNADDR register builds a list of extra DAs or SAs to match. It holds the last three matches.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0												MAPLASTM2			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				MAPLASTM1				0			LASTSTA...	MAPLAST			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-20 —	Reserved
19-16 MAPLASTM2	Matched Previous Index 2 Indicates index 2 of the previous matched address (0 for the base address).
15-12 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
11-8 MAPLASTM1	Matched Previous Address Index 1 Indicates index 1 of the previous matched address (0 for the base address).
7-5 —	Reserved
4 LASTSTATIC	Last Static Address Matched Indicates whether the last matched address was an I2C static address or an I3C dynamic address. 0b - I3C dynamic address 1b - I2C static address
3-0 MAPLAST	Matched Address Index Indicates the matched address index for current or last matched message (0 for the base address).

45.7.29 Controller Extended Configuration (MCONFIG_EXT)

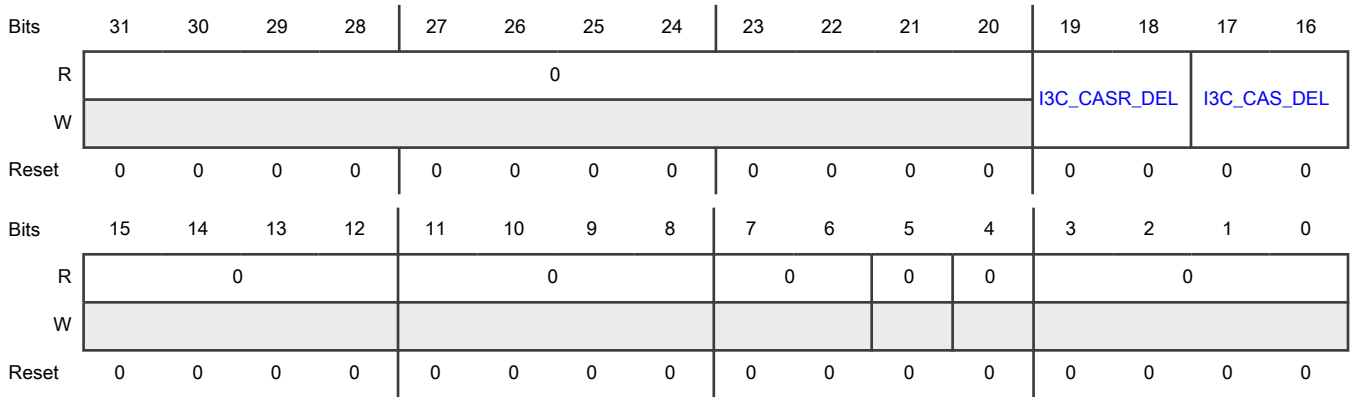
Offset

Register	Offset
MCONFIG_EXT	80h

Function

Allows special extended configurations, including for I2C use.

Diagram



Fields

Field	Function
31-20 —	Reserved
19-18 I3C_CASR_DEL	I3C CAS Delay After Repeated START Increases SCL clock period by a certain value. You can configure this field to delay the clock after a Repeated START to provide more time for slow I3C devices. The maximum value may be less if the internal clock is very fast. 00b - No delay 01b - Increases SCL clock period by 1/2 10b - Increases SCL clock period by 1 11b - Increases SCL clock period by 1 1/2
17-16 I3C_CAS_DEL	I3C CAS Delay After START Increases SCL clock period by a certain value. By increasing the SCL clock period, you can delay the clock to be longer after the START. The maximum value may be less if the internal clock is very fast. 00b - No delay 01b - Increases SCL clock period by 1/2 10b - Increases SCL clock period by 1 11b - Increases SCL clock period by 3/2
15-12 —	Reserved
11-8 —	Reserved
7-6 —	Reserved
5 —	Reserved
4 —	Reserved
3-0 —	Reserved

45.7.30 Controller Control (MCTRL)

Offset

Register	Offset
MCTRL	84h

Function

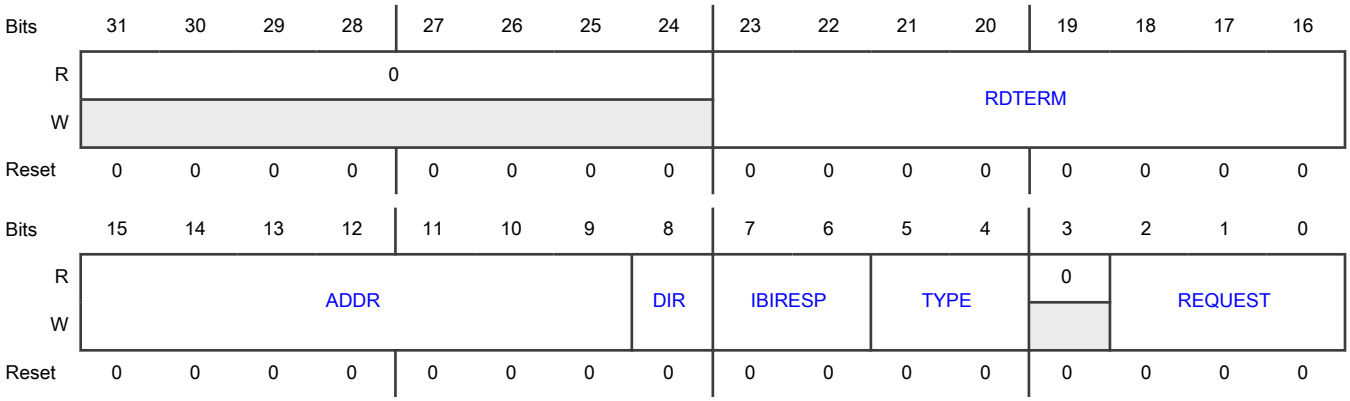
Starts activities on the I3C or I2C bus (see the MWMSG registers). A request cannot be changed when a message is in progress; the REQUEST field becomes 0 automatically.

You must write to MCTRL fields as per use case or as mentioned in Operating modes. Bit read and write checking may not work independently.

NOTE

If MCONFIG[MSTENA] is configured for I2C Controller mode (legacy I2C), only REQUEST = 1 and REQUEST = 2 are accepted. Also, fields are constrained to I2C-supported fields.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 RDTERM	Read Terminate Counter Determines when to terminate a read operation: • For I2C, this field controls when to NACK a read. • For I3C, this field can be used to terminate (end) a read: — If RDTERM is 0, it has no effect. — If RDTERM is 1, the read terminates after the next character.

Table continues on the next page...

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Field	Function
	— If RDTERM is 2, the read terminates after the next two characters. The field supports up to 255 characters. In DDR mode, RDTERM terminates the read based on word counts (for DDR) instead of byte counts (for SDR). The field self-clears when MSTATUS[COMPLETE] becomes 1. **NOTE** You may write 1 to this field anytime, but a value greater than 1 must be written when starting EmitStartAddress.
15-9 ADDR	Address Indicates the type of address: I3C dynamic address or I2C static address. Some values are not allowed based on the bus that is used (I3C or I2C).
8 DIR	Direction Indicates the direction, write or read. 0b - Write 1b - Read
7-6 IBIRESP	In-Band Interrupt Response Indicates the response to use when you get an IBI from START, and when to force using an IBI ACK NACK request when completing a manual IBI. Completion of a manual IBI means that the target DA is known, and so the mandatory byte (or not) is specified by the application when acknowledging. This field is also used when a message is emitted in Message mode using the MWMSG_SDR or MWMSG_DDR registers. If an IBI with MDB (mandatory byte) is ACKed, the controller limits it to a maximum of eight more bytes after the MDB. RDTERM = 1 can be used with REQUEST = NONE to terminate data from a target sooner. If this field is 0b, it indicates ACK (acknowledge). When REQUEST = 1 (EmitStartAddr) or REQUEST = 7 (AutoIBI), Controller In-band Interrupt Registry and Rules (MIBIRULES) decides whether to ACK with mandatory byte. When REQUEST = 3 (IBIAckNack), ACK with no mandatory byte. If this field is 1b, it indicates NACK (reject) or no acknowledgement. If this field is 10b, it indicates acknowledge with mandatory byte. When REQUEST = 1 or REQUEST = 7, ignore Controller In-band Interrupt Registry and Rules (MIBIRULES). Do not use this setting unless only targets with a mandatory byte can cause an IBI. When REQUEST = 3, ACK with mandatory byte. If this field is 11b, it indicates manual. When REQUEST = 1 or REQUEST = 7, stop and wait for a decision using the IBI ACK NACK request. When REQUEST = 3, this field is reserved. **NOTE** A CR and HJ always cause IBIRESP to become 3 (manual) so the application must decide. 00b - ACK (acknowledge) 01b - NACK (reject) 10b - Acknowledge with mandatory byte

Table continues on the next page...

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Field	Function
	11b - Manual
5-4 TYPE	Bus Type with EmitStartAddr Works with REQUEST to determine the bus type. See Determining bus types and modes for more information. The following values are valid only if REQUEST is 1. 00b - I3C 01b - I2C 10b - DDR 11b - Reserved
3 —	Reserved
2-0 REQUEST	Request Emits the requested operation when performing in pieces, instead of performing by message. You must check Controller Status (MSTATUS) because some requests can only be made in some states. For example, the system cannot enter SDR mode from DDR mode, and it cannot use an incorrect request in DAA mode. If this field is 0b, it indicates that no request is present (NONE). The REQUEST field returns to NONE after finishing a request. Controller Status (MSTATUS) indicates the state of the controller. See AutoIBI mode. NONE is written as 0 only in these cases: when writing 1 to MCTRL[RDTERM] (to stop a read in progress) or when configuring MCTRL[IBIRESP] for MSG use. If this field is 1b, it emits START with address and direction (EMITSTARTADDR), either from Stopped state or in the middle of a single data rate (SDR) message. If from Stopped state (Idle), then EmitStart may be prevented by an event (such as IBI, CR, HJ). In this case, an appropriate interrupt is signaled. EmitStart can be resubmitted. If this field is 10b, it emits a STOP on bus (EMITSTOP). Must be in SDR mode. In DAA mode, emitting STOP exits DAA mode. If this field is 11b, it indicates manual IBI ACK or NACK (IBIACKNACK). When MCTRL[IBIRESP] indicates a hold on an IBI to allow a manual decision, this request completes it. The field uses MCTRL[IBIRESP] to provide the information. If this field is 100b, and if currently not in DAA mode, it emits START, 7E, ENTDAA sequence, and then emits 7E/R to process the first target (PROCESSDAA). Stops just before the new dynamic address (DA) is to be emitted. The DA is written using Controller Write Data Byte (MWDATAB), then process DAA is requested again to write the new address, and then it starts the next unless marked to STOP. An MSTATUS indicating NACK means DA was not accepted (for example, parity error). If PROCESSDAA is NACKed on the 7E/R request, meaning no more targets need a DA, then a COMPLETE is signaled (along with DONE) and a STOP issued. If TYPE = 2 or 3, the DA is assigned and then it emits a STOP (instead of starting a new 7E/R request). If TYPE = 1 or 3, then the DA is taken from the ADDR field (bits 6:0). If this field is 110b, it emits an exit pattern from any state (force exit and target reset). End DDR mode (including MSGDDR), including a STOP afterward. If MCTRL[TYPE] is 2, perform a target reset action

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Field	Function
	(RSTACT can prevent the reset in the target). Target reset may follow immediately after RSTACT CCC or STOP. If this field is 111b, the target is held in a Stopped state, but autoemits a START, 7E sequence when the target holds SDA low for an IBI (AUTOIBI). Actual IBI handling is defined by MCTRL[IBIRESP]. 000b - NONE 001b - EMITSTARTADDR 010b - EMITSTOP 011b - IBIACKNACK 100b - PROCESSDAA 101b - Reserved 110b - Force Exit and Target Reset 111b - AUTOIBI

45.7.31 Controller Status (MSTATUS)

Offset

Register	Offset
MSTATUS	88h

Function

Indicates the controller status, including which events cause interrupts. The peripherals share the IRQ (called parallel-to-target status).

Because a peripheral can either be in Controller or Target mode, but not both at the same time, only one (target or controller peripheral) can cause the IRQ. If there is an IRQ and the peripheral is a controller, then this register (MSTATUS) indicates the status.

If there is an IRQ and the peripheral is a target, then Target Status (SSTATUS) indicates the status.

This register self-clears if the COMPLETE field becomes 1.

If the MCONFIG register is configured only for I2C, some states and fields never remain active (for example, DAA or IBI).

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	IBIADDR							0				NOWMAST...	0		
W													W1C			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	ERRWARN	0	IBIWON	TXNOTFU...	RXPEND	COMPLETE	MCTRLDO...	SLVSTART	IBITYPE		NACKED	BETWEEN	0	STATE		
W			W1C			W1C	W1C	W1C								
Reset	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 —	Reserved
30-24 IBIADDR	IBI Address Indicates the address of: • The IBI when MSTATUS[IBITYPE] = 1. • The CR, when MSTATUS[IBITYPE] = 2. • 7'h2 when HJ, when MSTATUS[IBITYPE] = 3.
23-20 —	Reserved
19 NOWMASTER	Module is now Controller Flag Indicates whether the module is now a controller. That is, it was previously a target, and controllership acceptance was requested from the previous controller and controllership was accepted. The reverse operation (controller becomes a target) does not need an interrupt because the application grants it through the GETACCMST CCC. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not a controller 1b - Controller When writing 0b - No effect 1b - Clear the flag

Table continues on the next page...

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Field	Function
18-16 —	Reserved
15 ERRWARN	Error or Warning Indicates whether an error occurred, such as improper register use, overrun, or underrun of FIFO or buffer, or invalid parity or CRC in a DDR read. See Controller Errors and Warnings (MERRWARN) for more information. 0b - No error or warning 1b - Error or warning
14 —	Reserved
13 IBIWON	In-Band Interrupt (IBI) Won Flag Indicates whether an IBI, CR, or HJ has won the arbitration on a header address, regardless of whether it was NACKed or ACKed. Arbitration requires manual intervention for CR and HJ, and optionally requires it for IBI if MCTRL[IBIRESP] = 3 (manual). **NOTE** This field behaves differently for register reads and writes. When reading 0b - No IBI arbitration won 1b - IBI arbitration won When writing 0b - No effect 1b - Clear the flag
12 TXNOTFULL	TX Buffer or FIFO Not Full Indicates whether the buffer, FIFOm, or message register can accept another byte or halfword. FIFO uses trigger level. If DMA is enabled for transmitting, it transfers data as long as it is not full. 0b - Receive buffer or FIFO full 1b - Receive buffer or FIFO not full
11 RXPEND	RXPEND Indicates whether a message is being received from a target and bytes are in the input buffer or FIFO: • When using a FIFO, this message is at least one FIFO trigger's worth (a minimum of one byte in the FIFO). • When DMA is enabled for receiving, the DMA is signaled. RXPEND becomes 0 when the data is read.

Table continues on the next page...

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Field	Function
	0b - No receive message pending 1b - Receive message pending
10 COMPLETE	Complete Flag Indicates whether a message is complete: • With MWMSG_SDR or MWMSG_DDR, the COMPLETE condition occurs when MWMSG_SDR_CONTROL[LEN] or MWMSG_DDR_CONTROL[LEN] reaches 0. • When MCTRL[REQUEST] = 1 (EmitStartAddr), this COMPLETE condition occurs after the end of a write operation, or after a read operation has terminated or ended. • With an IBI (AutoIBI or EmitStartAddr), the COMPLETE condition occurs at the end of IBI data (if any). **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not complete 1b - Complete When writing 0b - No effect 1b - Clear the flag
9 MCTRLDONE	Controller Control Done Flag Indicates whether the module has completed an MCTRL request. MCTRLDONE automatically becomes 0 when writing a new control. If MCTRL[REQUEST] = 1 (EmitStartAddr), MCTRLDONE becomes 1 when the address goes out (and is ACKed, NACKed, or ended in an IBI). If ACKed, MSTATUS[COMPLETE] becomes 1 after the write or read data is complete. If MCTRL[REQUEST] = 4 (ProcessDAA), MCTRLDONE becomes 1 when the module is ready to emit the dynamic address (DA) for the target, or when no more targets are ACKing. This condition can be determined by using the MSTATUS[BETWEEN] and MSTATUS[STATE] fields. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not done 1b - Done When writing 0b - No effect 1b - Clear the flag

Table continues on the next page...

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Field	Function
8 SLVSTART	Target Start Flag Indicates whether a target is or was requesting a START by holding SDA low. Handling starts automatically when MCTRL[REQUEST] = 7 (AutoIBI). **NOTE** This field behaves differently for register reads and writes. When reading 0b - Target not requesting START 1b - Target requesting START When writing 0b - No effect 1b - Clear the flag
7-6 IBITYPE	In-Band Interrupt (IBI) Type Indicates the type of IBI of the last event that won the arbitration, whether the interrupt was ACKed, NACKed, or pending. 00b - NONE (no IBI: this status occurs when MSTATUS[IBIWON] becomes 0) 01b - IBI 10b - CR 11b - HJ
5 NACKED	Not Acknowledged Indicates whether the last start and address sequence was NACKed (was not ACKed by the addressed target). 0b - Not NACKed 1b - NACKed (not acknowledged)
4 BETWEEN	Between Indicates whether the controller is active between messages or dynamic address assignments (DAA). It is active when: • MSTATUS[STATE] is MSGSDR, DDR, or DAA, or NORMACT, and the state is between messages or DAAs. It is expecting a new message or DAA to start (or STOP or exit). • MSTATUS[STATE] is NORMACT. The module is waiting for the transmit FIFO to be not empty or the receive FIFO to be not full. 0b - Inactive (for other cases) 1b - Active
3 —	Reserved

Table continues on the next page...

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Field	Function
2-0 STATE	State of the Controller Indicates the current controller state. If this field is 0b, it indicates that the controller is idle (the bus has stopped.) If this field is 1b, it indicates target request. The bus has stopped but a target is holding SDA low. When using auto-emit IBI (MCTRL[REQUEST] = 7), the controller does not remain in this state. If this field is 10b, it indicates entry into Single Data Rate Message mode, using MWMSG_SDR. If this field is 11b, it indicates entry into normal active SDR mode, using MCTRL, MWDATA*n*, and MRDATA*n* registers. The controller remains in this state until a STOP is issued. If this field is 100b, it indicates entry into Double Data Rate Message mode, using MWMSG_DDR or the normal method with DDR. The controller remains in the DDR state until the controller exits using EXIT (emitting the Exit pattern). If this field is 101b, it indicates entry into Dynamic Address Assignment (ENTDAA) mode. If this field is 110b, it indicates wait for an IBI ACK/NACK decision. If this field is 111b, it indicates receiving an IBI. This state is used after IBI, CR, or HJ has won an arbitration. The IBIRCV state is also used for IBI mandatory byte (if any) and any bytes that follow. 000b - IDLE (bus has stopped) 001b - SLVREQ (target request) 010b - MSGSDR 011b - NORMACT 100b - MSGDDR 101b - DAA 110b - IBIACK 111b - IBIRCV

45.7.32 Controller In-band Interrupt Registry and Rules (MIBIRULES)

Offset

Register	Offset
MIBIRULES	8Ch

Function

Contains the rules for using IBI, and keeps a registry of the targets that use the IBI byte.

This register defines the IBI mandatory byte rules for the targets and determines which targets do (or do not) have a mandatory byte.

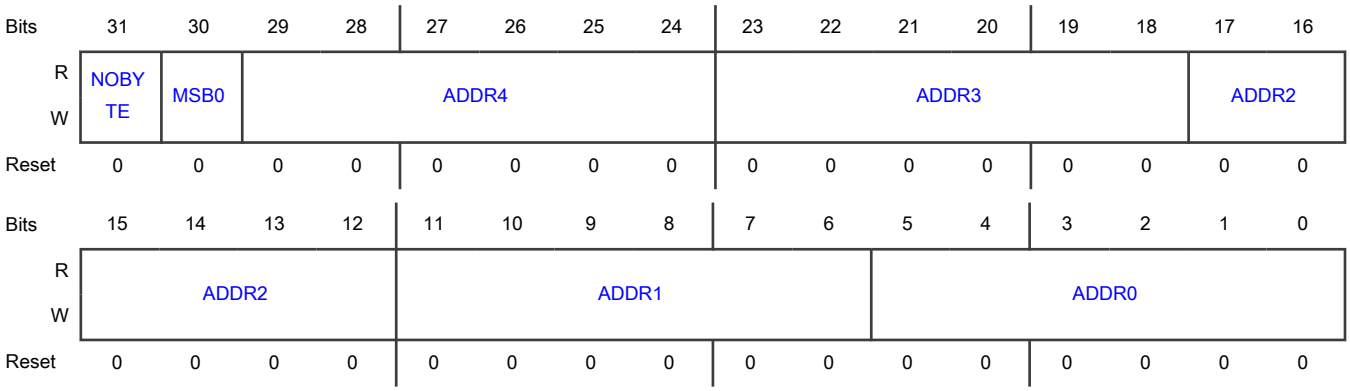
Concerning ADDR*n* fields: The address has 6 bits. Assuming that MIBIRULES[MSB0] = 1, the most significant bit of each address is 0. In this case, each address is 7 bits (usually written as A7 to A1) and A7 must be 0. If the application does not use that optimal convention, the "manual" method of IBI ACK handling must be used (see MCTRL[IBIRESP] for more information).

By default, the ADDR*n* values indicate the targets with a mandatory byte. If MIBIRULES[NOBYTE] = 1, the ADDR*n* values indicate targets that do not have a mandatory IBI byte.

NOTE

A7 = 0 is only needed for targets that use IBI. For legacy I2C devices, A7 can use any valid value because I2C devices cannot cause an IBI.

Diagram



Fields

Field	Function
31 NOBYTE	No IBI byte Specifies whether the ADDR*n* fields refer to targets with or without a mandatory IBI byte. 0b - With mandatory IBI byte 1b - Without mandatory IBI byte
30 MSB0	Most Significant Address Bit is 0 Specifies whether MSB is 0 for all I3C dynamic addresses. Assigning 1 to this field allows the START header to be optimized. 0b - MSB is not 0 1b - MSB is 0
29-24 ADDR4	ADDR4 Specifies the address of the target with or without mandatory IBI byte. If 0, then the address does not apply.
23-18 ADDR3	ADDR3 Specifies the address of the target with or without mandatory IBI byte. If 0, then the address does not apply.
17-12 ADDR2	ADDR2 Specifies the address of the target with or without mandatory IBI byte. If 0, then the address does not apply.

Table continues on the next page...

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Field	Function
11-6 ADDR1	ADDR1 Specifies the address of the target with or without mandatory IBI byte. If 0, then the address does not apply.
5-0 ADDR0	ADDR0 Specifies the address of the target with or without mandatory IBI byte. If 0, then the address does not apply.

45.7.33 Controller Interrupt Set (MINTSET)

Offset

Register	Offset
MINTSET	90h

Function

Returns the status of the interrupt enables when read. This register sets interrupt enables for select fields in Controller Status (MSTATUS):

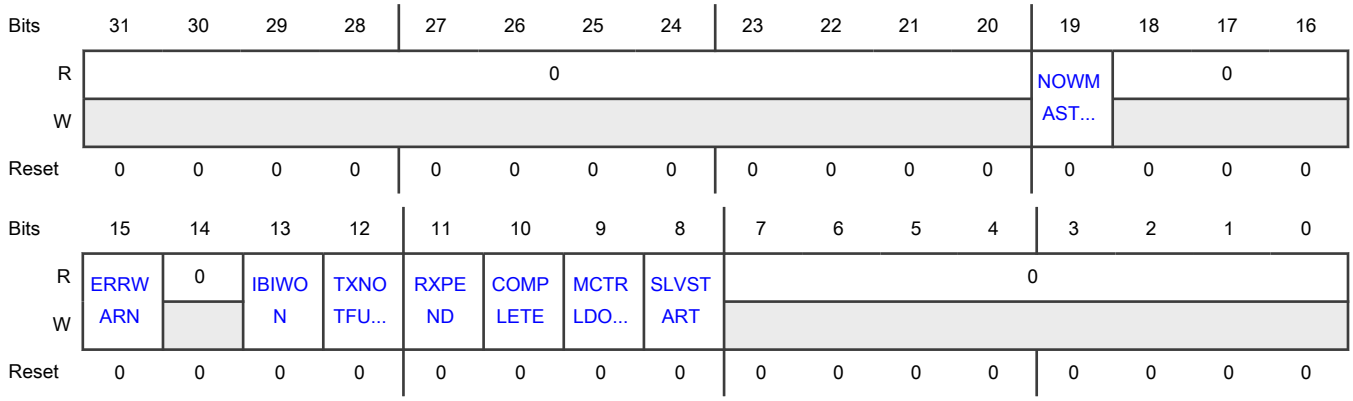
- To activate an interrupt enable, write 1 to its corresponding field.
- To disable an interrupt enable, write 1 to the appropriate field in Controller Interrupt Clear (MINTCLR). Writing 0 to the interrupt enable in MINTSET does not disable the interrupt.

The interrupt registers allow masking of interrupt sources as well as checking which interrupts are activated in Controller Status (MSTATUS). The normal method is to enable an interrupt and then after that interrupt fires, clear the interrupt either by writing to Controller Status (MSTATUS) or via an action on the corresponding data register. The interrupt is level-held, meaning that the interrupt remains 1 until the cause is cleared by some method. The module prevents races; if a new event comes in, that new event is not lost.

These interrupts are parallel to Target Interrupt Set (SINTSET) and Target Interrupt Clear (SINTCLR), and only one interrupt set is active depending on the state (controller or target operation):

- MINTSET: Sets interrupt enables for MSTATUS fields. Reading the MINTSET register returns the status of the interrupt enables.
- MINTCLR: Clears interrupt enables for MSTATUS fields.
- MINTMASKED: Returns the value of the MSTATUS fields ANDed with their interrupt enables.

Diagram



Fields

Field	Function
31-20 —	Reserved
19 NOWMASTER	Now Controller Interrupt Enable Enables the corresponding interrupt to indicate whether the module is now a controller (now this I3C module is a controller). That is, it was previously a target; controllership acceptance was requested from the previous controller and it was accepted. 0b - Disable 1b - Enable
18-16 —	Reserved
15 ERRWARN	Error or Warning (ERRWARN) Interrupt Enable Enables the corresponding interrupt to indicate whether an error occurred, such as improper register use, overrun or underrun of FIFO or buffer, or invalid parity or CRC in a DDR read. 0b - Disable 1b - Enable
14 —	Reserved
13 IBIWON	IBI Won Interrupt Enable Enables the corresponding interrupt to indicate whether an IBI, CR, or HJ has won the arbitration on a header address, regardless of whether it was NACKed or ACKed. 0b - Disable 1b - Enable
12	Transmit Buffer/FIFO Not Full Interrupt Enable

Table continues on the next page...

Table continued from the previous page...

Field	Function
TXNOTFULL	Enables the corresponding interrupt to indicate whether the buffer, FIFOm, or message register can accept another byte or halfword. 0b - Disable 1b - Enable
11 RXPEND	Receive Pending Interrupt Enable Enables the corresponding interrupt to indicate whether a message is being received from a target and bytes are in the input buffer or FIFO.
10 COMPLETE	Completed Message Interrupt Enable Enables the corresponding interrupt to indicate whether a message is complete. 0b - Disable 1b - Enable
9 MCTRLDONE	Controller Control Done Interrupt Enable Enables the corresponding interrupt to indicate whether the module has completed an MCTRL request. 0b - Disable 1b - Enable
8 SLVSTART	Target Start Interrupt Enable Enables the corresponding interrupt to indicate whether a target is or was requesting a START by holding SDA low. 0b - Disable 1b - Enable
7-0 —	Reserved

45.7.34 Controller Interrupt Clear (MINTCLR)

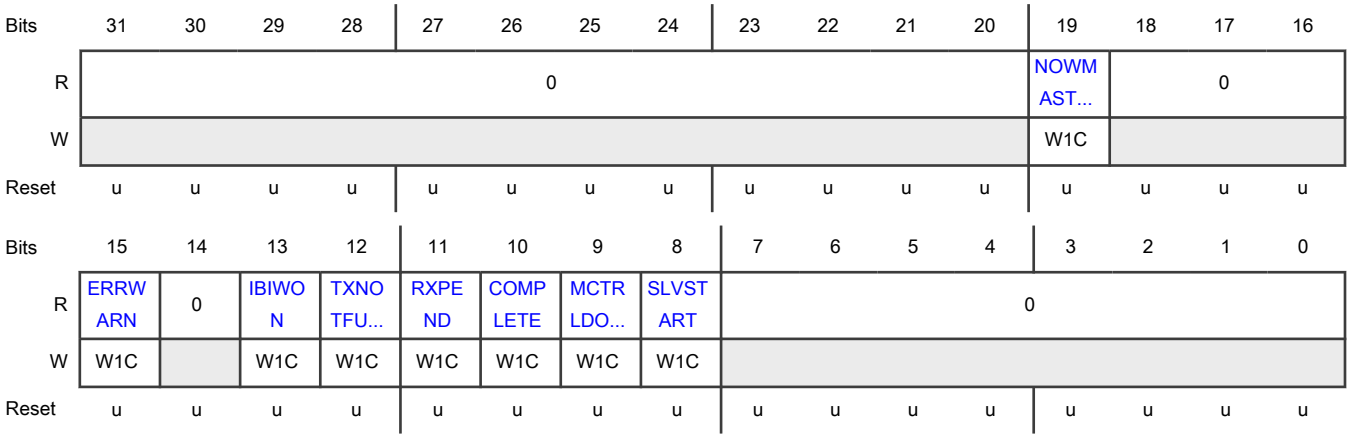
Offset

Register	Offset
MINTCLR	94h

Function

Clears interrupt enables for select fields in Controller Status (MSTATUS). Writing 1 clears the corresponding interrupt enable. Writing 0 has no effect.

Diagram



Fields

Field	Function
31-20 —	Reserved
19 NOWMASTER	NOWCONTROLLER Interrupt Enable Clear Flag Clears the corresponding NOWCONTROLLER interrupt enable. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No effect 1b - Interrupt enable cleared When writing 0b - No effect 1b - Clear the flag
18-16 —	Reserved
15 ERRWARN	ERRWARN Interrupt Enable Clear Flag Clears the corresponding ERRWARN interrupt enable. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No effect 1b - Interrupt enable cleared

Table continues on the next page...

Table continued from the previous page...

Field	Function
	When writing 0b - No effect 1b - Clear the flag
14 —	Reserved
13 IBIWON	IBIWON Interrupt Enable Clear Flag Clears the corresponding IBIWON interrupt enable. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No effect 1b - Interrupt enable cleared When writing 0b - No effect 1b - Clear the flag
12 TXNOTFULL	TXNOTFULL Interrupt Enable Clear Flag Clears the corresponding TXNOTFULL interrupt enable. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No effect 1b - Interrupt enable cleared When writing 0b - No effect 1b - Clear the flag
11 RXPEND	RXPEND Interrupt Enable Clear Flag Clears the corresponding RXPEND interrupt enable. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No effect

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Interrupt enable cleared When writing 0b - No effect 1b - Clear the flag
10 COMPLETE	COMPLETE Interrupt Enable Clear Flag Clears the corresponding COMPLETE interrupt enable. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No effect 1b - Interrupt enable cleared When writing 0b - No effect 1b - Clear the flag
9 MCTRLDONE	MCTRLDONE Interrupt Enable Clear Flag Clears the corresponding MCTRLDONE interrupt enable. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No effect 1b - Interrupt enable cleared When writing 0b - No effect 1b - Clear the flag
8 SLVSTART	SLVSTART Interrupt Enable Clear Flag Clears the corresponding SLVSTART interrupt enable. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No effect 1b - Interrupt enable cleared When writing

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - No effect 1b - Clear the flag
7-0 —	Reserved

45.7.35 Controller Interrupt Mask (MINTMASKED)

Offset

Register	Offset
MINTMASKED	98h

Function

Returns the status of enabled interrupts (the value of Controller Status (MSTATUS) ANDed with the value of Controller Interrupt Set (MINTSET)).

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0												NOWMAST...	0		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	ERRWARN	0	IBIWON	TXNOTFU...	RXPEND	COMPLETE	MCTRLDO...	SLVSTART	0							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-20 —	Reserved
19 NOWMASTER	NOWCONTROLLER Interrupt Mask Indicates whether the NOWCONTROLLER interrupt is enabled and active.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Disabled 1b - Enabled
18-16 —	Reserved
15 ERRWARN	ERRWARN Interrupt Mask Indicates whether the ERRWARN interrupt is enabled and active. 0b - Disabled 1b - Enabled
14 —	Reserved
13 IBIWON	IBIWON Interrupt Mask Indicates whether the IBIWON interrupt is enabled and active. 0b - Disabled 1b - Enabled
12 TXNOTFULL	TXNOTFULL Interrupt Mask Indicates whether the TXNOTFULL interrupt is enabled and active. 0b - Disabled 1b - Enabled
11 RXPEND	RXPEND Interrupt Mask Indicates whether the RXPEND interrupt is enabled and active.
10 COMPLETE	COMPLETE Interrupt Mask Indicates whether the COMPLETE interrupt is enabled and active. 0b - Disabled 1b - Enabled
9 MCTRLDONE	MCTRLDONE Interrupt Mask Indicates whether the MCTRLDONE interrupt is enabled and active. 0b - Disabled 1b - Enabled
8 SLVSTART	SLVSTART Interrupt Mask Indicates whether the SLVSTART interrupt is enabled and active.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Disabled 1b - Enabled
7-0 —	Reserved

45.7.36 Controller Errors and Warnings (MERRWARN)

Offset

Register	Offset
MERRWARN	9Ch

Function

Contains errors and warnings. When any errors or warnings are not 0, then MSTATUS[ERRWARN] is 1.

Parallel-to-target ERRWARN:

- In Controller mode, use this register (MERRWARN).
- In Target mode, use Target Errors and Warnings (SERRWARN).

The error fields in both registers (MERRWARN and SERRWARN) are similar in meaning.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0										0	TIMEOUT	INVREQ	MSGERR	OWRITE	OREAD
W												W1C	W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0			0	0	HCRC	HPAR	0				TERM	WRABT	NACK	URUN	0
W						W1C	W1C					W1C	W1C	W1C	W1C	
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-22 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
21 —	Reserved
20 TIMEOUT	Timeout Error Flag Indicates an error caused by the module stalling for too long in a frame. This stalling occurs when: • The transmit FIFO or receive FIFO is not handled, and the bus is stuck in the middle of a message. • No STOP is issued after data transfer (there is a gap between messages). • IBI manual is used and no decision has been made. The maximum stall period is 10 kHz or 100 µs. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No error 1b - Error When writing 0b - No effect 1b - Clear the flag
19 INVREQ	Invalid Request Error Flag Indicates an error caused by an invalid use of a request: • Not using IBI ACK NACK when stopped in manual hold for IBI acknowledgment. • Using a request other than ForceStop or ForceExit when in a message. Other requests are valid when the message is done. • Other mismatched uses (for example, IBI ACK NACK in normal states). **NOTE** This field behaves differently for register reads and writes. When reading 0b - No error 1b - Error When writing 0b - No effect 1b - Clear the flag
18 MSGERR	Message Error Flag Indicates an error caused by:

Table continues on the next page...

Table continued from the previous page...

Field	Function
	• Trying to write to or read from the MWMSG_SDR register when in a DDR message. • Trying to write to or read from the MWMSG_DDR register when in an SDR message. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No error 1b - Error When writing 0b - No effect 1b - Clear the flag
17 OWRITE	Overwrite Error Flag Indicates an error caused by trying to write to Controller Write Data Byte (MWDATAB) when the FIFO is full. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No error 1b - Error When writing 0b - No effect 1b - Clear the flag
16 OREAD	Overread Error Flag Indicates an error caused by: • Trying to read from Controller Read Data Byte (MRDATAB) when the FIFO is empty. • Trying to read from the MRMSG_SDR register or the MRMSG_DDR register when no message has yet started. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No error 1b - Error When writing

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - No effect 1b - Clear the flag
15-13 —	Reserved
12 —	Reserved
11 —	Reserved
10 HCRC	High Data Rate CRC Error Flag Indicates that a cyclic redundancy check (CRC) error occurred from a DDR read. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No error 1b - Error When writing 0b - No effect 1b - Clear the flag
9 HPAR	High Data Rate Parity Flag Indicates a parity error from a DDR read, including a bad preamble on a read. This does not stop the read because it is not safe to terminate; the read data may become misframed. Ends on a run of 1 second. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No error 1b - Error When writing 0b - No effect 1b - Clear the flag
8-5 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
4 TERM	Terminate Error Flag Indicates an error when this controller terminates a target read because the read exceeded the count for the message. This error is valid only when using the MWMSG_SDR or MWMSG_DDR register. If you write to the MWMSG_SDR or MWMSG_DDR register, this field automatically becomes 0. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No error 1b - Error When writing 0b - No effect 1b - Clear the flag
3 WRABT	Write Abort Error Flag Indicates an error caused by the I2C target NACKing the write data, terminating the message. For example, the controller is writing in I2C and the target NACKed the write. If you write to the MCTRL register, this field automatically becomes 0. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No error 1b - Error When writing 0b - No effect 1b - Clear the flag
2 NACK	Not Acknowledge Error Flag Indicates an error caused by the target or targets NACKing (not acknowledging) the last address. If 7Eh is the address, then it indicates all targets NACKed the last address. If you write to the MCTRL register, this field automatically becomes 0. **NOTE** In HDR mode, this error occurs when an address is not accepted (as opposed to NACKed). **NOTE** This field behaves differently for register reads and writes. When reading

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - No error 1b - Error When writing 0b - No effect 1b - Clear the flag
1 URUN	Underrun Error Flag Indicates an underrun for HDR-BT. This error occurs when attempting to write from an empty transmit FIFO. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No error 1b - Error When writing 0b - No effect 1b - Clear the flag
0 —	Reserved

45.7.37 Controller DMA Control (MDMACTRL)

Offset

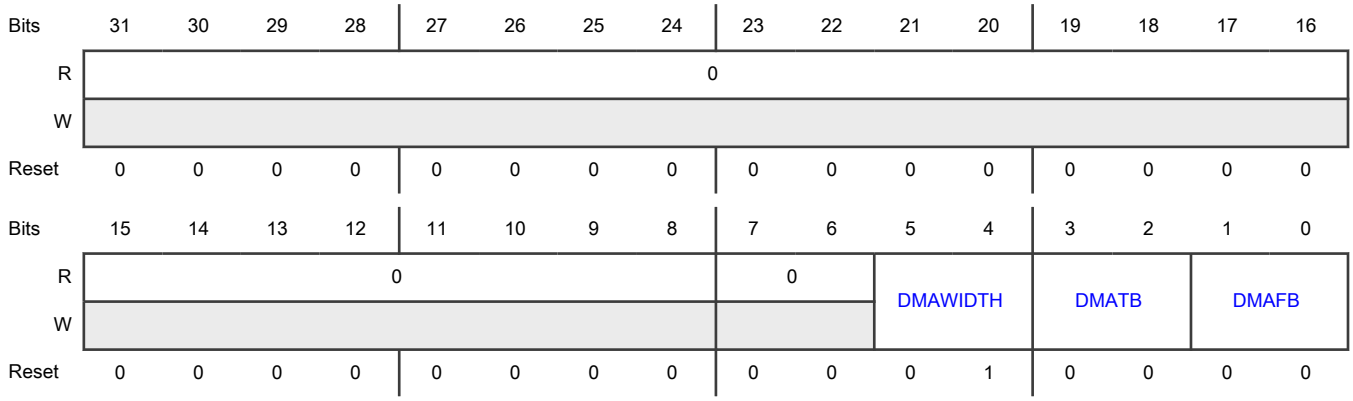
Register	Offset
MDMACTRL	A0h

Function

Allows DMA to be used for inbound and outbound messages. DMA is much more useful for a controller than for a target because the controller directs the bus traffic and actions. DMA can be used with a controller in these ways:

- Push or pull data for MCTRL[REQUEST] = 1 (EmitStartAddr) request written by the processor.
- Implementing message mode, completely controlled by DMA.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-6 —	Reserved
5-4 DMAWIDTH	DMA Width Specifies the data width of DMA operations. The halfword (16 bits) setting ensures that two bytes are free or available in FIFO. 00b,01b - Byte 10b - Halfword (16 bits) 11b - Reserved
3-2 DMATB	DMA to Bus Represents the DMA write (to-bus) trigger. When DMATB = 1 or DMATB = 2, I3C requests DMA when a transmit trigger occurs (see Controller Data Control (MDATACTRL)). I3C requests until full, unless the DMA is set up as a trigger. DMAFB becomes 0 when MSTATUS[ERRWARN] = 1. If this field is 1b, STOP or repeated START causes DMATB to become 0 (see SCONFIG[MATCHSS]). Normally, DMA enable must be used only in Controller Message mode. 00b - DMA not used 01b - Enable DMA for one frame (ended by DMA or terminated) 10b - Enable DMA until DMA is turned off. Recommended mode, instead of 01b, to enable DMA. This setting provides better software control. 11b - Reserved
1-0	DMA from Bus

Table continues on the next page...

Table continued from the previous page...

Field	Function
DMAFB	Represents the DMA read (from-bus) trigger. When DMAFB = 1 or DMAFB = 2, I3C requests DMA when a receive trigger occurs (see Controller Data Control (MDATACTRL)). I3C requests until empty unless the DMA is set up as a trigger. DMAFB becomes 0 when MSTATUS[ERRWARN] = 1. If this field is 1b, STOP or Repeated START causes DMAFB to automatically become 0 (see SCONFIG[MATCHSS]). **NOTE** Do not enable DMA after a transaction starts. It must be enabled only when enabling the controller and interrupts to avoid any kind of RX FIFO overrun. 00b - DMA not used 01b - Enable DMA for one frame 10b - Enable DMA until DMA is turned off. Recommended mode, instead of 01b, to enable DMA. This setting provides better software control. 11b - Reserved

45.7.38 Controller Data Control (MDATACTRL)

Offset

Register	Offset
MDATACTRL	ACh

Function

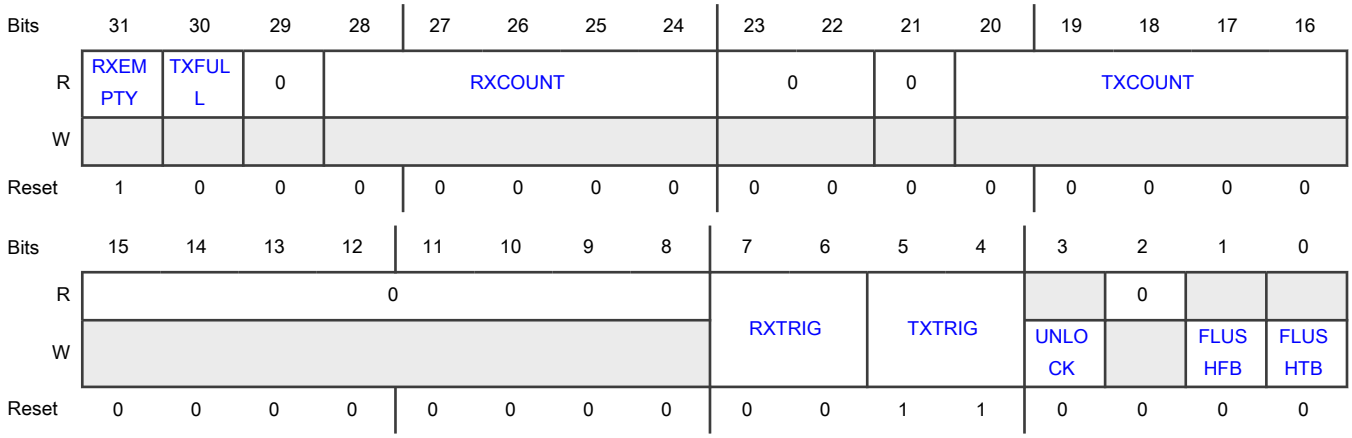
Assists in data control when there is no FIFO. This register also assists the FIFO when FIFO is available (regardless of size), and this assistance allows some control over the FIFO behavior. In particular, the register provides control over when to interrupt when a particular state of fullness or emptiness is reached. It also controls behavior related to width, when the width is not 1 byte wide.

This register acts as an alias of Target Data Control (SDATACTRL).

NOTE

When flushing a FIFO if DMA is in use, disable the DMA channel first. You must not use FIFO flush when a message (in that direction) is in flight.

Diagram



Fields

Field	Function
31 RXEMPTY	Receive is Empty Indicates whether the receive FIFO or buffer is empty. 0b - Not empty 1b - Empty
30 TXFULL	Transmit is Full Indicates whether the transmit FIFO or buffer is full. 0b - Not full 1b - Full
29 —	Reserved
28-24 RXCOUNT	Receive Entry Count Contains the count of entries in the receive FIFO or buffer. Entry size for SDR and HDR-DDR is in bytes.
23-22 —	Reserved
21 —	Reserved
20-16 TXCOUNT	Transmit Entry Count Contains the count of entries waiting in the TXFIFO. This count is the number of entries that the application has written to the transmit FIFO that have not yet gone onto the bus. Entry size for SDR and HDR-DDR is in bytes.

Table continues on the next page...

Table continued from the previous page...

Field	Function
15-8 —	Reserved
7-6 RXTRIG	Receive Trigger Level Indicates the trigger level for receive fullness when using a FIFO. This field affects the RXPEND interrupt. 00b - Trigger when not empty (default) 01b - Trigger when 1/4 full or more 10b - Trigger when 1/2 full or more 11b - Trigger when 3/4 full or more
5-4 TXTRIG	Transmit Trigger Level Indicates the trigger level for transmit emptiness when using a FIFO. This field affects the TXNOTFULL interrupt. 00b - Trigger when empty 01b - Trigger when 1/4 full or less 10b - Trigger when 1/2 full or less 11b - Trigger when 1 less than full or less (default)
3 UNLOCK	Unlock Unlocks the functionality so that the RXTRIG and TXTRIG fields can be changed on a write. This field must be 1 (unlocked) in the same cycle when writing to TXTRIG or RXTRIG. If this field is 0 (locked), RXTRIG and TXTRIG fields cannot be changed on a write. 0b - Locked 1b - Unlocked
2 —	Reserved
1 FLUSHFB	Flush From-Bus Buffer or FIFO Flushes from-bus buffer or FIFO. You normally do not use this field. **NOTE** Before using FLUSHFB, disable the DMA (MDMACTRL[DMAFB] = 0). Then use FLUSHFB to flush the FIFO and then re-enable the DMA. 0b - No action 1b - Flush the buffer
0	Flush To-Bus Buffer or FIFO

Table continues on the next page...

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Field	Function
FLUSHTB	Flushes to-bus buffer or FIFO. This field is used when the controller terminates a to-bus message (read) prematurely. **NOTE** Before using FLUSHTB, disable the DMA (MDMACTRL[DMATB] = 0). Then use FLUSHTB to flush the FIFO and then re-enable the DMA. 0b - No action 1b - Flush the buffer

45.7.39 Controller Write Data Byte (MWDATAB)

Offset

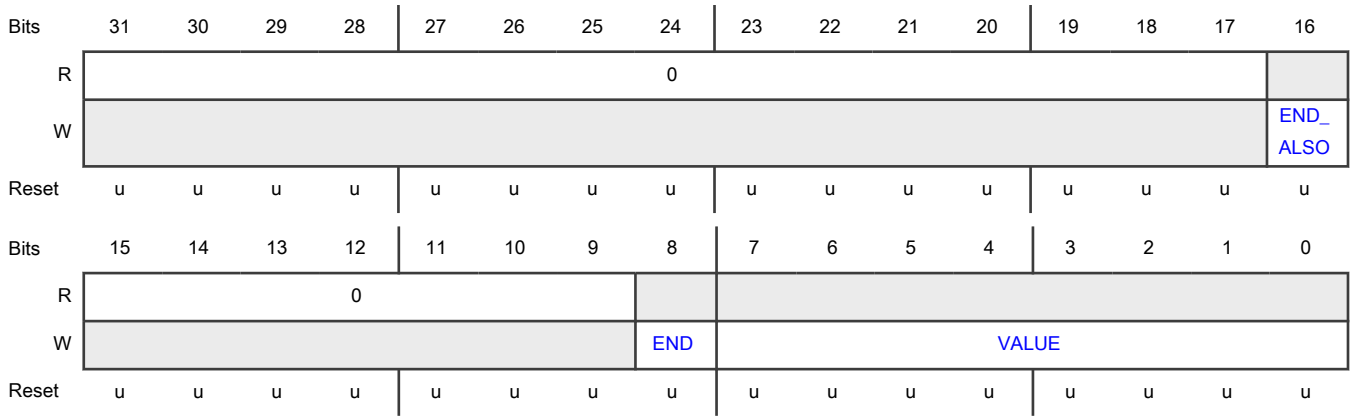
Register	Offset
MWDATAB	B0h

Function

Allows writing bytes to send onto the bus. This register is used only when using Controller Control (MCTRL) to start the message. If MWMSG_SDR or MWMSG_DDR is used to start a message, that interface must be used exclusively.

This register acts as an alias of Target Write Data Byte (SWDATAB).

Diagram



Fields

Field	Function
31-17 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
16 END_ALSO	End of Message ALSO Indicates end of message, used to end an outbound message normally. Every message must indicate when it is the last message to be sent. This method can be used with the MDATABE register. This field is required for I3C and is optional for I2C. For HDR-DDR, the byte with END_ALSO must be an even byte (second, fourth, sixth, and so on) because DDR uses byte pairs. If this field is 0, more bytes are assumed to be in the message. If this field is 1, the END bit marks the last byte of the message. 0b - Not the end 1b - End
15-9 —	Reserved
8 END	End of Message Indicates the end of a message. This field is required for I3C and is optional for I2C. For HDR-DDR, the byte with the END must be an even byte (second, fourth, sixth, and so on) because DDR uses byte pairs. If this field is 0, more bytes are assumed to be in the message. If this field is 1, the END bit marks the last byte of the message. 0b - Not the end 1b - End
7-0 VALUE	Data Byte Represents the byte written to the target (stored in transmit FIFO): • I3C computes the parity. • I2C manages the ACK or NACK.

45.7.40 Controller Write Data Byte End (MWDATABE)

Offset

Register	Offset
MWDATABE	B4h

Function

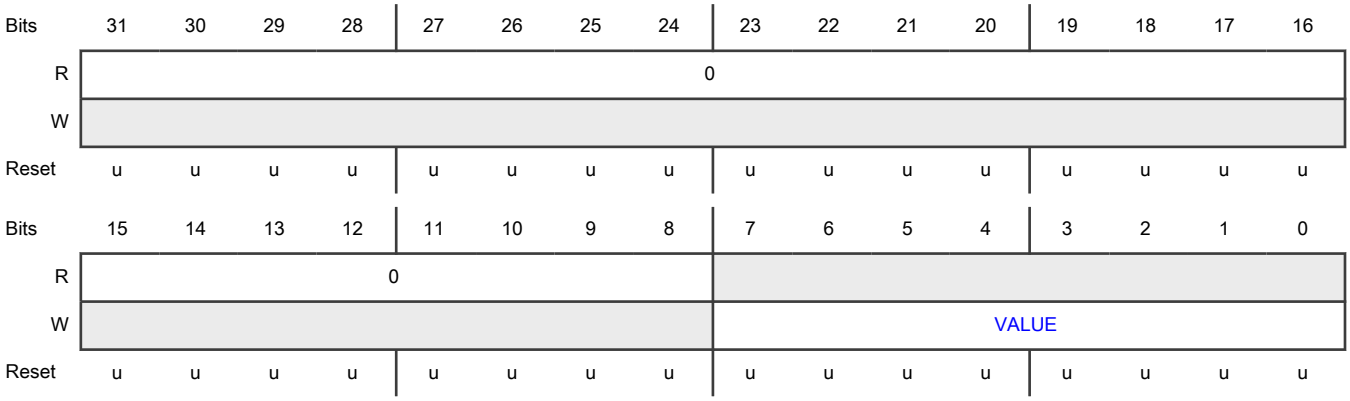
Allows writing the last byte to send onto the bus. This register is used only when using Controller Control (MCTRL) to start the message. If MWMSG_SDR or MWMSG_DDR is used to start a message, that interface must be used exclusively.

This register acts as an alias of Target Write Data Byte End (SWDATABE).

NOTE

MWDATABE can also indicate END using bit 8.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 VALUE	Data Represents the last byte written to the target (stored in transmit FIFO): • I3C computes the parity. • I2C manages the ACK or NACK.

45.7.41 Controller Write Data Halfword (MWDATAH)

Offset

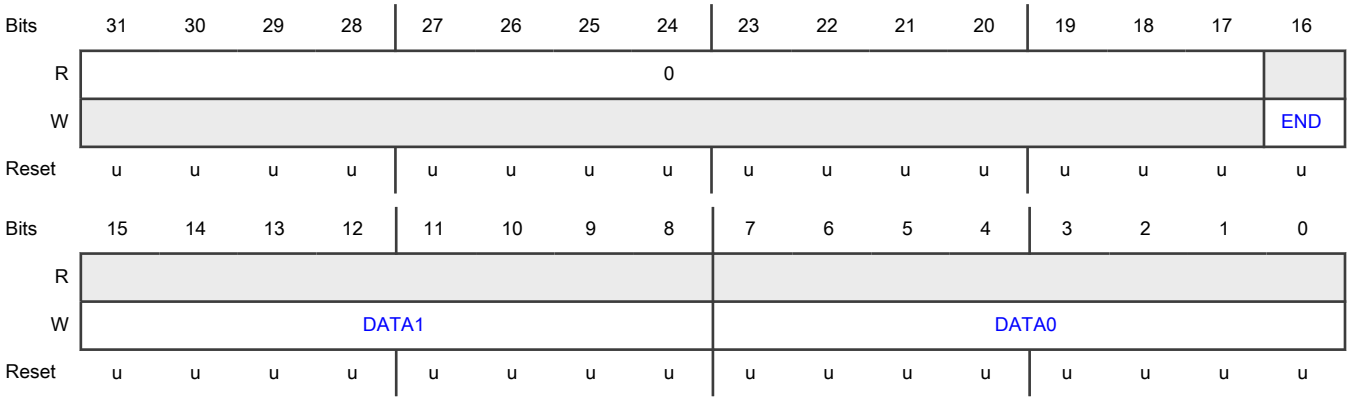
Register	Offset
MWDATAH	B8h

Function

Allows writing a halfword (pair of bytes) to the bus unless an external FIFO is used, sending the low byte followed by the high byte. An end-of-data (last) marker bit is allowed (or must be 0). A halfword must not be written unless there is room for both, as indicated by the use of transmit FIFO level trigger or MDATACTRL[TXCOUNT].

This register acts as an alias of Target Write Data Halfword (SWDATAH).

Diagram



Fields

Field	Function
31-17 —	Reserved
16 END	End of Message Indicates the end of a message. For this register, this field always marks DATA1 as the end. This field is required for I3C and is optional for I2C. For HDR-DDR, the byte with the END must be an even byte (second, fourth, sixth, and so on) because DDR uses byte pairs. If this field is 0, more bytes are assumed to be in the message. If this field is 1, the END bit marks the last byte of the message. 0b - Not the end 1b - End
15-8 DATA1	Data Byte 1 Represents the second byte that is sent to the target (written to transmit FIFO).
7-0 DATA0	Data Byte 0 Represents the first byte that is sent to the target (written to transmit FIFO).

45.7.42 Controller Write Data Halfword End (MWDATAHE)

Offset

Register	Offset
MWDATAHE	BCh

Function

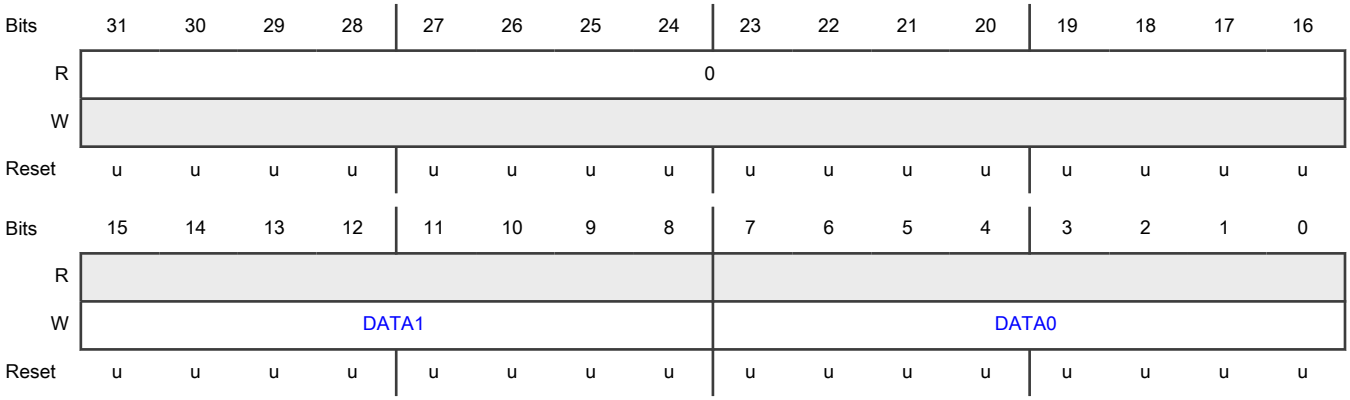
Allows writing a halfword of data, which is the end (the last byte of the halfword is the end). The target writes the halfword (byte pair) in the same way as it does to Controller Write Data Halfword (MWDATAH), but marks the second byte as end-of-data (last byte).

For HDR-DDR, the byte with the END must be even (second, fourth, sixth, and so on) because DDR uses byte pairs.

You must not write a halfword unless there is room for both, as indicated by the use of transmit FIFO level trigger or MDATACTRL[TXCOUNT].

This register acts as an alias of Target Write Data Halfword End (SWDATAHE).

Diagram



Fields

Field	Function
31-16 —	Reserved
15-8 DATA1	Data Byte 1 Represents the second byte that is sent to the target (written to transmit FIFO).
7-0 DATA0	Data Byte 0 Represents the first byte that is sent to the target (written to transmit FIFO).

45.7.43 Controller Read Data Byte (MRDATAB)

Offset

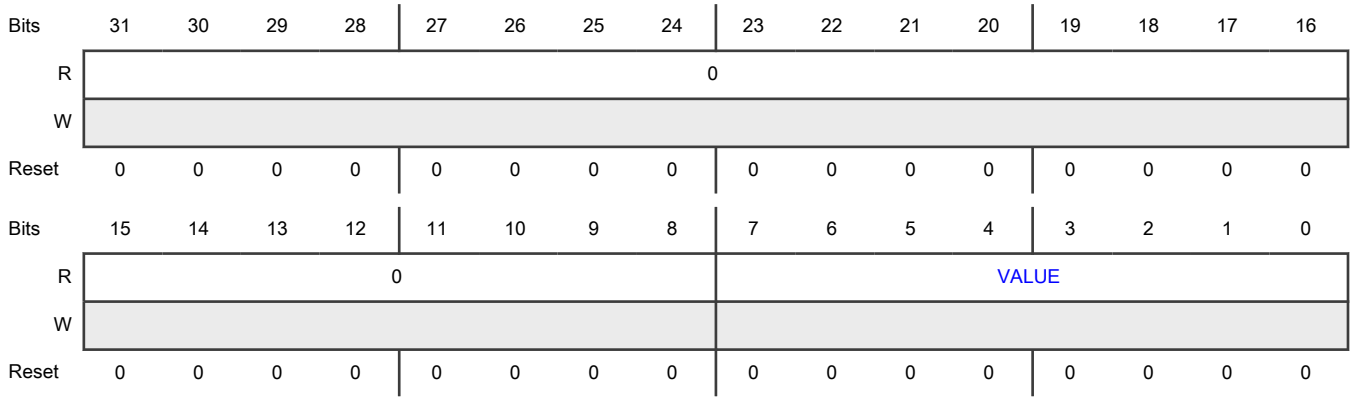
Register	Offset
MRDATAB	C0h

Function

Allows reading bytes written by the target after an SDR read, or DAA or DDR. This register is used only when using Controller Control (MCTRL) to start the message. If MWMSG_SDR or MWMSG_DDR is used to start a message, that interface must be used exclusively.

This register acts as an alias of Target Read Data Byte (SRDATAB).

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 VALUE	Value Represents the byte read from the controller (and written by the target).

45.7.44 Controller Read Data Halfword (MRDATAH)

Offset

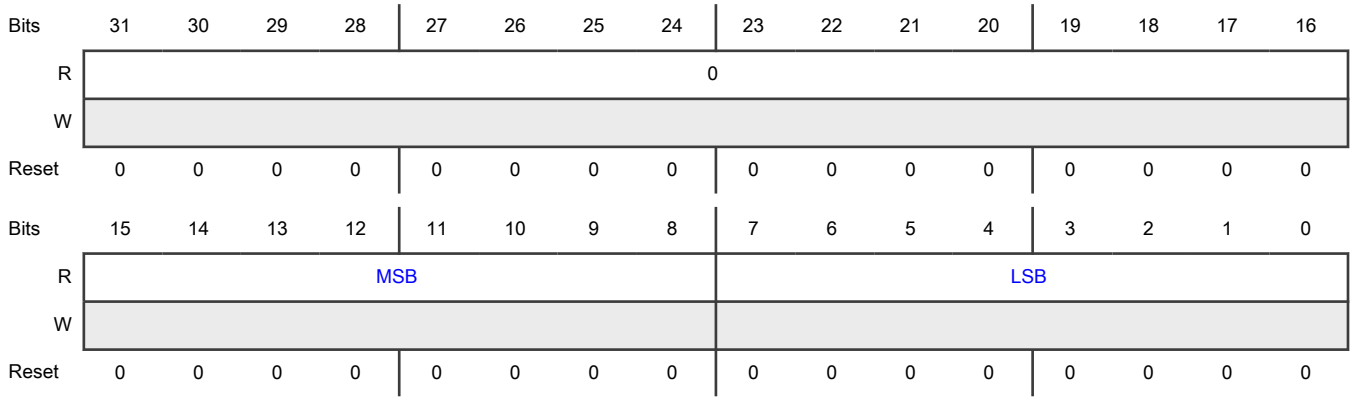
Register	Offset
MRDATAH	C8h

Function

Allows reading a halfword (byte pair) written by the target after an SDR read or DAA or DDR. This register is used only when using Controller Control (MCTRL) to start the message. If MWMSG_SDR or MWMSG_DDR is used to start a message, that interface must be used exclusively.

A halfword must not be read unless there are at least two bytes of data waiting, as indicated by the receive FIFO level trigger or MDATACTRL[RXCOUNT].

Diagram



Fields

Field	Function
31-16 —	Reserved
15-8 MSB	High Byte Represents the second byte read from the controller (and written by the target).
7-0 LSB	Low Byte Represents the first byte read from the controller (and written by the target).

45.7.45 Controller Write Byte Data 1 (to Bus) (MWDATAB1)

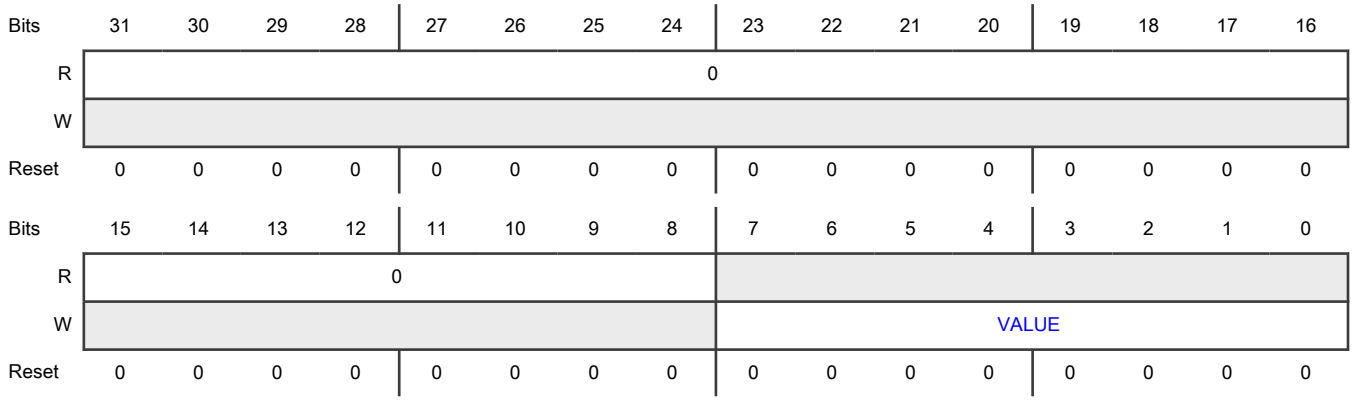
Offset

Register	Offset
MWDATAB1	CCh

Function

Allows writing bytes to send onto the bus, and is intended for DMAs that do not clear the upper bits of the word. This register does not have the END bits and is only used when using Controller Control (MCTRL) to start the message. If MWMSG_SDR or MWMSG_DDR is used to start a message, that interface must be used exclusively.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 VALUE	Value Represents the byte to write out. The I3C module computes the parity for I3C, or manages the ACK or NACK for I2C.

45.7.46 Controller Write Halfword Data (to Bus) (MWDATAH1)

Offset

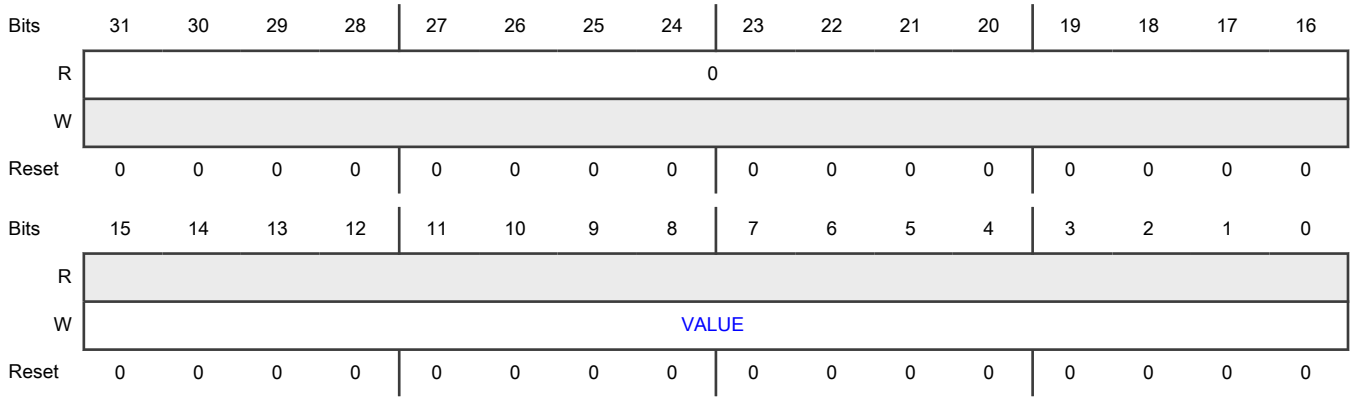
Register	Offset
MWDATAH1	CCh

Function

Allows writing a byte pair (halfword) to send onto the bus, and is intended for DMAs that do not clear the upper bits of the word. It does not have the END bits as present in Controller Write Data Halfword (MWDATAH). This register is only used when using Controller Control (MCTRL) to start the message. If MWMSG_SDR or MWMSG_DDR is used to start a message, that interface must be used exclusively.

MWDATAH1 shares the same address as MWDATAB1. MDMACTRL[DMAWIDTH] determines which one is set.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 VALUE	Value Represents the byte to write out. The I3C module computes the parity for I3C, or manages the ACK or NACK for I2C.

45.7.47 Controller Write Message Control in SDR mode (MWMSG_SDR_CONTROL)

Offset

Register	Offset
MWMSG_SDR_CONTROL	D0h

Function

Allows setting up and writing 16-bit words in Single Data Rate (SDR) mode. The MWMSG_SDR_ register is modal and has two modes—control and data:

- For the first write to set up a new message, this register functions as the MWSMSG_SDR_CONTROL register.
- For subsequent writes, this register functions as MWMSG_SDR_DATA.
- The control information is not pipelined. You must write to control information registers for a start and do not write to them until data is sent.

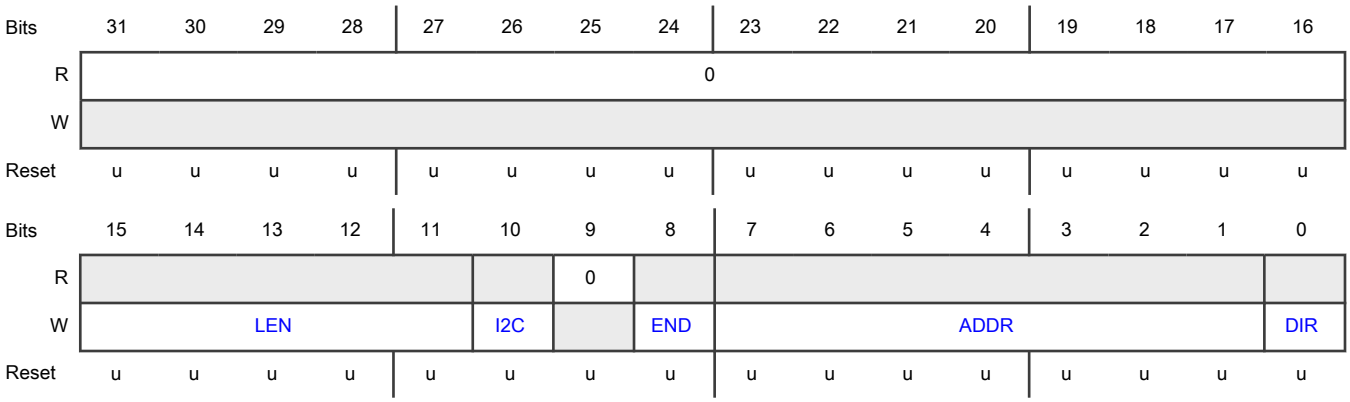
When not in the middle of a message, the MWMSG_SDR_CONTROL register is used to start a new message (or emit a STOP). After starting a message, the MWMSG_SDR_DATA register is used until the length (see the LEN field) counts down, or until data with END = 1 is used.

The MWMSG_SDR_CONTROL register is written with the 16-bit control word if currently stopped or after the end of the previous message. If MSTATUS[STATE] = 2 (MSGSDR) and MSTATUS[BETWEEN] = 0, the register (at this offset address) functions as the MWMSG_SDR_DATA register. Otherwise, this register (at this offset address) functions as the MWMSG_SDR_CONTRL register, as long as MSTATUS[STATE] is not in another mode.

The control word contains the byte length (6-bit), address, direction, and how it ends (stop, ready for next, continuation with more length). If the command is START and an event (IBI, CR, HJ) occurs, MCTRL[IBIRESP] is used to determine action, and the corresponding interrupt occurs. In that case, the message is restarted.

The MWMSG_SDR_CONTROL and MWMSG_SDR_DATA registers are only targeted for DMA operations, but the processor can also write to the MWMSG_SDR_CONTROL register (instead of using MCTRL and MxDATAB).

Diagram



Fields

Field	Function
31-16 —	Reserved
15-11 LEN	Length Indicates the byte length of the message. If LEN = 0, then only END is used (and it does not use the address if stopped). LEN = 1 must not be used. The minimal LEN size is 2 bytes (LEN = 2).
10 I2C	I2C Specifies whether the message is I2C or I3C. 0b - I3C message 1b - I2C message
9 —	Reserved
8 END	End of SDR Message Indicates the end of SDR message. MSTATUS[COMPLETE] = 1 when done. The end can happen: • Before LEN bytes are read in I3C mode, if a target ends sooner. • Before LEN bytes are written in I2C mode, if a target NACKs. If this field is 0, the SDR message ends waiting for a new SDR message (issues a Repeated START for a new message). If this field is 1, the SDR message ends at the STOP.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Not the end 1b - End
7-1 ADDR	Address Contains the address to be written.
0 DIR	Direction 0b - Write 1b - Read

45.7.48 Controller Write Message Data in SDR mode (MWMSG_SDR_DATA)

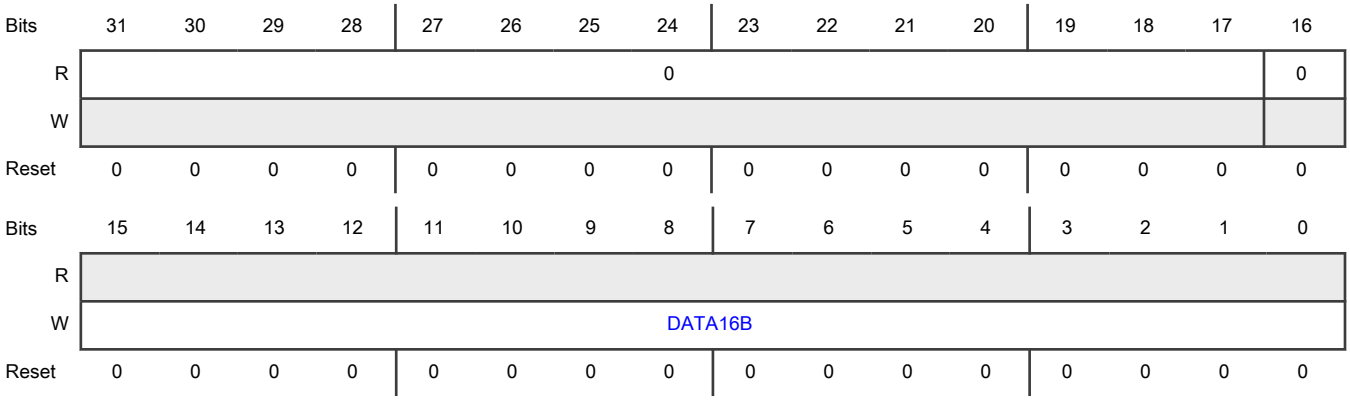
Offset

Register	Offset
MWMSG_SDR_DATA	D0h

Function

Contains the 16-bit word to be written in Single Data Rate (SDR) mode. This register functions in a way similar to MWMSG_SDR_CONTROL.

Diagram



Fields

Field	Function
31-17 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
16 —	Reserved
15-0 DATA16B	Data

45.7.49 Controller Read Message in SDR mode (MRMSG_SDR)

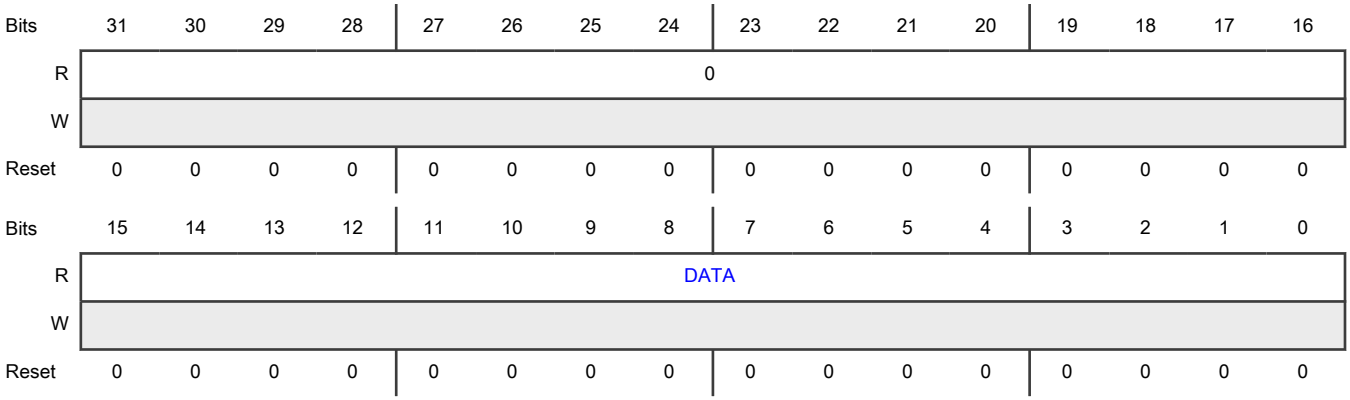
Offset

Register	Offset
MRMSG_SDR	D4h

Function

Allows reading 16-bit words from a target in SDR Message mode. The MRMSG_SDR register is used to read 16-bit words from an active message started with MWMSG_SDR. These words are intended to be read by DMA.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 DATA	Data Contains the 16-bit word read from the target: • If the length (LEN) is an odd number, the upper byte is 0.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	• If the target ends before LEN is finished, the module treats the read as completed. • If the target is not done before LEN is finished and END is not a continuation, the read is terminated.

45.7.50 Controller Write Message in DDR mode: First Control Word (MWMSG_DDR_CONTROL)

Offset

Register	Offset
MWMSG_DDR_CONTROL	D8h

Function

Allows setting up and writing 16-bit words in DDR mode. The register has three modes:

- The first write to set up a new message functions as the MWSMSG_DDR_CONTROL register.
- The second write contains the functions as shown in the MWMSG_DDR_CONTROL2 register.
- For subsequent writes, this register functions in a way similar to Controller Write Message Data in DDR mode (MWMSG_DDR_DATA).
- The control information is not pipelined. You must write to control information registers for a start and do not write to them until data is sent.

When not in the middle of a message, the MWMSG_DDR_CONTROL register is used to start a new message (or emit a STOP). After starting a message, the MWMSG_DDR_DATA register is used until the length (see LEN field) counts down or until data with END = 1 is used.

The MWMSG_DDR_CONTROL register is written with the 16-bit control word if currently stopped or after the end of the previous message. If MSTATUS[STATE] = 4 (MSGDDR) and MSTATUS[BETWEEN] = 0, then the register (at this offset address) functions as the MWMSG_DDR_DATA register. Otherwise, this register (at this offset address) functions as the MWMSG_DDR_CONTROL register, as long as MSTATUS[STATE] is not in another mode.

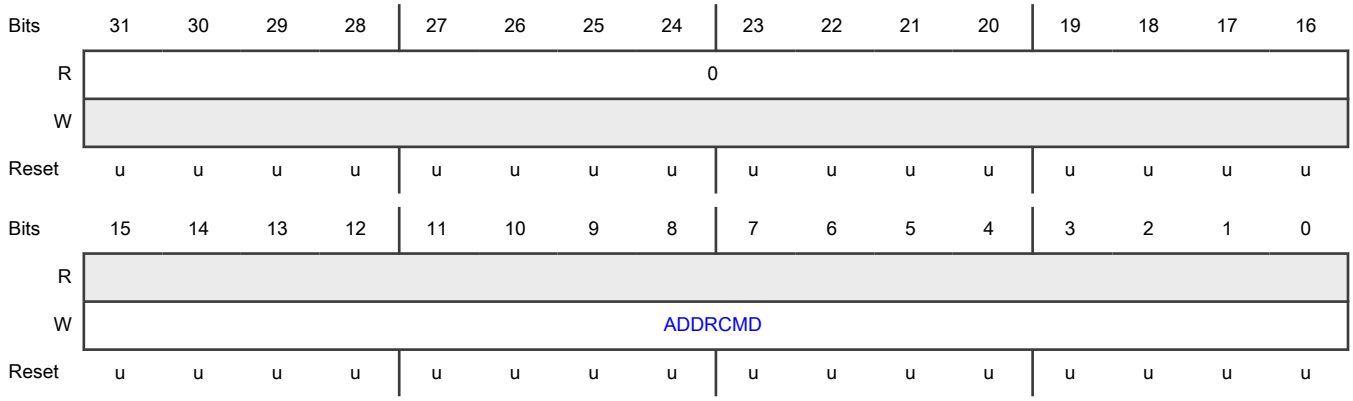
The main control word contains the 16-bit word length and how it ends (stop, ready for next, continuation with more length). Then the command word contains the command and address for read or write. If the command is START and an event (IBI, CR, HJ) occurs, MCTRL[IBIRESP] is used to determine action, and the corresponding interrupt occurs. In that case, the message is restarted.

The MWMSG_DDR_CONTROL, MWMSG_DDR_CONTROL2, and MWMSG_DDR_DATA registers are only targeted for DMA operations, but the processor can also write to the MWMSG_DDR_CONTROL register (instead of using MCTRL and MxDATAB).

NOTE

The module handles preamble, parity, and CRC.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 ADDRCMD	Address Command Indicates the first data write after control write, with LEN ≠ 0. This is formatted as: • Bits 15:9: target address to read or write • Bit 8: reserved, must be 0 • Bit 7: 1 if read, 0 if write • Bits 6:0: CMD as 7-bit value, always for controller

45.7.51 Controller Write Message in DDR Mode Control 2 (MWMSG_DDR_CONTROL2)

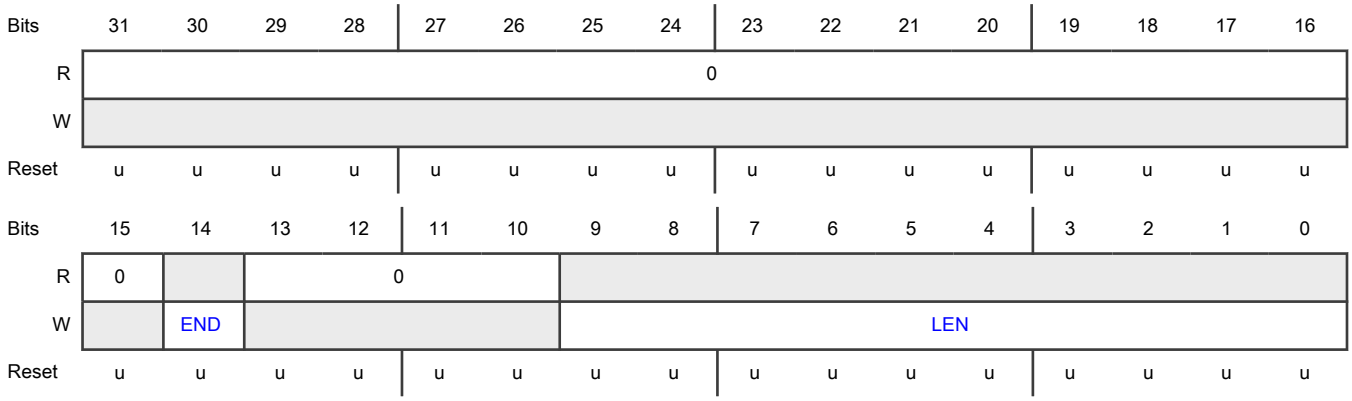
Offset

Register	Offset
MWMSG_DDR_CONTROL2	D8h

Function

Contains the second control word instructions with the length of message and end.

Diagram



Fields

Field	Function
31-16 —	Reserved
15 —	Reserved
14 END	End of Message Indicates the end of DDR message. MSTATUS[COMPLETE] becomes 1 when done. The end can happen before LEN bytes are read if the target ends sooner. If this field is 0, DDR message ends waiting for a new DDR message (issues an HDR restart for the new message). If this field is 1, DDR message ends on HDR exit. 0b - Not the end 1b - End
13-10 —	Reserved
9-0 LEN	Length of Message Contains the length of the message (including the command) in halfwords, up to 2046 bytes. If LEN = 0, then only END is applied: • For reads, + 1 for the CRC. For example, to read 4 bytes (2 halfwords), use 1 + 2 + 1 for CMD + 2 halfwords + CRC. • For writes, LEN is the number of halves of data bytes + 1 (for command).

45.7.52 Controller Write Message Data in DDR mode (MWMSG_DDR_DATA)

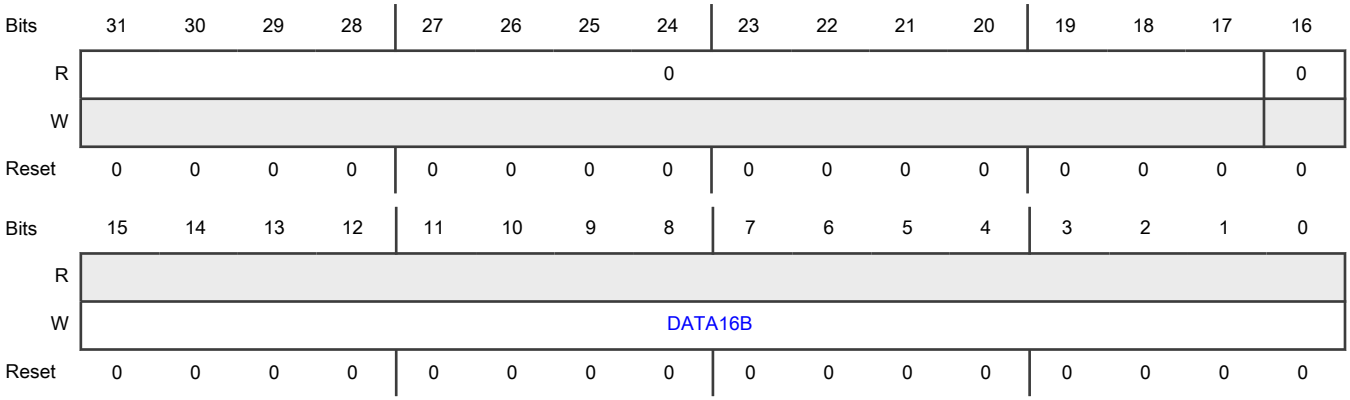
Offset

Register	Offset
MWMSG_DDR_DATA	D8h

Function

Contains the 16-bit word to be written in DDR mode. This register functions in a way similar to Controller Write Message in DDR mode: First Control Word (MWMSG_DDR_CONTROL).

Diagram



Fields

Field	Function
31-17 —	Reserved
16 —	Reserved
15-0 DATA16B	Data

45.7.53 Controller Read Message in DDR mode (MRMSG_DDR)

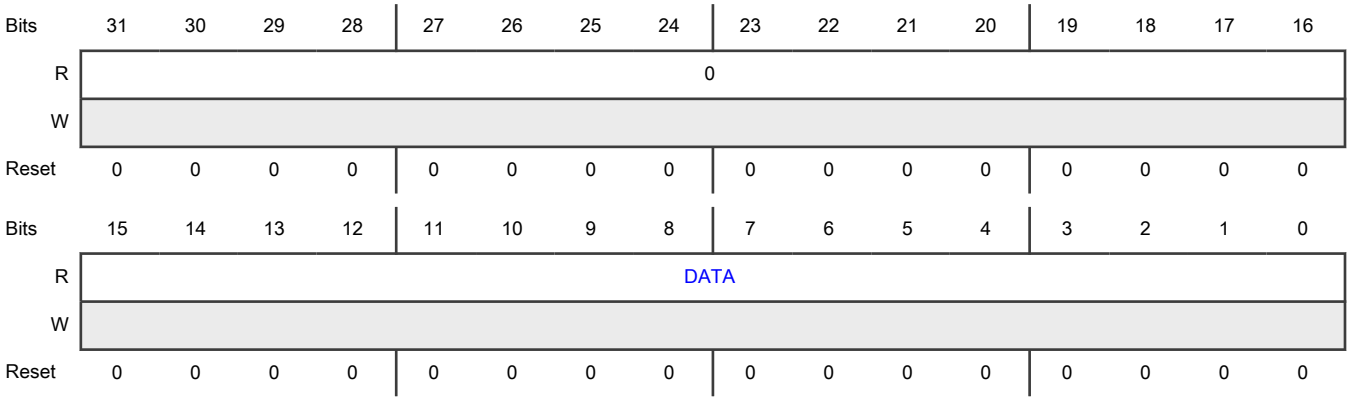
Offset

Register	Offset
MRMSG_DDR	DCh

Function

Allows reading 16-bit words from a target in DDR Message mode from an active message started with MWMSG_DDR. These words are intended to be read by DMA.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 DATA	Data Contains the 16-bit word read from a target. The first byte is the LSB, and is in DATA[7:0]. The second byte is the MSB, and is in DATA[15:8]: • If the target ends before the entire length of the message (MWMSG_DDR[LEN]) is read, the module considers the DATA read as completed. In I3C mode, the target can indicate the end of message (the last byte). Otherwise, the controller terminates the message if the message is more than the controller can accept. • If the target has not yet finished sending DATA before the entire length of the message (MWMSG_DDR[LEN]) is read and END is not a continuation, the DATA read is terminated.

45.7.54 Controller Dynamic Address (MDYNADDR)

Offset

Register	Offset
MDYNADDR	E4h

Function

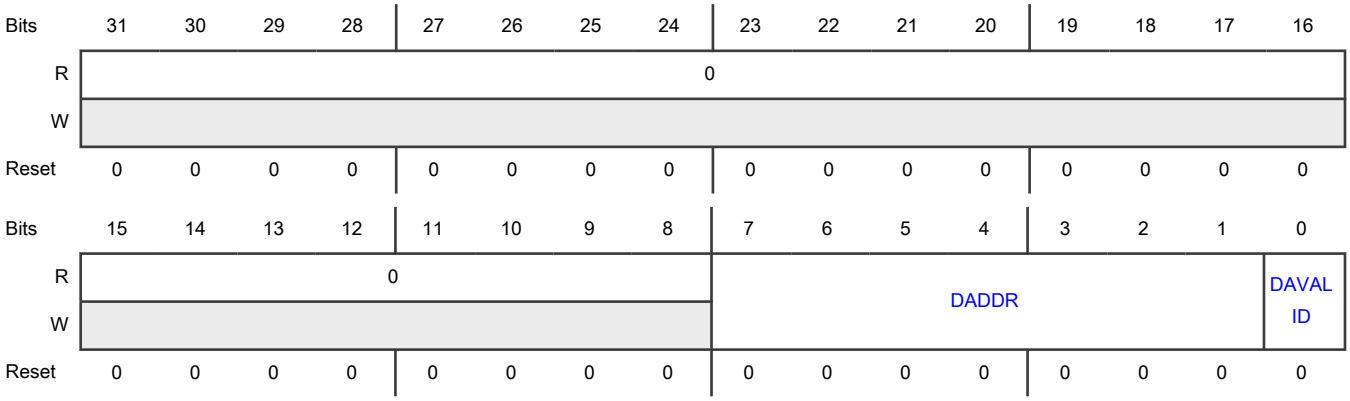
Allows the I3C module to write its own dynamic address (DA) when the module changes from Controller mode to Target mode.

If this device is the main controller (the controller during bus initialization), then the device may use this mechanism to assign itself its DA. When the device hands off control to a secondary controller, it becomes a target itself. This DA must be written before switching to Target mode and must not be changed once in Target mode (it is not clock-safe to do so). It must be written with a valid address value in DADDR if DAVALID = 1.

NOTE

The main controller also uses DEFSLVS CCC to define the target addresses, including itself. This mechanism is how secondary controllers know this address. If the controller is not the main controller, then this mechanism must not be used.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-1 DADDR	Dynamic Address Contains the assigned dynamic address when DAVALID = 1.
0 DAVALID	Dynamic Address Valid 0b - No valid DA assigned 1b - Valid DA assigned

45.7.55 Map Feature Control 0 (SMAPCTRL0)

Offset

Register	Offset
SMAPCTRL0	11Ch

Function

Provides map feature control.

The SMAPCTRL*n* registers are named SMAPCTRL0, SMAPCTRL1, and so on based on the number of mapped addresses. MAPCTRL0 represents the primary DA or SA with SMAPCTRL1 onwards being the mapped addresses.

The features of the SMAPCTRL*n* registers depend on configuration. SMAPCTRL0 acts differently, as described in this chapter.

In general, this mechanism is intended to replace the DYNADDR register for all MAP-related uses.

When using the Auto-MAP and DASA or AASA, the slot is changed from SA to DA. If the controller then issues RSTDAA, the application must rewrite the static addresses and enable them because they are marked disabled.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				CAUSE				DA							ENA
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-17 —	Reserved
16 —	Reserved
15-11 —	Reserved
10-8 CAUSE	Cause Indicates the cause of the most recent DA assignment, which lead to SSTATUS[DACHG] interrupt. This field has MAP enabled. If this field is 100b (auto MAP change happened last), the change may have changed this DA as well (for example, ENTDAA and SETAASA), but at least one MAP entry automatically changed after that. 000b - No information (this value occurs when not configured to write DA) 001b - Set using ENTDAA 010b - Set using SETDASA, SETAASA, or SETNEWDA 011b - Cleared using RSTDAA 100b - Auto MAP change happened last All other values are reserved.
7-1 DA	Dynamic Address Contains primary DA when ENA = 1. When ENA = 0, static address is used (but not described here). This field has MAP enabled.

Table continues on the next page...

Table continued from the previous page...

Field	Function
0 ENA	Enable Primary Dynamic Address Indicates whether the MAP is enabled. 0b - Disabled 1b - Enabled

45.7.56 Extended IBI Data 1 (IBIEXT1)

Offset

Register	Offset
IBIEXT1	140h

Function

Contains extended IBI data.

The CTRL register is used to submit IBI, CR, and Hot-Join when enabled to do so. If allowed, an IBI may have additional bytes following the mandatory data byte (MDB). Extended IBI data is allowed when SCTRL[EXTDATA] = 1. If allowed, the extra bytes are indicated using these registers.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	EXT3								EXT2							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	EXT1								0	MAX			0	CNT		
W																
Reset	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0

Fields

Field	Function
31-24 EXT3	Extra Byte 3 Contains the third extra byte.
23-16 EXT2	Extra Byte 2 Contains the second extra byte.

Table continues on the next page...

Table continued from the previous page...

Field	Function
15-8 EXT1	Extra Byte 1 Contains the first extra byte.
7 —	Reserved
6-4 MAX	Maximum Indicates the maximum number of extra bytes allowed by configuration. This field is 0 if there are no extra bytes.
3 —	Reserved
2-0 CNT	Count Contains the number of extra bytes beyond the MDB to be used. This field is 0 if there are no extra bytes.

45.7.57 Extended IBI Data 2 (IBIEXT2)

Offset

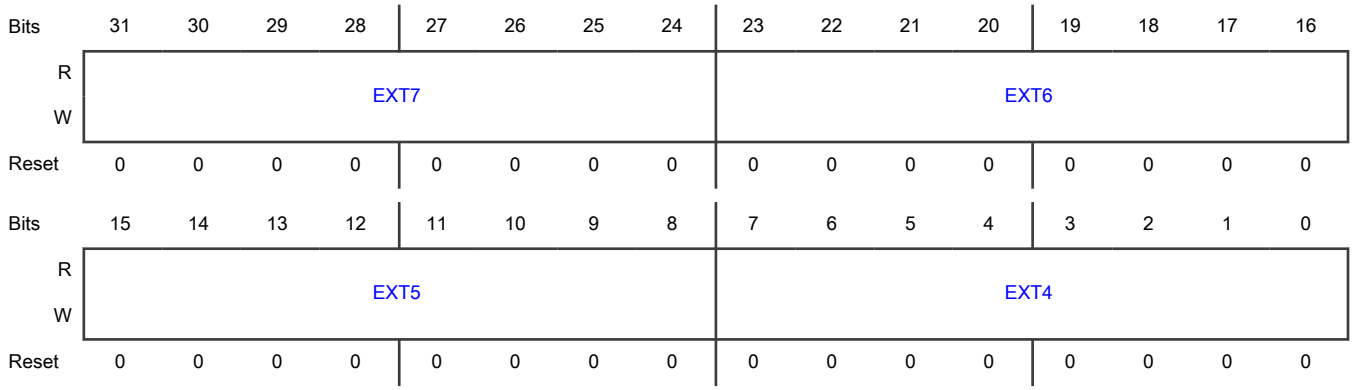
Register	Offset
IBIEXT2	144h

Function

Contains extended IBI data.

The CTRL register is used to submit IBI, CR, and Hot-Join when enabled to do so. If allowed, an IBI may have additional bytes following the mandatory data byte (MDB). Extended IBI data is allowed when SCTRL[EXTDATA] = 1. If allowed, the extra bytes are indicated using these registers.

Diagram



Fields

Field	Function
31-24 EXT7	Extra Byte 7 Contains the seventh extra byte.
23-16 EXT6	Extra Byte 6 Contains the sixth extra byte.
15-8 EXT5	Extra Byte 5 Contains the fifth extra byte.
7-0 EXT4	Extra Byte 4 Contains the forth extra byte.

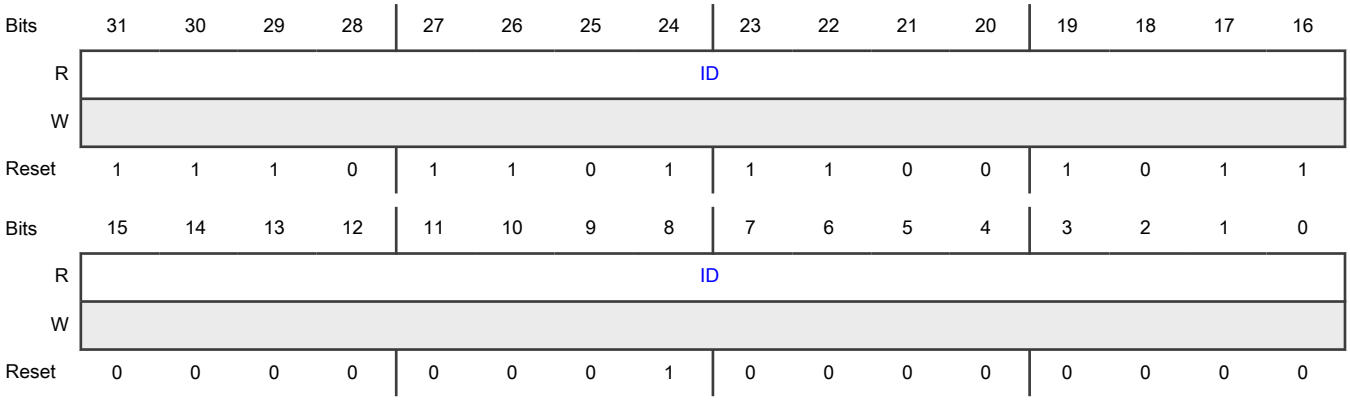
45.7.58 Target Module ID (SID)

Offset

Register	Offset
SID	FFCh

Function
Allows software to detect the module and its version information, if BlockID is enabled.

Diagram



Fields

Field	Function
31-0 ID	ID Indicates the ID. The ID meaning is specific to each use of the I3C module. ID = EDCB0100h.

Chapter 46
Low Power Serial Peripheral Interface (LPSPI)

46.1 Chip-specific LPSPI information

Table 328. Reference links to related information

Topic	Related module	Reference
Full description	LPSPI	LPSPI
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

46.1.1 Module instances

This device has two instances of the LPSPI module, LPSPI0, and LPSPI1.

46.1.2 Host request configuration

Both of the LPSPI0 and LPSPI1 support host request feature.

The input trigger that can be used as host request input is from TRGMUX, refer to Trigger multiplexer (TRGMUX) for more details.

46.2 Overview

LPSPI provides an efficient interface (either as a controller or peripheral) to an SPI bus, which is a synchronous serial communication interface used in embedded systems. It is typically used to perform short distance communications between microcontrollers and peripheral devices, on printed circuit boards. Typical applications include interfacing with secure digital cards and LCD displays.

NOTE

The terminology in this chapter has been updated to align with NXP's inclusive language standards, as shown in the table below.

Table 329. Updated terms

Updated term	Deprecated term
Controller	Master
Peripheral	Slave

46.2.1 Block diagram

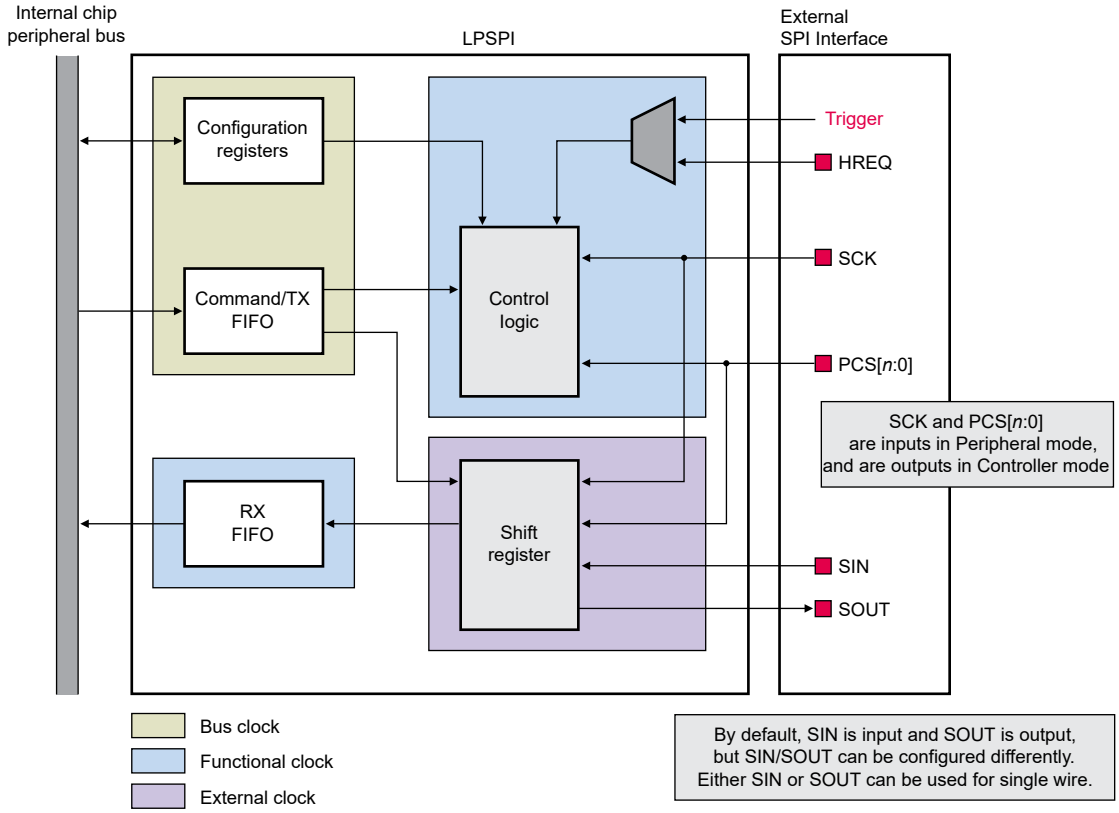


Figure 173. Block diagram

46.2.2 Features

- Minimal CPU overhead, with DMA transmit and receive requests supporting FIFO register accesses
- Operation continues in Sleep mode, if configured to do so and an appropriate clock is available
- Support available for 32-bit word size
- Configurable clock polarity and phase
- Support available for 4 peripheral chip selects in Controller mode
- Support available for Peripheral mode
- 8-word transmit and command FIFO
- 8-word receive FIFO
- Flexible timing parameters in Controller mode, including SCK frequency and duty cycle, and delays between PCS and SCK edges
- Continuous transfer option to keep PCS asserted across multiple frames
- Full-duplex transfers that support 1-bit transmit and receive on each clock edge
- Half-duplex transfers that support:
  - 1-bit transmit or receive on each clock edge
  - 2-bit transmit or receive on each clock edge
  - 4-bit transmit or receive on each clock edge

- Option to use host request to control the start of an SPI bus transfer
- Receive data match logic that discards nonmatching data and interrupt on data match

46.3 Functional description

46.3.1 Controller mode

46.3.1.1 Transmit and command FIFO commands

The transmit and command FIFO is a combined FIFO that includes both transmit data words and command words. You store:

- Transmit data words in the transmit and command FIFO, by writing to Transmit Data (TDR).
- Command words in the transmit and command FIFO, by writing to Transmit Command (TCR).

When a command word is at the top of the transmit and command FIFO, the actions that can occur depend on whether LPSPI is busy or between frames (see TCR[CONT] and TCR[CONTC]). See Table 330 for conditions and possible corresponding actions when a command word is at the top of the transmit and command FIFO.

Table 330. Possible actions when a command word is at the top of the transmit and command FIFO

Condition	Action
LPSPI is enabled and idle.	The command word is pulled from the FIFO, and this command word controls all subsequent transfers.
LPSPI is busy and TCR[CONTC] is 0.	The SPI frame completes at the end of the existing word, ignoring TCR[FRAMESZ]. The command word is then pulled from the FIFO and that command word controls all subsequent transfers (or until the next update to the command word). Note that a command word with TCR[CONTC] = 0 always terminates the existing transfer regardless of the previous TCR[CONT] value.
LPSPI is busy; the existing TCR[CONT] value is 1 and the new TCR[CONTC] value is 1.	The command word must be updated at the frame boundary. The command word is pulled from the FIFO during the last SCK pulse of the existing frame (based on the value of FRAMESZ), and the frame continues using the new command value for the rest of the frame (or until the next update to the command word). When TCR[CONTC] = 1, only the lower 24 bits of the command word are updated. If the command word is updated at a word boundary, then the transfer halts (stops) after that word. TCR[CONTC] is ignored when not at a frame boundary, so the frame ends prematurely.

TCR[CONT] = 1 keeps PCS asserted at end of frame, allowing the transfer to continue.

TCR[CONTC] = 1 specifies that this command word must not terminate the existing frame, and the transfer can continue using the new command word.

TCR[CONTC] = 1 is restricted in the sense that the new command must load on a frame boundary, and the only way for a transfer to continue from a frame boundary is when the previous command has TCR[CONT] = 1.

You can read the current state of the existing command word from Transmit Command (TCR). It requires at least three LPSPI functional clock cycles for Transmit Command (TCR) to update after you write to it (assuming an empty FIFO), and LPSPI must be enabled (CR[MEN] = 1).

Writing to Transmit Command (TCR) does not initiate an SPI bus transfer, unless TCR[TXMSK] = 1. When TCR[TXMSK] = 1, a new command word is not loaded until the end of the existing frame (based on the value of TCR[FRAMESZ]); at the end of the transfer, TCR[TXMSK] transitions to 0.

In Controller mode, the LPSPI command word in Transmit Command (TCR) controls SPI attributes based on the selections in register fields. See Table 331 for TCR fields and associated functionality related to data transfer.

Table 331. Command word in Controller mode

Transmit Command (TCR)		Description	Can this field be modified during a data transfer?
Field	Name		
CPOL	Clock polarity	Specifies the polarity of the SCK pin. Any change of CPOL value causes a transition on the SCK pin.	N
CPHA	Clock phase	Specifies the clock phase of the transfer.	N
PRESCALE	Prescaler value	Specifies a prescaler used to divide the LPSPI functional clock, to generate the timing parameters of the SPI bus transfer. Changing PRESCALE in conjunction with PCS enables LPSPI to connect to different peripheral devices at different frequencies.	N
PCS	Peripheral chip select	Specifies which PCS pin asserts for the transfer; the polarity of PCS is static and specified by CFGR1[PCSPOL]. If CFGR1[PCSCFG] = 1, do not select PCS[3:2].	N
LSBF	LSB first	Specifies whether LSB (bit 0) or MSB (bit 31 for a 32-bit word) is transmitted or received first.	Y
BYSW	Byte swap	Enables byte swap on each 32-bit word when transmitting and receiving data. Byte swapping can be useful when interfacing with devices that organize data as big-endian.	Y
CONT	Continuous transfer	Configures LPSPI for a continuous transfer that keeps PCS asserted between frames (as specified by FRAMESZ). You must write a new command word to cause PCS to negate. Also, this field supports changing the command word at frame size boundaries.	Y
CONTC	Continuing command	Indicates that this is a new command word for the existing continuous transfer. When CONTC = 1, the command word must only be written to the transmit and command FIFO on a frame boundary.	Y
RXMSK	Receive data mask	Masks the receive data and does not store the masked receive data in the receive FIFO or perform receive data matching. This option is useful for half-duplex transfers or to specify which fields are compared during receive data matching.	Y
TXMSK	Transmit data mask	Masks the transmit data; masked transmit data is not pulled from the transmit FIFO, and the output data pin is 3-stated (unless otherwise configured by CFGR1[OUTCFG]). This option is useful for half-duplex transfers.	Y
WIDTH	Transfer width	Specifies the number of bits shifted on each SCK pulse: • 1-bit transfers support traditional SPI bus transfers in either half-duplex or full-duplex data formats. • 2-bit and 4-bit half-duplex transfers are useful for interfacing with QuadSPI memory devices, and either TXMSK or RXMSK must also be 1.	Y
FRAMESZ	Frame size	Configures the frame size in number of bits equal to (FRAMESZ + 1):	Y

Table continues on the next page...

Table 331. Command word in Controller mode (continued)

Transmit Command (TCR)		Description	Can this field be modified during a data transfer?
Field	Name		
		• The minimum frame size is 8 bits. • If the frame size is larger than 32 bits, then the frame is divided into multiple words of 32 bits; each word is loaded from the transmit FIFO and stored in the receive FIFO separately. • If the size of the frame is not divisible by 32, then the last load of the transmit FIFO and store of the receive FIFO contains the remaining bits. For example, a 72-bit transfer consists of three words: the first and second words are 32 bits, and the third word is 8 bits.	

46.3.1.1.1 SPI bus transfers

LPSPI initiates an SPI bus transfer when all these conditions are true:

- Data is written to the transmit FIFO.
- The HREQ pin is asserted (or the HREQ function is disabled).
- LPSPI is enabled.

To perform the SPI bus transfer, LPSPI uses the attributes configured in Transmit Command (TCR) and the timing parameters defined in Clock Configuration (CCR).

The SPI bus transfer ends after the number of bits indicated by the value of FRAMESZ have been transferred (provided CONT = 0), or at the end of a word when a new transmit command word is at the top of the transmit and command FIFO. When LPSPI is disabled, the SPI bus transfers end after the transmit FIFO is empty and LPSPI is idle.

The HREQ input is only checked when PCS is negated.

46.3.1.1.2 Circular FIFO

The transmit and command FIFO supports a circular FIFO feature. This feature enables the LPSPI controller to (periodically) repeat a short data transfer that fits within the transmit and command FIFO, without requiring additional FIFO accesses. When the circular FIFO is enabled (CFGR0[CIRFIFO] = 1), the current state of the FIFO read pointer is saved and the status flags are not updated. After the FIFO is empty and LPSPI is idle, the FIFO read pointer is restored with the saved version, so the contents of the transmit and command FIFO are not permanently pulled from the FIFO when Circular FIFO mode is enabled.

46.3.1.2 Receive FIFO and data match

The receive FIFO stores received data during SPI bus transfers. When TCR[RXMSK] = 1, the received data is discarded instead of being stored in the receive FIFO:

- Received data is written to the receive FIFO when the last bit of the word is sampled.
- If the transmit FIFO is empty during a multiple-word or continuous transfer, then the receive data is written to the receive FIFO before the transfer stalls (assuming CFGR1[NOSTALL] = 0) while waiting for new transmit data or for a command word to be written.

LPSPI provides a receive data match function that can match received data against one of the two words in DMR0 and DMR1, or against a masked data word. You can also configure the received data match function to compare only the first one or two received data words since the start of the frame:

- Received data that is already discarded because of TCR[RXMSK] cannot cause the data match flag to set, and delays the receive data match on the first received data word, until all discarded data is received.

- You can configure the receive data match function to discard all received data until a data match is detected, using CFGR0[RDMO].
- After a receive data match, to allow all subsequent data to be received, write 0 to CFGR0[RDMO], and then write 0 to SR[DMF].

46.3.1.3 Timing parameters

The timing parameters that are used for all SPI bus transfers are relative to the LPSPI functional clock divided by the selection specified in TCR[PRESCALE]. Although you can only change Clock Configuration (CCR) when LPSPI is disabled (CR[MEN] = 0), to support interfacing with different peripheral devices at different frequencies, you can change the TCR[PRESCALE] selection between SPI bus transfers by using Transmit Command (TCR).

NOTE

The minimum value shown in Table 332 is the minimum counter value, but the values of Clock Configuration (CCR) must also satisfy the data sheet specs based on the LPSPI functional clock frequency and prescaler value.

Table 332. Timing parameters

Clock Configuration (CCR) Clock Configuration 1 (CCR1)		Description	Minimum value	Maximum value
Field	Name			
SCKSET	SCK setup phase	Configures the SCK setup phase to (SCKSET + 1) cycles. The setup phase is the SCK high period when either CPHA = 0 and CPOL = 1, or CPHA = 1 and CPOL = 0. Otherwise, it is the SCK low period. The SCK period is defined as (SCKSET + SCKHLD + 2) and the duty cycle is the difference between SCKSET and SCKHLD.	0 (1 cycle)	255 (256 cycles)
SCKHLD	SCK hold phase	Configures the SCK hold phase to (SCKHLD + 1) cycles. The hold phase is the SCK low period when either CPHA = 0 and CPOL = 1, or CPHA = 1 and CPOL = 0. Otherwise, it is the SCK high period. The SCK period is defined as (SCKSET + SCKHLD + 2) and the duty cycle is the difference between SCKSET and SCKHLD.	0 (1 cycle)	255 (256 cycles)
PCSPCS	PCS-to-PCS delay	Configures the minimum delay between PCS negation and the next PCS assertion to (PCSPCS + PCSPCS + 2) cycles. When the command word is updated between transfers, there is a minimum of (PCSPCS + 1) cycles between the command word update and any change on PCS pins.	0 (2 cycles)	255 (512 cycles)
SCKSCK	SCK-to-SCK delay	Configures the delay during a continuous transfer between the last SCK edge of a frame and the first SCK edge of the continuing frame to (SCKSCK + 1) cycles. This is useful when the external peripheral requires a large delay between different words of an SPI bus transfer.	0 (1 cycle)	255 (256 cycles)

Table continues on the next page...

Table 332. Timing parameters (continued)

Clock Configuration (CCR) Clock Configuration 1 (CCR1)		Description	Minimum value	Maximum value
Field	Name			
PCSSCK	PCS-to-SCK delay	Configures the minimum delay between PCS assertion and the first SCK edge to (PCSSCK + 1) cycles.	0 (1 cycle)	255 (256 cycles)
SCKPCS	SCK-to-PCS delay	Configures the minimum delay between the last SCK edge and the PCS negation to (SCKPCS + 1) cycles.	0 (1 cycle)	255 (256 cycles)

Figure 174 shows the timing settings controlled by:

- TCR[CPHA]
- TCR[CPOL]
- CCR[SCKPCS]
- CCR[PCSSCK]
- CCR1[SCKSET]
- CCR1[SCKHLD]

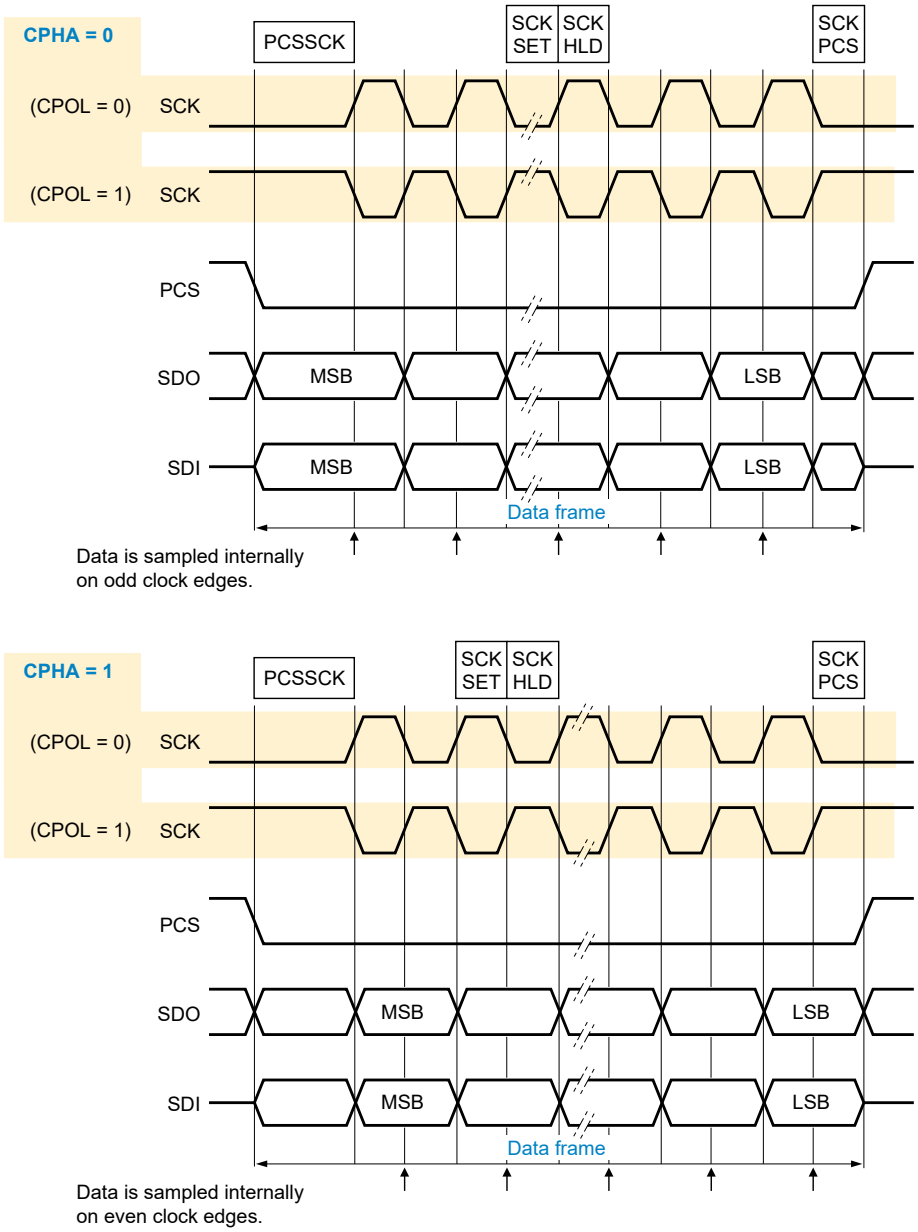


Figure 174. Clock phase (TCR[CPHA]) timing diagram example

To configure for a baud rate of 10 MHz with 50/50 duty cycle and with a functional clock frequency of 100 MHz, use the following settings:

- CCR1[SCKSET] = 0x4 (5 cycles)
- CCR1[SCKHLD] = 0x4 (5 cycles)
- CCR1[PCSPCS] = 0x8 (10 cycles)
- CCR1[SCKSCK] = 0x4 (5 cycles)
- CRR[PCSSCK] = 0x4 (5 cycles)
- CRR[SCKPCS] = 0x4 (5 cycles)
- TCR[PRESCALE] = 0x0 (divide by 1)

46.3.1.4 Pin configuration

Following are the pin configuration settings for half-duplex transfers:

- To swap directions or to support half-duplex transfers on the same pin, you can configure the SIN and SOUT pins using CFGR1[PINCFG].
- To specify whether an output data pin (SOUT, for example) 3-states when PCS is negated, or if the output data pin retains the last value, use CFGR1[OUTCFG].
- When configuring half-duplex transfers, you must configure the output data pins to 3-state when PCS is negated (CFGR1[OUTCFG] = 1).
- When performing half-duplex 2-bit transfers, you can write any value to CFGR1[PCSCFG].
- When performing half-duplex 4-bit transfers, you must write 1h to CFGR1[PCSCFG].

46.3.1.5 Clock loopback

Configure the LPSPI controller to use one of the following clocks to sample the input data:

- The SCK output clock
- A delayed version of the SCK output clock

The delayed version of the SCK is chosen by the SCK pin output delay, plus the SCK pin input delay, and is selected by writing 1 to CFGR1[SAMPLE]. Enabling the loopback version of the SCK pin can improve the setup time of the input data from the peripheral.

See the chip data sheet for the specific input setup time in Controller Loopback mode.

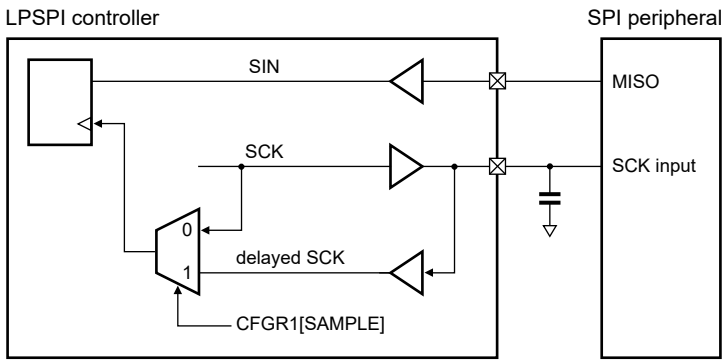


Figure 175. Clock loopback

46.3.2 Peripheral mode

LPSPI Peripheral mode:

- Uses the same shift register and logic that Controller mode uses.
- Does not use Clock Configuration (CCR).
- Requires Transmit Command (TCR) to remain static (unchanged) during SPI bus transfers.

46.3.2.1 Transmit and command FIFO commands

You must initialize Transmit Command (TCR) before enabling LPSPI in Peripheral mode, although this register is not updated until after LPSPI is enabled. After LPSPI is enabled, you must make changes to this register only when LPSPI is idle. In Peripheral mode, the LPSPI command word in this register controls SPI attributes. Before the PCS input asserts, the transmit FIFO must be filled with transmit data, or the transmit error flag sets.

Table 333. Command word in Peripheral mode

Transmit Command (TCR)		Description
Field	Name	
CPOL	Clock polarity	Specifies the polarity of the external SCK input.
CPHA	Clock phase	Specifies the clock phase of transfer.
PRESCALE	Prescaler value	Specifies the LPSPI functional clock prescaler.
PCS	Peripheral chip select	Specifies which PCS is used. The polarity of PCS is static and configured by CFGR1[PCSPOL]. If CFGR1[PCSCFG] is not equal to zero, then do not select the PCS[3:2] pins.
LSBF	LSB first	Specifies whether LSB (bit 0) or MSB (bit 31 for a 32-bit word) is transmitted or received first.
BYSW	Byte swap	Enables byte swap on each 32-bit word when transmitting and receiving data. Byte swapping can be useful when interfacing with devices that organize data as big-endian.
CONT	Continuous transfer	When continuous transfer is selected in Peripheral mode, after the number of bits indicated by FRAMESZ are transferred, LPSPI passes through and transmits the received data until the next PCS negation. Whatever is shifted in on the receive data is shifted out as transmit data considering that there is a 32-bit shift register.
CONTC	Continuing command	When the continuing command is enabled in Peripheral mode, after the number of bits indicated by FRAMESZ are transferred, RXMSK is considered equal to 1 and TXMSK is considered equal to 0 until the next PCS negation. CONTC can be used to change the direction of a transfer after the number of bits indicated by FRAMESZ.
RXMSK	Receive data mask	Masks the receive data; LPSPI does not store masked receive data in the receive FIFO or perform receive data matching. This option is useful for half-duplex transfers or to specify which fields are compared during receive data matching.
TXMSK	Transmit data mask	Masks the transmit data so that the masked transmit data is not pulled from transmit FIFO, and the output data pin is 3-stated (unless otherwise specified in CFGR1[OUTCFG]). This option is useful for half-duplex transfers.
WIDTH	Transfer width	Specifies the number of bits shifted on each SCK pulse: • 1-bit transfers support traditional SPI bus transfers in either half-duplex or full-duplex data formats. • 2-bit and 4-bit half-duplex transfers are useful for interfacing with QuadSPI memory devices, and at least either TCR[TXMSK] or TCR[RXMSK] must be 1.
FRAMESZ	Frame size	Specifies the frame size in number of bits equal to (FRAMESZ + 1): • The minimum frame size is 8 bits. • If the frame size is larger than 32 bits, then the frame is divided into multiple words of 32 bits; each word is loaded from the transmit FIFO and stored in the receive FIFO separately. • If the size of the frame is not divisible by 32, then the last load of the transmit FIFO and store of the receive FIFO contain the remainder bits. For example, a 72-bit transfer consists of three words: the first and second words are 32 bits, and the third word is 8 bits.

46.3.2.2 Receive FIFO and data match

The receive FIFO stores receive data during SPI bus transfers. When TCR[RXMSK] = 1, the received data is discarded instead of storing the received data in the receive FIFO.

Receive data supports a receive data match function that can match received data against one of the two words in DMR0 and DMR1 or against a masked data word. You can also configure the data match function to compare only the first one or two received data words since the start of the frame.

- Received data that is already discarded because TCR[RXMSK] = 1 cannot cause the data match to set, and delays the match on the first received data word, until all discarded data is received.
- By using CFGR0[RDMO], you can also configure the receiver match function to discard all received data until a data match is detected.
- After a receive data match, to allow all subsequent data to be received, first write 0 to CFGR0[RDMO], then clear SR[DMF].

46.3.2.3 Partial received word

When the PCS pin deasserts and the receive shift register shifts in a partial word, you can configure the receive shift register to either discard the partial word or to store it in the receive FIFO. You must specify this using CFGR1[PARTIAL].

A partial word is defined as less than TCR[FRAMESZ] bits (when TCR[FRAMESZ] is equal or less than 32 bits, or it is the last word in a multi-word frame) or less than 32 bits (when TCR[FRAMESZ] is greater than 32 bits and not the last word in a multi-word frame).

A single-bit frame is not supported. A partial received word of 1 bit is supported, but a partial received frame of 1 bit is not supported.

46.3.2.4 Clocked interface

LPSPI supports interfacing with external controllers that provide only clock and data pins (PCS is not required). This interface requires:

- Writing 1 to TCR[CPHA] (data is changed on the leading edge of SCK and captured on the following edge).
- Configuring the PCS input to be always asserted (CFGR1[PCSPOL*n*] = 1). For example, to configure PCS[0] to be always asserted, write 1 to PCSPOL[0], and do not configure PCS[0] in the pin muxing. The chip-level drives PCS to a certain value (ideally 1); you could use CFGR1[PCSPOL*n*] to invert that value.
- Writing 1 to CFGR1[AUTOPCS] to enable automatic PCS generation. When CFGR1[AUTOPCS] = 1, a minimum of four LPSPI functional clock cycles (divided by the selection specified in TCR[PRESCALE]) is required between the last SCK edge of one word and the first SCK edge of the next word.

46.3.3 Low-power modes

LPSPI remains functional during low-power modes, if CR[DOZEN] = 0 and LPSPI uses an external or internal clock source that remains enabled. LPSPI can generate an interrupt or DMA request to cause a wake-up from low-power modes.

46.3.4 Debug mode

Table 334. Debug mode

Chip mode	LPSPI operation
Debug (the core is in Debug or Halted mode)	Can continue operating in Debug mode, if CR[DBGEN] = 1

46.3.5 Clocking

Table 335. LPSPI clocks

Type of clock	Description
Functional	• Asynchronous to the bus clock. • If the LPSPI functional clock remains enabled in low-power modes, then LPSPI can perform SPI bus transfers and low-power wakeups in both Controller and Peripheral modes. • LPSPI divides the functional clock by a prescaler; the resulting frequency must be at least two times faster than the SPI external clock frequency (SCK).
External	• The LPSPI shift register is clocked directly by the SCK clock. • How the SCK clock is generated or supplied depends on the mode (Controller or Peripheral): — In Controller mode, the SCK clock is generated internally. — In Peripheral mode, the SCK clock is supplied externally.
Bus	The bus clock is only used for bus accesses to the LPSPI control and configuration registers. The bus clock frequency must be high enough to support the data bandwidth requirements of the LPSPI registers, including the FIFOs.

See the chip-specific LPSPI information for more.

46.3.6 Reset

Table 336. LPSPI resets

Type of reset	Description
Chip	Resets the LPSPI logic and registers to their default states.
Software	• Resets the LPSPI logic and registers to their default states, except for the Control register. • The LPSPI software reset is controlled using CR[RST].
FIFO	• Resets the transmit and command FIFO and the receive FIFO. • CR[RTF] and CR[RRF] are write-only. • After being reset, FIFO is empty.

46.3.7 Interrupts and DMA requests

The following table lists sources (status flags) that can generate LPSPI interrupts and LPSPI transmit and receive DMA requests.

Table 337. Interrupts and DMA requests

Status (SR)		Description	Can generate		
Status flag	Name		Interrupt?	DMA request?	Low-power wake-up?
TDF	Transmit data flag	Indicates that data can be written to transmit FIFO, as configured by the transmit FIFO watermark, FCR[TXWATER].	Y	TX	Y

Table continues on the next page...

Table 337. Interrupts and DMA requests (continued)

Status (SR)		Description	Can generate		
Status flag	Name		Interrupt?	DMA request?	Low-power wake-up?
RDF	Receive data flag	Indicates that data can be read from the receive FIFO, as configured by the receive FIFO watermark, FCR[RXWATER].	Y	RX	Y
WCF	Word complete flag	Indicates that the word is complete and the last bit of the word has been sampled.	Y	N	Y
FCF	Frame complete flag	Indicates that the frame is complete and PCS is deasserted.	Y	RX	Y
TCF	Transfer complete flag	Indicates that transfer is complete, PCS is deasserted, and the transmit and command FIFO is empty.	Y	N	Y
TEF	Transmit error flag	Indicates a transmit and command FIFO underrun. In Controller mode, when CFGR1[NOSTALL] = 0 (transfers stall when transmit FIFO is empty), TEF cannot be set.	Y	N	Y
REF	Receive error flag	Indicates a receive FIFO overflow. In Controller mode, when CFGR1[NOSTALL] = 0 (transfers stall when receive FIFO is full), REF cannot be set.	Y	N	Y
DMF	Data match flag	Indicates that the received data matches the configured data match value.	Y	N	Y
MBF	Module busy flag	Indicates that LPSPI is busy performing an SPI bus transfer.	N	N	N

46.3.7.1 End-of-packet DMA transfer

The end-of-packet functionality is designed for serial interfaces where you may not be aware of the size of the transfer in advance and the data is pushed by an external device. Examples include UART receive, I2C Peripheral mode, and SPI Peripheral mode. The end-of-packet processing is intended to ensure that data is not stranded in either the receive FIFO or the DMA receive buffer. Support for end-of-packet processing must be implemented in both the serial interfaces and the DMA controller.

The condition that signals the end of packet is different for each serial interface but the serial peripheral and DMA process it in the same way. For example, UART end of packet is signaled by an idle line condition, I2C end of packet by a stop and/or repeated start condition, and SPI end of packet by PCS negation.

If you configure the serial peripheral to signal the end-of-packet condition to the DMA and the serial interface detects an end-of-packet condition, it asserts the DMA request for the receive FIFO irrespective of the watermark configuration. For larger watermark configurations, this ensures that the last few words of the transfer are first flushed from the receive FIFO.

The DMA then reads the contents of the receive FIFO, depending on the first word in the FIFO:

- If the receive FIFO is empty, the serial interface signals an end-of-packet condition to the DMA controller.
- If the receive FIFO is not empty, but the first word in the FIFO is the start of a new packet, then data is not pulled from the receive FIFO and the serial interface signals an end-of-packet condition to the DMA controller.
- If the receive FIFO is not empty, and the first word in the FIFO is not the start of a new packet, the DMA transfers the receive data as normal.

Because the DMA may be transferring multiple words on each request, the end-of-packet condition persists until the DMA minor loop is complete and no additional data is pulled from the receive FIFO. The status flag that triggered the end-of-packet condition is cleared when the minor loop completes following end of packet being signaled to the DMA controller.

When the DMA detects the end-of-packet condition, it writes all received words up to the end of the packet into the system memory and saves the destination address for the word after the last valid data. The DMA then terminates the channel as if the major loop is complete, including final offsets and optional interrupts, channel linking and scatter/gather. The final destination address can optionally be saved in the system memory or is available in the destination address register.

After the DMA terminates the major loop, no servicing of the receive FIFO occurs until either software or hardware reconfigures the DMA (for example, channel linking or scatter/gather). This delay must be minimized to avoid receiver FIFO overrun. NXP does not recommend automatic DMA end-of-packet processing when there are only a few words transferred between end-of-packet conditions. That is because the DMA spends more time processing the end of packet than transferring the data. For example, the UART idle line length must be increased as needed to avoid an excessive number of idle conditions.

46.3.7.2 DMA support registers

To support efficient DMA transfers to the transmit and control FIFO, an alias register supports 32-bit write access to the Transmit Command (TCR) and an alias region supports incrementing 32-bit write accesses to the Transmit Data (TDR).

- Transmit Command Burst (TCBR) is a 32-bit alias register for writing to TCR.
- Transmit Data Burst (TDBR0 - TDBR127) is a 512-byte alias region that supports writing to the TDR.

The burst alias locations are contiguous. A DMA transfer can start by writing to the TCBR register to initialize the transfer and then increment into the TDBR region without changing the DMA transfer size. The alias registers can also be used by the DMA to perform burst transfers when accessing the transmit FIFO.

The transmit FIFO prevents writes that overflow the FIFO, but this prevention does not signal an error. Do not perform writes to the TDBR unless there is sufficient room in the transmit FIFO.

Receive Data Burst (RDBR0 - RDBR127) is a 512-byte alias region that supports reading the Receive Data. This can be used by the DMA to perform burst transfers when accessing the receive FIFO.

46.3.8 Peripheral triggers

The connection of the LPSPI peripheral triggers with other peripherals depends on the device that is used.

Table 338. Peripheral triggers

Type of trigger	Description	Additional information
Frame output	The frame output trigger: • Asserts at the end of each frame (when PCS deasserts). • Remains asserted for one cycle of the LPSPI functional clock divided by the configuration defined in TCR[PRESCALE].	LPSPI generates two output triggers that can be connected to other peripherals on the chip.
Word output	The word output trigger: • Asserts at the end of each received word. • Remains asserted for one cycle of the LPSPI functional clock divided by the configuration defined in TCR[PRESCALE].	
Input	To control the start of an LPSPI bus transfer, the LPSPI input trigger can be selected instead of the HREQ input:	

Table continues on the next page...

Table 338. Peripheral triggers (continued)

Type of trigger	Description	Additional information
	• The LPSPI input trigger is synchronized, and must assert for at least two cycles of the LPSPI functional clock divided by the configuration defined in TCR[PRESCALE] so that the input trigger can be detected. • When LPSPI is busy, the HREQ input (and therefore the LPSPI input trigger) is ignored. • When LPSPI is busy, both the HREQ and LPSPI input triggers are ignored. They are used to start a new transfer when LPSPI is idle.	

46.4 External signals

Table 339. External signals

Signal	Name	Description	I/O
SCK	Serial clock	• Input in Peripheral mode • Output in Controller mode	I/O
PCS[0]	Peripheral chip select	• Input in Peripheral mode • Output in Controller mode	I/O
PCS[1]/HREQ	Peripheral chip select or host request	Host request pin is selected when CFGR0[HREN] = 1 and CFGR0[HRSEL] = 0: • Input in either Peripheral mode or when used as controller host request • Output in either Controller mode or when used as peripheral host request	I/O
PCS[2]/DATA[2]	Peripheral chip select or data pin 2 during parallel data transfers	When CFGR1[PCSCFG] = 0: • Input in Peripheral mode • Output in Controller mode When CFGR1[PCSCFG] = 1: • Input in half-duplex parallel data receive transfers • Output in half-duplex parallel data transmit transfers	I/O
PCS[3]/DATA[3]	Peripheral chip select or data pin 3 during parallel data transfers	When CFGR1[PCSCFG] = 0: • Input in Peripheral mode • Output in Controller mode When CFGR1[PCSCFG] = 1: • Input in half-duplex parallel data receive transfers	I/O

Table continues on the next page...

Table 339. External signals (continued)

Signal	Name	Description	I/O
		• Output in half-duplex parallel data transmit transfers	
SOUT/DATA[0]	Serial data output	Can be configured as serial data input signal (used as data pin 0 in half-duplex parallel data transfers)	I/O
SIN/DATA[1]	Serial data input	Can be configured as serial data output signal (used as data pin 1 in half-duplex parallel data transfers)	I/O

46.5 Initialization

This module does not require initialization.

46.6 Memory map and registers

NOTE

- Writing to a read-only register or reading a write-only register can cause bus errors.
- LPSPI does not check values programmed in registers for validity, so you must take care to write valid values only.

46.6.1 LPSPI register descriptions

46.6.1.1 LPSPI memory map

LPSPI0 base address: 4003_6000h

LPSPI1 base address: 4003_7000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	0200_0004h
4h	Parameter (PARAM)	32	R	0004_0303h
10h	Control (CR)	32	RW	0000_0000h
14h	Status (SR)	32	RW	0000_0001h
18h	Interrupt Enable (IER)	32	RW	0000_0000h
1Ch	DMA Enable (DER)	32	RW	0000_0000h
20h	Configuration 0 (CFGR0)	32	RW	0000_0000h
24h	Configuration 1 (CFGR1)	32	RW	0000_0000h
30h	Data Match 0 (DMR0)	32	RW	0000_0000h
34h	Data Match 1 (DMR1)	32	RW	0000_0000h
40h	Clock Configuration (CCR)	32	RW	0000_0000h
44h	Clock Configuration 1 (CCR1)	32	RW	0000_0000h

Table continues on the next page...

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Offset	Register	Width (In bits)	Access	Reset value
58h	FIFO Control (FCR)	32	RW	0000_0000h
5Ch	FIFO Status (FSR)	32	R	0000_0000h
60h	Transmit Command (TCR)	32	RW	0000_001Fh
64h	Transmit Data (TDR)	32	W	0000_0000h
70h	Receive Status (RSR)	32	R	0000_0002h
74h	Receive Data (RDR)	32	R	0000_0000h
78h	Receive Data Read Only (RDROR)	32	R	0000_0000h
3FCh	Transmit Command Burst (TCBR)	32	W	0000_0000h
400h - 5FCh	Transmit Data Burst (TDBR0 - TDBR127)	32	W	0000_0000h
600h - 7FCh	Receive Data Burst (RDBR0 - RDBR127)	32	R	0000_0000h

46.6.1.2 Version ID (VERID)

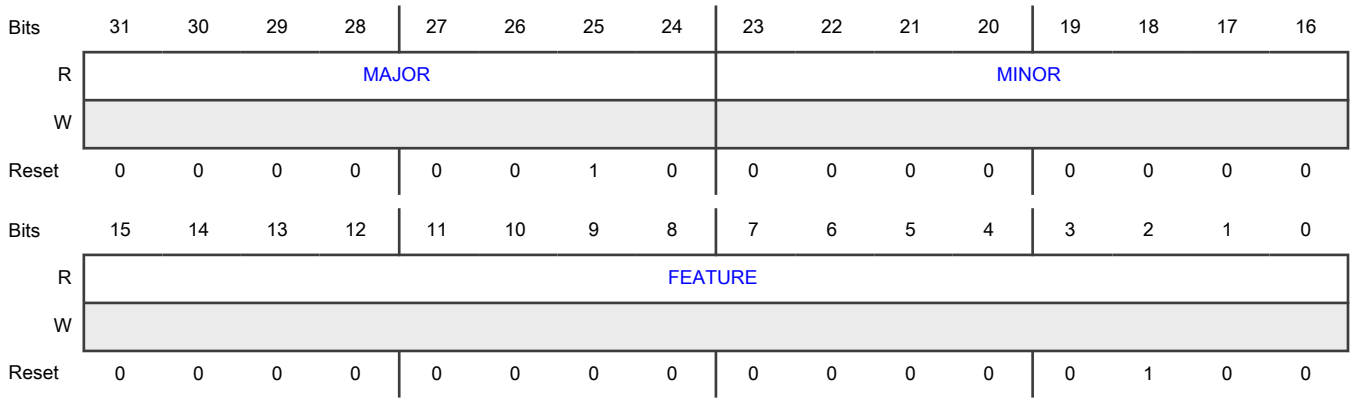
Offset

Register	Offset
VERID	0h

Function

Contains version numbers for the module design and feature set.

Diagram



Fields

Field	Function
31-24 MAJOR	Major Version Number Indicates the major version number of the module specification.
23-16 MINOR	Minor Version Number Indicates the minor version number of the module specification.
15-0 FEATURE	Module Identification Number Indicates the feature set number 0000_0000_0000_0100b - Standard feature set supporting a 32-bit shift register. All other values are reserved.

46.6.1.3 Parameter (PARAM)

Offset

Register	Offset
PARAM	4h

Function

Contains:

- Number of PCS pins.
- Receive FIFO size.
- Transmit FIFO size.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0								PCSNUM							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	RXFIFO								TXFIFO							
W																
Reset	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1

Fields

Field	Function
31-24 —	Reserved
23-16 PCSNUM	PCS Number Indicates the number of PCS pins supported.
15-8 RXFIFO	Receive FIFO Size Indicates the maximum number of words in the receive FIFO. The maximum number of words is 2^{RXFIFO}.
7-0 TXFIFO	Transmit FIFO Size Indicates the maximum number of words in the transmit FIFO. The maximum number of words is 2^{TXFIFO}.

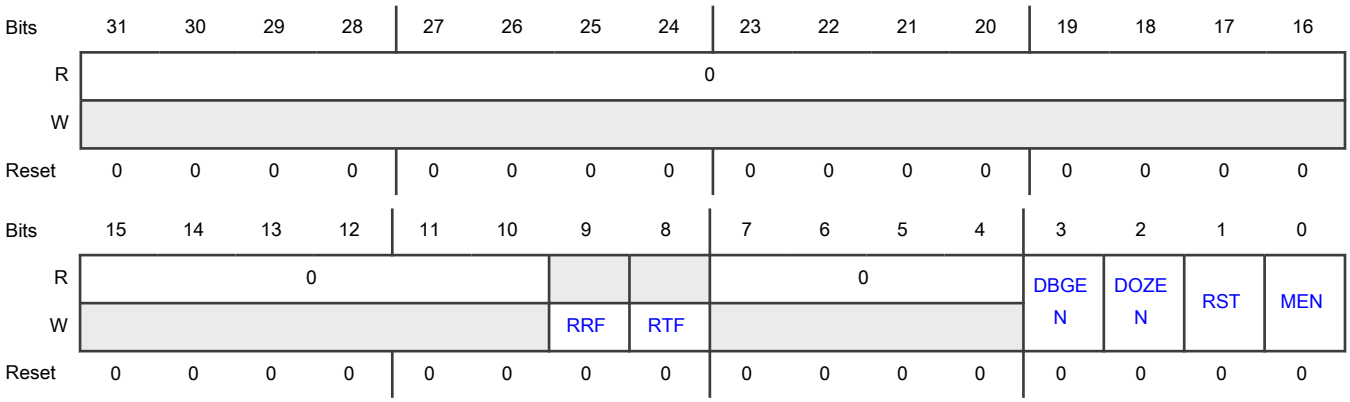
46.6.1.4 Control (CR)

Offset

Register	Offset
CR	10h

Function
Contains fields that control the module operation.

Diagram



Fields

Field	Function
31-10	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
9 RRF	Reset Receive FIFO Deletes all entries in the receive FIFO. This field always reads 0. 0b - No effect 1b - Reset
8 RTF	Reset Transmit FIFO Deletes all entries in the transmit FIFO. This field always reads 0. 0b - No effect 1b - Reset
7-4 —	Reserved
3 DBGEN	Debug Enable Enables LPSPI when the CPU is in Debug mode. If this field is 0, LPSPI is disabled when the CPU is halted; the PCS pin is deasserted after the transmit FIFO is empty regardless of the state of Transmit Command (TCR). You must update this field only when LPSPI is disabled (MEN = 0). 0b - Disable 1b - Enable
2 DOZEN	Doze Mode Enable Enables LPSPI when the chip is in Doze mode. You must update this field only when LPSPI is disabled (MEN = 0). 0b - Enable 1b - Disable
1 RST	Software Reset Resets all internal logic and registers, except Control (CR). The reset takes effect immediately and remains asserted until you write 0 to it. There is no minimum delay required before clearing the software reset by writing 0. 0b - Not reset 1b - Reset
0 MEN	Module Enable Enables the module. After writing 0, MEN remains set until LPSPI has completed the current transfer and is idle.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Disable 1b - Enable

46.6.1.5 Status (SR)

Offset

Register	Offset
SR	14h

Function
Contains data flow status.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0							MBF	0							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		DMF	REF	TEF	TCF	FCF	WCF	0						RDF	TDF
W			W1C	W1C	W1C	W1C	W1C	W1C								
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Fields

Field	Function
31-25 —	Reserved
24 MBF	Module Busy Flag Indicates, in Controller mode, whether there is data to transmit and LPSPI is able to transmit (for example, the HREQ pin is asserted). The HREQ pin deasserts after the PCS pin deasserts and the LPSPI controller has waited for half the time specified in CCR[DBT] with no new data to transmit. Peripheral mode sets this flag when LPSPI is enabled and PCS is asserted. 0b - LPSPI is idle 1b - LPSPI is busy

Table continues on the next page...

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Field	Function
23-14 —	Reserved
13 DMF	Data Match Flag Indicates whether the received data matches DMR0[MATCH0] and/or DMR1[MATCH1] (as configured by CFGR1[MATCFG]). **NOTE** This field behaves differently for register reads and writes. When reading 0b - No match 1b - Match When writing 0b - No effect 1b - Clear the flag
12 REF	Receive Error Flag Indicates a receive FIFO overflow error. When this flag is set: 1. End the transfer. 2. Empty the receive FIFO. 3. Clear this flag. 4. Restart the transfer from the beginning. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No overflow 1b - Overflow When writing 0b - No effect 1b - Clear the flag
11 TEF	Transmit Error Flag Indicates a transmit FIFO underrun error. When this flag is set: 1. End the transfer. 2. Clear this flag. 3. Restart the transfer from the beginning.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	NOTE This field behaves differently for register reads and writes. When reading 0b - No underrun 1b - Underrun When writing 0b - No effect 1b - Clear the flag
10 TCF	Transfer Complete Flag Indicates, in Controller mode, whether all transfers are complete and LPSPI has returned to the Idle state and the transmit FIFO is empty. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not complete 1b - Complete When writing 0b - No effect 1b - Clear the flag
9 FCF	Frame Complete Flag Indicates whether a frame transfer is complete after PCS deasserts. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not complete 1b - Complete When writing 0b - No effect 1b - Clear the flag
8 WCF	Word Complete Flag Indicates whether the last bit of a received word is sampled.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	NOTE This field behaves differently for register reads and writes. When reading 0b - Not complete 1b - Complete When writing 0b - No effect 1b - Clear the flag
7-2 —	Reserved
1 RDF	Receive Data Flag Indicates whether the number of words in the receive FIFO is greater than the value in FCR[RXWATER]. 0b - Receive data not ready 1b - Receive data ready
0 TDF	Transmit Data Flag Indicates whether the number of words in the transmit FIFO is equal to or less than the value in FCR[TXWATER]. 0b - Transmit data not requested 1b - Transmit data requested

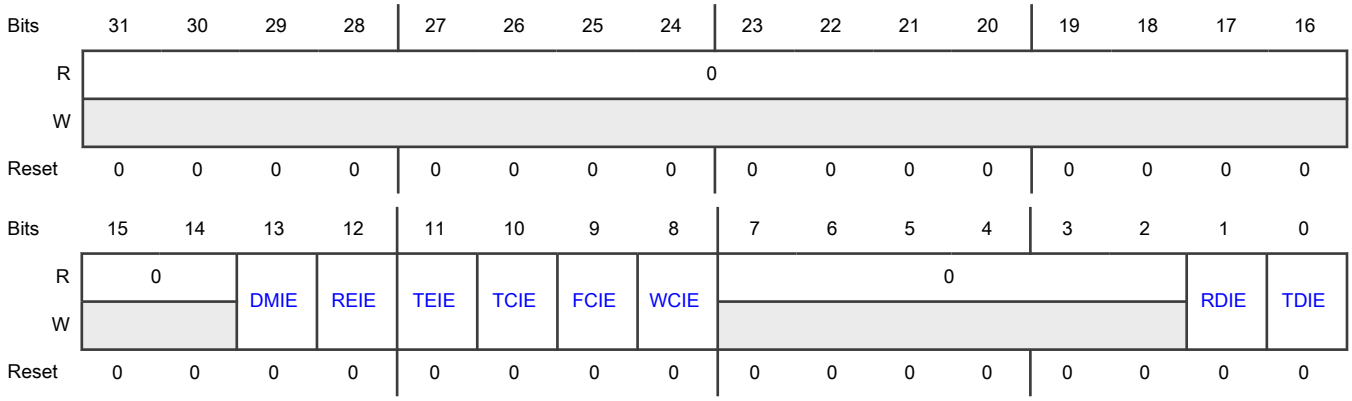
46.6.1.6 Interrupt Enable (IER)

Offset

Register	Offset
IER	18h

Function
Enables interrupts based on data flow and errors.

Diagram



Fields

Field	Function
31-14 —	Reserved
13 DMIE	Data Match Interrupt Enable Enables the data match interrupt. 0b - Disable 1b - Enable
12 REIE	Receive Error Interrupt Enable Enables the receive error interrupt. 0b - Disable 1b - Enable
11 TEIE	Transmit Error Interrupt Enable Enables the transmit error interrupt. 0b - Disable 1b - Enable
10 TCIE	Transfer Complete Interrupt Enable Enables the transfer complete interrupt. 0b - Disable 1b - Enable
9 FCIE	Frame Complete Interrupt Enable Enables the frame complete interrupt. 0b - Disable 1b - Enable

Table continues on the next page...

Table continued from the previous page...

Field	Function
8 WCIE	Word Complete Interrupt Enable Enables the word complete interrupt. 0b - Disable 1b - Enable
7-2 —	Reserved
1 RDIE	Receive Data Interrupt Enable Enables the receive data interrupt. 0b - Disable 1b - Enable
0 TDIE	Transmit Data Interrupt Enable Enables the transmit data interrupt. 0b - Disable 1b - Enable

46.6.1.7 DMA Enable (DER)

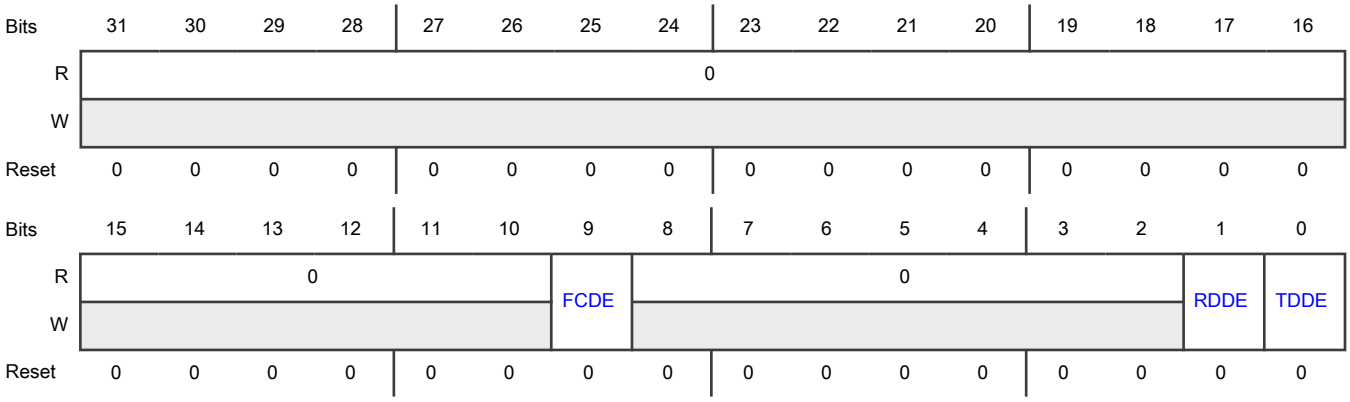
Offset

Register	Offset
DER	1Ch

Function

Enables the DMA data flow.

Diagram



Fields

Field	Function
31-10 —	Reserved
9 FCDE	Frame Complete DMA Enable Enables DMA end-of-packet processing. After the last word of a frame is read from the receive data FIFO, reading the receive data FIFO returns an end-of-packet signal with the receive data forced to FFFF_FFFFh. This continues until the DMA minor loop completes, and then SR[FCF] deasserts if the receive FIFO is empty or if LPSPI is busy (SR[MBF] = 1). 0b - Disable 1b - Enable
8-2 —	Reserved
1 RDDE	Receive Data DMA Enable Enables the receive data DMA. 0b - Disable 1b - Enable
0 TDDE	Transmit Data DMA Enable Enables the transmit data DMA. 0b - Disable 1b - Enable

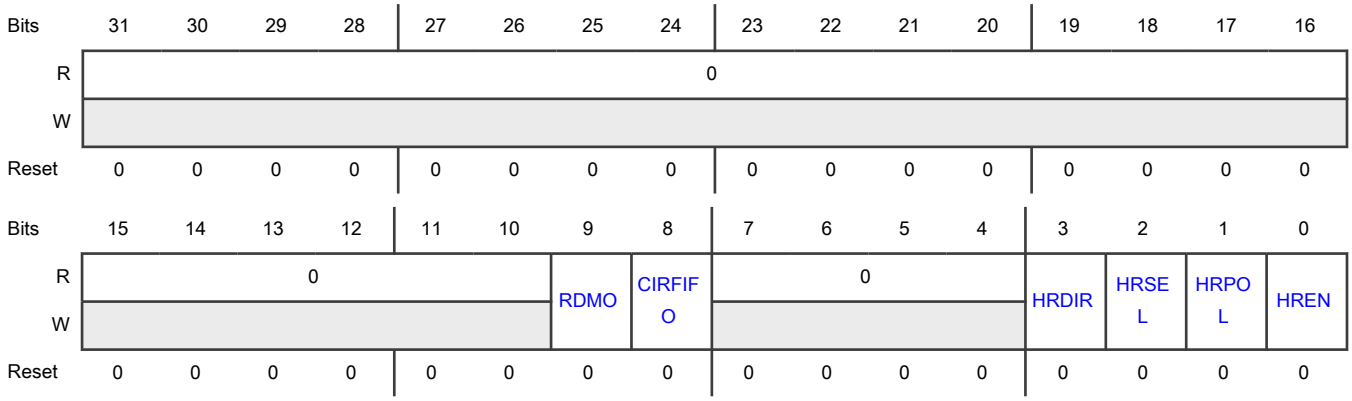
46.6.1.8 Configuration 0 (CFGR0)

Offset

Register	Offset
CFGR0	20h

Function
Includes fields to configure LPSPI.

Diagram



Fields

Field	Function
31-10 —	Reserved
9 RDMO	Receive Data Match Only Enables receive data match. When enabled, all received data that does not cause SR[DMF] to assert is discarded: • Write 1 to this field when LPSPI is idle and SR[DMF] = 0. • After SR[DMF] = 1, this field is ignored. • To ensure that no receive data is lost when disabling RDMO, write 0 to this field before clearing SR[DMF]. See CFGR1[MATCFG] for the received data matching options. When disabled, all received data is stored in the receive FIFO. 0b - Disable 1b - Enable
8 CIRFIFO	Circular FIFO Enable Enables circular FIFO. When enabled, the transmit FIFO read pointer is saved to a temporary register. The transmit FIFO is emptied as in normal operation, but when LPSPI is idle and the transmit FIFO is empty, the read pointer value is restored from the temporary register. This restoring of the read pointer causes the contents of the transmit FIFO to be cycled through repeatedly. **NOTE** The read pointer is restored for as long as this field is 1. Writing additional words to the FIFO when this field is 1 adds them to the end of the FIFO, up to the size of the transmit FIFO. 0b - Disable 1b - Enable

Table continues on the next page...

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Field	Function
7-4 —	Reserved
3 HRDIR	Host Request Direction Specifies the direction of the HREQ pin. You must configure the HREQ pin only as an output when LPSPI is in Peripheral mode. The HREQ pin direction must be an input for Controller mode. 0b - Input 1b - Output
2 HRSEL	Host Request Select Specifies the source of the host request input. When the host request function is enabled with the HREQ pin, the PCS[1] function is disabled. 0b - HREQ pin 1b - Input trigger
1 HRPOL	Host Request Polarity Specifies the polarity of the HREQ pin or input trigger. 0b - Active high 1b - Active low
0 HREN	Host Request Enable Enables LPSPI, in Controller mode, to start a new SPI bus transfer only if the host request input is asserted. When LPSPI is busy, the host request input is ignored. In Peripheral mode, causes the HREQ output pin to assert when data is available to be transmitted. 0b - Disable 1b - Enable

46.6.1.9 Configuration 1 (CFGR1)

Offset

Register	Offset
CFGR1	24h

Function

Includes fields to configure LPSPI. You must write to this register only when LPSPI is disabled.

In addition to pin and output configurations, this register contains match configuration details; the following table shows match conditions specified in MATCFG.

Table 340. Match conditions for CFGR1[MATCFG]

Condition	Description
Match first data word with compare word	Match if first data word equals MATCH0 logically ORed with MATCH1 first_data_word == (MATCH0 || MATCH1)
Match any data word with compare word	Match if any data word equals MATCH0 logically ORed with MATCH1 any_data_word == (MATCH0 || MATCH1)
Sequential match, first data word	Match if first data word equals MATCH0, and second data word equals MATCH1 (first_data_word == MATCH0) && (second_data_word == MATCH1)
Sequential match, any data word	Match if any data word equals MATCH0, and the next data word equals MATCH1 (any_data_word == MATCH0) && (next_data_word == MATCH1)
Match first data word (masked) with compare word (masked)	Match if first data word logically ANDed with MATCH1 equals MATCH0 logically ANDed with MATCH1 (first_data_word && MATCH1) == (MATCH0 && MATCH1)
Match any data word (masked) with compare word (masked)	Match if any data word logically ANDed with MATCH1 equals MATCH0 logically ANDed with MATCH1 (any_data_word && MATCH1) == (MATCH0 && MATCH1)

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0			0	PCSCFG	OUTCFG	PINCFG		0				MATCFG			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				PCSPOL				0			PARTIAL	NOSTALL	AUTOPCS	SAMPLE	MASTER
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-29 —	Reserved
28 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
27 PCSCFG	Peripheral Chip Select Configuration Specifies PCS pin configuration. When performing parallel transfers, you must configure this field to enable the desired transfer. 0b - PCS[3:2] configured for chip select function 1b - PCS[3:2] configured for half-duplex 4-bit transfers (PCS[3:2] = DATA[3:2])
26 OUTCFG	Output Configuration Specifies whether the output data is 3-stated between accesses (when PCS is deasserted). When performing half-duplex transfers, this field must be 1. 0b - Retain last value 1b - 3-stated
25-24 PINCFG	Pin Configuration Specifies the pins used for input and output data during serial transfers. **NOTE** When performing parallel transfers, this field must be 00b or 10b. 00b - SIN is used for input data; SOUT is used for output data 01b - SIN is used for both input and output data; only half-duplex serial transfers are supported 10b - SOUT is used for both input and output data; only half-duplex serial transfers are supported 11b - SOUT is used for input data; SIN is used for output data
23-19 —	Reserved
18-16 MATCFG	Match Configuration Specifies the condition that causes SR[DMF] to assert. See the match conditions listed in Table 1 for more information. **NOTE** When writing to this field, either the old value or new value must be in the disabled state (0). You cannot transition from a nonzero value to another nonzero value. 000b - Match is disabled 001b - Reserved 010b - Match first data word with compare word 011b - Match any data word with compare word 100b - Sequential match, first data word 101b - Sequential match, any data word 110b - Match first data word (masked) with compare word (masked)

Table continues on the next page...

Table continued from the previous page...

Field	Function
	111b - Match any data word (masked) with compare word (masked)
15-12 —	Reserved
11-8 PCSPOL	Peripheral Chip Select Polarity Specifies the polarity of each PCS pin. Bit *n* in this field (the least-significant bit is bit 0) corresponds to PCS[*n*]. 0000b - Active low 0001b - Active high
7-5 —	Reserved
4 PARTIAL	Partial Enable Specifies whether LPSPI, when in Peripheral mode, stores a partial received word in the receive FIFO, or discards it, when PCS deasserts. See Partial received word for more information. 0b - Discard 1b - Store
3 NOSTALL	No Stall Disables a normal operating feature that causes LPSPI, when in Controller mode, to stall transfers when the transmit FIFO is empty or when the receive FIFO is full. This feature prevents transmit FIFO underruns and receive FIFO overruns. Writing 1 to this field disables this functionality. 0b - Disable 1b - Enable
2 AUTOPCS	Automatic PCS Enables automatic PCS generation. For correct operation in Peripheral mode, LPSPI requires the PCS signal to deassert between frames. Writing 1 to this field generates an internal PCS signal at the end of each transfer word when TCR[CPHA] = 1. When this field is 1, SCK must remain idle for at least four LPSPI functional clock cycles, divided by the prescaler (see TCR[PRESCALE]) selected between each word to ensure correct operation. This field is ignored in Controller mode. **NOTE** Set TCR[CPHA] = 1 before enabling the module by setting CR[MEN] = 1. 0b - Disable 1b - Enable
1	Sample Point

Table continues on the next page...

Table continued from the previous page...

Field	Function
SAMPLE	Specifies the SCK clock edge on which LPSPI, when in Controller mode, samples input data. Writing 1 to this field causes LPSPI to sample input data on a delayed loopback SCK clock edge, which improves the setup time when sampling data (see Clock loopback). In this configuration, the input data setup time in Controller mode is equal to the input data setup time in Peripheral mode. In Peripheral mode, this field is ignored. **NOTE** When SAMPLE = 1, both the input and output buffers must be enabled for the SCK pin. Buffers are configured at the chip level. 0b - SCK edge 1b - Delayed SCK edge
0 MASTER	Controller Mode Specifies the LPSPI operating mode, Controller or Peripheral. This field directly controls the direction of the SCK and PCS pins. 0b - Peripheral mode 1b - Controller mode

46.6.1.10 Data Match 0 (DMR0)

Offset

Register	Offset
DMR0	30h

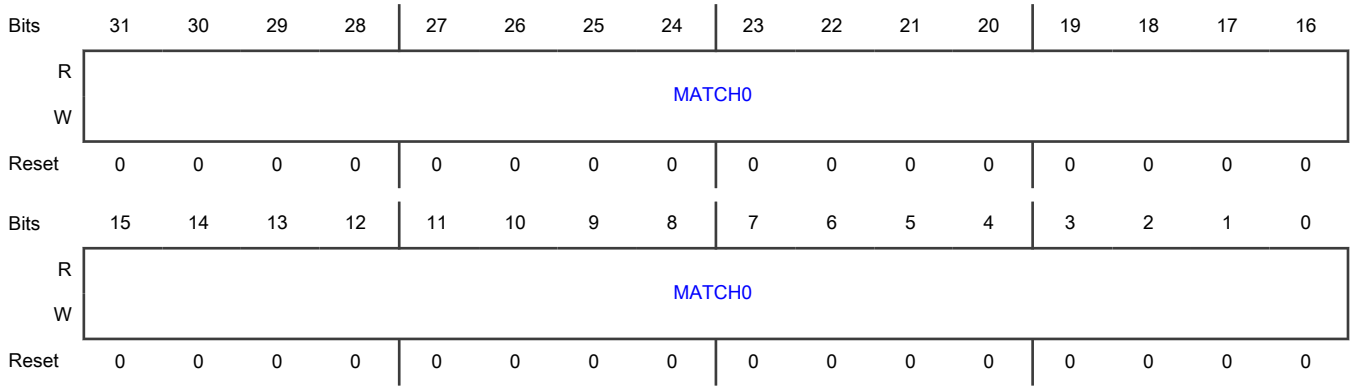
Function

Specifies the match data to be used when data matching is enabled. See CFGR1[MATCFG] for the received data matching options.

NOTE

Do not change the value in this register when CFGR1[MATCFG] > 0.

Diagram



Fields

Field	Function
31-0 MATCH0	Match 0 Value Specifies the MATCH0 value to be compared against received data.

46.6.1.11 Data Match 1 (DMR1)

Offset

Register	Offset
DMR1	34h

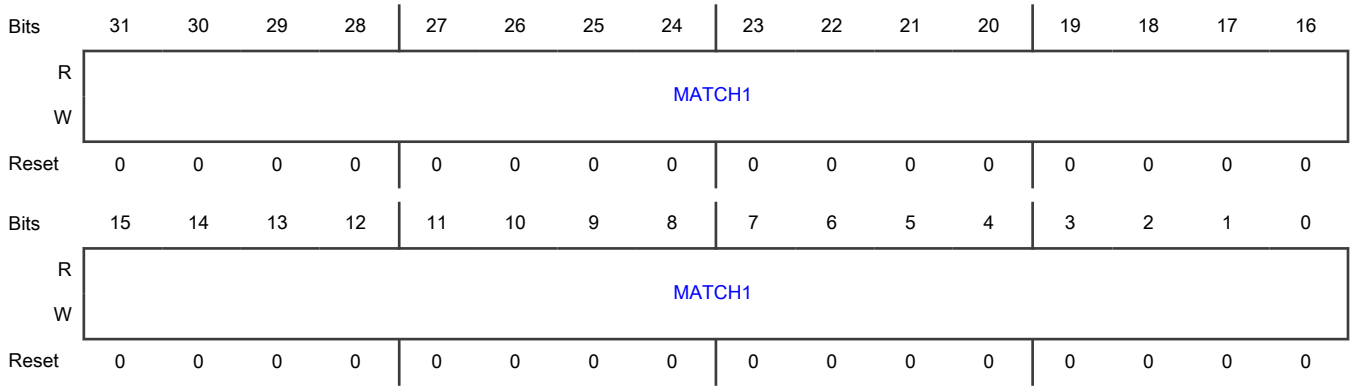
Function

Specifies the match data to be used when data matching is enabled. See CFGR1[MATCFG] for the received data matching options.

NOTE

Do not change the value in this register while CFGR1[MATCFG] > 0.

Diagram



Fields

Field	Function
31-0 MATCH1	Match 1 Value Specifies the MATCH1 value to be compared against received data.

46.6.1.12 Clock Configuration (CCR)

Offset

Register	Offset
CCR	40h

Function

Contains clock configuration fields that are used only in Controller mode; you can only change them when LPSPI is disabled (CR[MEN] = 0).

Warning

Writing a 32-bit value to this register overwrites Clock Configuration 1 (CCR1); DBT and SCKDIV always read 0.

To avoid overwriting CCR1, do one of the following:

- Write to all four fields in Clock Configuration (CCR) simultaneously and only once in a 32-bit data.
- Modify the values of CCR[SCKPCS] and/or CCR[PCSSCK]; write only these two upper bytes in a 16-bit data or one of them in an 8-bit data.
- Modify CCR1[PCSPCS] and CCR1[SCKSCK] only or CCR1[SCKSET] and CCR1[SCKHLD] only, write respectively to CCR[DBT] or CCR[SCKDIV] in 8-bit data.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SCKPCS								PCSSCK							
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								0							
W	DBT								SCKDIV							
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24	SCK-to-PCS Delay

Table continues on the next page...

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Field	Function
SCKPCS	Configures SCK-to-PCS delay. In Controller mode, this field helps you configure the delay from the last SCK edge to PCS negation: • The delay is equal to (SCKPCS + 1) cycles of the LPSPI functional clock divided by the selected prescaler (see TCR[PRESCALE]). • The minimum delay is one cycle. See Figure 174 for more information.
23-16 PCSSCK	PCS-to-SCK Delay Configures PCS-to-SCK delay. In Controller mode, this field helps you configure the delay from PCS assertion to the first SCK edge: • The delay is equal to (PCSSCK + 1) cycles of the LPSPI functional clock divided by the selected prescaler (see TCR[PRESCALE]). • The minimum delay is one cycle. See Figure 174 for more information.
15-8 DBT	Delay Between Transfers Configures the delay between transfers. Writing to this field updates the contents of CCR1[PCSPCS] and CCR1[SCKSCK].
7-0 SCKDIV	SCK Divider Updates the contents of CCR1[SCKSET] and CCR1[SCKHLD]. Baud rate = function clock ÷ (2^PRESCALE × (SCKSET + SCKHLD + 2))

46.6.1.13 Clock Configuration 1 (CCR1)

Offset

Register	Offset
CCR1	44h

Function

Contains clock configuration fields, which are used only in Controller mode. You can change them only when LPSPI is disabled (CR[MEN] = 0).

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SCKSCK								PCSPCS							
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SCKHLD								SCKSET							
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 SCKSCK	SCK Inter-Frame Delay Configures SCK inter-frame delay in Controller mode: • This field helps you configure the delay from the last SCK pulse of a frame and the first SCK pulse of the following frame, in a continuous transfer. • The delay is equal to (SCKSCK + 1) cycles of the LPSPI functional clock divided by the selected prescaler (see TCR[PRESCALE]). • The minimum delay is one cycle. **NOTE** For backward compatibility, writing to CCR[DBT] updates this field with the value written.
23-16 PCSPCS	PCS to PCS Delay Configures PCS to PCS delay in Controller mode: • This field helps you configure the delay from the PCS negation to the next PCS assertion. • The delay is equal to (PCSPCS + PCSPCS + 2) cycles of the LPSPI functional clock divided by the selected prescaler (see TCR[PRESCALE]). • The minimum delay is two cycles. • Half of the delay (PCSPCS + 1) occurs before PCS assertion and the other half of the delay (PCSPCS + 1) occurs after PCS negation. If the command word is updated between two transfers, then the command word is updated halfway between the PCS negation of the last transfer and PCS assertion of the next transfer. • The command word specifies which PCS signal is used, the polarity and phase of the SCK signal, and the selected prescaler. **NOTE** For backward compatibility, writing to CCR[DBT] updates this field with (DBT÷2) rounded up.
15-8	SCK Hold

Table continues on the next page...

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Field	Function
SCKHLD	Configures the hold phase of the SCK pin in Controller mode: • The hold phase is the delay between the SCK edge that samples the receive data and the SCK edge that drives the transmit data. • It is the SCK low period when CPHA = 0 and CPOL = 1, or CPHA = 1 and CPOL = 0. It is the SCK high period when CPHA = 0, CPOL = 0 and CPHA = 1, CPOL = 1. • The SCK hold phase delay is equal to (SCKHLD + 1) cycles of the LPSPI functional clock divided by the selected prescaler (see TCR[PRESCALE]). • The minimum delay is one cycle. • The SCK period is equal to (SCKSET + SCKHLD + 2) cycles of the LPSPI functional clock divided by the selected prescaler (see TCR[PRESCALE]). • The SCK duty cycle is based on the difference between SCKSET and SCKHLD. You must configure both these fields to the same value for a 50/50 duty cycle. See Figure 174 for more information. **NOTE** For backward compatibility, writing to CCR[SCKDIV] updates this field with (SCKDIV ÷ 2) rounded down.
7-0 SCKSET	SCK Setup Configures the setup phase of the SCK pin in Controller mode: • The setup phase is the delay between the SCK edge that drives the transmit data and the SCK edge that samples the receive data. • It is the SCK high period when CPHA = 0 and CPOL = 1, or CPHA = 1 and CPOL = 0. It is the SCK low period when CPHA = 0 and CPOL = 0, or CPHA = 1 and CPOL = 1. • The SCK setup phase delay is equal to (SCKSET + 1) cycles of the LPSPI functional clock divided by the selected prescaler (see TCR[PRESCALE]). • The minimum delay is one cycle. • The SCK period is equal to (SCKSET + SCKHLD + 2) cycles of the LPSPI functional clock divided by the selected prescaler (see TCR[PRESCALE]). • The SCK duty cycle is based on the difference between SCKSET and SCKHLD. You must configure both these fields to the same value for a 50/50 duty cycle. See Figure 174 for more information. **NOTE** For backward compatibility, writing to CCR[SCKDIV] updates this field with (SCKDIV ÷ 2) rounded up.

46.6.1.14 FIFO Control (FCR)

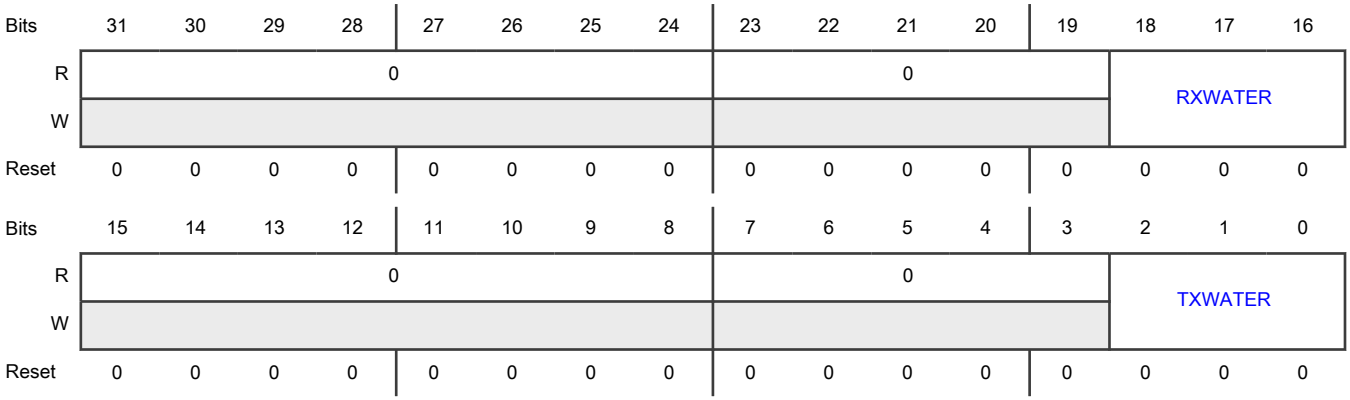
Offset

Register	Offset
FCR	58h

Function

Contains the receive FIFO and transmit FIFO watermark values.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-19 —	Reserved
18-16 RXWATER	Receive FIFO Watermark Causes LPSPI to set SR[RDF] when the number of words in the receive FIFO is greater than RXWATER. Writing a value equal to or greater than the FIFO size truncates the written value.
15-8 —	Reserved
7-3 —	Reserved
2-0 TXWATER	Transmit FIFO Watermark Causes LPSPI to set SR[TDF] when the number of words in the transmit FIFO is equal to or less than TXWATER. Writing a value equal to or greater than the FIFO size truncates the written value.

46.6.1.15 FIFO Status (FSR)

Offset

Register	Offset
FSR	5Ch

Function

Contains fields that indicate the number of words currently stored in the receive and transmit FIFOs.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0								0				RXCOUNT			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								0				TXCOUNT			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 —	Reserved
23-20 —	Reserved
19-16 RXCOUNT	Receive FIFO Count Indicates the number of words currently stored in the receive FIFO.
15-8 —	Reserved
7-4 —	Reserved
3-0 TXCOUNT	Transmit FIFO Count Indicates the number of words currently stored in the transmit FIFO.

46.6.1.16 Transmit Command (TCR)

Offset

Register	Offset
TCR	60h

Function

Pushes the data into the transmit FIFO, in the same order as written.

When you write to either this register or to Transmit Data (TDR), each write pushes data into the transmit FIFO. You must write to this register only using 32-bit writes, which are tagged and cause the command register to update; after that the entry reaches the top of the FIFO and LPSPI is enabled. This allows changes to the command word and the transmit data itself to be interleaved. That is, writes to the two registers can be interleaved (write command word, then data word, then command word, and so on). Changing the command word causes all subsequent SPI bus transfers to be performed using the new command word:

- In Controller mode, writing a new command word does not initiate a new transfer, unless TXMSK is 1. Transfers are initiated by transmit data in the transmit FIFO, or by a new command word (with TXMSK = 1). Hardware writes 0 to TXMSK when PCS deasserts.
- In Controller mode, if the command word is changed before an existing frame has completed, then the existing frame terminates and the command word updates. The command word can be changed during a continuous transfer, if CONTC of the new command word is 1 and the command word is written on a frame size boundary.
- In Peripheral mode, the command word must be changed only when LPSPI is idle and there is no SPI bus transfer.

Avoid resetting the transmit FIFO after writing to this register; wait for the command register to update from the FIFO first.

Avoid register reading problems: Reading this register returns the current state of the register. Reading this register at the same time that it is loaded from the transmit FIFO can return an incorrect register value. It is recommended to:

- Read this register when the transmit FIFO is empty.
- Read this register more than once and then compare the returned values.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	CPOL	CPHA	PRESCALE			Reserved	PCS		LSBF	BYSW	CONT	CONTC	RXMSK	TXMSK	WIDTH	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved				FRAMESZ											
W	0															
Reset	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1

Fields

Field	Function
31 CPOL	Clock Polarity Specifies the value of SCK when it is idle. You can update this field only when PCS is deasserted. See Figure 174 for more information. 0b - Inactive low 1b - Inactive high
30 CPHA	Clock Phase Indicates whether data is captured or changed on the leading edge of SCK and captured or changed on the following edge of SCK. You can update this field only when PCS is deasserted. See Figure 174 for more information. 0b - Captured 1b - Changed
29-27 PRESCALE	Prescaler Value Specifies the division of the LPSPI functional clock. For all SPI bus transfers, this value is applied to Clock Configuration (CCR). You can update this field only when PCS is deasserted. 000b - Divide by 1 001b - Divide by 2 010b - Divide by 4 011b - Divide by 8 100b - Divide by 16 101b - Divide by 32 110b - Divide by 64 111b - Divide by 128
26 —	Reserved
25-24 PCS	Peripheral Chip Select Configures the peripheral chip select used for the transfer. This field is updated only when PCS is deasserted. **NOTE** This entire field is not fully supported in every LPSPI module instance. See the chip-specific LPSPI information. 00b - Transfer using PCS[0] 01b - Transfer using PCS[1] 10b - Transfer using PCS[2]

Table continues on the next page...

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Field	Function
	11b - Transfer using PCS[3]
23 LSBF	LSB First Indicates whether data is transferred with MSB first or LSB first. 0b - MSB first 1b - LSB first
22 BYSW	Byte Swap Swaps the contents of [31:24] with [7:0] and [23:16] with [15:8] for each transmit data word read from the FIFO and for each received data word stored to the FIFO (or compared with match registers). 0b - Disable byte swap 1b - Enable byte swap
21 CONT	Continuous Transfer Enables continuous transfer: • In Controller mode, this field keeps PCS asserted at the end of the frame size until a command word is received that starts a new frame. • In Peripheral mode, when this field is enabled, LPSPI only transmits the first FRAMESZ bits, after which LPSPI transmits received data (assuming a 32-bit shift register) until the next PCS negation. 0b - Disable 1b - Enable
20 CONTC	Continuing Command Enables the command word to be changed within a continuous transfer in Controller mode: • The initial command word must enable continuous transfer (CONT = 1). • The continuing command must have CONTC = 1. • The continuing command word must be loaded on a frame size boundary. For example, if the continuous transfer has a frame size of 64 bits, then a continuing command word must be loaded on a 64-bit boundary. In Peripheral mode, this field modifies the internal RXMSK and TXMSK configuration after the first FRAMESZ bits and until PCS negation: • Receive data is discarded after the first FRAMESZ bits. If CONT is also 1, this does not block the transmission of received data. • Transmit data is not masked after the first FRAMESZ bits. This allows the first FRAMESZ bits to be received and a response transmitted. 0b - Command word for start of new transfer 1b - Command word for continuing transfer
19	Receive Data Mask

Table continues on the next page...

Table continued from the previous page...

Field	Function
RXMSK	Masks receive data (receive data is not stored in the receive FIFO). 0b - Normal transfer 1b - Mask receive data
18 TXMSK	Transmit Data Mask Masks transmit data (no data is loaded from the transmit FIFO and the output pin is 3-stated). In Controller mode, TXMSK initiates a new transfer that cannot be aborted by another command word. TXMSK automatically transitions to 0 at the end of the transfer. 0b - Normal transfer 1b - Mask transmit data
17-16 WIDTH	Transfer Width Configures serial (1-bit) or parallel transfers. For half-duplex parallel transfers, either RXMSK or TXMSK must be 1. 00b - 1-bit transfer 01b - 2-bit transfer 10b - 4-bit transfer 11b - Reserved
15-12 —	Reserved
11-0 FRAMESZ	Frame Size Configures the frame size in number of bits equal to (FRAMESZ + 1): • The minimum frame size is 8 bits. • If the frame size is larger than 32 bits, then the frame is divided into multiple words of 32 bits; each word is loaded from the transmit FIFO and stored in the receive FIFO separately. • If the size of the frame is not divisible by 32, then the last load of the transmit FIFO and store of the receive FIFO contains the remainder bits. For example, a 72-bit transfer consists of three words: the first and second words are 32 bits, and the third word is 8 bits.

46.6.1.17 Transmit Data (TDR)

Offset

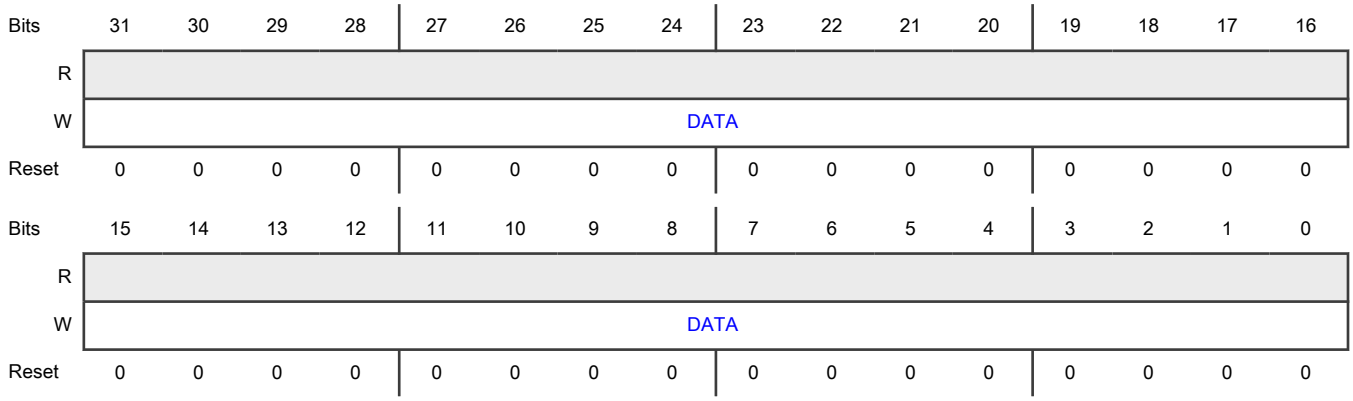
Register	Offset
TDR	64h

Function

Pushes the data into the transmit FIFO, in the same order that the data is written. You can write to this register using 32-, 16-, or 8-bit writes.

When you write to this register or to Transmit Command (TCR), each write pushes data into the FIFO with zero pushed in unwritten bytes.

Diagram



Fields

Field	Function
31-0 DATA	Transmit Data Indicates transmit data. Both 8-bit and 16-bit writes of transmit data zero-extend the data written and push the data into the transmit FIFO. To zero-extend 8-bit and 16-bit writes (to 32 bits) means that the higher order (most significant) empty parts of the 8-bit and 16-bit writes are filled with zeroes.

46.6.1.18 Receive Status (RSR)

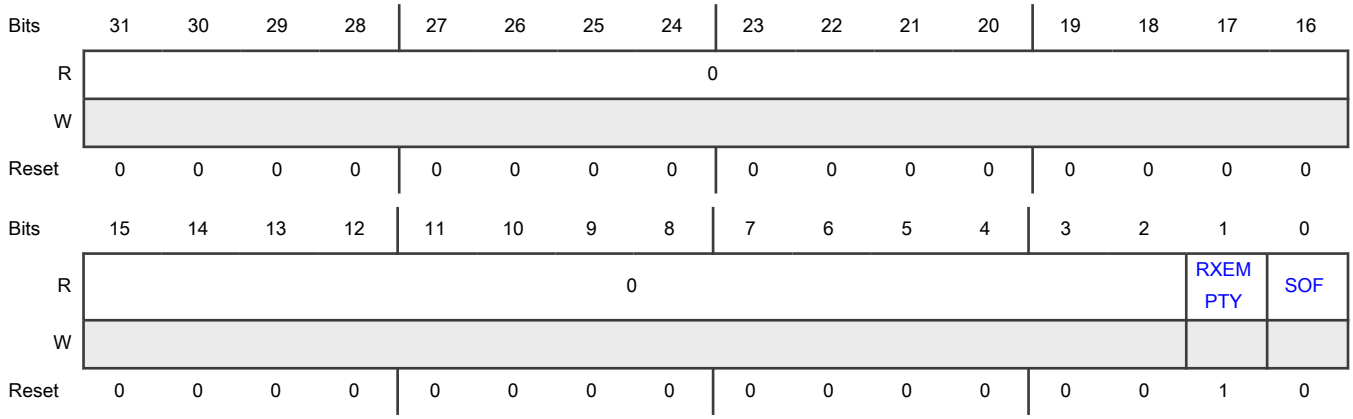
Offset

Register	Offset
RSR	70h

Function

Contains data flow status fields for receive FIFO.

Diagram



Fields

Field	Function
31-2 —	Reserved
1 RXEMPTY	RX FIFO Empty Indicates whether the receive FIFO is empty. 0b - Not empty 1b - Empty
0 SOF	Start of Frame Indicates whether this is the first data word received after PCS assertion. 0b - Subsequent data word or RX FIFO is empty (RXEMPTY=1). 1b - First data word

46.6.1.19 Receive Data (RDR)

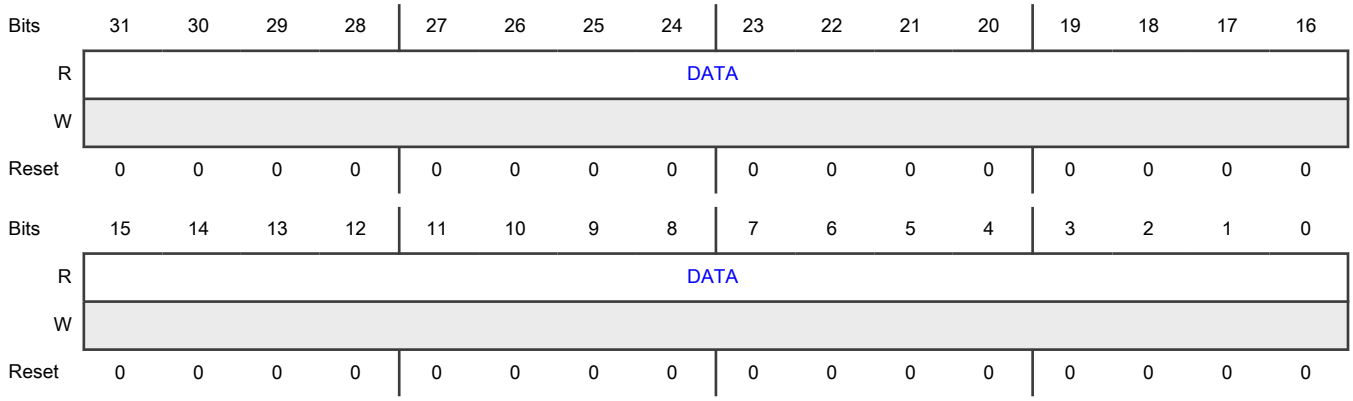
Offset

Register	Offset
RDR	74h

Function

Pulls the first entry from the receive FIFO.

Diagram



Fields

Field	Function
31-0 DATA	Receive Data

46.6.1.20 Receive Data Read Only (RDROR)

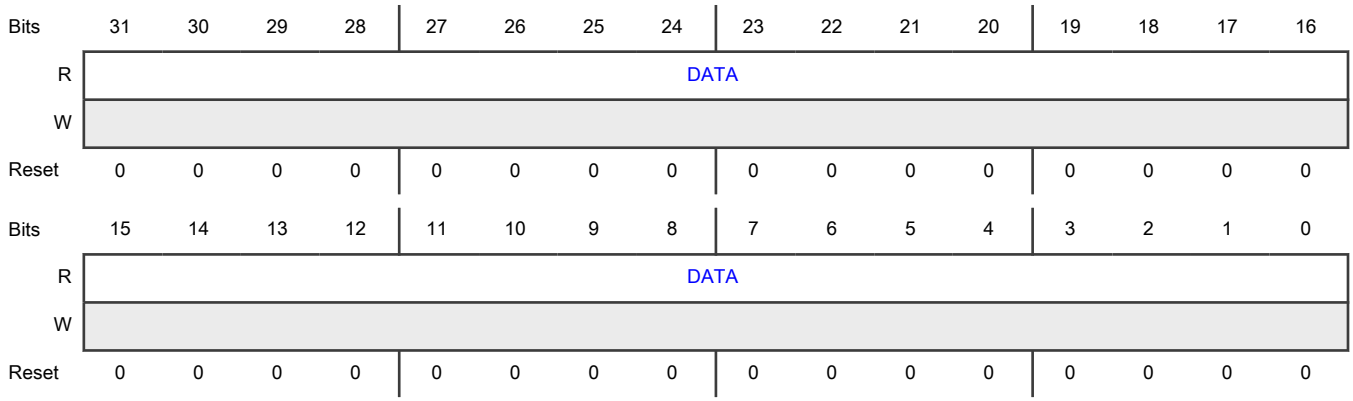
Offset

Register	Offset
RDROR	78h

Function

Returns the first entry in the receive FIFO but does not remove the data from the FIFO.

Diagram



Fields

Field	Function
31-0 DATA	Receive Data

46.6.1.21 Transmit Command Burst (TCBR)

Offset

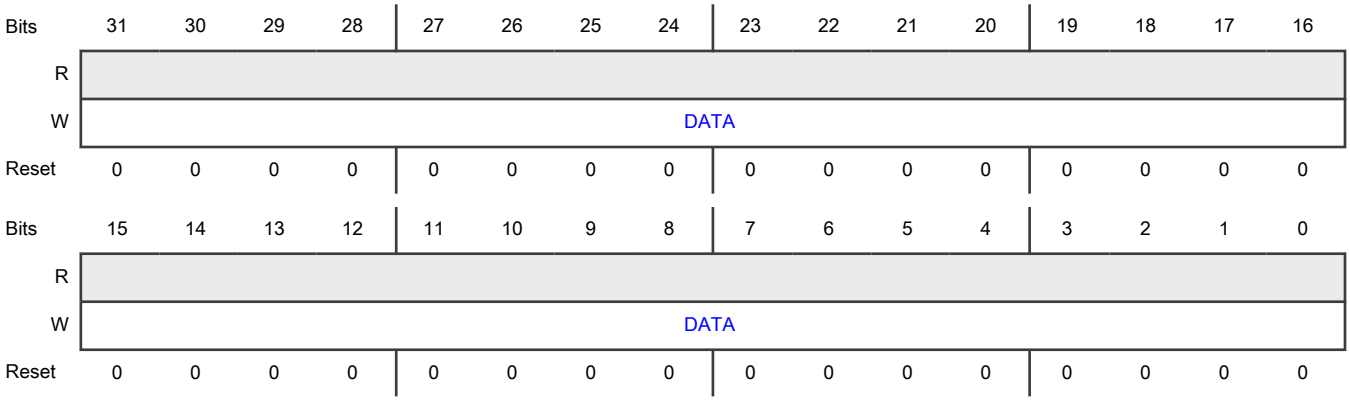
Register	Offset
TCBR	3FCh

Function

Supports burst transfers of command data to the transmit FIFO for use with the DMA controller.

See DMA support registers.

Diagram



Fields

Field	Function
31-0 DATA	Command Data Writes data to Transmit Command (TCR).

46.6.1.22 Transmit Data Burst (TDBR0 - TDBR127)

Offset

For n = 0 to 127:

Register	Offset
TDBRn	400h + (n × 4h)

Function

Supports burst transfers of data to the transmit FIFO for use with the DMA controller. The size of this register is 512 bytes.

See DMA support registers.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R																
W	DATA															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R																
W	DATA															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 DATA	Data Writes data to Transmit Data (TDR).

46.6.1.23 Receive Data Burst (RDBR0 - RDBR127)

Offset

For n = 0 to 127:

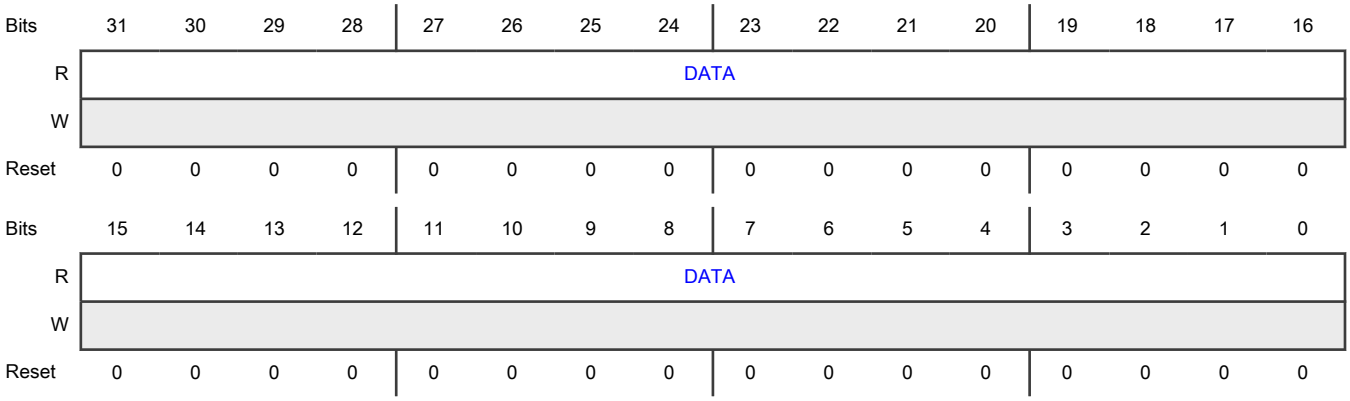
Register	Offset
RDBRn	600h + (n × 4h)

Function

Supports burst transfers of data from the receive FIFO. The size of this register is 512 bytes.

See DMA support registers.

Diagram



Fields

Field	Function
31-0 DATA	Data Reads data from Receive Data (RDR).

Chapter 47
Low Power Universal Asynchronous Receiver/ Transmitter (LPUART)

47.1 Chip-specific LPUART information

Table 341. Reference links to related information

Topic	Related module	Reference
Full description	LPUART	LPUART
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

47.1.1 Module instances

This device has two instances of the LPUART module, LPUART0, and LPUART1.

47.2 Overview

LPUART provides asynchronous, serial communication capabilities with external devices. It supports the non-return-to-zero (NRZ) encoding format and infrared data association (IrDA)-compatible, low-speed serial infrared (SIR) protocol. LPUART can continue operating when the processor is in Low-Power mode, if an appropriate peripheral clock is available.

47.2.1 Block diagram

Figure 176 shows the transmitter portion of LPUART.

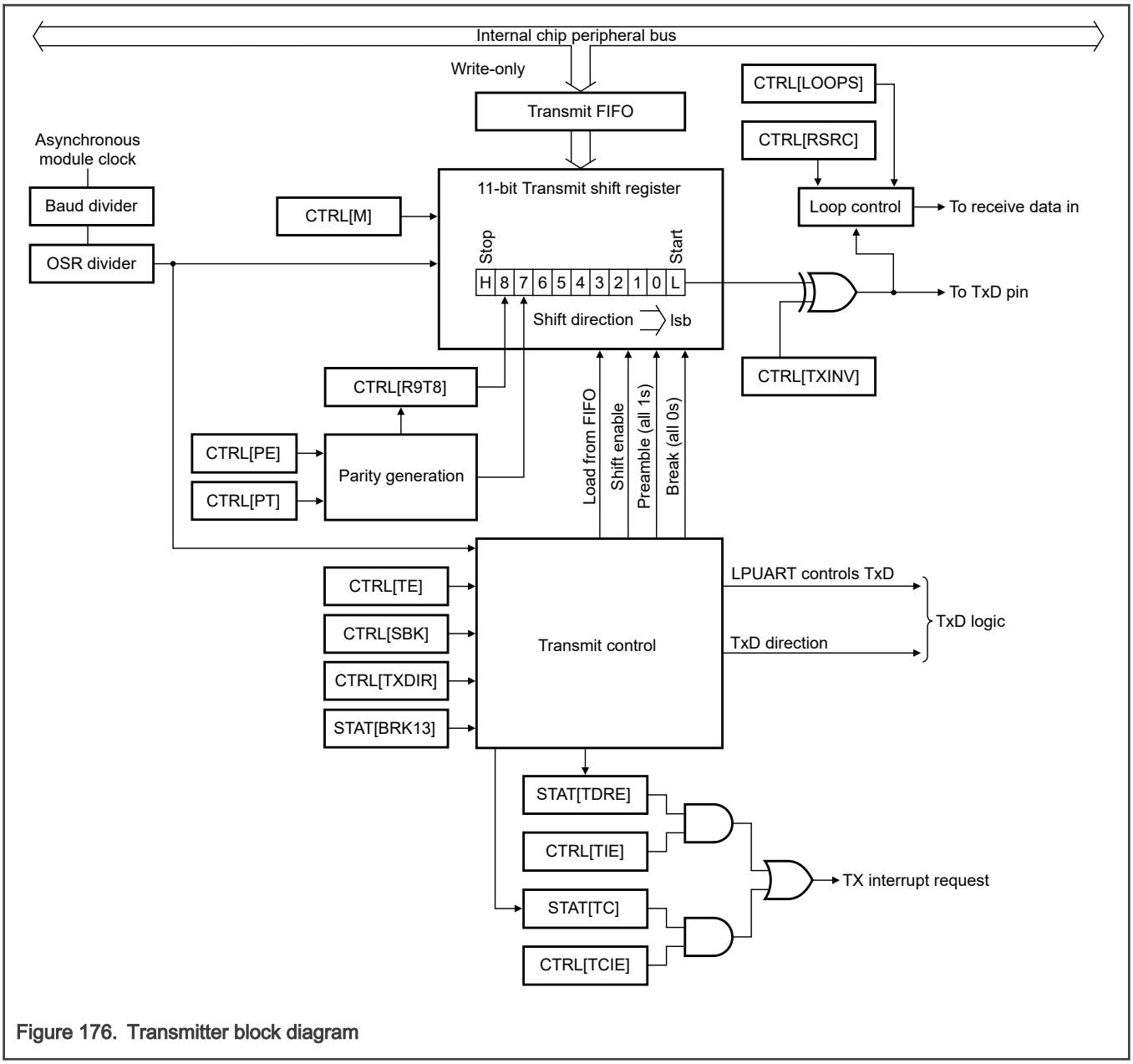


Figure 176. Transmitter block diagram

Figure 177 shows the receiver portion of LPUART.

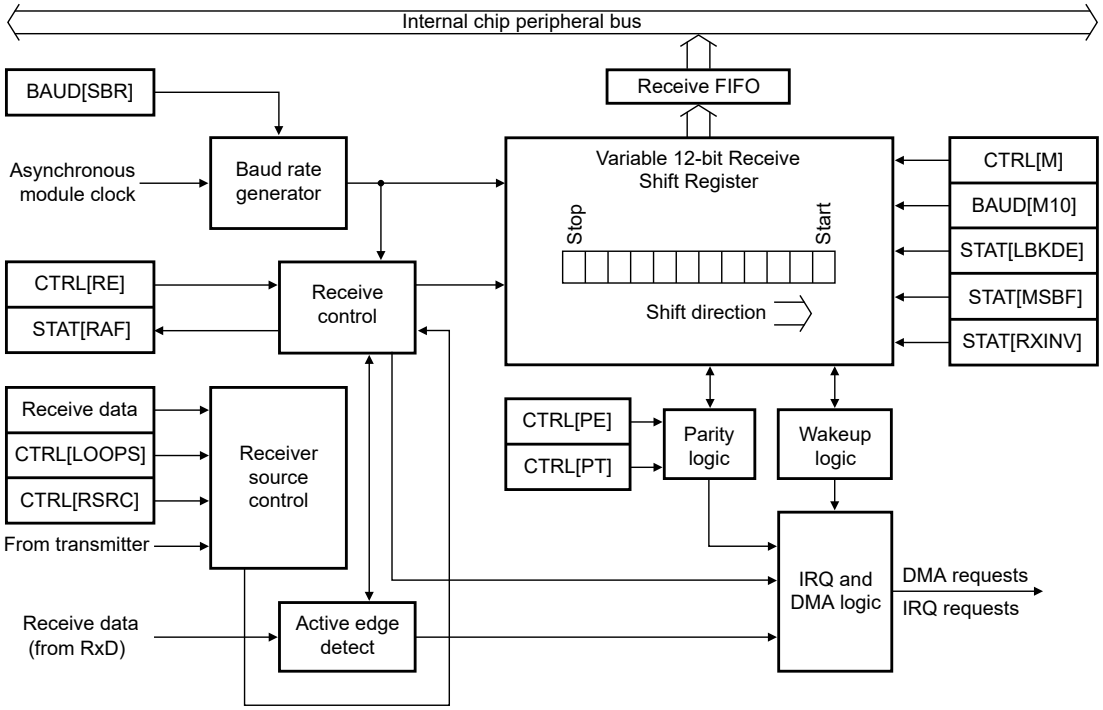


Figure 177. Receiver block diagram

47.2.2 Features

- Full-duplex, standard NRZ format
- Programmable baud rates (13-bit modulo divider) with a configurable oversampling ratio (OSR) from 4× to 32×
- Asynchronous operation of transmit and receive baud rates with respect to the bus clock:
  - Baud rate can be configured independently of the bus clock frequency.
  - Operation in Low-Power modes is supported.
- Interrupt, DMA, or polled operations:
  - Transmit data empty and transmission complete
  - Receive data full
  - Receive overrun, parity error, framing error, and noise error
  - Idle receiver detect
  - Active edge on receive pin
  - Break detect supporting LIN
  - Receive data match
- Hardware parity generation and checking
- Programmable 7-bit, 8-bit, 9-bit, or 10-bit character length
- Programmable 1-bit or 2-bit stop bits
- Support for three receiver wake-up methods:
  - Idle line wake-up

  - Address mark wake-up
  - Receive data match
- Automatic address matching to reduce ISR overhead:
  - Address mark matching
  - Idle line address matching
  - Address match start, address match end
- Optional 13-bit and 11-bit break character generation
- Configurable idle length detection supporting 1, 2, 4, 8, 16, 32, 64, or 128 idle characters
- Selectable transmitter output and receiver input polarity
- Hardware flow control support for request to send (RTS) and clear to send (CTS) signals
- Selectable IrDA 1.4 return-to-zero-inverted (RZI) format with a programmable pulse width
- Independent FIFO structure for transmit and receive functions:
  - Separate configurable watermarks for receive and transmit requests
  - Option for receiver to assert request after a configurable number of idle characters, if receive FIFO is not empty

47.3 LPUART register descriptions

LPUART includes registers to control baud rate, select options, report status, and store transmit and receive data. Access to an address outside the valid memory map generates a bus error.

NOTE

Writing to a read-only (RO) register or reading a write-only (WO) register can cause bus errors. LPUART does not verify whether programmed values in the registers are correct; you must write valid values to them.

47.3.1 LPUART memory map

LPUART0 base address: 4003_8000h

LPUART1 base address: 4003_9000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	0403_0003h
4h	Parameter (PARAM)	32	R	0000_0303h
8h	Global (GLOBAL)	32	RW	0000_0000h
Ch	Pin Configuration (PINCFG)	32	RW	0000_0000h
10h	Baud Rate (BAUD)	32	RW	0F00_0004h
14h	Status (STAT)	32	RW	00C0_0000h
18h	Control (CTRL)	32	RW	0000_0000h
1Ch	Data (DATA)	32	RW	0000_1000h
20h	Match Address (MATCH)	32	RW	0000_0000h

Table continues on the next page...

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Offset	Register	Width (In bits)	Access	Reset value
24h	MODEM IrDA (MODIR)	32	RW	0000_0000h
28h	FIFO (FIFO)	32	RW	00C0_0022h
2Ch	Watermark (WATER)	32	RW	0000_0000h
30h	Data Read-Only (DATARO)	32	R	0000_1000h

47.3.2 Version ID (VERID)

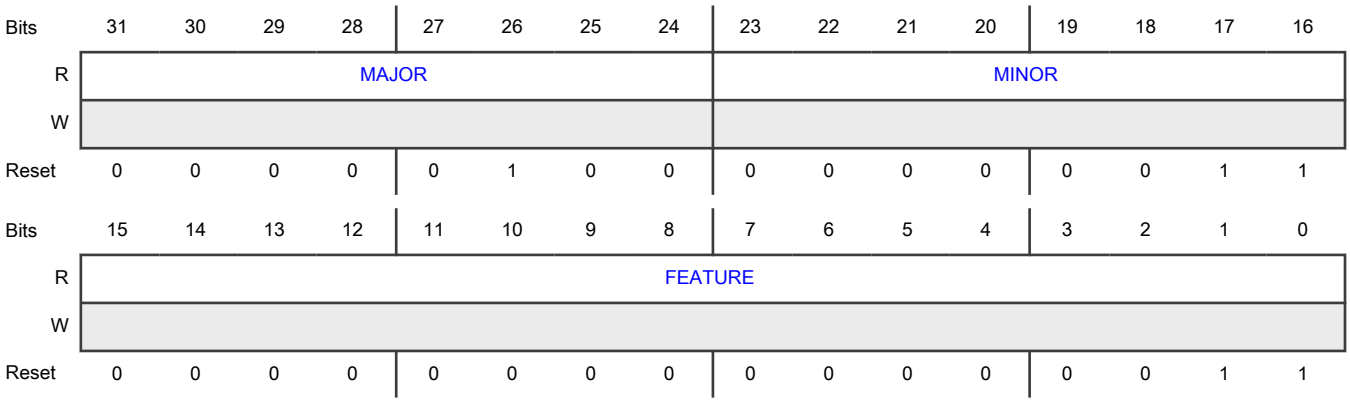
Offset

Register	Offset
VERID	0h

Function

Indicates the version integrated for this instance on the chip and also specifies the inclusion and exclusion of several optional features.

Diagram



Fields

Field	Function
31-24 MAJOR	Major Version Number Indicates the major version number for the module specification.
23-16 MINOR	Minor Version Number Indicates the minor version number for the module specification.

Table continues on the next page...

Table continued from the previous page...

Field	Function
15-0 FEATURE	Feature Identification Number Indicates the feature set number. 0000_0000_0000_0001b - Standard feature set 0000_0000_0000_0011b - Standard feature set with MODEM and IrDA support

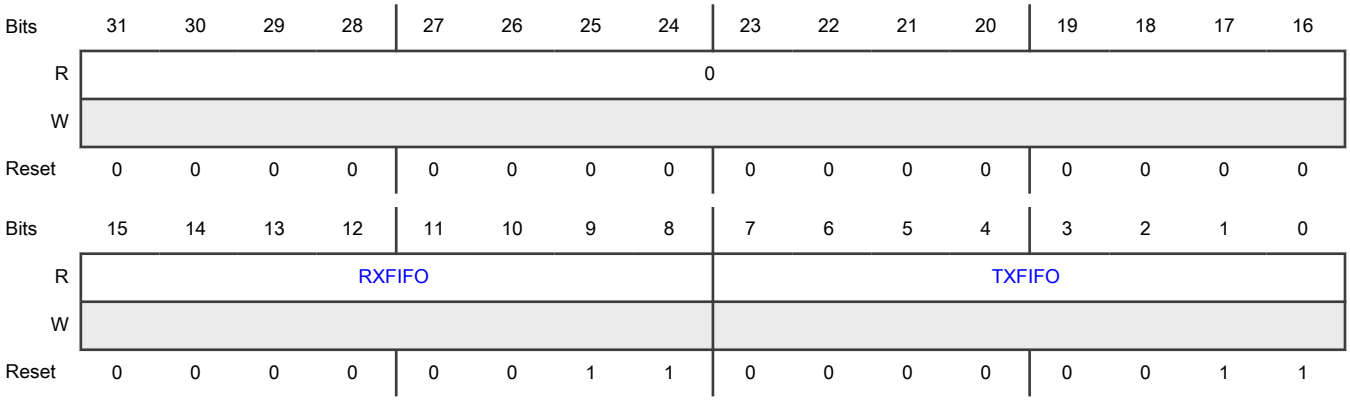
47.3.3 Parameter (PARAM)

Offset

Register	Offset
PARAM	4h

Function
Indicates the parameter configuration for this instance on the chip.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-8 RXFIFO	Receive FIFO Size Indicates the number of characters in the receive FIFO, which is 2^RXFIFO.
7-0 TXFIFO	Transmit FIFO Size Indicates the number of characters in the transmit FIFO, which is 2^TXFIFO.

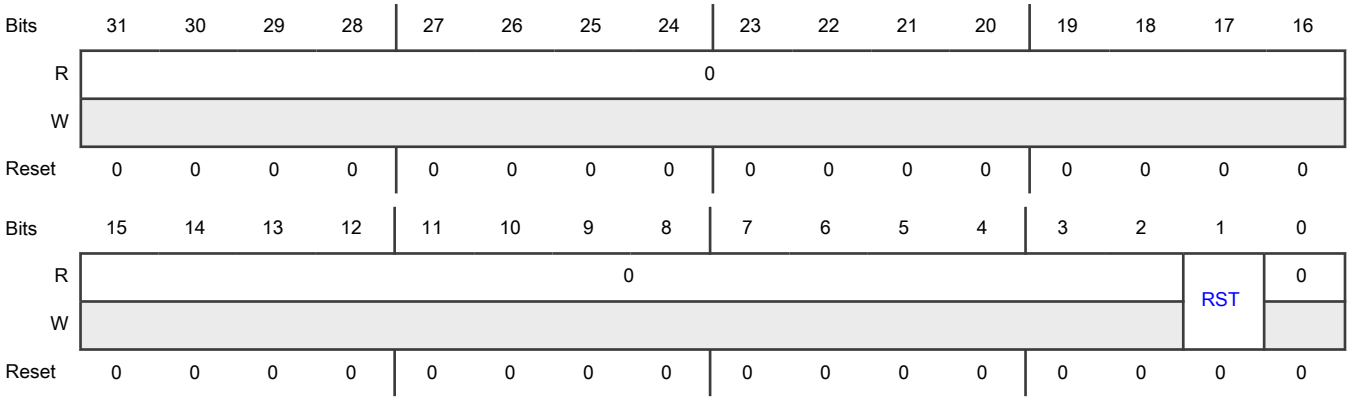
47.3.4 Global (GLOBAL)

Offset

Register	Offset
GLOBAL	8h

Function
Performs global functions.

Diagram



Fields

Field	Function
31-2 —	Reserved
1 RST	Software Reset Specifies whether the module is reset. This field resets all internal logic and registers, except Global (GLOBAL). The reset takes effect immediately and remains asserted until you negate it. There is no minimum delay required before clearing the software reset. 0b - Not reset 1b - Reset
0 —	Reserved

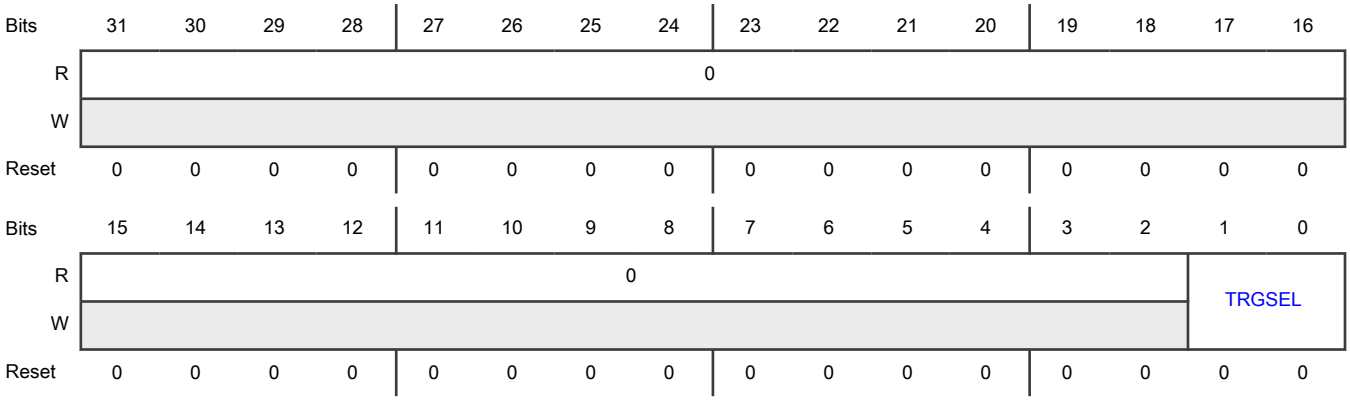
47.3.5 Pin Configuration (PINCFG)

Offset

Register	Offset
PINCFG	Ch

Function
Enables the selection of input pins.

Diagram



Fields

Field	Function
31-2 —	Reserved
1-0 TRGSEL	Trigger Select Configures the input trigger usage. You must change the value of this field only when both the transmitter and receiver are disabled. 00b - Input trigger disabled 01b - Input trigger used instead of the RXD pin input 10b - Input trigger used instead of the CTS_B pin input 11b - Input trigger used to modulate the TXD pin output, which (after TXINV configuration) is internally ANDed with the input trigger

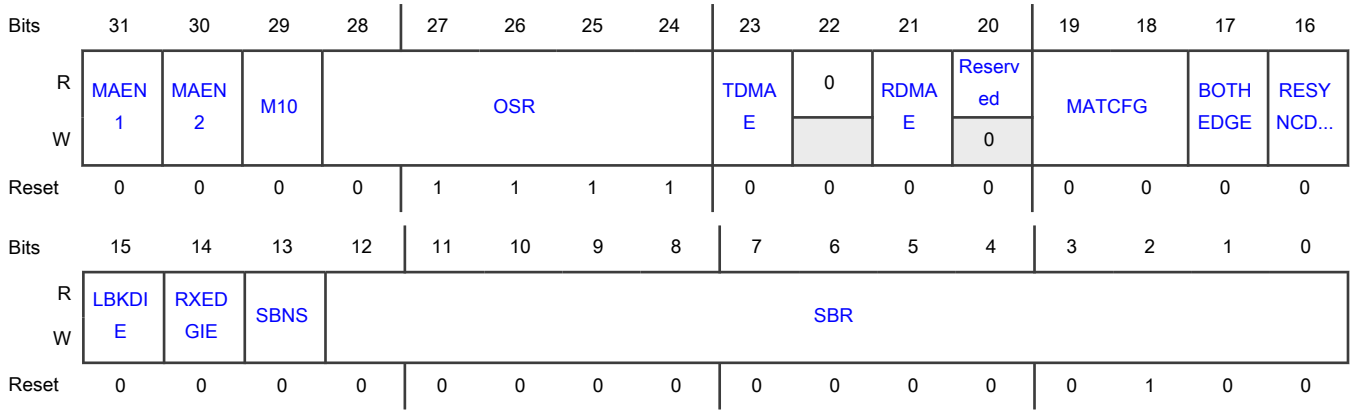
47.3.6 Baud Rate (BAUD)

Offset

Register	Offset
BAUD	10h

Function
Configures the baud rate.

Diagram



Fields

Field	Function
31 MAEN1	Match Address Mode Enable 1 Enables automatic address matching or data matching mode for MATCH[MA1]. If this field is 0, normal operation takes place. 0b - Disable 1b - Enable
30 MAEN2	Match Address Mode Enable 2 Enables automatic address matching or data matching mode for MATCH[MA2]. If this field is 0, normal operation takes place. 0b - Disable 1b - Enable
29 M10	10-Bit Mode Select Causes the tenth bit to be a part of the serial transmission. You must change the value of this field only when both the transmitter and receiver are disabled. 0b - Receiver and transmitter use 7-bit to 9-bit data characters

Table continues on the next page...

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Field	Function
	1b - Receiver and transmitter use 10-bit data characters
28-24 OSR	Oversampling Ratio Configures the OSR of the receiver. You must change the value of this field only when both the transmitter and receiver are disabled. **NOTE** BAUD[OSR] results in an OSR of BAUD[OSR] + 1, for example, BAUD[OSR] = 0_0101b results in a final division by 6. 0_0000b - Results in an OSR of 16 0_0001b - Reserved 0_0010b - Reserved 0_0011b - Results in an OSR of 4 (requires BAUD[BOTHEDGE] to be 1) 0_0100b - Results in an OSR of 5 (requires BAUD[BOTHEDGE] to be 1) 0_0101b - Results in an OSR of 6 (requires BAUD[BOTHEDGE] to be 1) 0_0110b - Results in an OSR of 7 (requires BAUD[BOTHEDGE] to be 1) 0_0111b - Results in an OSR of 8 0_1000b - Results in an OSR of 9 0_1001b - Results in an OSR of 10 0_1010b - Results in an OSR of 11 0_1011b - Results in an OSR of 12 0_1100b - Results in an OSR of 13 0_1101b - Results in an OSR of 14 0_1110b - Results in an OSR of 15 0_1111b - Results in an OSR of 16 1_0000b - Results in an OSR of 17 1_0001b - Results in an OSR of 18 1_0010b - Results in an OSR of 19 1_0011b - Results in an OSR of 20 1_0100b - Results in an OSR of 21 1_0101b - Results in an OSR of 22 1_0110b - Results in an OSR of 23 1_0111b - Results in an OSR of 24 1_1000b - Results in an OSR of 25 1_1001b - Results in an OSR of 26

Table continues on the next page...

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Field	Function
	1_1010b - Results in an OSR of 27 1_1011b - Results in an OSR of 28 1_1100b - Results in an OSR of 29 1_1101b - Results in an OSR of 30 1_1110b - Results in an OSR of 31 1_1111b - Results in an OSR of 32
23 TDMAE	Transmitter DMA Enable Enables STAT[TDRE] to generate a DMA request. 0b - Disable 1b - Enable
22 —	Reserved
21 RDMAE	Receiver Full DMA Enable Enables STAT[RDRF] to generate a DMA request. 0b - Disable 1b - Enable
20 —	Reserved
19-18 MATCFG	Match Configuration Configures the match addressing mode used. You must change the value of this field only when both the transmitter and receiver are disabled. 00b - Address match wake-up 01b - Idle match wake-up 10b - Match on and match off 11b - Enables RWU on data match and match on or off for the transmitter CTS input
17 BOTHEDGE	Both Edge Sampling Enables sampling of the received data on both edges of the baud rate clock, effectively doubling the number of times the receiver samples the input data for a given OSR. This field must be 1 for OSRs between x4 and x7 and is optional for higher OSRs. You must change the value of this field only when the receiver is disabled. If this field is 0, the receiver samples input data using the rising edge of the baud rate clock. If this field is 1, the receiver samples input data using the rising and falling edges of the baud rate clock.

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Field	Function
	0b - Rising edge 1b - Both rising and falling edges
16 RESYNCDIS	Resynchronization Disable Disables resynchronization of the received data word when a data one followed by data zero transition is detected. You must change the value of this field only when the receiver is disabled. 0b - Enable 1b - Disable
15 LBKDIE	LIN Break Detect Interrupt Enable Enables STAT[LBKDIF] to generate hardware interrupt requests. If this field is 0, hardware interrupts from STAT[LBKDIF] (uses polling) are disabled. If this field is 1, hardware interrupts are requested when STAT[LBKDIF] is 1. 0b - Disable 1b - Enable
14 RXEDGIE	RX Input Active Edge Interrupt Enable Enables STAT[RXEDGIF] to generate interrupt requests. If this field is 0, hardware interrupts from STAT[RXEDGIF] are disabled. If this field is 1, hardware interrupts are requested when STAT[RXEDGIF] is 1. Changing the value of CTRL[LOOPS] or CTRL[RSRC] when this field (RXEDGIE) is 1 can cause STAT[RXEDGIF] to become 1. 0b - Disable 1b - Enable
13 SBNS	Stop Bit Number Select Determines whether data characters include one or two stop bits. You must change the value of this field only when both the transmitter and receiver are disabled. 0b - One stop bit 1b - Two stop bits
12-0 SBR	Baud Rate Modulo Divisor Sets the modulo divide rate for the baud rate generator. • If SBR is 0, baud rate generator is disabled. • If SBR is 1–8191, baud rate = baud clock ÷ ((OSR + 1) × SBR). You must update the 13-bit baud rate setting [SBR12:SBR0] only when both the transmitter and receiver are disabled (both CTRL[RE] and CTRL[TE] are 0).

47.3.7 Status (STAT)

Offset

Register	Offset
STAT	14h

Function

Provides the module status.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LBKDIF	RXEDGIF	MSBF	RXINV	RWUID	BRK13	LBKDE	RAF	TDRE	TC	RDRF	IDLE	OR	NF	FE	PF
W	W1C	W1C										W1C	W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	MA1F	MA2F	0				0		0						AME	LBKFE
W	W1C	W1C														
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 LBKDIF	LIN Break Detect Interrupt Flag Indicates whether a LIN break character is detected. This field becomes 1 when the LIN break detect circuitry is enabled and a LIN break character is detected. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not detected 1b - Detected When writing 0b - No effect 1b - Clear the flag
30 RXEDGIF	RXD Pin Active Edge Interrupt Flag Indicates whether an active edge on the receive pin has occurred.

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Field	Function
	This field becomes 1 whenever the receiver is enabled and an active edge (falling if STAT[RXINV] is 0; rising if STAT[RXINV] is 1) on the RXD pin occurs. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not occurred 1b - Occurred When writing 0b - No effect 1b - Clear the flag
29 MSBF	MSB First Specifies the first bit that is transmitted after the start bit. If this field is 0, LSB (bit 0) is the first bit transmitted after the start bit (which means, the first bit received after the start bit is identified as bit 0). If this field is 1, MSB (identified as bit 9, bit 8, bit 7, or bit 6) is the first bit that is transmitted, after the start bit, depending on the settings of CTRL[M], CTRL[PE], and BAUD[M10]. Writing 1 to this field reverses the order of the bits that are transmitted and received on the wire. This field does not affect the polarity of the bits, the location of the parity bit, or the location of the start or stop bits. You must change the value of this field only when both the transmitter and receiver are disabled. 0b - LSB 1b - MSB
28 RXINV	Receive Data Inversion Specifies whether receive data is inverted. Writing 1 to this field reverses the polarity of the received data input. You must change the value of this field only when the receiver is disabled. **NOTE** Writing 1 to this field inverts the RXD input for all cases: data bits, start and stop bits, break, and idle. 0b - Inverted 1b - Not inverted
27 RWUID	Receive Wake Up Idle Detect Controls, for CTRL[RWU] on idle character detection, whether the idle character that wakes up the receiver writes 1 to STAT[IDLE]. For address match wake-up, this field controls whether STAT[IDLE] = 1 when the address does not match. You must change the value of this field only when the receiver is disabled.

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Field	Function
	If this field is 0, during the Receive Standby state (CTRL[RWU] = 1), STAT[IDLE] does not become 1 upon detection of an idle character. During address match wake-up, STAT[IDLE] does not become 1 when an address does not match. If this field is 1, during the Receive Standby state (CTRL[RWU] = 1), STAT[IDLE] becomes 1 upon detection of an idle character. During address match wake-up, STAT[IDLE] becomes 1 when an address does not match. 0b - STAT[IDLE] does not become 1 1b - STAT[IDLE] becomes 1
26 BRK13	Break Character Generation Length Selects the longer transmitted break character length. The state of this field does not affect the detection of a framing error. You must change the value of this field only when the transmitter is disabled. You can send a break character by writing 1 to CTRL[SBK], or by writing the transmit FIFO when DATA[FRETSC] is 1 and DATA[R9T9] is 0. 0b - 9 to 13 bit times 1b - 12 to 15 bit times
25 LBKDE	LIN Break Detection Enable Enables LIN break detection. If this field is 0, LIN break detect is disabled, and only a normal break character can be detected. If this field is 1, LIN break detect is enabled and the LIN break character is detected at a length of 11 bit times (if CTRL[M] is 0), 12 bit times (if CTRL[M] is 1), or 13 bit times (if BAUD[M10] is 1). This field selects a longer break character detection length. When the field is 1, receive data is not stored in the receive FIFO. **NOTE** This field enables the LIN break detect circuit and disables writing receive data to FIFO. Therefore, it ignores all characters except a LIN break. 0b - Disable 1b - Enable
24 RAF	Receiver Active Flag Indicates whether the LPUART receiver is idle or active. This field becomes 1 when the receiver detects the beginning of a valid start bit, and the field becomes 0 automatically when the receiver detects an idle line. 0b - Idle, waiting for a start bit 1b - Receiver active (RXD pin input not idle)
23 TDRE	Transmit Data Register Empty Flag Indicates whether the transmit FIFO level is greater than, equal to, or less than the watermark.

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Field	Function
	After the transmit FIFO is enabled, this field becomes 1 when the number of datawords in the transmit FIFO is equal to, or less than the number that WATER[TXWATER] indicates. To make the value of this field 0, write to it until the number of words in the transmit FIFO is greater than the number that WATER[TXWATER] indicates. After the transmit FIFO is disabled, this field becomes 1 to indicate that the FIFO level is less than the watermark. To make the value of this field 0 again, write to Data (DATA). This register is not affected by a character that is in the process of being transmitted; it is updated at the start of each transmitted character. 0b - Greater than watermark 1b - Equal to or less than watermark
22 TC	Transmission Complete Flag Indicates whether the transmitter is active. This field becomes 0 when a transmission is in progress or a preamble or break character is loaded; in other words, when the transmitter is active (sending data, a preamble, or a break). The field becomes 1 when the transmit buffer is empty and no data, preamble, or break character is being transmitted; in other words, when the transmission activity is complete. When this happens, the transmit data output signal becomes idle (logic 1). This field becomes 0 after you write to Data (DATA) to transmit new data, queuing a preamble by first writing 0 and then writing 1 to CTRL[TE], queuing a break character by writing 1 to CTRL[SBK]. 0b - Transmitter active 1b - Transmitter idle
21 RDRF	Receive Data Register Full Flag Indicates whether the receive FIFO level is less than, equal to, or greater than the watermark. This field becomes 1 when the number of datawords in the receive buffer is greater than the number that WATER[RXWATER] indicates and the receive FIFO is enabled. To write 0 to this field, read Data (DATA) until the number of datawords in the receive FIFO is equal to, or less than the number that WATER[RXWATER] indicates. When the receive FIFO is disabled, this field (RDRF) becomes 1 if the receive buffer (Data (DATA)) is full. To make this field 0, read Data (DATA). A character that is in the process of being received does not cause a change in this field until the entire character is received. Even if this field is 1, the character continues to be received until an overrun condition occurs after the entire character is received. 0b - Equal to or less than watermark 1b - Greater than watermark
20 IDLE	Idle Line Flag Indicates whether an idle line is detected. This field becomes 1 when the LPUART receive line becomes idle for a full character time after a period of activity. When CTRL[ILT] is 0, the receiver starts counting idle bit times after the start bit. If the receive character is all 1s, these bit times and the stop bit time count towards the full character time of logic high, 10 to 13 bit times, needed for the receiver to detect an idle line. After CTRL[ILT] becomes 1, the receiver does not start counting idle bit times until after the stop bits. The stop bits and any logic high bit times at the end

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Field	Function
	of the previous character do not count towards the full character time of logic high needed for the receiver to detect an idle line. For this field to become 0, write 1 to it. After the field becomes 0, you cannot write 1 to it again until after a new character is stored in the receive buffer or a LIN break character writes 1 to STAT[LBKDIF]. This field becomes 1 only once, even if the receive line remains idle for an extended period. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Idle line detected 1b - Idle line not detected When writing 0b - No effect 1b - Clear the flag
19 OR	Receiver Overrun Flag Indicates whether there is receive overrun. This field becomes 1 when you cannot prevent STAT[RDRF] from overflowing with data. The field becomes 1 immediately after the stop bit is completely received for the dataword that overflows the buffer and all the other error fields (STAT[FE], STAT[NF], and STAT[PF]) are prevented from becoming 1. The data in the shift register is lost, but the data already in the LPUART data registers is not affected. If STAT[LBKDE] is enabled and a LIN break is detected, this field becomes 1 if STAT[LBKDIF] is not 0 before the next data character is received. When this field is 1, no additional data is stored in the receive FIFO even if sufficient room exists. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No overrun 1b - Receive overrun (new LPUART data is lost) When writing 0b - No effect 1b - Clear the flag
18 NF	Noise Flag Indicates whether noise is detected in the received character of Data (DATA). The advanced sampling technique used in the receiver takes three samples in each of the received bits. If some of these samples disagree with the rest of the samples within any bit time in the frame, then noise is detected for that character. This field becomes 1 whenever the next character to be read from Data (DATA) is received with noise detected within the character.

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Field	Function
	NOTE This field behaves differently for register reads and writes. When reading 0b - No noise detected 1b - Noise detected When writing 0b - No effect 1b - Clear the flag
17 FE	Framing Error Flag Indicates whether a framing error is detected. This field becomes 1 whenever the next character to be read from Data (DATA) is received with logic 0 detected where a stop bit was expected. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No framing error detected (this does not guarantee that the framing is correct) 1b - Framing error detected When writing 0b - No effect 1b - Clear the flag
16 PF	Parity Error Flag Indicates whether a parity error is detected. This field becomes 1 whenever the next character to be read from Data (DATA) is received when parity is enabled (CTRL[PE] is 1) and the parity bit in the received character does not agree with the expected parity value. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No parity error detected 1b - Parity error detected When writing 0b - No effect 1b - Clear the flag

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Field	Function
15 MA1F	Match 1 Flag Indicates whether the received data is equal to MATCH[MA1]. This field becomes 1 whenever the next character to be read from Data (DATA) matches the value of MATCH[MA1]. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not equal to MA1 1b - Equal to MA1 When writing 0b - No effect 1b - Clear the flag
14 MA2F	Match 2 Flag Indicates whether the received data is equal to MATCH[MA2]. This field becomes 1 whenever the next character to be read from Data (DATA) matches the value of MATCH[MA2]. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not equal to MA2 1b - Equal to MA2 When writing 0b - No effect 1b - Clear the flag
13-10 —	Reserved
9-8 —	Reserved
7-2 —	Reserved
1 AME	Address Mark Enable Configures the location of the address mark when configured for MSB first transfers.

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Field	Function
	This field has no effect when configured for LSB first and you must change the value of this field only when both the transmitter and receiver are disabled. If this field is 0, address mark in character is MSB. If this field is 1, the address mark is stored in Data (DATA) at MSB (or MSB-1 when the parity bit is enabled). In other words, the address mark in character is the last bit before the stop bit (or parity bit when enabled). 0b - Disable 1b - Enable
0 LBKFE	LIN Break Flag Enable Enables the LIN break flag to assert whenever a LIN break character is detected. Unlike STAT[LBKDE], this does not impact data being stored in the receive data buffer, but does cause STAT[LBKDIF] to become 1 whenever a LIN break is detected. Because a LIN break is longer than a normal character, the LIN break triggers a write to STAT[RDRF] with the data fields as 0 and STAT[FE] as 1. The character following the LIN break has DATA[LINBRK] as 1 to indicate that the previous character was a LIN break. You must change the value of this field only when both the transmitter and receiver are disabled. If this field is 1, the LIN break character is detected at a length of 11-bit times (if CTRL[M] is 0), 12 (if CTRL[M] is 1), or 13 (if BAUD[M10] is 1). 0b - Disable 1b - Enable

47.3.8 Control (CTRL)

Offset

Register	Offset
CTRL	18h

Function

Controls various optional features of the LPUART system.

You must write to the fields of this register only when both the transmitter and receiver are disabled.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	R8T9	R9T8	TXDIR	TXINV	ORIE	NEIE	FEIE	PEIE	TIE	TCIE	RIE	ILIE	TE	RE	RWU	SBK
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	MA1IE	MA2IE	0	0	M7	IDLECFG			LOOPS	DOZEEN	RSRC	M	WAKE	ILT	PE	PT
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 R8T9	Receive Bit 8 Transmit Bit 9 Contains R8 and T9 that correspond to different functions. R8 is the ninth data bit received after you configure LPUART for 9-bit or 10-bit data formats. When reading 9-bit or 10-bit data, read R8 before reading Data (DATA). T9 is the tenth data bit transmitted after you configure LPUART for 10-bit data formats. When writing 10-bit data, write T9 before writing to Data (DATA). If T9 does not need to change from its previous value, such as when it is used to generate address mark or parity, then you need not write to it each time you write to Data (DATA). **NOTE** R8 is a read-only bit and T9 is a write-only bit; the value read is different from the value written.
30 R9T8	Receive Bit 9 Transmit Bit 8 Contains R9 and T8 that correspond to different functions. R9 is the tenth data bit received after you configure LPUART for 10-bit data formats. When reading 10-bit data, read R9 before reading Data (DATA). T8 is the ninth data bit transmitted after you configure LPUART for 9-bit or 10-bit data formats. When writing 9-bit or 10-bit data, write T8 before writing to Data (DATA). If T8 does not need to change from its previous value, such as when it is used to generate address mark or parity, then you need not write to it each time you write to Data (DATA). **NOTE** R9 is a read-only field and T8 is a write-only field; the value read is different from the value written.
29 TXDIR	TXD Pin Direction in Single-Wire Mode Determines the direction of data at the TXD pin, in Single-Wire mode, when LPUART is configured for a single-wire half-duplex operation (CTRL[LOOPS] and CTRL[RSRC] are 1). When writing 0 to this field, the transmitter finishes transmitting the current character (if any) before the receiver starts receiving data from the TXD pin.

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Field	Function
	0b - Input 1b - Output
28 TXINV	Transmit Data Inversion Specifies whether transmit data is inverted. Writing 1 to this field reverses the polarity of the transmitted data output. This action inverts the TXD output for all cases: data bits, start and stop bits, break, and idle. 0b - Not inverted 1b - Inverted
27 ORIE	Overrun Interrupt Enable Enables STAT[OR] to generate hardware interrupt requests. When this field is 1, a hardware interrupt is requested. Use polling when OR interrupts are disabled. 0b - Disable 1b - Enable
26 NEIE	Noise Error Interrupt Enable Enables STAT[NF] to generate hardware interrupt requests. When this field is 1, a hardware interrupt is requested. Use polling when NF interrupts are disabled. 0b - Disable 1b - Enable
25 FEIE	Framing Error Interrupt Enable Enables STAT[FE] to generate hardware interrupt requests. When this field is 1, a hardware interrupt is requested. Use polling when FE interrupts are disabled. 0b - Disable 1b - Enable
24 PEIE	Parity Error Interrupt Enable Enables STAT[PF] to generate hardware interrupt requests. When this field is 1, a hardware interrupt is requested. Use polling when PF interrupts are disabled. 0b - Disable 1b - Enable
23 TIE	Transmit Interrupt Enable Enables STAT[TDRE] to generate interrupt requests if STAT[TDRE] is 1. 0b - Disable 1b - Enable
22	Transmission Complete Interrupt Enable

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Field	Function
TCIE	Enables STAT[TC] to generate interrupt requests if STAT[TC] is 1. 0b - Disable 1b - Enable
21 RIE	Receiver Interrupt Enable Enables STAT[RDRF] to generate hardware interrupt requests if STAT[RDRF] is 1. 0b - Disable 1b - Enable
20 ILIE	Idle Line Interrupt Enable Enables hardware interrupts. This field enables STAT[IDLE] to generate interrupt requests. If this field is 0, hardware interrupts from STAT[IDLE] are disabled and polling is used, and if this field is 1, hardware interrupts are enabled when STAT[IDLE] is 1. 0b - Disable 1b - Enable
19 TE	Transmitter Enable Enables the LPUART transmitter. Using this field, you can also queue an idle preamble by first writing 0 and then writing 1 to this field. After this field becomes 0, the field reads 1 until the transmitter has completed the current character and the TXD pin is tristated. You can also queue a single idle character by writing to the transmit FIFO with DATA[FRETSC] and DATA[R9T9] = 1. 0b - Disable 1b - Enable
18 RE	Receiver Enable Enables the LPUART receiver. After you write 0 to this field, this field remains 1 until the receiver finishes receiving the current character (if any). 0b - Disable 1b - Enable
17 RWU	Receiver Wake-Up Control Specifies whether the LPUART receiver in standby is waiting for a wake-up condition. You can write 1 to this field to place the LPUART receiver in a Standby state. The field becomes 0 automatically when an RWU event occurs, that is, in case of an idle event when CTRL[WAKE] is 0 or an address match when CTRL[WAKE] is 1 and STAT[RWUID] is 0.

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Field	Function
	NOTE You must write 1 to this field only when CTRL[WAKE] is 0 (wake-up on idle), if the channel is currently not idle. You can determine this by the value of STAT[RAF]. If the field is 1 to wake up an idle event and the channel is already idle, LPUART, possibly, discards the data. This is because the data must be received or a LIN break is detected after an Idle condition is detected before the IDLE flag is allowed to be reasserted. 0b - Normal receiver operation 1b - LPUART receiver in standby, waiting for a wake-up condition
16 SBK	Send Break Specifies whether queue break character(s) are to be sent. Writing 1 and then 0 to this field queues a break character in the transmit data stream. Additional break characters of 9 to 13 bits, or 12 to 15 bits if STAT[BRK13] is 1, and bit times of logic 0 are queued as long as this field is 1. Depending on the timing when this field is 1 and 0, relative to the character currently being transmitted, a second break character may be queued before you write 0 to this field. If the time taken to write 0 to this field is too long, for example, if the field does not become 0 by the end of the first break character, a second break character is sent. This is compared to queuing a break character through the transmit FIFO that guarantees only one break character is sent. You can also queue a single break character by writing to the transmit FIFO when DATA[FRETSC] is 1 and DATA[R9T9] is 0. 0b - Normal transmitter operation 1b - Queue break character(s) to be sent
15 MA1IE	Match 1 (MA1F) Interrupt Enable Enables the MA1F interrupt. 0b - Disable 1b - Enable
14 MA2IE	Match 2 (MA2F) Interrupt Enable Enables the MA2F interrupt. 0b - Disable 1b - Enable
13 —	Reserved
12 —	Reserved
11 M7	7-Bit Mode Select Specifies the data characters that the receiver and transmitter use.

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Field	Function
	You must change the value of this field only after both the transmitter and receiver are disabled. 0b - 8-bit to 10-bit 1b - 7-bit
10-8 IDLECFG	Idle Configuration Configures the number of idle characters that must be received before you write 1 to STAT[IDLE]. 000b - 1 001b - 2 010b - 4 011b - 8 100b - 16 101b - 32 110b - 64 111b - 128
7 LOOPS	Loop Mode Select Selects Loop mode. After this field becomes 1, the RXD pin is disconnected from LPUART and the transmitter output is internally connected to the receiver input. The transmitter and receiver must be enabled to use the loop function. In Loop mode or Single-Wire mode, the transmitter outputs are internally connected to the receiver input (see CTRL[RSRC]). 0b - Normal operation: RXD and TXD use separate pins 1b - Loop mode or Single-Wire mode
6 DOZEEN	Doze Mode Enables LPUART in Doze mode. If this field is 1, LPUART remains active when not in Doze mode. 0b - Enable 1b - Disable
5 RSRC	Receiver Source Select Determines the source of the receiver shift register input if CTRL[LOOPS] is 1. This field has no effect unless CTRL[LOOPS] is 1. If this field is 0, internal Loopback mode is selected. LPUART does not use the RXD pin. If this field is 1, single-wire LPUART mode is selected where the TXD pin is connected to the transmitter output and receiver input. 0b - Internal Loopback mode

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Field	Function
	1b - Single-wire mode
4 M	9-Bit Or 8-Bit Mode Select Specifies the data characters that the receiver and transmitter use. 0b - 8-bit 1b - 9-bit
3 WAKE	Receiver Wake-Up Method Select Determines which condition wakes up LPUART when CTRL[RWU] = 1 and BAUD[MATCFG] = 0 (this field must be 1 when BAUD[MATCFG] = 11): • Address mark in the bit preceding the stop bit (or bit preceding the parity bit when parity is enabled) of the received data character • An idle condition on the receive pin input signal If this field is 0, CTRL[RWU] is configured for idle line wake-up, and if this field is 1, CTRL[RWU] is configured with address mark wake-up. 0b - Idle 1b - Mark
2 ILT	Idle Line Type Select Determines when the receiver starts counting logic 1s as idle character bits. The count begins either after a valid start bit or the stop bit. If the count begins after the start bit, a string of logic 1s preceding the stop bit can cause false recognition of an idle character. Beginning the count after the stop bit avoids false idle character recognition, but requires properly synchronized transmissions. **NOTE** In case you write 1 to this field, a logic 0 is automatically shifted after a received stop bit, therefore resetting the idle count. 0b - After the start bit 1b - After the stop bit
1 PE	Parity Enable Enables hardware parity generation and checking. If parity is enabled, the bit immediately before the stop bit is treated as the parity bit. 0b - Disable 1b - Enable
0 PT	Parity Type Selects the type of parity, even or odd, if parity is enabled (CTRL[PE] = 1): • Odd parity means that the total number of logic 1 bits in the data character, including the parity bit, is odd.

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Field	Function
	• Even parity means that the total number of 1s in the data character, including the parity bit, is even. 0b - Even parity 1b - Odd parity

47.3.9 Data (DATA)

Offset

Register	Offset
DATA	1Ch

Function

Supports 8-bit, 16-bit, or 32-bit writes, each type of write performing a separate function. An 8-bit write to DATA[7:0] pushes {CTRL[R8T9], CTRL[R9T8], DATA[7:0]} the transmit FIFO with TSC clear. A 16-bit or 32-bit write pushes the data written into the FIFO and does not update the value of CTRL[R8T9] or CTRL[R9T8].

Reads and writes of this register are also involved in the automatic flag clearing mechanisms for some of the LPUART status fields.

NOTE

Reads return the contents of the read-only receive FIFO and writes go to the write-only transmit FIFO, making this register work as a set of two separate registers.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	NOISY	PARITYE	FRETSC	RXEMPT	IDLINE	LINBRK	R9T9	R8T8	R7T7	R6T6	R5T5	R4T4	R3T3	R2T2	R1T1	R0T0
W																
Reset	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-16 —	Reserved

Table continues on the next page...

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Field	Function
15 NOISY	Noisy Data Received Indicates whether the current received dataword contained in DATA[R9:R0] is received with noise. 0b - Received without noise 1b - Received with noise
14 PARITYE	Parity Error Indicates whether the current received dataword contained in DATA[R9:R0] is received with a parity error. 0b - Received without a parity error 1b - Received with a parity error
13 FRETSC	Frame Error Transmit Special Character Specifies the way the dataword is received. For reads, this field indicates that the current received dataword contained in DATA[R9:R0] is received with a frame error. For writes, the field indicates that a break or idle character is to be transmitted instead of the contents in DATA[T9:T0]. T9 indicates a break character when it is 0 and indicates an idle character when it is 1. The contents of DATA[T8:T0] must be 0. 0b - Received without a frame error on reads or transmits a normal character on writes 1b - Received with a frame error on reads or transmits an idle or break character on writes
12 RXEMPT	Receive Buffer Empty Indicates whether the receive buffer contains valid data. This field becomes 1 when there is no data in the receive buffer. The field does not consider data in the receive shift register. 0b - Valid data 1b - Invalid data and empty
11 IDLINE	Idle Line Indicates whether the receiver line was idle before receiving the character in DATA[9:0]. It can be read as “1” on the first character when the receiver is first enabled. The difference between this field and STAT[IDLE] is that, STAT[IDLE] flag does not set on an idle line after the receiver is first enabled, it needs to receive a character before it can become set, whereas this field does not have this limitation and can be set on the first character received if an idle line is detected beforehand. 0b - Not idle 1b - Idle
10 LINBRK	LIN Break Indicates whether the receiver line detected a LIN break before receiving the character in DATA[9:0]. This field requires the value of STAT[LBKDIF] to be 1. If this field is 0, the LIN break detect circuitry is disabled.

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Field	Function
	0b - Not detected 1b - Detected
9 R9T9	Read receive FIFO bit 9 or write transmit FIFO bit 9
8 R8T8	Read receive FIFO bit 8 or write transmit FIFO bit 8
7 R7T7	Read receive FIFO bit 7 or write transmit FIFO bit 7
6 R6T6	Read receive FIFO bit 6 or write transmit FIFO bit 6
5 R5T5	Read receive FIFO bit 5 or write transmit FIFO bit 5
4 R4T4	Read receive FIFO bit 4 or write transmit FIFO bit 4
3 R3T3	Read receive FIFO bit 3 or write transmit FIFO bit 3
2 R2T2	Read receive FIFO bit 2 or write transmit FIFO bit 2
1 R1T1	Read receive FIFO bit 1 or write transmit FIFO bit 1
0 R0T0	Read receive FIFO bit 0 or write transmit FIFO bit 0

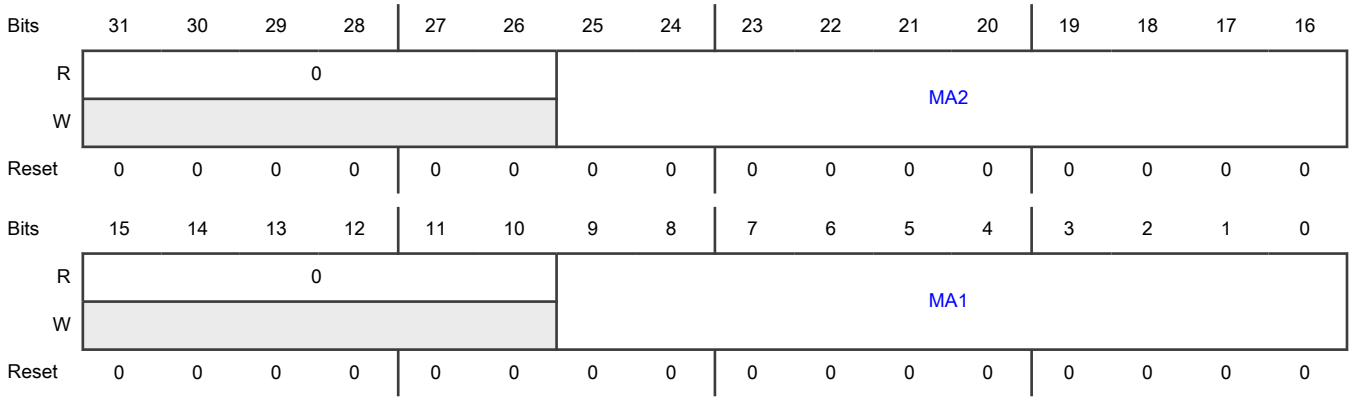
47.3.10 Match Address (MATCH)

Offset

Register	Offset
MATCH	20h

Function
Provides addresses for address matching during the receiver operation.

Diagram



Fields

Field	Function
31-26 —	Reserved
25-16 MA2	Match Address 2 Is compared to input data addresses when the most significant bit is 1 and the associated Baud Rate (BAUD) field is 1. If a match occurs, the data that follows is transferred to Data (DATA). If a match fails, the data that follows is discarded. You must write to MATCH[MA1] and MATCH[MA2] only when the associated Baud Rate (BAUD) field is 0.
15-10 —	Reserved
9-0 MA1	Match Address 1 Is compared to input data addresses when the most significant bit is 1 and the associated Baud Rate (BAUD) field is 1. If a match occurs, the data that follows is transferred to Data (DATA). If a match fails, the data that follows is discarded. You must write to MATCH[MA1] and MATCH[MA2] fields only when the associated field in Baud Rate (BAUD) is 0.

47.3.11 MODEM IrDA (MODIR)

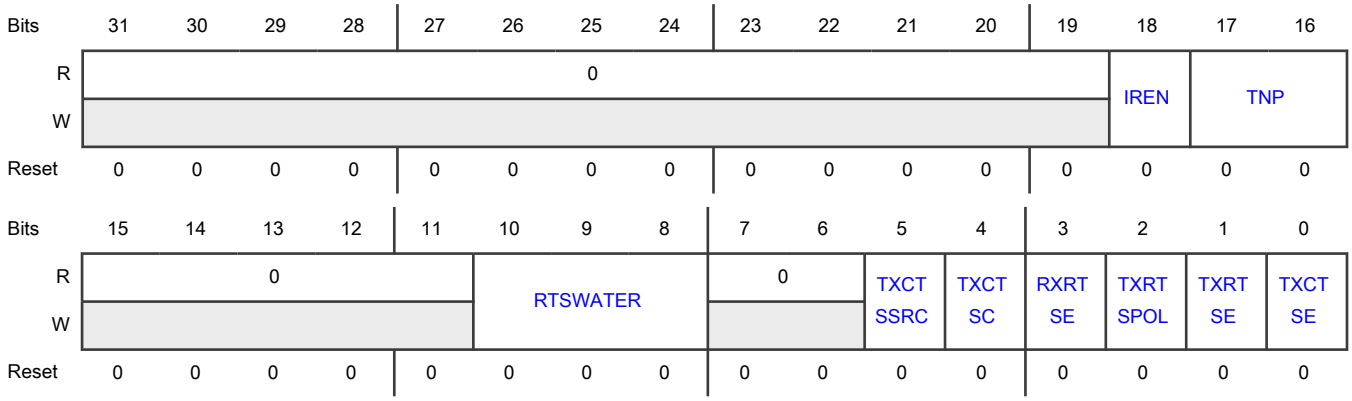
Offset

Register	Offset
MODIR	24h

Function

Controls options for setting the MODEM configuration.

Diagram



Fields

Field	Function
31-19 —	Reserved
18 IREN	IR Enable Enables IR modulation and demodulation. You must change the value of this field only when both the transmitter and receiver are disabled. 0b - Disable 1b - Enable
17-16 TNP	Transmitter Narrow Pulse Specifies whether LPUART transmits a 1 ÷ OSR, 2 ÷ OSR, 3 ÷ OSR, or 4 ÷ OSR narrow pulse when the IR pulse is enabled. You must change the value of this field only when both the transmitter and receiver are disabled. The IR pulse width must be configured to less than half of the OSR. Common pulse widths are 3 ÷ 16, 1 ÷ 16, 1 ÷ 32, or 1 ÷ 4 of the bit length. You can configure these by selecting the appropriate OSR and pulse width. 00b - 1 ÷ OSR 01b - 2 ÷ OSR 10b - 3 ÷ OSR 11b - 4 ÷ OSR
15-11 —	Reserved
10-8 RTSWATER	Receive RTS Configuration Configures the assertion and negation of the receiver's RTS_B output. The receiver's RTS_B output negates when the number of empty words in the receive FIFO is greater or equal to the value of this field. If this field is 0, the RTS_B pin negates when the receive FIFO is full. For the

Table continues on the next page...

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Field	Function
	purpose of receive RTS_B generation, the number of words in the receive FIFO updates when a start bit is detected. This supports additional latency between RTS_B negation and the external transmitter ceasing transmission. If both receive RTS_B and address or data matching is enabled, RTS_B could assert at the end of a character if there exists no match. You must change the value of this field only when the receiver is disabled.
7-6 —	Reserved
5 TXCTSSRC	Transmit CTS Source Configures the source of the CTS input. 0b - The CTS_B pin 1b - An internal connection to the receiver address match result
4 TXCTSC	Transmit CTS Configuration Configures whether the CTS state or input is checked or sampled at the start of each character or only when the transmitter is idle. 0b - Sampled at the start of each character 1b - Sampled when the transmitter is idle
3 RXRTSE	Receiver RTS Enable Allows the RTS output to control the CTS input of the transmitting device to prevent receiver overrun. You must change the value of this field only when the receiver is disabled. If this field is 0, the receiver has no effect on RTS. If this field is 1, RTS is deasserted if STAT[RDRF] is 1 or a start bit is detected that causes STAT[RDRF] to become 1. RTS is asserted if STAT[RDRF] is 0 and has not detected a start bit that causes STAT[RDRF] to become 1. **NOTE** Do not write 1 to both MODIR[RXRTSE] and MODIR[TXRTSE]. 0b - Disable 1b - Enable
2 TXRTSPOL	Transmitter RTS Polarity Controls the polarity of the transmitter RTS. This field does not affect the polarity of the receiver RTS that remains negated in the active-low state unless MODIR[TXRTSE] is 1. You must change the value of this field only when the transmitter is disabled. 0b - Active low 1b - Active high
1	Transmitter RTS Enable

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Field	Function
TXRTSE	Controls the operation of RTS before and after a transmission. You must change the value of this field only when the transmitter is disabled. If this field is 0, the transmitter has no effect on RTS, and if this field is 1, a character is placed into an empty transmit shift register. RTS asserts 1-bit time before the start bit is transmitted and deasserts 1-bit time after all characters in the transmitter FIFO and shift register are completely sent, including the last stop bit. 0b - Disable 1b - Enable
0 TXCTSE	Transmitter CTS Enable Enables the operation of the transmitter. You can write 1 to this field irrespective of the states of MODIR[TXRTSE] and MODIR[RXRTSE]. If this field is 1, the transmitter checks the state of the CTS signal each time it is ready to send a character. If CTS is asserted, the character is sent. If CTS is deasserted, the TXD signal remains in the mark state and transmission is delayed until CTS is asserted. Changes in CTS, when a character is being sent, do not affect its transmission. 0b - Disable 1b - Enable

47.3.12 FIFO (FIFO)

Offset

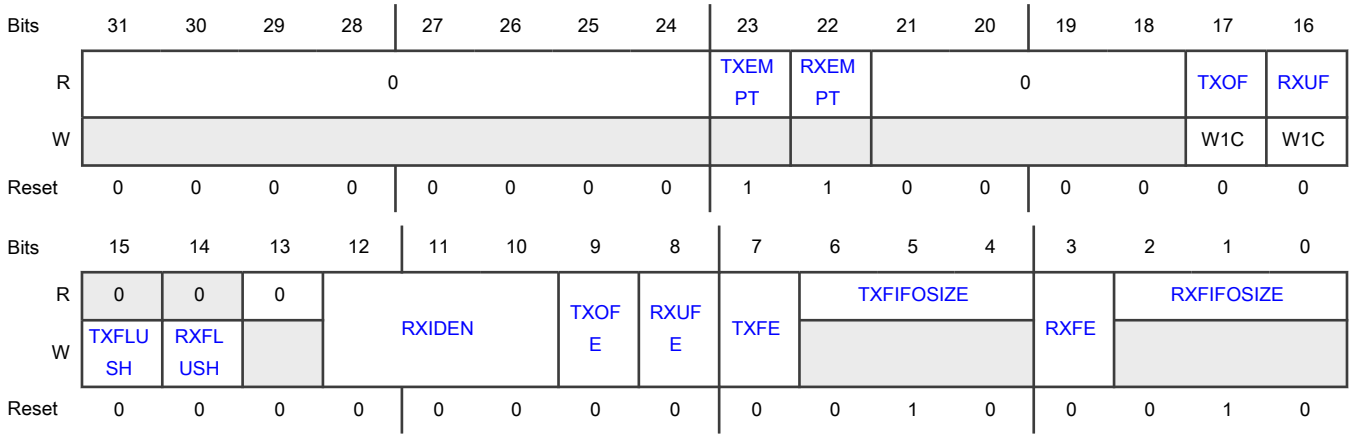
Register	Offset
FIFO	28h

Function

Provides you the ability to turn on and turn off the FIFO functionality.

This register also provides you the size of the FIFO that has been implemented. You can read this register at any time and must write to it only when CTRL[RE] and CTRL[TE] are 0 and the FIFO is empty.

Diagram



Fields

Field	Function
31-24 —	Reserved
23 TXEMPT	Transmit FIFO Or Buffer Empty Indicates whether the transmit buffer is empty. This field becomes 1 when there is no data in the transmit FIFO or buffer. The field does not consider data in the transmit shift register. 0b - Not empty 1b - Empty
22 RXEMPT	Receive FIFO Or Buffer Empty Indicates whether the receive buffer is empty. This field becomes 1 when there is no data in the receive FIFO or buffer. The field does not consider data in the receive shift register. 0b - Not empty 1b - Empty
21-18 —	Reserved
17 TXOF	Transmitter FIFO Overflow Flag Indicates whether more data has been written to the transmit FIFO than it can hold. If this field is 0, no transmit FIFO overflow has occurred since the last time the field was cleared, and if this field is 1, at least one transmit FIFO overflow has occurred since the last time the field was cleared. This field becomes 1 regardless of the value of FIFO[TXOFE]. However, an interrupt is issued to the host only if FIFO[TXOFE] is 1.

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Field	Function
	NOTE This field behaves differently for register reads and writes. When reading 0b - No overflow 1b - Overflow When writing 0b - No effect 1b - Clear the flag
16 RXUF	Receiver FIFO Underflow Flag Indicates whether more data has been read from the receive FIFO than was present. If this field is 0, no receive FIFO underflow has occurred since the last time the field was cleared, and if this field is 1, at least one receive FIFO underflow has occurred since the last time the field was cleared. This field becomes 1 regardless of the value of FIFO[RXUFE]. However, an interrupt is issued to the host only if FIFO[RXUFE] is 1. **NOTE** This field behaves differently for register reads and writes. When reading 0b - No underflow 1b - Underflow When writing 0b - No effect 1b - Clear the flag
15 TXFLUSH	Transmit FIFO Flush Causes all data that is stored in the transmit FIFO to be flushed. If you write 0 to this field, no flush operation occurs, and if you write 1 to this field, all data in the transmit FIFO or buffer clears out. This does not affect data in the transmit shift register. 0b - No effect 1b - All data flushed out
14 RXFLUSH	Receive FIFO Flush Causes all data that is stored in the receive FIFO to be flushed. If you write 0 to this field, no flush operation occurs, and if you write 1 to this field, all data in the receive FIFO or buffer clears out.

Table continues on the next page...

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Field	Function
	This does not affect data in the receive shift register. 0b - No effect 1b - All data flushed out
13 —	Reserved
12-10 RXIDEN	Receiver Idle Empty Enable Enables STAT[RDRF] to become 1 when the receiver is idle for a number of idle characters and the FIFO is not empty. 000b - Disable STAT[RDRF] to become 1 because of partially filled FIFO when the receiver is idle 001b - Enable STAT[RDRF] to become 1 because of partially filled FIFO when the receiver is idle for one character 010b - Enable STAT[RDRF] to become 1 because of partially filled FIFO when the receiver is idle for two characters 011b - Enable STAT[RDRF] to become 1 because of partially filled FIFO when the receiver is idle for four characters 100b - Enable STAT[RDRF] to become 1 because of partially filled FIFO when the receiver is idle for eight characters 101b - Enable STAT[RDRF] to become 1 because of partially filled FIFO when the receiver is idle for 16 characters 110b - Enable STAT[RDRF] to become 1 because of partially filled FIFO when the receiver is idle for 32 characters 111b - Enable STAT[RDRF] to become 1 because of partially filled FIFO when the receiver is idle for 64 characters
9 TXOFE	Transmit FIFO Overflow Interrupt Enable Enables FIFO[TXOF] to generate an interrupt to the host. 0b - Disable 1b - Enable
8 RXUFE	Receive FIFO Underflow Interrupt Enable Enables FIFO[RXUF] to generate an interrupt to the host. 0b - Disable 1b - Enable
7 TXFE	Transmit FIFO Enable Enables the transmit FIFO. If this field is 0, the transmit buffer operates as a FIFO of depth equal to 1 dataword, regardless of the value in FIFO[TXFIFOSIZE]. Both CTRL[TE] and CTRL[RE] must be 0 before you change the value of this field.

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Field	Function
	If this field is 1, the built-in FIFO structure for the transmit buffer is enabled. FIFO[TXFIFOSIZE] indicates the size of the FIFO structure. 0b - Disable 1b - Enable
6-4 TXFIFOSIZE	Transmit FIFO Buffer Depth Indicates the maximum number of transmit datawords (transmit FIFO buffer depth) that can be stored in the transmit buffer. 000b - 1 001b - 4 010b - 8 011b - 16 100b - 32 101b - 64 110b - 128 111b - 256
3 RXFE	Receive FIFO Enable Enables the receive FIFO. If this field is 0, the receive buffer operates as a FIFO of depth equal to 1 dataword, regardless of the value in FIFO[RXFIFOSIZE]. Both CTRL[RE] and CTRL[TE] must be 0 before you change the value of this field. If this field is 1, the built-in FIFO structure for the receive buffer is enabled. FIFO[RXFIFOSIZE] indicates the size of the FIFO structure. 0b - Disable 1b - Enable
2-0 RXFIFOSIZE	Receive FIFO Buffer Depth Indicates the maximum number of receive datawords (receive FIFO buffer depth) that can be stored in the receive buffer before an overrun occurs. 000b - 1 001b - 4 010b - 8 011b - 16 100b - 32 101b - 64 110b - 128 111b - 256

47.3.13 Watermark (WATER)

Offset

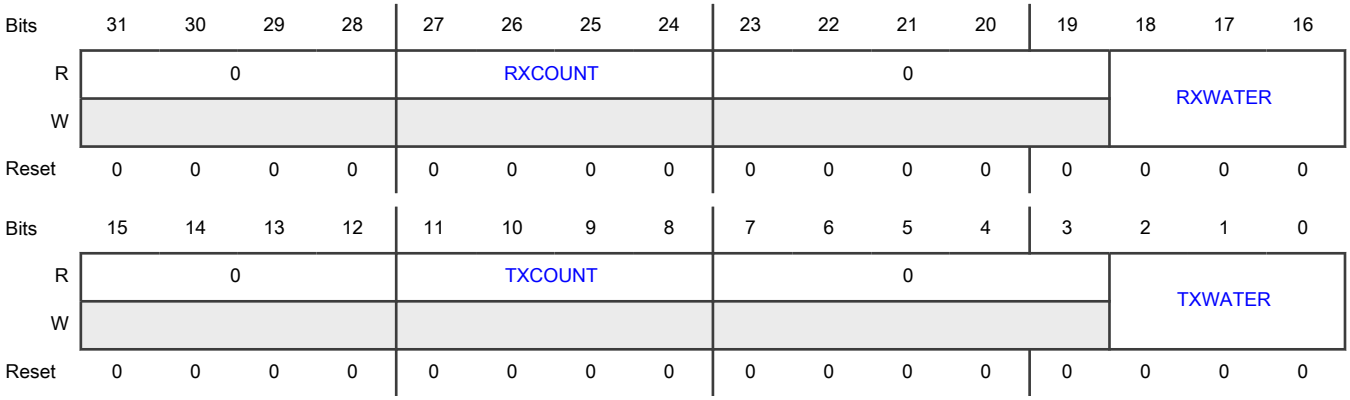
Register	Offset
WATER	2Ch

Function

Provides the ability to set a programmable threshold for notification, or sets the programmable thresholds to indicate that transmit data can be written or receive data can be read.

You may read this register at any time but must write to it only when CTRL[TE] is 0.

Diagram



Fields

Field	Function
31-28 —	Reserved
27-24 RXCOUNT	Receive Counter Indicates the number of datawords in the receive FIFO or buffer. If a dataword is being received in the receive shift register, it is not included in the count. This value may be used in conjunction with FIFO[RXFIFOSIZE] to calculate the room left in the receive FIFO or buffer.
23-19 —	Reserved
18-16 RXWATER	Receive Watermark Generates an interrupt or a DMA request if the number of datawords in the receive FIFO or buffer is greater than the value of this field. For proper operation, the value of this field must be less than the size of the receive FIFO or buffer, as indicated by FIFO[RXFIFOSIZE] and FIFO[RXFE].

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Table continued from the previous page...

Field	Function
15-12 —	Reserved
11-8 TXCOUNT	Transmit Counter Indicates the number of datawords in the transmit FIFO or buffer. If a dataword is being transmitted to the transmit shift register, it is not included in the count. This value may be used in conjunction with the value of FIFO[TXFIFOSIZE] to calculate the room left in the transmit FIFO or buffer.
7-3 —	Reserved
2-0 TXWATER	Transmit Watermark Generates an interrupt or a DMA request when the number of datawords in the transmit FIFO or buffer is equal to or less than the value of this field. For proper operation, the value of this field must be less than the size of the transmit buffer or FIFO, as indicated by FIFO[TXFIFOSIZE] and FIFO[TXFE].

47.3.14 Data Read-Only (DATARO)

Offset

Register	Offset
DATARO	30h

Function

Indicates the first entry in the receive FIFO, but does not pull data from the FIFO.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	DATA															
W																
Reset	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-16 —	Reserved
15-0 DATA	Receive Data Indicates the first entry from the receive FIFO. This register has the same functionality as that of Data (DATA).

47.4 Functional description

LPUART supports full-duplex, asynchronous, NRZ serial communication and comprises a baud rate generator, transmitter, and receiver block. The transmitter and receiver operate independently, although they use the same baud rate generator. The following sections describe all LPUART blocks.

47.4.1 Baud rate generation

A 13-bit modulus counter in the baud rate generator derives the baud rate for both the receiver and transmitter. The value, ranging from 1 to 8191, written to BAUD[SBR] determines the baud clock divisor for the asynchronous LPUART baud clock. The baud rate clock drives the receiver, while a bit clock, generated from the baud rate clock divided by the OSR, drives the transmitter. Depending on the OSR, the receiver has an acquisition rate of 4 to 32 samples per bit time. LPUART requires BAUD[SBR] and BAUD[OSR] to accurately match the baud rate requirement. There is a relationship between the required baud rate and the input clock frequency, SBR, and OSR. See the below figure for details.

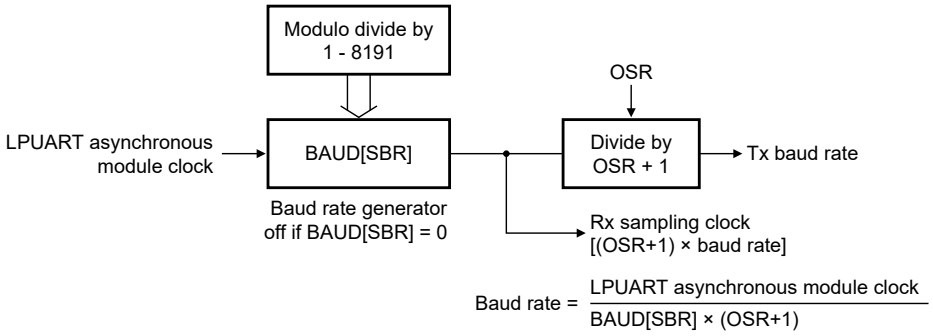

Figure 178. Baud rate generation

Baud rate generation is subject to these sources of error:

- Integer division of the asynchronous LPUART baud clock may not give the exact target frequency.
- Synchronization with the asynchronous LPUART baud clock can lead to a phase shift.

Baud rate generation is a free-running counter that continues whenever the transmitter or receiver is enabled. The transmitter bit clock continues whenever the transmitter is enabled; each transmitted character aligns to the next edge of the transmit bit clock.

In general, configuring OSR for a higher ratio and/or sampling on both edges of the clock slightly improves LPUART's tolerance to baud rate mismatch between the received data and LPUART configured baud rate. However, the three data samples in each bit (see Data sampling technique) are also closer together, which may impact noise sensitivity.

47.4.2 Baud rate tolerance

A transmitting device may operate at a baud rate below or above that of the receiver.

Accumulated bit time misalignment can cause one of the three stop bit data samples to fall outside the actual stop bit. A noise error will occur if the three samples are not all the same logical values. A framing error will occur if the receiver clock is misaligned in such a way that the majority of the three stop bit samples are a logic zero.

As the receiver samples an incoming frame, it may resynchronize the oversampling clock on any valid falling edge within the frame. Resynchronization within frames will correct a misalignment between transmitter bit times and receiver bit times.

In general, increasing the number of samples per bit will increase the baud rate tolerance and decreasing the number of samples per bit will reduce the baud rate tolerance. Note that since LPUART implements triple voting on consecutive receive data samples, increasing the number of samples per bit will move those samples closer together which would reduce the width of noise that can be filtered by the triple voting logic.

47.4.3 Calculating baud rate tolerance

Using the following definitions:

- SAM is the number of sample points per bit (valid range from 8 to 32; equal to (OSR + 1) × (BOTHEDGE + 1)).
- BIT is the number of bits in a character including start, data and stop bits (valid range from 9 to 13).

The ideal baud rate tolerance can be calculated as follows:

- Slow data rate tolerance = ((SAM ÷ 2) - 1) ÷ ((SAM × BIT) - (SAM ÷ 2) + 2)
- Fast data rate tolerance = ((SAM ÷ 2) - 2) ÷ (SAM × BIT)

As an example, if configured for 8-bit data, 1 stop bit (BIT = 10) and with OSR=0x7 and BOTHEDGE = 1 (SAM = 16):

- Slow data rate tolerance = (8 - 1) ÷ (160 - 8 + 2) = 7 ÷ 154 = 4.54%
- Fast data rate tolerance = (8 - 2) ÷ 160 = 6 ÷ 160 = 3.75%

If configured for 9-bit data with 1 stop bit (BIT = 11) with same oversampling configuration, then:

- Slow data rate tolerance = (8 - 1) ÷ (176 - 8 + 2) = 7 ÷ 170 = 4.12%
- Fast data rate tolerance = (8 - 2) ÷ 176 = 6 ÷ 176 = 3.41%

NOTE

Additional factors can contribute to a lower baud rate tolerance than the ideal. These include clock uncertainty or jitter on the LPUART functional clock source, differences in rise and fall times on the transmitter output and synchronization of the external receive pin to the local LPUART functional clock.

47.4.4 Transmitter functional description

This section describes the functioning of the LPUART transmitter, as shown in the transmitter portion of Block diagram, as well as specialized functions for sending break and idle characters.

The transmitter output (TXD) idle state defaults to logic high; the transmitter output is inverted when you write 1 to CTRL[TXINV], which becomes 0 following reset. You can enable the transmitter by writing 1 to CTRL[TE]. This queues a preamble character that is one full character frame of the Idle state. The transmitter then remains idle until data is available in the transmit FIFO and programs store data in the transmit FIFO by writing to Data (DATA).

The central element of the LPUART transmitter is the transmit shift register that is 9-bit to 13-bit long depending on the settings of CTRL[M], CTRL[M7], BAUD[M10], and BAUD[SBNS]. Going forward in this discussion, assume that CTRL[M], CTRL[M7], BAUD[M10], and BAUD[SBNS] are 0, selecting the normal 8-bit Data mode, in which the shift register holds a start bit, eight data bits, and a stop bit. When the transmit shift register is available for a new character, the value waiting in transmit FIFO is transferred to the transmit shift register, synchronized with the baud rate clock, and STAT[TDRE] becomes 1 to indicate that another character may be written to the transmit FIFO at Data (DATA).

If no new character is waiting in the transmit FIFO after a stop bit is shifted out of the TXD pin, the transmitter sets the transmit complete flag and enters an idle mode, with TXD high, waiting for more characters to transmit.

Writing 0 to CTRL[TE] does not immediately disable the transmitter. The current transmit activity in progress must first be completed (that could include a data character, idle character, or break character), although the transmitter does not start transmitting another character.

47.4.4.1 Break character length

CTRL[SBK] sends break characters, originally used to gain the attention of old teletype receivers. Break characters are a full character time of logic 0, 9-bit to 12-bit times, including the start and stop bits. You can enable a longer break of 13-bit times by writing 1 to STAT[BRK13]. Normally, a program waits for STAT[TDRE] to become 1 to indicate that the last character of a message has moved to the transmit shifter. Next, the program writes 1 and then writes 0 to CTRL[SBK]. This action queues a break character to be sent as soon as the shifter is available. If CTRL[SBK] remains 1 when the queued break moves into the shifter, synchronized with the baud rate clock, an additional break character is queued. When LPUART is the receiving module, it receives a break character as 0s in all data bits and a framing error (STAT[FE] = 1) is detected.

You can also transmit a break character by writing to Data (DATA) with DATA[FRETSC] = 1 and the data bits clear. This supports transmitting the break character as part of the normal data stream and also allows DMA to transmit a break character.

When idle line wake-up is used, a full character time of idle (logic 1) is needed between messages to wake up any sleeping receivers. Normally, a program waits for STAT[TDRE] to become 1 to indicate that the last character of a message has moved to the transmit shifter. Next, write 0 and then write 1 to CTRL[TE]. This action queues an idle character to be sent as soon as the shifter is available. As long as the character in the shifter does not finish while CTRL[TE] becomes 0, the LPUART transmitter does not release control of the TXD pin.

You can also write to Data (DATA) to transmit an idle character, with DATA[FRETSC] and DATA[R9T9] = 1 and the values of all the other fields = 0. This supports transmitting the idle character as part of the normal data stream and also allows DMA to transmit an idle character.

As shown in the following table, STAT[BRK13], CTRL[M], CTRL[M7], BAUD[M10], and BAUD[SBNS] affect the length of the break character.

Table 342. Break character length

STAT[BRK13]	CTRL[M]	BAUD[M10]	CTRL[M7]	BAUD[SBNS]	Break character length (in bit times)
0	0	0	0	0	10
0	0	0	0	1	11
0	0	0	1	0	9
0	0	0	1	1	10
0	1	0	—	0	11
0	1	0	—	1	12
0	—	1	—	0	12
0	—	1	—	1	13
1	0	0	0	0	13
1	0	0	0	1	13
1	0	0	1	0	12
1	0	0	1	1	12
1	1	0	—	0	14

Table continues on the next page...

Table 342. Break character length (continued)

STAT[BRK13]	CTRL[M]	BAUD[M10]	CTRL[M7]	BAUD[SBNS]	Break character length (in bit times)
1	1	0	—	1	14
1	—	1	—	0	15
1	—	1	—	1	15

47.4.4.2 Hardware flow control

The transmitter supports hardware flow control by gating the transmission with the value of CTS_B. If the CTS operation is enabled, the character is transmitted when CTS_B is asserted. If CTS_B is deasserted in the middle of a transmission with characters remaining in the transmitter FIFO, the character in the transmit shift register is complete. Any characters in the FIFO wait for CTS_B to assert again, and TXD remains in the mark state (idle state) until CTS_B is reasserted. The CTS_B pin must assert for longer than one bit period to guarantee that a new transmission is started when the transmitter is idle with CTS.

If the CTS operation is disabled, the transmitter ignores the state of CTS_B.

The transmitter's CTS_B signal can be enabled even if the same LPUART receiver's RTS_B signal is disabled.

47.4.4.3 Transceiver driver enable

The transmitter can use RTS_B as an enable signal for the driver of an external transceiver. See Transceiver driver enable using RTS_B for details. If the RTS operation is enabled, when a character is placed into an empty transmit shift register, RTS_B asserts 1-bit time before the start bit is transmitted. RTS_B remains asserted for the whole time that the transmit shift register has any characters. RTS_B deasserts 1-bit time after all characters in the transmit FIFO and shift register are completely sent, including the last stop bit. In other words, when RTS_B is used as a transceiver enable, RTS_B asserts 1-bit time before the transmitter starts transmitting and negates 1-bit time after the transmitter goes idle.

Transmitting a break character also asserts RTS_B, with the same assertion and deassertion timing as having a character in the transmit shift register.

The transmitter's RTS_B signal asserts only when the transmitter is enabled. However, the transmitter's RTS_B signal is unaffected by its CTS_B signal. RTS_B remains asserted until the transfer is complete, even if the transmitter is disabled mid-way through a data transfer.

47.4.4.4 Transceiver driver enable using RTS_B

RS-485 is a multiple drop communication protocol in which the LPUART transceiver's driver is three-stated unless LPUART is driving. The transmitter can use the RTS_B signal to enable the driver of a transceiver. The polarity of RTS_B can be matched to the polarity of the transceiver's driver enable signal.

The following figure shows the receiver enable signal asserted. This connection can also connect RTS_B to both DE and RE_B. The transceiver's receiver is disabled when driving. A pullup can pull RXD to a nonfloating value during this time. You can refine this option further by operating LPUART in Single-Wire mode, freeing the RXD pin for other uses.

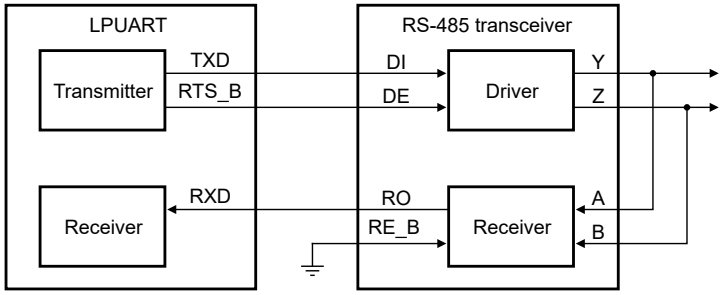

Figure 179. Transceiver driver enable using RTS_B

47.4.5 Receiver functional description

This section discusses the functioning of the LPUART receiver, as shown in the receiver portion of Block diagram. The section also discusses:

- The data sampling technique used to reconstruct receiver data.
- Different variations of the receiver wake-up function.

You can invert the receiver input by writing 1 to STAT[RXINV] and enable the receiver by writing 1 to CTRL[RE]. Character frames consist of a start bit of logic 0, along with N (7, 8, 9, 10) bits (MSB or LSB first), and one or two stop bits of logic 1. For information about 7-bit, 9-bit, or 10-bit Data mode, see Data modes. Going forward in this discussion, assume that LPUART is configured for a normal 8-bit Data mode.

After receiving the stop bit into the receive shifter, and provided the receive data register is not already full (STAT[RDRF] = 0), the data character is transferred to the receive FIFO, resulting in STAT[RDRF] becoming 1. However, if STAT[RDRF] is already 1, indicating that the receive data buffer is already full, STAT[OR] becomes 1 and the new data is lost.

Because the LPUART receiver is separate from the receive FIFO, the receive shift register can receive the next word when the receive FIFO is full, and it is only at the end of the character that the next data is written into the receive FIFO, potentially triggering the overrun flag if the FIFO is full.

When a program detects that the receive data register is full (STAT[RDRF] = 1), it gets the data from the FIFO by reading Data (DATA). See Interrupts for details about flag clearing.

47.4.5.1 Data sampling technique

The LPUART receiver supports a configurable oversampling rate of between 4× and 32× of the baud rate clock for sampling. The receiver starts by considering logic level samples at the oversampling rate times the baud rate to search for a falling edge on the RXD serial data input pin. A falling edge is defined as a logic 0 sample after three consecutive logic 1 samples. The oversampling baud rate clock divides the bit time into 4 to 32 segments from 1 to OSR (where OSR is the configured oversampling ratio). When a falling edge is located, three more samples are taken at (OSR ÷ 2), (OSR ÷ 2) + 1, and (OSR ÷ 2) + 2 to ensure that this is a real start bit and not merely noise. If at least two of these three samples are 0, the receiver assumes they are synchronized to a received character. If another falling edge is detected before the receiver is considered synchronized, the receiver restarts sampling from the first segment.

The receiver then samples each bit time, including the start and stop bits, at (OSR ÷ 2), (OSR ÷ 2) + 1, and (OSR ÷ 2) + 2, to determine the logic level for that bit. The logic level is interpreted to be that of the majority of the samples taken during the bit time. If any sample in any bit time, including the start and stop bits, in a character frame fails to agree with the logic level for that bit, noise flag (STAT[NF]) becomes 1 when the received character is transferred to the receive FIFO.

When the LPUART receiver is configured to sample on both edges of the baud rate clock (that is, when BAUD[BOTHEDGE] = 1), the number of segments in each received bit is effectively doubled (from 1 to OSR× 2). The start and data bits are then sampled at OSR, OSR + 1, and OSR + 2. You must enable sampling on both edges of the clock for oversampling rates of 4× to 7×. This sampling is optional for higher oversampling rates.

The synchronization feature of LPUART synchronizes the internal oversampling counter with a detected falling edge on the receive signal, and to adjust the data sampling window. The falling edge detection needs three consecutive 1s prior to the "1->0" (one to zero) transition. After the initial falling edge detection for the start bit, the circuit continuously monitors the next falling edge, and resets the counter after another falling edge is detected. This synchronization to the start bit is termed as resynchronization.

When BAUD[RESYNCDIS] is 0, you perform this falling edge detection and resynchronization not only for the start bit but also for the rest of the character reception after the start bit.

When BAUD[RESYNCDIS] is 1, you perform the falling edge detection and resynchronization only for the start bit. The use case for disabling the resynchronization is protocols that require this (for example, LIN 2.1 prohibits resynchronization within a byte).

The following table and figure explain LPUART resynchronization.

Table 343. LPUART resynchronization settings

Resynchronization	BAUD[RESYNCDIS] = 0	BAUD[RESYNCDIS] = 1
For the starting bit falling edge	Yes	Yes
For all falling edges after the start bit	Yes	No

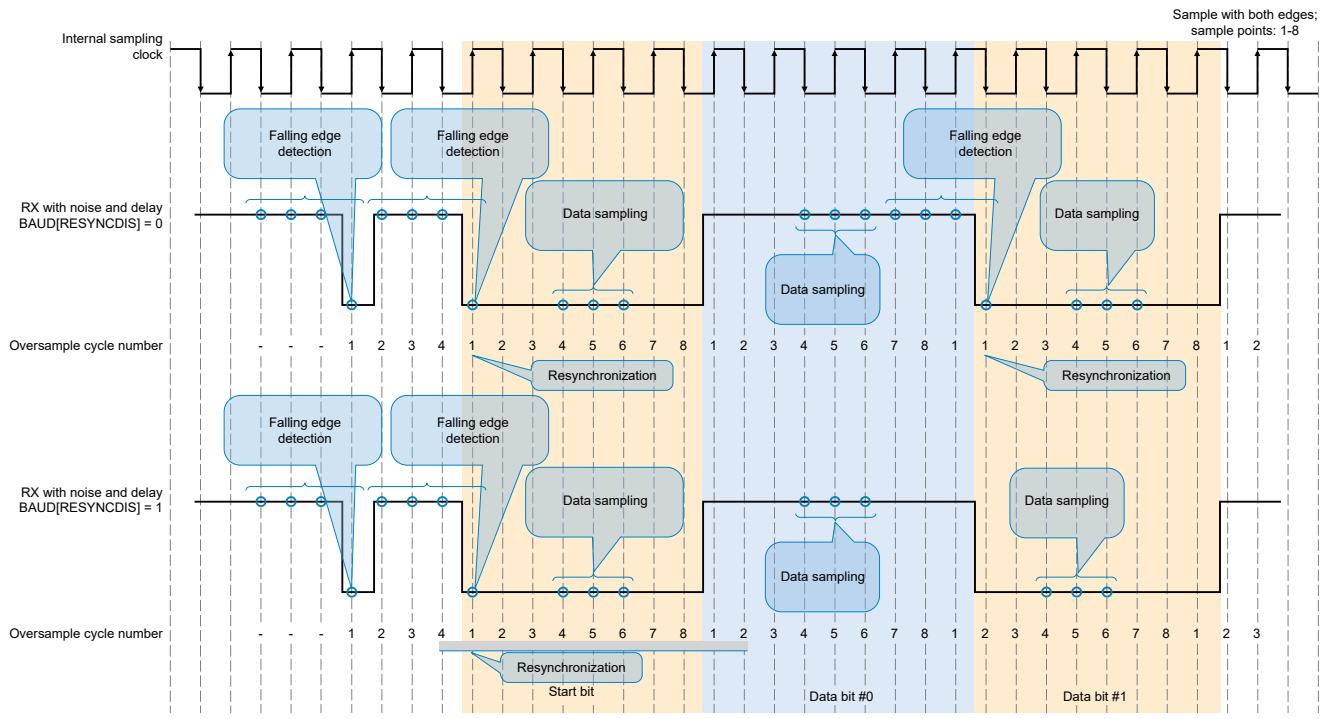

Figure 180. LPUART resynchronization diagram

47.4.5.2 Receiver wake-up operation

Receiver wake-up and receiver address matching are hardware mechanisms that allow an LPUART receiver to ignore the characters in a message intended for a different receiver.

During receiver wake-up, all receivers evaluate the first character(s) of each message, and as soon as they determine the message is intended for a different receiver, they write 1 to CTRL[RWU].

When CTRL[RWU] and STAT[RWUID] are 1, the status fields associated with the receiver, with the exception of STAT[IDLE], are inhibited from becoming 1, thus eliminating the software overhead for handling the unimportant message characters. At the end of a message, all receivers automatically force CTRL[RWU] to become 0. This results in all receivers waking up in time to look at the first character(s) of the next message.

During receiver address matching, the address matching is performed in hardware and the LPUART receiver ignores all characters that do not meet the address match requirements.

Table 344. Receiver wake-up options

CTRL[RWU]	BAUD[MAEN1] | BAUD[MAEN2]	BAUD[MATCFG]	CTRL[WAKE]: STAT[RWUID]	Receiver wake-up
0	0	X	X	Normal operation
1	0	00	00	Receiver wake-up on idle line; STAT[IDLE] = 0
1	0	00	01	Receiver wake-up on idle line; STAT[IDLE] = 1
1	0	00	10	Receiver wake-up on address mark
1	1	11	10	Receiver wake-up on data match
0	1	00	X0	Address mark address match; STAT[IDLE] = 0 for discarded characters
0	1	00	X1	Address mark address match; STAT[IDLE] = 1 for discarded characters
0	1	01	X0	Idle line address match
0	1	10	X0	Match on and match off; STAT[IDLE] = 0 for discarded characters
0	1	10	X1	Match on and match off; STAT[IDLE] = 1 for discarded characters

47.4.5.2.1 Idle line wake-up

When CTRL[WAKE] is 0, you can configure the receiver for an idle line wake-up. In this mode, CTRL[RWU] becomes 0 automatically when the receiver detects a full character time of the idle-line level.

When CTRL[RWU] is set the receiver ignores everything until an idle condition is detected. After the idle condition is detected the CTRL[RWU] is cleared by hardware and the receiver starts receiving data.

The STAT[RWUID] indicates that whether the STAT[IDLE] flag is set or not as a result of the idle condition detection which clears CTRL[RWU].

The STAT[RWUID] says that if the STAT[IDLE] flag is to be set as a result of the idle condition which clears CTRL[RWU].

CTRL[M], CTRL[M7], and BAUD[M10] select 7-bit to 10-bit Data mode and BAUD[SBNS] selects a 1-bit or 2-bit stop bit number that determines how many bit times of idle are needed to constitute a full character time, 9 to 13 bit times because of the start and stop bits.

When CTRL[RWU] is 1 and STAT[RWUID] is 0, the idle condition that wakes up the receiver does not lead to STAT[IDLE] becoming 1. The receiver wakes up and waits for the first data character of the next message that leads to STAT[RDRF] becoming 1 and generates an interrupt if enabled. When STAT[RWUID] is 1, any idle condition leads to STAT[IDLE] becoming 1 and generates an interrupt if enabled, regardless of whether CTRL[RWU] is 0 or 1.

These are the ways to detect an idle line:

- When CTRL[ILT] is 0, the idle bit counter starts after the start bit so that the stop bit and any logic 1s at the end of a character count to calculate the full character time of idle.
- When CTRL[ILT] is 1, the idle bit counter does not start until after the stop bit time so that the data in the last character of the previous message does not impact the idle detection.

47.4.5.2.2 Address mark wake-up

When CTRL[WAKE] is 1, you can configure the receiver for an address mark wake-up. In this mode, CTRL[RWU] becomes 0 automatically when the receiver detects a logic 1 in the most significant bit of the received character. When parity is enabled, the second most significant bit is used for address mark wake-up.

Address mark wake-up allows messages to contain idle characters, but requires one bit to be reserved for use in address frames. The logic 1 in the most significant bit (or second most significant bit when parity is enabled) of an address frame writes 0 to CTRL[RWU] and writes 1 to STAT[RDRF]. In this case, the character with the address mark bit is received even if the receiver is sleeping during most of this character time.

47.4.5.2.3 Data match wake-up

When CTRL[RWU] and CTRL[WAKE] are 1, and BAUD[MATCFG] equals 11, the receiver is configured for a data match wake-up. In this mode, CTRL[RWU] becomes 0 automatically when the receiver detects a character that matches MATCH[MA1] when BAUD[MAEN1] is 1, or that matches MATCH[MA2] when BAUD[MAEN2] is 1.

47.4.5.2.4 Address match operation

You can enable the address match operation when either BAUD[MAEN1] or BAUD[MAEN2] is 1 and BAUD[MATCFG] is 0. In this function, a character that the RXD pin receives with a logic 1 in the most significant bit (or the second most significant bit when parity is enabled) is considered an address and is compared to the associated MATCH[MA1] or MATCH[MA2]. The character is only transferred to the receive buffer, and STAT[RDRF] becomes 1 if the comparison matches. All subsequent characters received with a logic 0 in the most significant bit (or the second most significant bit when parity is enabled) are considered to be data associated with the address and are transferred to the receive FIFO. If no marked address match occurs, no transfer is made to the receive FIFO, and all the characters that follow, with logic 0 in the most significant bit (or second most significant bit when parity is enabled), are also discarded. If both BAUD[MAEN1] and BAUD[MAEN2] are 0, the receiver operates normally, and all the received data is transferred to the receive FIFO.

The address match operation functions in the same way for both MATCH[MA1] and MATCH[MA2]:

- If either BAUD[MAEN1] or BAUD[MAEN2] is 1, a marked address is compared only to the associated Match Address (MATCH) and data is transferred to the receive FIFO only on a match.
- If both BAUD[MAEN1] and BAUD[MAEN2] are 1, a marked address is compared to both MATCH[MA1] and MATCH[MA2] and data is transferred only on a match with either of these fields.

47.4.5.2.5 Idle match operation

You can enable the idle match operation when either BAUD[MAEN1] or BAUD[MAEN2] is 1 and BAUD[MATCFG] is 1. In this function, the first character that the RXD pin receives after an idle line condition is considered an address and is compared to the associated MATCH[MA1] or MATCH[MA2]. The character is transferred only to the receive buffer, and STAT[RDRF] becomes 1, if the comparison matches. All subsequent characters are considered to be data associated with the address and are transferred

to the receive FIFO until the next idle line condition is detected. If no address match occurs, no transfer is made to the receive FIFO, and all the frames that follow, until the next idle condition, are also discarded. If both BAUD[MAEN1] and BAUD[MAEN2] are 0, the receiver operates normally, and all the received data is transferred to the receive FIFO.

An idle match operation functions in the same way for both MATCH[MA1] and MATCH[MA2]:

- If either BAUD[MAEN1] or BAUD[MAEN2] is 1, the first character after an idle line is compared only to the associated Data (DATA) and data is transferred to the receive FIFO only on a match.
- If both BAUD[MAEN1] and BAUD[MAEN2] are 1, the first character after an idle line is compared to both MATCH[MA1] and MATCH[MA2] and data is transferred only on a match with either of these fields.

47.4.5.2.6 Match on, match off operation

The match on, match off operation is enabled when both BAUD[MAEN1] and BAUD[MAEN2] are 1 and BAUD[MATCFG] = 10. In this function, a character that the RXD pin receives matches MATCH[MA1] and is transferred to the receive buffer, and STAT[RDRF] becomes 1. All subsequent characters are considered to be data and are also transferred to the receive FIFO, until a character that matches MATCH[MA2] is received. The character that matches MATCH[MA2], along with all subsequent characters, is discarded; and this continues until another character that matches MATCH[MA1] is received. If both BAUD[MAEN1] and BAUD[MAEN2] are 0, the receiver operates normally, and all the received data is transferred to the receive FIFO.

NOTE

The match on, match off operation requires both BAUD[MAEN1] and BAUD[MAEN2] to be 1.

47.4.5.3 Hardware flow control

To support hardware flow control, you can program the receiver to automatically assert and deassert RTS_B:

- RTS_B remains asserted until the transfer is complete, even if the transmitter is disabled midway through a data transfer. See Transceiver driver enable using RTS_B for more information.
- If the receiver RTS functionality is enabled, the receiver automatically deasserts RTS_B if STAT[RDRF] is 1 or a start bit is detected that causes STAT[RDRF] to become 1.
- The receiver asserts RTS_B when STAT[RDRF] is 0 and has not detected a start bit that causes STAT[RDRF] to become 1. There is no impact if STAT[RDRF] is 1 already.
- Even if RTS_B is deasserted, the receiver continues to receive characters until the receive FIFO is overrun.
- If the receiver RTS functionality is disabled, the receiver's RTS_B remains deasserted.
- When RTS is driven by receiver, it will be negated when the receiver is disabled irrespective of the FIFO level.

47.4.6 Additional LPUART functions

47.4.6.1 Data modes

You can configure the LPUART transmitter and receiver to operate in 7-bit Data mode by writing 1 to CTRL[M7], 9-bit Data mode by writing 1 to CTRL[M], or 10-bit Data mode by writing 1 to BAUD[M10]. In 9-bit Data mode, there exists a ninth data bit and in 10-bit mode, there exists a tenth data bit.

When performing 8-bit writes to the transmit FIFO, the ninth and tenth bits are pushed into the FIFO from CTRL[T8] and CTRL[T9]. For coherent 8-bit writes, you must write to CTRL[T8] and CTRL[T9] before writing to Data (DATA)[7:0]. However, if the values in CTRL[T8] or CTRL[T9] do not need to change, it is not necessary to update CTRL[T8] and CTRL[T9] before every 8-bit write to Data (DATA).

When performing 16-bit or 32-bit writes to the transmit FIFO, all 10 bits are pushed into the transmit FIFO from the write data.

When performing 8-bit reads of the receive FIFO, the ninth and tenth bits are held in CTRL[R8] and CTRL[R9] but you must read them before reading Data (DATA). A 16-bit or 32-bit read of the receive FIFO returns all 10 bits in Data (DATA).

The 9-bit Data mode is typically used with parity to allow eight bits of data plus the parity in the ninth bit, or it is used with the address mark wake-up so that the ninth data bit can serve as the wake-up bit. The 10-bit Data mode is typically used with parity and address mark wake-up so that the ninth data bit can serve as the wake-up bit and the tenth bit can serve as the parity bit. In custom protocols, the ninth and/or tenth bits can also serve as software-controlled markers.

47.4.6.2 Idle length

An idle character is one where the start bit, all data bits, and stop bits are in the mark position (idle state, generally logic 1). You can configure CTRL[ILT] to start detecting an idle character from the previous start bit (any data bits and stop bits count for idle character detection) or from the previous stop bit.

You can also use CTRL[IDLECFG] to configure the number of idle characters that must be received before an idle line condition is detected. This field configures the number of idle characters that must be received before STAT[IDLE] becomes 1, STAT[RAF] becomes 0, and DATA[IDLINE] becomes 1 with the next received character.

CTRL[IDLECFG] also affects the idle line wake-up and idle match operations. When either the address match or match on/off operation is enabled, writing 1 to STAT[RWUID] causes any discarded characters to be treated as idle characters.

47.4.6.3 Loop mode

Enable Loop mode by setting CTRL[LOOPS] = 1 and CTRL[RSRC] = 0. You, sometimes, use Loop mode to check software, independent of connections in the external system, to help isolate system problems. In this mode, the transmitter output is internally connected to the receiver input and LPUART does not use the RXD pin.

47.4.6.4 Single-Wire mode

Enable Single-Wire mode by setting CTRL[LOOPS] = 1 and CTRL[RSRC] = 1. Single-Wire mode implements a half-duplex serial connection. The receiver is internally connected to the transmitter output and TXD pin (the RXD pin is not used).

In Single-Wire mode, CTRL[TXDIR] controls the direction of serial data on the TXD pin. When CTRL[TXDIR] becomes 0, the TXD pin is an input to the receiver and the transmitter is temporarily disconnected from the TXD pin so that an external device can send serial data to the receiver. When CTRL[TXDIR] = 1, the TXD pin is an output that the transmitter drives. The internal loop back connection is disabled, and as a result, the receiver is unable to receive characters that the transmitter sends out.

47.4.7 Peripheral triggers

The connection of the LPUART peripheral triggers with other peripherals is chip-specific.

47.4.7.1 Output triggers

LPUART generates the following output triggers that can be connected to other peripherals on the chip:

- The transmit word trigger asserts at the end of each transmitted word and negates after 1-bit period.
- The transmit data trigger is identical to the TXD pin output, but without support for input trigger modulation.
- The receive word trigger asserts at the end of each received word that is written to the receive FIFO, for one oversampling clock period.
- The receive idle trigger asserts when STAT[IDLE] becomes 1, for one oversampling clock period.

47.4.7.2 Input trigger

LPUART supports a peripheral input trigger that you can configure in one of the following ways:

- By enabling the CTS function: You can connect the input trigger (active high) instead of the CTS_B (active low) pin input. The input trigger must assert for longer than 1-bit clock period when the transmitter is idle, with data to send, to guarantee a new transmission.

- By making the input trigger modulate the transmit data output (trigger is logically ANDed with the TXD output): The input trigger is expected to be a free-running clock (carrier signal) that generates from a timer or PWM source with a frequency that is greater than the bit-clock frequency. The carrier signal must not toggle faster than the maximum supported bit time.
- By connecting the input trigger instead of the RXD pin input: The input trigger is expected to be generated from a receive data source, such as an analog comparator or external pin.

47.4.8 Infrared (IR) interface

LPUART provides the capability of transmitting narrow pulses to an IR LED and receiving narrow pulses, transforming them to serial bits, which are then sent to LPUART. The IrDA physical layer specification defines a half-duplex IR communication link for exchanging data. The full standard includes data rates up to 16 Mbit/s. The LPUART IrDA support is limited to SIR mode that supports data rates only between 2.4 kbit/s and 115.2 kbit/s.

LPUART has an infrared transmit encoder and a receive decoder. The infrared decoder converts the received character from the IrDA format to the NRZ format, which the receiver uses. It also has an OSR oversampling baud rate clock counter that filters noise and indicates when a 1 is received. LPUART transmits serial bits of data, which the infrared submodule encodes, to transmit a narrow pulse for every zero bit. No pulse is transmitted for every single bit. When receiving data, an IR photo diode (external to LPUART) detects the IR pulses. The IR receive decoder transforms them to CMOS levels. The infrared receive decoder then stretches the narrow pulses to get back to a serial bit stream that LPUART receives. You can invert the polarity of transmitted pulses and expected receive pulses so that a direct connection can be made to external IrDA transceiver modules that use active-high pulses.

The IR submodule receives its clock sources from LPUART. The submodule selects one of these clocks to generate either 1 ÷ OSR, 2 ÷ OSR, 3 ÷ OSR, or 4 ÷ OSR narrow pulses during transmission.

47.4.8.1 Infrared transmit encoder

The infrared transmit encoder converts serial bits of data from the transmit shift register to the TXD signal. A narrow pulse is transmitted for a 0 bit and no pulse is transmitted for a 1 bit. The narrow pulse is sent at the start of the bit with a duration of 1 ÷ OSR, 2 ÷ OSR, 3 ÷ OSR, or 4 ÷ OSR of a bit time. A narrow low pulse is transmitted for a 0 bit when CTRL[TXINV] is 0, while a narrow high pulse is transmitted for a 0 bit when CTRL[TXINV] is 1.

47.4.8.2 Infrared receive decoder

The infrared receive block converts data from the RXD signal to the receive shift register. A narrow pulse is expected for each 0 received and no pulse is expected for each 1 received. A narrow low pulse is expected for a 0 bit when STAT[RXINV] is 0, while a narrow high pulse is expected for a 0 bit when STAT[RXINV] is 1. This receive decoder meets the edge jitter requirement as defined by the IrDA serial infrared physical layer specification.

47.4.8.3 Start-bit detection

When STAT[RXINV] is 0, the first falling edge of the received character corresponds to the start bit. The infrared decoder resets its counter. At this time, the receiver also begins its start bit detection process. After the start bit is detected, the receiver synchronizes its bit times to this start bit time. For the rest of the character reception, the infrared decoder's counter and the receiver's bit time counter count independently of each other.

47.4.8.4 Noise filtering

The decoder ignores any rising edges detected during the first half of the infrared decoder counter, and can leave any pulses less than one oversampling baud clock as undetected. This is regardless of whether the pulse is seen in the first or second half of the count.

47.4.8.5 Low-bit detection

During the second half of the decoder count, a rising edge is decoded as 0, which is sent to the receiver. The decoder counter is also reset.

47.4.8.6 High-bit detection

At OSR oversampling baud rate clocks after the previous rising edge, if a rising edge is not seen, the decoder sends a 1 to the receiver.

If the next bit is 0, which arrives late, a low bit is detected according to Low-bit detection. The value sent to the receiver is changed from 1 to 0. Then, if a noise pulse occurs outside the receiver's bit time sampling period, the delay of a 0 is not recorded as noise.

47.4.9 Modes of operation

47.4.9.1 Low-Power modes

LPUART remains functional during low-power modes, provided CTRL[DOZEEN] is 0 and the LPUART functional clock is enabled. LPUART can generate an interrupt or DMA request to cause a wake-up from low-power modes.

You can configure LPUART to be disabled in low-power modes, when CTRL[DOZEEN] is 1. In this case, the transmitter and receiver finish transmitting and receiving the current word.

If LPUART is disabled in low-power modes, it can generate a wake-up via STAT[RXEDGIF] if the receiver detects an active edge.

NOTE

See the chip-specific information for specific low-power modes available on your chip.

47.4.9.2 Debug mode

LPUART remains functional in Debug mode.

47.4.10 Clocking

Table 345. Types of clocks

Clock	Description
Functional	Is asynchronous to the bus clock and can remain enabled in Low-Power modes to support transmit and/or receive functions, including low-power wake-up.
Bus	Is only used for bus accesses to the control and configuration registers. The bus clock frequency must be sufficient to support the data bandwidth requirements of the LPUART transmit and receive registers, including the FIFOs.

47.4.11 Reset

Table 346. Types of resets

Reset	Description
Chip	Enables the logic and registers for the LPUART transmitter and receiver to reset to their default states.
Software	Resets the LPUART logic and registers to their default states, except for Global (GLOBAL). GLOBAL[RST] controls the LPUART software reset.
FIFO	Implements write-only control fields that reset the transmit FIFO (FIFO[TXFLUSH]) and receive FIFO (FIFO[RXFLUSH]). After a FIFO is reset, that FIFO becomes empty.

47.4.12 Interrupts

The LPUART transmitter has two status fields that can optionally generate hardware interrupt requests. If STAT[TDRE] is 1, it indicates that there is room in the transmit FIFO to write another transmit character to Data (DATA). If CTRL[TIE] is 1, a hardware interrupt is requested when STAT[TDRE] is 1.

STAT[TC] indicates that the transmitter is finished transmitting all data, preamble, and break characters and is idle with TXD at the inactive level. This field is often used in systems with modems to determine when it is safe to turn off the modem. If CTRL[TCIE] is 1, a hardware interrupt is requested when STAT[TC] is 1. Instead of hardware interrupts, software polling may be used to monitor STAT[TDRE] and STAT[TC] if the corresponding CTRL[TIE] or CTRL[TCIE] field is 0.

When a program detects that STAT[RDRF] is 1, it gets the data from this field by reading Data (DATA). The field becomes 0 by reading Data (DATA).

STAT[IDLE] includes logic that prevents it from becoming 1 repeatedly when the RXD line remains idle for an extended period of time. STAT[IDLE] becomes 0 when you write 1 to it, and cannot become 1 again until the receiver has received at least one new character and has 1 as the value of STAT[RDRF].

If the associated error is detected in the received character that caused STAT[RDRF] to become 1, STAT[NF], STAT[FE], and STAT[PF] become 1 at the same time STAT[RDRF] becomes 1. These flags do not become 1 in overrun cases.

If STAT[RDRF] is already 1 when a new character is ready to be transferred from the receive shifter to the receive FIFO, STAT[OR] becomes 1, instead of the data along with any associated STAT[NF], STAT[FE], or STAT[PF] condition getting lost.

If the received character matches the contents of MATCH[MA1] and/or MATCH[MA2], then STAT[MA1F] and/or STAT[MA2F] become 1 at the same time that STAT[RDRF] becomes 1.

At any time, an active edge on the RXD serial data input pin causes STAT[RXEDGIF] to become 1. STAT[RXEDGIF] becomes 0 when you write 1 to it. This function depends on the receiver being enabled (the value of CTRL[RE] being 1).

47.5 External signals

Table 347. External signals

Signal	Description	I/O
TXD	Transmit data: This pin is normally an output, but is an input (tristated) in Single-Wire mode whenever the transmitter is disabled or the transmit direction is configured for receive data.	I/O
RXD	Receive data	I
CTS_B	Clear-to-send	I
RTS_B	Request-to-send	O

47.6 Initialization

This module does not require initialization.

Chapter 48
CAN (FlexCAN)

48.1 Chip-specific FlexCAN information

Table 348. Reference links to related information

Topic	Related module	Reference
Full description	CAN	CAN
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

48.1.1 Module instances

The parts with CAN module have two instance: CAN0 and CAN1. Refer to Ordering information for parts have CAN module.

48.1.2 Enhanced Rx FIFO under DMA operation

In order to use the DMA feature, the ERFCR[ERFWM] must be configured as 0b.

ERFSR[ERFDA] is set by the hardware when there is at least one frame available to be read from the Enhanced Rx FIFO, and ERFSR[ERFWMI] is set by the hardware when the number of frames stored in the FIFO is greater than 0 (the watermark defined by ERFCR[ERFWM]). A DMA request is generated when ERFSR[ERFWMI] is set. Upon receiving the request, the DMA controller can read the message in the Enhanced Rx FIFO output. The DMA controller performs one read loops in the FIFO output defined by ERFCR[ERFWM]. Also, each message reading process must end by the address defined in ERFCR[DMALW].

48.1.3 Maximum data rate

The maximum data rate for CAN in this device is 8 Mbps. Refer to device's Data sheet for more information.

48.1.4 Can timestamp

The CAN module includes two clock inputs.

- Interface clock- the interface clock provides the timing reference for the bus transactions between the module and the bus fabric of the chip.
- Functional clock- the functional clock provides the timing reference for the operation of the module.

The system clock generator (SCG) and peripheral clock controller (PCC) control both these clocks. No additional clocking options are available for this module.

This chip implements two FlexCAN modules with the same configuration. The chip adds the 32-bit timestamp feature as follows:

- Input tmr_tick_ext on CANn is driven by a synchronized version (to CANn bus clock) of the LPIT0 Channel n trigger output (where n is the CAN instance number).

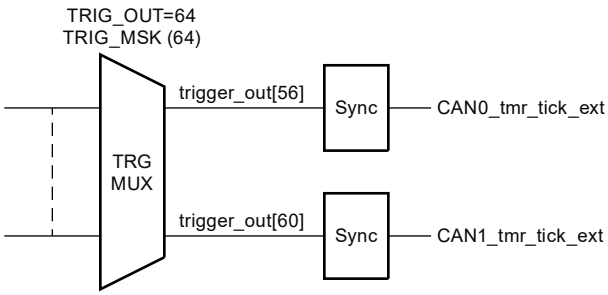

Figure 181. FlexCAN 0/1 Timer Tick Connections

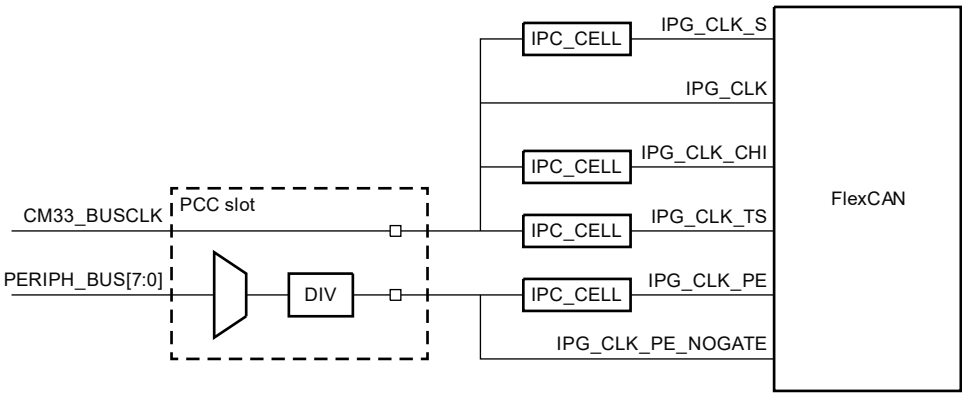

Figure 182. FlexCAN 0/1 Clocking

- Input timestamp_base[31:0] to both instances shall be driven by a free running 32-bit counter ,which increments on every clock cycle that is clocked by the CAN0 bus clock and reset by CAN0 peripheral reset.

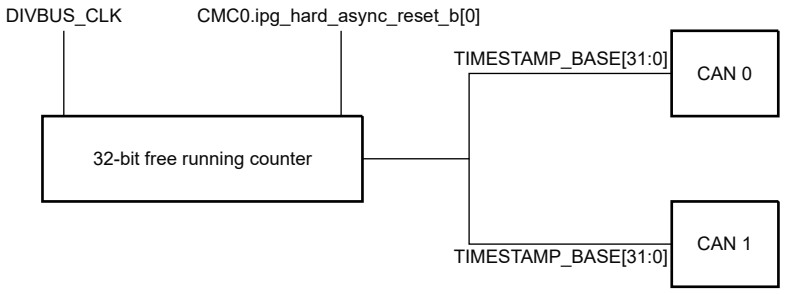

Figure 183. FlexCAN 0/1 Timestamp

NOTE

To enable CAN1 high-resolution timestamp counter, software must bring the CAN0 module out of reset, which means, MRCC_CAN0[RSTB] = 1 and MRCC_CAN0[CC] != 0.

48.1.5 FlexCAN reset

The chip level hard reset input of FlexCAN is controlled by MRCC_CANn[RSTB], therefore a FlexCAN hard reset leads to reset all the module which result in all registers being affected by this reset. The chip level soft reset input is not supported on this device, use MCR[SOFTRST] to initiate a soft reset of the FlexCAN.

48.2 Overview

FlexCAN is a communication controller implementing the CAN protocol according to the ISO 11898-1:2015 standard and CAN 2.0 Part B protocol specifications.

The CAN protocol was primarily designed to be used as a vehicle serial data bus, meeting the specific real-time processing and reliable operation requirements in the electromagnetic interference (EMI) environment of a vehicle. FlexCAN is a full implementation of the CAN protocol specification, the CAN with flexible data rate (CAN FD) protocol, and the CAN version 2.0 Part B protocol. It supports both standard and extended message frames and long payloads.

NOTE

Legacy Receive (RX) FIFO cannot be used in CAN Flexible Data (FD) mode. In CAN FD mode, use the Enhanced Receive FIFO feature instead of the Legacy Receive FIFO.

48.2.1 Block diagram

Figure 184 shows the main submodules implemented in FlexCAN.

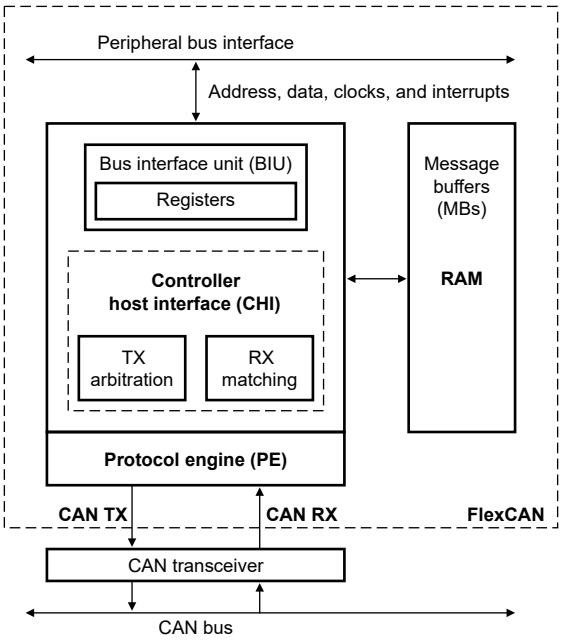

Figure 184. Block diagram

The Protocol Engine (PE) submodule manages the serial communication on the CAN bus:

- RAM access for receiving and transmitting message frames
- Receive message validation
- Error handling
- CAN FD message detection

Controller Host Interface (CHI) manages:

- Message buffer (MB) selection for reception and transmission
- Arbitration and ID matching algorithms for both CAN FD and non-CAN FD message formats

Bus Interface Unit (BIU) controls access to and from the internal interface bus to establish connection to the CPU and to other blocks. The BIU manages access to:

- Clocks

- Address and data buses
- Interrupt outputs
- DMA
- Test signals

48.2.2 Features

- Full implementation of *CAN with Flexible data rate (CAN FD) protocol specification* and *CAN Specification Version 2.0, Part B*:
  - Standard data frames
  - Extended data frames
  - Data length of 0–64 bytes
  - Programmable bit rate (see chip-specific FlexCAN information for specific maximum rate configuration)
  - Content-related addressing
- Compliance with the ISO 11898-1:2015 standard
- Flexible message buffers that can be configured to store a payload of 0, 8, 16, 32, or 64 bytes
  - Increasing the payload size decreases the number of supported message buffers (see FlexCAN memory partition for CAN FD).
  - Message buffers are configurable as receive or transmit, supporting standard and extended messages.
- Individual Receive Mask registers for each message buffer
- Full-featured Legacy RX FIFO with storage capacity for six frames and automatic internal pointer handling with DMA support
- Full-featured Enhanced RX FIFO with storage capacity of 12 CAN FD frames and automatic internal pointer handling with DMA support
- Transmission abort capability
- Optional general purpose RAM space, using RAM not used by reception or transmission structures
- Listen-Only mode
- Programmable loopback mode supporting self-test operation
- Programmable transmission priority scheme: lowest ID, lowest buffer number, or highest priority
- Timestamp based on 32-bit free-running timer, with optional external time tick
- Global network time, synchronized by specific message
- Maskable interrupts
- Independence from transmission medium (external transceiver is assumed)
- Short latency time due to arbitration scheme for high-priority messages
- Low-power modes, with programmable wake-up on bus activity or matching with received frames (Pretended Networking mode)
- Transceiver delay compensation when transmitting CAN FD messages at faster data rates
- Management of remote request frames, automatically or by software
- Restriction only to write CAN bit time settings and configuration bits in Freeze mode
- Transmit message buffer status (lowest-priority buffer or empty buffer)
- Identifier Acceptance Filter Hit Indicator (IDHIT) register for received frames

- ESR1[SYNCH] to indicate module is synchronous with CAN bus
- CRC status for transmitted message
- Legacy RX FIFO Global Mask register
- Selectable priority between message buffers and receive FIFO during matching process
- Powerful legacy RX FIFO ID filtering, capable of matching incoming IDs against either 128 extended IDs, 256 standard IDs, or 512 partial (8-bit) IDs, with 32 individual masking capability
- Powerful enhanced RX FIFO ID filtering, capable of matching incoming IDs against either 16 extended or 32 standard ID filter elements with three filtering schemes: mask plus filter, range, and two filters without mask
- Complete backward compatibility with previous FlexCAN version
- Pretended networking functionality in low power: Doze mode, Stop mode

48.3 Functional description

FlexCAN is a CAN protocol engine with a flexible message buffer system for transmitting and receiving CAN frames. The system is a set of message buffers (MBs) that stores configuration and control data, timestamp, message ID, and data (see Message buffer structure).

For classical CAN frames, FlexCAN supports simultaneous reception through Legacy FIFO and message buffer. For CAN FD frames, FlexCAN supports reception through message buffer and enhanced receive FIFO.

For message buffer reception, a matching algorithm makes it possible to store received frames only into MBs that have the same ID programmed in the ID field. A masking scheme makes it possible to match the ID programmed on the message buffer with a range of IDs on received CAN frames. For transmission, an arbitration algorithm decides the prioritization of message buffers to be transmitted based on the message ID (optionally augmented by three local priority bits) or the message buffer ordering.

A message buffer is active at a given time if it can participate in both the matching and arbitration processes. A receive message buffer with a 0b code is inactive (see Table 384). A transmit message buffer with a 1000b or 1001b code is also inactive (see Table 385).

FlexCAN can receive and transmit messages in CAN FD format. The message buffers are sized to store the quantity of data bytes selected by FDCTRL[MBDSRn]. The quantity of FD message buffers available for a given quantity of data bytes is described in the CAN FD Control (FDCTRL) register. See also FlexCAN memory partition for CAN FD.

48.3.1 Modes of operation

FlexCAN has these functional modes:

Table 349. Functional modes

Mode	Description
Normal	In Normal mode, FlexCAN receives and transmits message frames, manages errors normally, and enables all CAN Protocol functions.
Freeze	Freeze mode is enabled when MCR[FRZ] = 1. If enabled, FlexCAN enters Freeze mode when MCR[HALT] is 1 or when is requested at chip level and FlexCAN writes 1 to MCR[FRZACK]. In this mode, no transmission or reception of frames is done, and synchronicity to the CAN bus is lost. See Freeze mode.
Loopback	FlexCAN enters this mode when CTRL1[LPB] becomes 1. In this mode, FlexCAN performs an internal loopback that can be used for self-test. The bit stream output of the transmitter is internally fed back to the receiver input. The receiving CAN input pin is ignored and the transmitting CAN output goes to the recessive state (logic 1). FlexCAN behaves as it normally does when transmitting and treats its own transmitted message as a message received from a remote node. To ensure proper reception of its own

Table continues on the next page...

Table 349. Functional modes (continued)

Mode	Description
	message, FlexCAN ignores the bit sent during the ACK slot in the CAN frame acknowledge field. Both transmit and receive interrupts are generated.
Listen-Only	FlexCAN enters this mode when CTRL1[LOM] becomes 1. In this mode, transmission is disabled, all error counters are frozen, and the module operates in a CAN Error Passive mode. Only messages acknowledged by another CAN station are received. If FlexCAN detects an unacknowledged message, it flags a BIT0 error (without changing the REC), as if it was trying to acknowledge the message.
CAN FD Active	In this mode, FlexCAN can transmit and receive all messages formatted according to the CAN FD Standard (2.0) and 2.0B Protocol in an interleaved fashion. The CPU can put FlexCAN into CAN FD Active mode by configuring MCR[FDEN] in Freeze mode.

Some features available in classical CAN are unavailable in CAN FD mode.

Table 350. Differences between classical CAN and CAN FD

Feature	Classical CAN	CAN FD
Legacy RX FIFO DMA	Yes	No
Legacy RX FIFO	Yes	No
Enhanced RX FIFO DMA	Yes	Yes
Enhanced RX FIFO	Yes	Yes
Pretended network support	Yes	No

FlexCAN can operate in these low-power modes:

Table 351. Low-power modes

Mode	Description
Module Disable	FlexCAN enters this mode when the CPU writes 1 to MCR[MDIS] and FlexCAN writes 1 to MCR[LPMACK]. After FlexCAN is disabled, it issues a request to disable the clocks to the CAN Protocol Engine and Controller Host Interface submodules. Writing 0 to MCR[MDIS] exits this mode. See Module Disable mode.
Doze	FlexCAN enters this mode when MCR[DOZE] is 1, Doze mode is requested at chip level, and FlexCAN writes 1 to MCR[LPMACK]. When in Doze mode, FlexCAN issues a request to disable the clocks to the CAN Protocol Engine and the CAN Controller-Host Interface submodules. This mode is exited when: • MCR[DOZE] becomes 0 • The chip is removed from Doze mode • Or activity is detected on the CAN bus and the Self-Wake-up mechanism is enabled. See Doze mode.
Stop	FlexCAN enters this mode when Stop mode is requested at chip level and FlexCAN writes 1 to MCR[LPMACK]. When in Stop mode, FlexCAN puts itself in an inactive state and then informs the CPU that the clocks can be shut down globally. Exit from this mode occurs when the Stop mode request is removed, or when activity is detected on the CAN bus and the Self-Wake-up mechanism is enabled. See Stop mode.

Table continues on the next page...

Table 351. Low-power modes (continued)

Mode	Description
Pretended Network (PN)	FlexCAN can operate in this mode with Doze mode or Stop mode. Before entering one of these low-power modes, you must write 1 to MCR[PNET_EN]. When in a low-power mode, CHI subblock clocks are shut down and CAN_PE subblock remains clocked. The receive process remains active to filter incoming messages (see Receive process in Pretended Networking mode) as defined by the configuration registers (see Pretended Networking Control 1 (CTRL1_PN)). Upon detecting a wake-up event, a wake-up interrupt is issued to the system. When MCR[PNET_EN] becomes 1, the CPU must disable Self-Wake-up by writing 0 to MCR[SLFWAK] (see Module Configuration (MCR).

48.3.1.1 Modes of operation details

FlexCAN has functional modes and low-power modes. See Modes of operation for an introductory description of all the modes of operation. The following subsections contain functional details about Freeze mode and low-power modes.

CAUTION

FlexCAN does not support "Permanent Dominant" failure on the CAN bus line. If a Low-Power request or Freeze mode request occurs during a "Permanent Dominant" condition, the corresponding acknowledgment field can never be 1.

48.3.1.1.1 Freeze mode

This mode is requested either by the CPU writing 1 to MCR[HALT] or when the chip is put into Debug mode. MCR[FRZ] must be 1 and the module must not be in a low-power mode.

To obtain acknowledgment, FlexCAN writes 1 to MCR[FRZACK]. The CPU must only consider FlexCAN to be in Freeze mode when both request and acknowledgment conditions are satisfied.

When Freeze mode is requested, FlexCAN:

1. Waits to be in either Intermission, Error Passive, Bus Off, or Idle state.
2. Waits for all internal activities like arbitration, matching, move-in, and move-out to finish. A pending move-in does not prevent entering Freeze mode.
3. Ignores the receive input pin and drives the transmit pin as recessive.
4. Stops the prescaler, halting all CAN protocol activities.
5. Grants write access to the Error Counters register, which is read-only in other modes.
6. Writes 1 to MCR[NOTRDY] and MCR[FRZACK].

After requesting Freeze mode, you must wait for MCR[FRZACK] to become 1 before executing any other action, otherwise FlexCAN may operate unpredictably. In Freeze mode, all memory-mapped registers are accessible.

Freeze mode is exited in one of these conditions:

- CPU writes 0 to MCR[FRZ].
- The chip is removed from Debug mode or the MCR[HALT] becomes 0.

MCR[FRZACK] becomes 0 after the protocol engine recognizes the negation of the freeze request. After leaving Freeze mode, FlexCAN tries to resynchronize to the CAN bus by waiting for 11 consecutive recessive bits.

48.3.1.1.2 Module Disable mode

This low-power mode is normally used to disable a complete FlexCAN block temporarily, with no power consumption. The CPU requests this mode by writing 1 to MCR[MDIS], and FlexCAN acknowledges the request by writing 1 to MCR[LPMACK]. The CPU must only consider FlexCAN to be in Disable mode when both the request and acknowledgment conditions are satisfied.

If FlexCAN is disabled during Freeze mode, the module requests to disable the clocks to the PE and CHI submodules, writes 1 to MCR[LPMACK] and writes 0 to MCR[FRZACK].

It is not recommended to use Module Disable mode under Pretended Networking mode. Write 0 to MCR[MDIS] and wait for MCR[LPMACK] to become 0 before writing 1 to MCR[PNET_EN].

If the module is disabled during transmission or reception, FlexCAN:

1. Waits to be in either Idle or Bus Off state, or waits for the third bit of Intermission and then checks that it is recessive.
2. Waits for all internal activities like arbitration, matching, move-in, and move-out to finish. FlexCAN does not take a pending move-in into account.
3. Ignores its receive input pin and drives its transmit pin as recessive.
4. Shuts down the clocks to the PE and CHI submodules.
5. Writes 1 to MCR[NOTRDY] and MCR[LPMACK].

In this mode, the Bus Interface Unit continues to operate, enabling the CPU to access memory-mapped registers, except for:

- The Receive Message Buffers Global Mask registers
- The Receive Buffer 14 Mask register
- The Receive Buffer 15 Mask register

When in Disable mode, these items are accessible:

- The message buffers
- The Receive Individual Mask registers
- The reserved words within RAM

To exit this mode, the CPU writes 0 to MCR[MDIS], causing FlexCAN to request to resume the clocks and write 0 to MCR[LPMACK]. This write occurs after the CAN protocol engine recognizes the negation of disable mode requested by the CPU.

48.3.1.1.3 Doze mode

This is a system low-power mode in which the CPU bus is kept alive and a global Doze mode request is sent to all peripherals asking them to enter low-power mode. When Doze mode is globally requested, MCR[DOZE] needs to have been asserted previously for Doze mode to be triggered. The acknowledgement is obtained through the assertion of MCR[LPMACK] by FlexCAN. The CPU must only consider FlexCAN to be in Doze mode when both request and acknowledgement conditions are satisfied.

If Doze mode is triggered during Freeze mode, FlexCAN requests to shut down the clocks to the PE and CHI submodules, sets MCR[LPMACK] and negates MCR[FRZACK]. If Doze mode is triggered during transmission or reception, FlexCAN does the following:

- Waits to be in either Idle or Bus Off state, or else waits for the third bit of Intermission and checks it to be recessive.
- Waits for all internal activities like arbitration, matching, move-in, and move-out to finish. A pending move-in is not taken into account.
- Ignores its Rx input pin and drives its Tx pin as recessive.
- Shuts down the clocks to the PE and CHI submodules.
- Sets MCR[NOTRDY] and MCR[LPMACK].

The Bus Interface Unit continues to operate, enabling the CPU to access memory-mapped registers, except the Rx Mailboxes Global Mask registers, the Rx Buffer 14 Mask register, the Rx Buffer 15 Mask register.

Also, the message buffers, the Rx Individual Mask registers, and the reserved words within RAM may not be accessed when the module is in Doze mode.

Exiting Doze mode is done in one of the following ways:

- CPU removing the Doze mode request

- CPU negating MCR [DOZE]
- Self-Wake mechanism

In the Self-Wake mechanism, if MCR[SLFWAK] was set at the time FlexCAN entered Doze mode, then after detection of a recessive to dominant transition on the CAN bus, FlexCAN negates the DOZE bit, requests to resume its clocks and negates the LPMACK after the CAN protocol engine recognizes the negation of the Doze mode request. It also sets ESR [WAKINT] and, if enabled by MCR[WAKMSK], generates a Wake-Up interrupt to the CPU. FlexCAN then waits for 11 consecutive recessive bits to synchronize to the CAN bus. As a consequence, it does not receive the frame that woke it up. The following table details the effect of SLFWAK and WAKMSK after wakeup from Doze mode.

Table 352. Wakeup from Doze mode

SLFWAK	WAKINT	WAKMSK	FlexCAN clocks enabled	Wakeup interrupt generated
0	—	—	No	No
0	—	—	No	No
1	0	0	No	No
1	0	1	No	No
1	1	0	Yes	No
1	1	1	Yes	Yes

48.3.1.1.4 Stop mode

In this low-power mode for the system, all chip clocks can be stopped for maximum power savings. Stop mode is globally requested by the CPU and FlexCAN writes 1 to a Stop Acknowledgment signal to indicate acknowledgment. The CPU must only consider FlexCAN to be in Stop mode when both request and acknowledgment conditions are satisfied.

If FlexCAN receives the global Stop mode request during Freeze mode, it shuts down the clocks globally by:

1. Writing 1 to MCR[LPMACK].
2. Writing 0 to MCR[FRZACK].
3. Sending the Stop Acknowledge signal to the CPU.

If Stop mode is requested during transmission or reception, FlexCAN:

1. Waits to be in either Idle or Bus Off state, or waits for the third bit of Intermission and verifies that it is recessive.
2. Waits for all internal activities like arbitration, matching, move-in, and move-out to finish. FlexCAN does not take a pending move-in into account.
3. Ignores its receive input pin and drives its transmit pin as recessive.
4. Writes 1 to MCR[NOTRDY] and MCR[LPMACK].
5. Sends a Stop Acknowledge signal to the CPU, so that the CPU can shut down the clocks globally.

FlexCAN exits Stop mode when the CPU resumes the clocks and removes the Stop mode request. This exit can occur as a result of the Self-Wake mechanism.

In Self-Wake, if MCR[SLFWAK] = 1 when FlexCAN enters Stop mode, then upon detecting a recessive-to-dominant transition on the CAN bus, FlexCAN writes 1 to ESR1[WAKINT]. If enabled by MCR[WAKMSK], FlexCAN generates a wake-up interrupt to the CPU. Upon receiving the interrupt, the CPU should resume the clocks and remove the Stop mode request. FlexCAN waits for 11 consecutive recessive bits to synchronize to the CAN bus. As a consequence, FlexCAN does not receive the frame that woke it

up. Table 353 details the effect of MCR[SLFWAK] and MCR[WAKMSK] upon wakeup from Stop mode. Waking from Stop mode only works when both fields are 1.

After the CAN protocol engine recognizes the negation of the Stop mode request, FlexCAN writes 0 to MCR[LPMACK]. FlexCAN then waits for 11 consecutive recessive bits to synchronize to the CAN bus. As a consequence, FlexCAN does not receive the frame that woke it up.

Table 353. Waking from Stop mode

SLFWAK	WAKINT	WAKMSK	Chip clocks enabled	Wake-up interrupt generated
0	—	—	No	No
0	—	—	No	No
1	0	0	No	No
1	0	1	No	No
1	1	0	No	No
1	1	1	Yes	Yes

NOTE

When FlexCAN is in the Bus Off state and Low-Power mode, FlexCAN may take an extra 128 IDLE cycles to leave the Bus Off state after exiting Low-Power mode.

48.3.1.1.5 Pretended Networking (PN) mode

This special low-power mode receives wake-up messages with low power consumption. This mode can be selected to operate together with Doze mode or Stop mode. Before entering a low-power mode, MCR[PNET_EN] must be 1. After entering a low-power mode, the CHI subblock is shut down and the CAN_PE subblock is kept active. The receive process is still active to filter incoming messages (see Receive process in Pretended Networking mode) as defined by the configuration registers (see Pretended Networking Control 1 (CTRL1_PN)). Upon detecting a wake-up event, FlexCAN issues a wake-up interrupt to the system.

To enter Pretended Networking mode, FlexCAN must be in Normal mode, not in Freeze or Module Disable mode. In Pretended Networking mode, FlexCAN keeps itself synchronized with the CAN bus in Doze or Stop mode. Then, when either Doze or Stop mode is requested, FlexCAN:

1. Waits to be in the Idle state, or waits for the third bit of Intermission, then verifies that it is recessive.
2. Writes 1 to MCR[LPMACK].
3. Requests the shutdown of the CHI submodule clock, while keeping the PE submodule clock active.

FlexCAN can exit Pretended Networking mode in one of these ways:

- The CPU removes the Doze mode request.
- The CPU writes 0 to MCR[DOZE].
- The CPU removes the Stop mode request.
- FlexCAN waits until Bus Idle, or until the third bit of Intermission state, to write 0 to MCR[LPMACK].

The above exit events can be triggered:

- By FlexCAN, after detecting a wake-up event and issuing the respective interrupt.
- By the CPU itself, when another method wakes it up.

Consequently, FlexCAN waits until the Bus Idle state, or until the third bit of the Intermission state, to write 0 to MCR[LPMACK] and resume Normal mode. This procedure ensures that FlexCAN is synchronized to the CAN bus after exiting Pretended Networking mode. The CPU must wait for MCR[LPM_ACK] to become 0 before performing any access to FlexCAN.

When MCR[PNET_EN] becomes 1, the CPU must disable the self-wake-up by writing 0 to MCR[SLFWAK] (see Module Configuration (MCR)).

NOTE

For more information about the difference between FD and non-FD regarding this feature, see Table 350.

48.3.2 Transmission process

NOTE

Instances of MB_CS in this topic refer to items in message buffers. See Message buffer structure for details.

To transmit a CAN frame, the CPU must prepare a message buffer for transmission by executing the following procedure:

1. Check whether the respective interrupt flag is set, and clear it if necessary.
2. If the message buffer is active (transmission pending), request an abort of the transmission. Write the ABORT code (1001b) to the CODE field of the Control and Status word.
3. Poll the IFLAG register until the corresponding IFLAG flag is set, or wait for the interrupt request (if enabled by the respective IMASK field).
4. Read the CODE field to identify whether the transmission was aborted or transmitted (see Transmission abort mechanism).
5. Clear the corresponding interrupt flag.
6. Write the ID register (containing the local priority if enabled via MCR[LPRIOEN]).
7. Write payload data bytes.
8. Configure the Control and Status word as needed.
    a. Set ID type via MB_CS[IDE].
    b. Set Remote Transmission Request (if needed) via MB_CS[RTR].
    c. If MCR[FDEN] = 1, configure MB_CS[EDL] and MB_CS[BRS]. For details about the relationship between the written value and transmitted value of MB_CS[ESI], see Table 364.[3]
    d. Configure Data Length Code in bytes via MB_CS[DLC]. See Table 388 for detailed information.
    e. To transmit the CAN frame, activate the message buffer by writing Ch to MB_CS[CODE].

NOTE

To maximize software performance, configure all the fields in the MB_CS word in a single 32-bit write operation. If the fields are configured in separate writes, MB_CS[CODE] must be the last write in the Control and Status word.

When the MB is activated, it participates in the arbitration process and its contents are eventually transmitted according to its priority. When the DLC value stored in the MB selected for transmission exceeds the MB payload size, FlexCAN completes the expected DLC by adding a constant CCh pattern.

After a successful transmission:

1. The value of the free-running timer is written into the timestamp field.
2. The CODE field in the Control and Status word is updated.

[3] There is no need to write the ESI field; it is automatically transmitted as dominant by error active nodes and as recessive by error passive nodes. If FlexCAN is operating as a network gateway, however, the CPU writes MB_CS[ESI] according to the error status of the node that sent the message.

3. Both Cyclic Redundancy Check (CRCR) and CAN FD CRC (FDCRC) are updated.
4. A status flag is set in the Interrupt Flag register.
5. If allowed by the corresponding Interrupt Mask Register field, an interrupt is generated.

After transmission, the new CODE field depends on the code used to activate the message buffer (see Table 384 and Table 385 in Message buffer structure).

When the Abort feature is enabled (MCR[AEN] is 1), after the Interrupt flag is set for an MB configured as transmit buffer, the message buffer is blocked. The CPU cannot update the message buffer until the Interrupt Flag is cleared by the CPU. The CPU must clear the corresponding IFLAG flag before preparing this MB for a new transmission or reception.

NOTE

For backward compatibility (MCR[AEN] is 0), write the INACTIVE code (1000b) to the CODE field to deactivate the MB. In this case, the pending frame may be transmitted without notification (see Message buffer inactivation).

48.3.3 Arbitration process

The arbitration process scans the message buffers, searching for the transmission MB that holds the message to be sent at the next opportunity. This MB is called the arbitration winner. The scan starts from the lowest number MB and continues to the higher ones.

The arbitration process is triggered when at least one of the following occur:

- CRC field of the CAN frame arrives. The starting point depends on the value of CTRL2[TASD].
- Error Delimiter field of a CAN frame is in progress.
- Overload Delimiter field of a CAN frame is in progress.
- The winner of the arbitration is deactivated, and the CAN bus has not reached the first bit of the Intermission field.
- CPU writes to the Control and Status word of a winner MB, and the CAN bus has not reached the first bit of the Intermission field.
- CHI is in the Idle state and the CPU writes to the Control and Status word of any message buffer.
- FlexCAN exits Bus Off state.
- FlexCAN leaves Freeze mode or a low-power mode.

If the arbitration process does not evaluate all message buffers before the CAN bus reaches the first bit of the Intermission field, the temporary arbitration winner is invalidated. FlexCAN will not compete for the CAN bus at the next opportunity.

The arbitration process selects the winner among the active transmission message buffers at the end of the scan according to the values of CTRL1[LBUF] and MCR[LPRIOEN].

See Arbitration process (continued) for more information about this process.

48.3.3.1 Lowest-number message buffer first

If CTRL1[LBUF] is 1, the first (lowest number) active transmission message buffer found is the arbitration winner. MCR[LPRIOEN] has no effect when CTRL1[LBUF] is 1.

48.3.3.2 Highest-priority message buffer first

If CTRL1[LBUF] is 0, the arbitration process searches for the active transmission message buffer with the highest priority. The frame of this message buffer has a higher probability of winning the arbitration on the CAN bus when multiple external nodes compete for the bus simultaneously.

The sequence of bits considered for this arbitration is called the arbitration value of the message buffer. The transmission message buffer with the lowest arbitration value among all transmission message buffers has the highest priority.

If two or more message buffers have equivalent arbitration values, the message buffer with the lowest number is the arbitration winner.

The composition of the arbitration value depends on MCR[LPRIOEN].

48.3.3.2.1 Local priority disabled

If MCR[LPRIOEN] = 0, the arbitration value is built using the exact sequence of bits that would be transmitted in a CAN frame where local priority is disabled.

Table 354. Composition of the arbitration value when local priority is disabled

Format	Message buffer arbitration value (32 bits)				
Standard (IDE = 0)	Standard ID (11 bits)	RTR (1 bit)	IDE (1 bit)	— (18 bits)	— (1 bit)
Extended (IDE = 1)	Extended ID[28:18] (11 bits)	SRR (1 bit)	IDE (1 bit)	Extended ID[17:0] (18 bits)	RTR (1 bit)

48.3.3.2.2 Local priority enabled

To enable local priority, MCR[LPRIOEN] must be 1. In this case, the message buffer PRIO field (see Message buffer structure) is included at the very left of the arbitration value.

Table 355. Composition of the arbitration value when local priority is enabled

Format	Message buffer arbitration value (35 bits)					
Standard (IDE = 0)	PRIO (3 bits)	Standard ID (11 bits)	RTR (1 bit)	IDE (1 bit)	— (18 bits)	— (1 bit)
Extended (IDE = 1)	PRIO (3 bits)	Extended ID[28:18] (11 bits)	SRR (1 bit)	IDE (1 bit)	Extended ID[17:0] (18 bits)	RTR (1 bit)

Because the PRIO field is the most significant part of the arbitration value, message buffers with low PRIO values have higher priority than message buffers with high PRIO values. This priority is maintained regardless of the rest of their arbitration values.

The PRIO field is not part of the frame on the CAN bus. Its purpose is only to affect the internal arbitration process.

48.3.3.3 Arbitration process (continued)

After the arbitration winner is found (see Arbitration process), its content is copied to a hidden auxiliary message buffer called a transmit serial message buffer (TX SMB). The TX SMB has the same structure as a normal message buffer, but is not user-accessible. This copy operation is called move-out. After it is done, write access to the Control and Status word of the corresponding MB is blocked (if MCR[AEN] = 1). Write access is restored in one of the following events:

- The CPU clears the corresponding IFLAG flag after the message buffer is transmitted.
- FlexCAN enters Freeze mode or Bus Off state.
- FlexCAN loses the bus arbitration, or there is an error during the transmission.

At the first opportunity window on the CAN bus, the message on the TX SMB is transmitted according to the CAN protocol rules.

The arbitration process can be triggered under the following conditions:

- During RX and TX frames from CAN CRC field to end of frame. The value of CTRL2[TASD] may be changed to optimize the arbitration start point.
- During CAN Bus Off state from TX_ERR_CNT = 124 to 128. The value of CTRL2[TASD] may be changed to optimize the arbitration start point.

- During Control and Status write by CPU in Bus Idle. The first Control and Status write starts the arbitration process, and a second Control and Status write during this same arbitration restarts the process. If other Control and Status writes are performed, the transmission arbitration process is pending. If there is no arbitration winner after the arbitration process has finished, then the TX arbitration machine begins a new arbitration process. If there is a pending arbitration and Bus Idle state starts, then an arbitration process is triggered. In this case, the first and second Control and Status writes in Bus Idle do not restart the arbitration process. If there is not enough time to finish arbitration in the Wait for Bus Idle state and the next state is Idle, the scan is not interrupted. That scan is completed during Bus Idle state. During this arbitration, a Control and Status write does not cause an arbitration restart.
- Deactivation of an arbitration winner during a valid arbitration window.
- Upon exiting Freeze mode (first bit of the Wait for Bus Idle state). If a resynchronization occurs during the Wait for Bus Idle state, the arbitration process is restarted.

The arbitration process stops when:

- All message buffers are scanned.
- A transmission message buffer is found (if lowest buffer feature is enabled).
- An arbitration winner deactivates or aborts during any arbitration process.
- There is not enough time to finish the transmission arbitration process (for instance, when a deactivation is performed near the end of frame). In this case, the arbitration process is pending.
- An error or overload flag occurs in the bus.
- A low-power or Freeze mode request occurs in Idle state.

Arbitration is considered pending when:

- It is not possible to finish arbitration process in time.
- A Control and Status write occurs during arbitration, when that write is performed in an MB whose number is lower than the transmission arbitration pointer.
- Any Control and Status write occurs when there is no transmission arbitration process in progress.
- RX Match has updated an RX code to TX code.
- FlexCAN enters the Bus Off state.

If a Control and Status write is performed in the arbitration winner, a new process is restarted immediately.

If a Control and Status write is performed in an MB whose number is higher than the transmission arbitration pointer, the ongoing arbitration process scans this MB as normal.

48.3.4 Receive process

To be able to receive CAN frames into a message buffer, the CPU must prepare it for reception by executing the following steps:

1. If the message buffer is active (either TX or RX), deactivate it (see Message buffer inactivation), preferably with a safe deactivation (see Transmission abort mechanism).
2. Write the ID word into the message buffer.
3. To activate the message buffer, write the EMPTY code (0100b) to the CODE field of the Control and Status word. No setup is required for EDL, BRS, and ESI fields. The respective fields in the received message overwrite these fields.

After the MB is activated, it can receive frames that match the programmed filter. At the end of a successful reception, the move-in process updates the message buffer (see Move-in) as follows:

1. The received data field (up to eight bytes for Classical CAN message format and up to 64 bytes for CAN FD message format) is stored.
2. The received Identifier field is stored.

3. The value of the free-running timer when the second bit of the Identifier field of the frame is written into the Timestamp field of the MB.
4. The received SRR, IDE, RTR, EDL, BRS, ESI, and DLC fields are stored.
5. The CODE field in the Control and Status word is updated (see Table 384 and Table 385 in Section Message buffer structure).
6. If allowed by the corresponding Interrupt Mask field, a status flag is set in the Interrupt Flag register and an interrupt is generated.

The recommended way for the CPU to service (read) the frame received in a message buffer is:

1. Read the Control and Status word of that message buffer.
2. Verify that the BUSY bit is 0, indicating that the message buffer is locked. If it is not 0, repeat step 1 until it becomes 0. See Message buffer lock mechanism.
3. Read the contents of the message buffer. After the message buffer is locked, FlexCAN move-in processes do not modify its contents. See Move-in.
4. Acknowledge the proper flag in the IFLAG registers.
5. Unlock the message buffer by reading the free-running timer.

To verify frame reception, the CPU should poll the status flag bit for that specific message buffer in one of the IFLAG registers, not the CODE field of that message buffer. Polling the CODE field does not work in this case. After a frame is received and the CPU services the message buffer (by reading the Control and Status word and unlocking the message buffer), the CODE field does not return to EMPTY. It remains FULL, as explained in Table 384. If the CPU tries to work around this behavior by writing to the Control and Status word to force an EMPTY code after reading the message buffer without a prior safe deactivation, a newly received frame matching the filter of that message buffer may be lost.

CAUTION

In summary: never poll by reading the Control and Status word of the message buffers directly. Instead, read the IFLAG registers.

The Identifier field of the received frame is always stored in the matching message buffer. If the match was due to masking, the contents of the ID field in a message buffer may change. When MCR[SRXDIS] becomes 1, FlexCAN does not store frames transmitted by itself in any MB, even if it contains a matching receive MB. Also, no interrupt flag or interrupt signal is generated. Otherwise, when MCR[SRXDIS] becomes 0, if a matching receive MB exists, FlexCAN can receive frames transmitted by itself.

When MCR[DMA]) becomes 1, upon receiving a frame in the Legacy FIFO, IFLAG1[BUF5I] generates a DMA request and does not generate a CPU interrupt (see Legacy RX FIFO in DMA operation). The IMASK1 fields in the Legacy RX FIFO region are not used.

The DMA controller must service the received frame using the following procedure:

1. Read the Control and Status word (read 80h address, optional).
2. Read the ID field (read 84h address, optional).
3. Read all data bytes (start read at 88h address, optional).

48.3.5 Matching process

The matching process scans the message buffer memory for RX MBs programmed with the same ID as the one received from the CAN bus. The matching starts from the lowest number message buffer and continues toward the higher-numbered ones.

For enhanced RX FIFO, see Enhanced RX FIFO.

For legacy RX FIFO, see Legacy RX FIFO.

As the frame is received, it is stored in a hidden auxiliary MB called Receive Serial Message Buffer (RX SMB).

The starting point of the matching process depends on the following conditions:

- If the received frame is a remote frame, the starting point is the CRC field of the frame.
- If the received frame is a data frame with DLC field equal to zero, the starting point is the CRC field of the frame.
- If the received frame is a data frame and the DLC field has a nonzero value, the starting point is the DATA field of the frame.

If a matching ID is found in one of the message buffers, the move-in process transfers the contents of the RX SMB to the matched MB. If any CAN protocol error is detected, no match results are transferred to the matched MB at the end of reception.

The matching process scans all matching elements of the active receive MBs (CODE is EMPTY, FULL, OVERRUN, or RANSWER). The process searches for a successful comparison to the matching elements of the RX SMB that is receiving the frame on the CAN bus. The RX SMB has the same structure as a message buffer. The reception structures (message buffers) associated with the matching elements that had a successful comparison are the matched structures. The matching winner is selected at the end of the scan among those matched structures. The matching winner depends on conditions described in Table 356.

Table 356. Matching architecture

Structure	SMB[RTR]	CTRL2[RRS]	CTRL2[EACEN]	MB[IDE]	MB[RTR]	MB[ID[1]]	MB[CODE]
Message buffer	0	—	0	cmp[2]	no_cmp[3]	cmp_msk[4]	EMPTY, FULL, or OVERRUN
Message buffer	0	—	1	cmp_msk	cmp_msk	cmp_msk	EMPTY, FULL, or OVERRUN
Message buffer	1	0	—	cmp	no_cmp	cmp	RANSWER
Message buffer	1	1	0	cmp	no_cmp	cmp_msk	EMPTY, FULL, or OVERRUN
Message buffer	1	1	1	cmp_msk	cmp_msk	cmp_msk	EMPTY, FULL, or OVERRUN

1. For message buffer structure, if SMB[IDE] is 1, the ID is 29 bits (ID Standard plus ID Extended). If SMB[IDE] is 0, the ID is 11 bits (ID Standard). For Legacy RX FIFO structure, the ID depends on IDAM.
2. cmp: Compares the RX SMB contents to the MB contents regardless of masks.
3. no_cmp: The RX SMB contents are not compared to the MB contents.
4. cmp_msk: Compares the RX SMB contents to MB contents, accounting for masks.

NOTE

For Enhanced RX FIFO, see Enhanced RX FIFO matching process.

A reception structure is free-to-receive when any of the following conditions is satisfied:

- The CODE field of the message buffer is EMPTY.
- The CODE field of the message buffer is either FULL or OVERRUN, and it has already been serviced (the CPU has read the Control and Status word and unlocked it as described in Message buffer lock mechanism).
- The CODE field of the message buffer is either FULL or OVERRUN and an inactivation (see Message buffer inactivation) is performed.

The scan order for message buffers is from the matching element with the lowest number to the higher ones.

48.3.5.1 Matching priority

MCR[IRMQ] affects the matching winner search for MBs. If the field is 0, the matching winner is the first matched MB whether it is free-to-receive or not. If it is 1, the matching winner is selected according to this priority:

1. The first free-to-receive matched message buffer
2. The last non-free-to-receive matched message buffer

48.3.5.2 Special cases

If a non-safe MB inactivation (see Message buffer inactivation) occurs during the matching process and the inactivated MB is the temporary matching winner, the temporary matching winner is invalidated. The matching elements scan is not stopped and not restarted; it continues normally. The consequence is that the current matching process works as if the matching elements compared before the inactivation did not exist. In this case, a message may be lost.

Consider an example where:

- MCR[IRMQ] is 1.
- There are two message buffers with the same ID: the second and fifth MBs in the array.
- FlexCAN starts receiving messages with that ID.

When the first message arrives, the matching algorithm finds the first match in message buffer number 2. The code of this message buffer is EMPTY, so the message is stored in that MB. When the second message arrives, the matching algorithm finds MB number 2 again, but it is not "free-to-receive." It continues looking, finds MB number 5, and stores the message in that MB. If yet another message with the same ID arrives, the matching algorithm finds no matching free-to-receive MBs, so it overwrites the last matched message buffer (MB number 5). In doing so, it updates the CODE field of the message buffer to OVERRUN.

The ability to match the same ID in more than one MB can be used to implement a reception queue to allow more time for the CPU to service the MBs. By programming more than one MB with the same ID, received messages are queued into the message buffers. The CPU can examine the Timestamp field of the message buffers to determine the order in which the messages arrived.

Matching a range of IDs is possible via ID acceptance masks. FlexCAN supports individual masking per message buffer (see Receive Individual Mask (RXIMR0 - RXIMR31)). During the matching algorithm, if a mask field is 1, the corresponding ID bit is compared. If the mask field is 0, the corresponding ID bit is a "don't care". Individual Mask Registers are implemented in RAM, so they are not initialized out of reset. Also, they can only be programmed when the module is in Freeze mode; otherwise, the module blocks them.

FlexCAN also supports an alternate masking scheme with only RX Message Buffers Global Mask (RXMGMASK), Receive 14 Mask (RX14MASK), and Receive 15 Mask (RX15MASK) for backward compatibility with legacy applications. This alternate masking scheme is enabled when the MCR[IRMQ] = 0.

48.3.6 Receive process in Pretended Networking mode

Pretended Networking mode adds specific wake-up functionality in low-power modes (Doze and Stop mode). When Pretended Networking (PN) mode is enabled by writing 1 to MCR[PNET_EN], FlexCAN continues processing received CAN messages in low-power mode. FlexCAN is able to detect specific wake-up messages by filtering them against identifier (ID) and payload target values using preselected matching criteria.

NOTE

Wake-up functionality is not available for messages in CAN FD format. When in PN mode, CAN FD format messages are ignored.

PN registers are located in the 0B00h–0B7Ch address range and can be written only in Freeze mode. These registers are used for writing PN configuration (both control and target values) prior to entering PN mode. They are also used for reading wake-up flags and the received message ID and data when returning to Normal mode after wake-up. The CPU must wait for MCR[LPMACK] to become 0 before performing any access to FlexCAN PN registers.

PN control registers are described in Pretended Networking Control 1 (CTRL1_PN) and Pretended Networking Control 2 (CTRL2_PN). The control fields that configure the filtering criteria are:

- Payload filtering selection: CTRL*n*_PN[PLFS]
- ID filtering selection: CTRL*n*_PN[IDFS]
- Filtering combination selection: CTRL*n*_PN[FCS]

Table 357. PN target values

Value	Description
FLT_IDE	IDE target value used to filter the incoming message by its format (standard or extended)
FLT_RTR	RTR target value used to filter the incoming message by its type (data or remote frame)
FLT_DLC_HI and FLT_DLC_LO	Target DLC range used to filter the size of the payload of an incoming message
FLT_ID1	ID target value used to filter the incoming message ID (equal to, smaller than or equal to, greater than or equal to, or the lower limit value in an ID range)
FLT_ID2	ID target value used as the upper limit in an ID range
PL1	Payload target value used to filter the incoming message payload (equal to, smaller than or equal to, greater than or equal to, or the lower limit value in a payload range)
PL2	Payload target value used as the upper limit in a payload range

IDE, RTR, ID, and payload filters have their respective masks. The ones in these masks determine which bits are considered in equality comparisons. The zeroes in these masks determine which bits are don't care. ID and payload masks are used only for exact ID and exact payload comparisons.

48.3.6.1 ID filtering

The IDs of incoming messages can be filtered based on the following criteria:

- Match the exact ID value, found by comparing the ID field of the incoming message to the content of target Pretended Networking ID Filter 1 (FLT_ID1). The ID mask is used.
- Less than or equal to the maximum range of ID. That is, any message with ID value smaller than or equal to the content of target FLT_ID1 is accepted. The ID mask is not used.
- Greater than or equal to the minimum range of ID. That is, any message with ID value greater than or equal to the content of target FLT_ID1 is accepted. The ID mask is not used.
- Inside a range of IDs. Any message with an ID value greater than or equal to the content of target FLT_ID1 and smaller than or equal to the content of target Pretended Networking ID Filter 2 or ID Mask (FLT_ID2_IDMASK) is accepted. The ID mask is not used.

See CTRL1_PN[IDFS].

The above criteria for ID filtering must be coherent with FLT_IDE and FLT_RTR target values in Pretended Networking ID Filter 1 (FLT_ID1). Only RX frames that match the respective IDE and RTR bits to the contents of FLT_ID1[FLT_IDE] and FLT_ID1[FLT_RTR] are compared. When a range of IDs is selected (CTRL1_PN[IDFS] = 11), both FLT_ID1 and FLT_ID2 are referred to the same FLT_IDE and FLT_RTR fields in FLT_ID1.

The ID mask is applied only to the exact ID comparison filtering option (CTRL1_PN[IDFS] = 00) to determine which bits are considered in the comparison. For the exact match option, the mask can select any bit within the ID field. For maximum range, minimum range, and inside range comparisons, the ID mask is not considered.

The IDE and RTR masks are applied in both exact and range ID comparison filtering options to determine which bits are considered in comparison.

48.3.6.2 Payload filtering

Similar to the ID criteria, 64-bit data or payloads (PL) of incoming messages can be filtered based on the following criteria:

- A match with the exact payload value, found by comparing the payload field of the incoming message to the content of PL1. The payload mask is used.
- Less than or equal to the maximum range of payload. That is, any message with payload value smaller than or equal to the content of PL1 is accepted. The payload mask is not used.
- Greater than or equal to the minimum range of payload. That is, any message with payload value greater than or equal to the content of PL1 is accepted. The payload mask is not used.
- Inside a range of payloads. Any message with a payload value greater than or equal to the content of PL1 and smaller than or equal to the content of PL2 is accepted. The payload mask is not used.

See CTRL1_PN[PLFS].

The above criteria for payload filtering must be coherent with upper and lower limit values in Pretended Networking Data Length Code (DLC) Filter (FLT_DLC). The payload of an incoming message is filtered using the selected criteria only if the DLC value of the incoming message is inside a DLC range:

- Greater than or equal to FLT_DLC[FLT_DLC_LO] (lower limit)
- Lower than or equal to FLT_DLC[FLT_DLC_HI] (upper limit)

A DLC value outside the specified range results in a mismatch. If you configure FLT_DLC_LO = FLT_DLC_HI, only payloads of the specified quantity of bytes are filtered. DLC is not maskable.

When the inside range of payloads option is selected (CTRL1_PN[PLFS] = 11), both PL1 and PL2 are considered with the 8-byte data length. All data bytes excluded by the DLC of the received message are considered to have value zero.

The payload mask is only used in the exact match option (CTRL1_PN[PLFS] = 00). This mask determines which bits or bytes in the 8-byte data field of both incoming message and the contents of PL1 register are used for matching. Mask length must meet the expected range of DLC values. For maximum range, minimum range, and inside range comparisons, the payload mask is not considered.

When FlexCAN receives a remote frame and CTRL1_PN[FCS] is configured to select payload comparison, payload filtering is not considered and the comparison results in a mismatch.

48.3.6.3 Other filtering

Incoming messages can also be filtered based on the quantity and rate of message reception, specifically:

- Several messages that match the filtering criteria for ID or payload for a predefined number of times. This number can be from 1 to 255. See Pretended Networking Control 1 (CTRL1_PN).
- No message matching the filtering criteria for ID or payload up to a timeout trigger. That is, non-reception of a matching message for a defined quantity of time. See Pretended Networking Control 2 (CTRL2_PN).

When the counter reaches the predefined timeout value, FlexCAN can generate a wake-up timeout event from an internal timer with associated comparator circuitry capable of generating a timeout flag. This behavior is specified in CTRL2_PN[MATCHTO].

The above filtering criteria can be used together as follows:

- Message ID filtering only
- Message ID filtering and Payload filtering
- Message ID filtering only occurring *n* times
- Message ID filtering and Payload filtering occurring *n* times

The timeout counter runs concurrently with the reception filtering process. Both engines (timeout counter and message filtering) are independent. If an incoming message matches the selected filter criteria, the timeout counter continues counting until the CPU wakes up. If the timeout counter reaches the target value, the message filtering process continues to filter incoming messages until the CPU wakes up. WU_MTC[MCOUNTER] reports the number of matched messages that occurred in Pretended Networking mode up to the moment the CPU wakes up.

In Pretended Networking mode, the wake-up event that may occur sets the respective wake-up flag (see Pretended Networking Wake-Up Match (WU_MTC)):

- WU_MTC[WUMF] indicates a successful match meeting the selected filtering criteria.
- WU_MTC[WTOF] indicates a timeout trigger.

Any of these flags generates interrupts to the CPU, provided the respective mask bits are enabled (CTRL1_PN[WUMF_MSK] = 1 or CTRL1_PN[WTOF_MSK] = 1).

There are four Wake-up Message Buffers (WMBs) used to store incoming messages in Pretended Networking mode. Up to four messages can be stored (see Wake-Up Message Buffer (WMB0_CS - WMB3_CS)).

When CTRL1_PN[NMATCH] = 1, only one message is received if the filtering criteria are matched. This message is stored in WMB0.

If CTRL1_PN[NMATCH] is between two and four, WMB1, WMB2, and WMB3 store the second, third, and fourth matching messages, respectively.

If CTRL1_PN[NMATCH] is greater than four, the last four matching messages are stored in the WMBs. The WMB index indicates the arrival order. The last message is stored in WMB3.

Only the valid data bytes of the incoming match message are stored in the data field of WMBs. The non-valid data bytes are read as zero. If DLC = 0 and RTR = 1, the data field is filled with zeroes. In any of the above cases, the wake-up interrupt is generated only when the filtering criteria are completed and CTRL1_PN[WUMF_MSK] = 1.

When a non-match wake-up event occurs (timeout or external) and WU_MTC[MCOUNTER] ≥ 4, the message stored in WMB0 does not have valid content. WMB0 is used as a buffer for the current message in the CAN bus. Messages received during Pretended Networking mode do not have time stamps, and the respective field in the WMB structure must be ignored.

In low-power mode (Doze or Stop), all processes are shut down except for the PN functionality inside the CAN_PE subblock, which remains clocked by the oscillator clock (see Clock domains and restrictions). FlexCAN continues to receive incoming messages, but only compares them to the predefined target values according to the selected filtering criteria. The matching, arbitration, move-in, and move-out processes, normally available in Normal mode, are not performed in Pretended Networking mode.

FlexCAN in Pretended Networking reacts to messages on the CAN bus in the same manner as in Normal mode. It generates acknowledge bits, detect and count errors, and so on.

48.3.7 Move process

There are two types of move process: move-in and move-out.

48.3.7.1 Move-in

The move-in process is the copying of a message received by an RX SMB to an RX message buffer that has matched it. Each RX SMB has its own move-in process, but only one is performed at a given time. The move-in starts only when the message held by the RX SMB has a corresponding match (see Matching process) and all of the following conditions are true:

- The CAN bus has reached or already gone past:
  - The second bit of Intermission field next to the frame that carried the message that is in the RX SMB.
  - The first bit of an overload frame next to the frame that carried the message in the RX SMB.
- There is no ongoing matching process.
- The CPU is not locking the destination message buffer.
- No move-in process from another RX SMB is ongoing. If more than one move-in process is to be started at the same time, both are performed and the newest process substitutes for the oldest.

The term "pending move-in" is used throughout the documentation and stands for a move-to-be that does not satisfy all of the above conditions.

If any of the following conditions is satisfied, the move-in is canceled and the RX SMB is able to receive another message:

- The destination message buffer is inactivated after the CAN bus has reached the first bit of the Intermission field next to the frame that carried the message. Also, its matching process has finished.
- There is a previous pending move-in to the same destination message buffer.
- The RX SMB is receiving a frame transmitted by FlexCAN itself and self-reception is disabled (MCR[SRXDIS] = 1).
- Any CAN protocol error is detected.

If the module enters Freeze or Low-Power mode, the pending move-in is not canceled. It remains on hold, waiting for Freeze and Low-Power mode to be exited and for the module to be unlocked. If a message buffer is unlocked during Freeze mode, the move-in occurs immediately.

The move-in process is FlexCAN executing the following steps:

1. Read all data words from the RX SMB in accordance with the selected payload size for the RX storage element.
2. Write all data words to the RX message buffer according to the selected payload size for the RX storage element. If the data size of the storage element is smaller than the original payload size described in the DLC field of the message, the payload is truncated. The high-order bytes that do not fit the destination size are lost.
3. Read the Control and Status and ID words from the RX SMB.
4. Write the Control and Status and ID words to the RX message buffer, and update the CODE field.

The move-in process is not atomic; the inactivation of the destination message buffer immediately cancels it (see Message buffer inactivation). In this case, the message buffer may remain partially updated, and therefore incoherent.

To alert the CPU that the message buffer content is temporarily incoherent, the BUSY Bit (least significant bit of the CODE field) of the destination message buffer becomes 1 during move-in.

48.3.7.2 Move-out

The move-out process is the copying of content from a TX message buffer to the TX SMB when a message for transmission is available (see Arbitration process). The move-out occurs in the following conditions:

- In the first bit of the Intermission field
- During the Bus Off state, when the TX error counter is in the 124 to 128 range
- During the Bus Idle state
- During the Wait for Bus Idle state

The move-out process is not atomic. Only the CPU has priority to access the memory concurrently outside the Bus Idle state. In Bus Idle, the move-out has the lowest priority of the concurrent memory accesses.

48.3.8 Data coherence

In order to maintain data coherency and proper FlexCAN operation, the CPU must obey the rules described in Transmission process and Receive process.

48.3.8.1 Transmission abort mechanism

The abort mechanism provides a safe way to request the abortion of a pending transmission. A feedback mechanism is provided to inform the CPU whether the transmission was aborted or the frame could not be aborted and was transmitted instead.

These primary conditions must be fulfilled in order to abort a transmission:

- MCR[AEN] must be 1.
- The first CPU action must be the writing of abort code (1001b) into the CODE field of the Control and Status word.

Active message buffers configured for transmission must be aborted before they can be updated. The write operation is blocked and the transmission is not disturbed when the abort code is written to:

- A message buffer currently being transmitted.

- A message buffer that was already loaded into the TX SMB for transmission.

In this case, the abort request is captured and kept pending until one of the following conditions is satisfied:

- The module loses the bus arbitration.
- There is an error during the transmission.
- The module is put into Freeze mode.
- The module enters the Bus Off state.
- There is an overload frame.

If none of the conditions above are reached:

1. The message buffer is transmitted correctly.
2. The interrupt flag is set in the proper IFLAG register.
3. If enabled, an interrupt to the CPU is generated.

The abort request is automatically cleared when the interrupt flag is set. If only one of the above conditions is reached, the frame is not transmitted. In this case:

1. The abort code is written into the CODE field.
2. The interrupt flag is set in the proper IFLAG register.
3. Optionally, an interrupt is generated to the CPU.

If the CPU writes the abort code before the transmission begins internally, the write operation is not blocked. The MB is updated and the interrupt flag is set. In this way, the CPU only needs to read the abort code to verify that the active MB was safely inactivated. In this case, although MCR[AEN] = 1 and the CPU wrote the abort code, the MB is inactivated and not aborted, because the transmission did not start yet. A message buffer is aborted only when the abort request is captured and kept pending until one of the previous conditions is satisfied.

48.3.8.2 Message buffer inactivation

Inactivation protects the message buffer against updates by FlexCAN internal processes. It allows the CPU to rely on message buffer data coherence after having updated it, even in Normal mode.

Inactivation of transmission message buffers must be performed only when MCR[AEN] = 0.

If a message buffer is inactivated, it does not participate in the arbitration process or the matching process until it is reactivated. See Transmission process and Receive process for detailed instructions on how to inactivate and reactivate a message buffer.

To inactivate a message buffer, the CPU must update its CODE field to INACTIVE (either 0b or 1000b).

Because you cannot synchronize the CODE field update with FlexCAN internal processes, an inactivation can have the following consequences:

- A frame in the bus that matches the filtering of an inactivated RX message buffer may be lost without notice. This loss can occur even if there are other message buffers with the same filter.
- A frame containing the message within an inactivated TX message buffer may be transmitted without setting the respective IFLAG flag.

To perform a safe inactivation and avoid the above consequences for TX message buffers, the CPU must use the transmission abort mechanism (see Transmission abort mechanism).

The inactivation automatically unlocks the message buffer (see Message buffer lock mechanism).

48.3.8.3 Message buffer lock mechanism

In addition to message buffer inactivation, FlexCAN uses a message buffer lock mechanism to maintain data coherence for the receive process. When the CPU reads the Control and Status word of an RX message buffer with codes FULL or OVERRUN,

FlexCAN is configured to allow the CPU to read the whole message buffer in an atomic operation. FlexCAN sets an internal lock flag for that message buffer.

The lock is released in any of the following events:

- The CPU reads the free-running timer (global unlock operation).
- The CPU reads the Control and Status word of another message buffer, regardless of its code.
- The CPU writes into the Control and Status word. This procedure is not recommended for normal unlocking, because it cancels a pending move and may lose a received message.

The message buffer lock prevents a new frame from being written into the message buffer when the CPU is reading it.

NOTE

The locking mechanism applies only to RX message buffers that have a code other than INACTIVE (0b) or EMPTY[1] (0100b). TX message buffers cannot be locked.

Consider an example where:

- The second and the fifth message buffers of the array are programmed with the same ID.
- FlexCAN has already received and stored messages into these two message buffers.
- The CPU reads message buffer number 5 while another message with the same ID is arriving.

When the CPU reads the Control and Status word of message buffer number 5, this message buffer is locked. The new message arrives and the matching algorithm finds no free-to-receive message buffers, so it overrides message buffer number 5. This message buffer is locked, so the new message cannot be written to it. The message remains in the RX SMB until the message buffer is unlocked, and only then is it written to the message buffer.

If the message buffer remains locked and another new message with the same ID arrives, the new message overwrites the one in the RX SMB. There is no indication of lost messages in the CODE field of the message buffer or in Error and Status 1 (ESR1).

When the message is moved from the RX SMB to the message buffer, the BUSY bit on the CODE field becomes 1. If the CPU reads the Control and Status word and identifies that the BUSY bit is 1, it must wait until the BUSY bit becomes 0 to access the MB.

NOTE

If the BUSY bit is 1 or the message buffer is empty, reading the Control and Status word does not lock the message buffer.

Inactivation takes precedence over locking. If the CPU inactivates a locked receive message buffer, then its lock status is negated and the message buffer is marked as invalid for the current matching round. Any pending message on the RX SMB is not transferred to the message buffer. A message buffer is unlocked when the CPU reads Free-Running Timer (TIMER) or the Control and Status word of another message buffer.

The lock and unlock mechanisms have the same functionality in Normal and Freeze modes.

An unlock during Normal or Freeze mode results in the move-in of the pending message. If unlocking occurs during a low-power mode, however, the move-in is postponed (see Modes of operation). Move-in takes place only when the module returns to Normal or Freeze mode.

48.3.9 Enhanced RX FIFO

FlexCAN supports an enhanced RX FIFO engine which can store up to 12 CAN FD messages. The region 2000h–204Fh contains the output of the FIFO, which the CPU should read. To enable the enhanced RX FIFO, write 1 to ERFCR[ERFEN]. FlexCAN has two FIFO options, Legacy RX FIFO and Enhanced RX FIFO, but both options cannot be enabled at the same time. See Legacy RX FIFO for additional information.

To configure the enhanced RX FIFO watermark, write a value to ERFCR[ERFWM]. If ERFCR[ERFWM] is configured, the CPU is notified only if a minimum number of messages is stored in the FIFO. When the number of stored messages is greater than the

[1] In previous FlexCAN versions, reading the Control and Status word locked the message buffer even when CODE indicates it is EMPTY. This behavior is maintained when the IRMQ bit is 0.

value in ERFCR[ERFWM], the module sets ERFSR[ERFWMI]. Optionally, if MCR[DMA] or ERFIER[ERFWMIIE] are enabled, a DMA transfer or an interrupt can be triggered, respectively.

For the enhanced RX FIFO to receive, the CPU must execute the configuration procedure below. If the CPU must change any configurations of the Enhanced RX FIFO, the same procedure must be followed.

Prerequisites

MCR[RFEN] must be 0.

Procedure

Step	Purpose	Programming	Notes
1	Enter Freeze mode.	See Freeze mode.	—
2	If enhanced RX FIFO is not already enabled, enable it.	Write 1 to ERFCR[ERFEN].	—
3	Reset enhanced RX FIFO engine.	Write 1 to ERFSR[ERFCLR].	—
4	If the enhanced RX FIFO error flags are set, clear them.	Write 1 to these flags: • ERFSR[ERFUFW] • ERFSR[ERFOVF] • ERFSR[ERFWMI] • ERFSR[ERFDA]	—
5	Specify the total number of enhanced RX FIFO filter elements to be used in Enhanced RX FIFO reception.	Write the number to ERFCR[NFE].	—
6	Specify the number of extended ID and standard ID filter elements to be used in Enhanced RX FIFO reception.	Write the number to ERFCR[NEXIF].	ERFCR[NEXIF] ≤ ERFCR[NFE] + 1.
7	If you are using DMA, enable DMA.	Write 1 to MCR[DMA].	—
8	If you are using DMA, specify the number of words to transfer for each Enhanced RX FIFO data element.	Write the number to ERFCR[DMALW].	—
9	Specify the Enhanced RX FIFO watermark.	Write the number to ERFCR[ERFWM].	If MCR[DMA] = 1, ERFCR[ERFWM] should be 0h.
10	If you are using interrupts, enable the interrupts.	Write 1 to the interrupt enables in Enhanced RX FIFO Interrupt Enable (ERFIER).	—
11	Configure the filter elements.	Write to the ERFFEL*n* registers.	ERFFEL*n* registers are implemented in RAM; you must explicitly initialize them before prior any reception.
12	Exit Freeze mode.	See Freeze mode.	—

There are two types of enhanced RX FIFO filter elements that can be stored in ERFFEL*n* registers: extended-ID filter elements and standard-ID filter elements. Each extended-ID filter element is stored in two ERFFEL*n* registers, and each standard-ID filter element is stored in one ERFFEL*n* register. ERFCR[NFE] defines the total number of Enhanced RX FIFO filter elements.

In addition, the filter memory space can be split into two regions: one for extended-ID filter elements and another for standard-ID filter elements, according to ERFCR[NEXIF]. Figure 185 shows how the enhanced RX filter elements are defined. See Enhanced RX FIFO matching process for information about the Enhanced RX FIFO matching process and filter element formats.

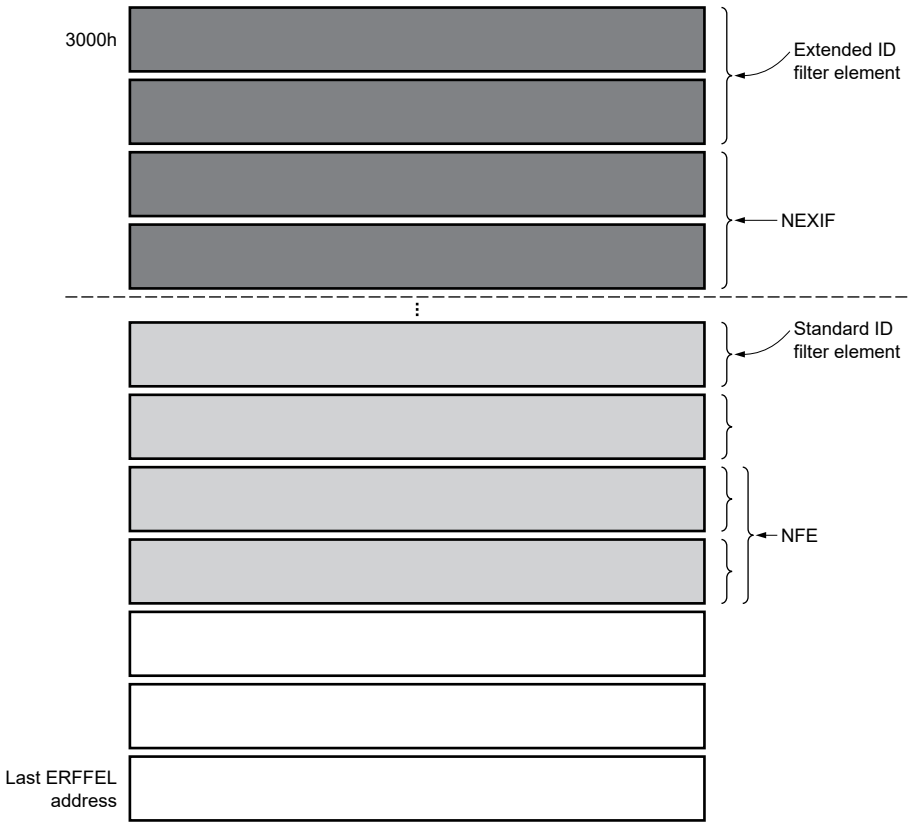

Figure 185. Number of enhanced RX FIFO filter elements

48.3.9.1 Enhanced RX FIFO matching process

When ERFCR[ERFEN] = 1, FlexCAN scans the ERFFEL*n* memory region. If at least one filter element satisfies the matching criteria, the CAN message content is transferred to the enhanced RX FIFO memory. If multiple filters match the incoming message ID, the first matching filter found by the matching process must be indicated in IDHIT.

Each ERFFEL*n* register can store one standard filter element. ERFFEL*n*[FEL][31:30], also called FSCH, determines the matching criteria in this way:

- If FSCH = b00, the filter scheme is based on mask and filter. A CAN message matches a standard ID filter element only if these criteria are reached:
  1. CAN message is base-frame format (IDE = 0).
  2. (ID[*n*] = STD ID filter [*n*]) or (STD ID Mask[*n*] = 0) for each bit *n* from 0 to 10.
  3. (RTR = RTR Filter) or (RTR MASK = 0).

In this explanation, RTR and ID are the Remote Transmit Request field and the ID from a CAN message, respectively.

If FSCH = b00, the filters and masks are defined as shown in Table 358.

Table 358. Standard ID filter element with filter and mask scheme (FSCH = b00)

31	30	29	28	27	26	16	15	12	11	10	0
FSCH = b00		Reserved		RTR Filter	STD ID Filter		Reserved		RTR MASK	STD ID MASK	

- If FSCH = b01, the filter scheme is based on range. A CAN message matches a standard ID filter element only if these criteria are reached:
  1. CAN message is base frame format (IDE = 0).
  2. ID ≥ STD ID Filter1.
  3. ID ≤ STD ID Filter2.
  4. (RTR = RTR filter) or (RTR MASK = 0).

RTR and ID are the Remote Transmit Request bit and ID from a CAN message, respectively. If FSCH = b01, the filters and mask are defined as shown in Table 359.

Table 359. Standard ID filter element with range scheme (FSCH = b01)

31	30	29	28	27	26	16	15	12	11	10	0
FSCH = b01		Reserved		RTR Filter	STD ID Filter2		Reserved		RTR MASK	STD ID Filter1	

- If FSCH = b10, the filter scheme is based on two filters without masks. A CAN message matches a standard ID filter element only if these criteria are reached:
  1. CAN message is base frame format (IDE = 0).
  2. (ID[*n*] = STD ID Filter1[*n*]) or (ID[*n*] = STD ID Filter2[*n*]) for each bit *n* from 0 to 10.
  3. (RTR = RTR Filter1) or (RTR = RTR Filter2).

RTR and ID are the Remote Transmit Request bit and ID from a CAN message, respectively. If FSCH = b10, the filters are defined as shown in Table 360.

Table 360. Standard ID filter element with two-filter scheme (FSCH = b10)

31	30	29	28	27	26	16	15	12	11	10	0
FSCH = b10		Reserved		RTR Filter 2	STD ID Filter2		Reserved		RTR Filter 1	STD ID Filter1	

Each pair of ERFFEL*n* registers can store one extended filter element. ERFFEL*n*[FSCH] determines the matching criteria in this way:

- If FSCH = b00, the filter scheme is based on mask and filter. A CAN message matches an extended ID filter element only if these criteria are reached:
  1. CAN message is extended frame format (IDE = 1).
  2. (ID[*n*] = EXT ID filter [*n*]) or (EXT ID Mask[*n*] = 0) for each bit *n* from 0 to 28.
  3. (RTR = RTR Filter) or (RTR MASK = 0).

If FSCH = b00, the filters and masks are defined as shown in Table 361.

Table 361. Extended ID filter element with filter + mask scheme (FSCH = b00)

31	30	29	28	0
FSCH		RTR Filter	EXT ID Filter	
Reserved		RTR MASK	EXT ID MASK	

- If FSCH = b01, the filter scheme is based on range. A CAN message matches an extended ID filter element only if the following criteria are reached:
  1. CAN message is extended frame format (IDE = 1).
  2. ID ≥ EXT ID Filter1.
  3. ID ≤ EXT ID Filter2.
  4. (RTR = RTR Filter) or (RTR MASK = 0).

If FSCH = b01, the filters and masks are defined as shown in Table 362.

Table 362. Extended ID filter element with range scheme (FSCH = b01)

31	30	29	28	0
FSCH		RTR Filter	EXT ID Filter2	
Reserved		RTR MASK	EXT ID Filter 1	

- If FSCH = b10, the filter scheme is based on two filters without masks. A CAN message matches an extended ID filter element only if these criteria are reached:
  1. CAN message is extended frame format (IDE = 1).
  2. (ID[*n*] = EXT ID Filter1[*n*]) or (ID[*n*] = EXT ID Filter2[*n*]) for each bit *n* from 0 to 28.
  3. (RTR = RTR Filter1) or (RTR = RTR Filter2).

If FSCH = b10, the filters are defined as shown in Table 363.

Table 363. Extended ID filter element with two-filter scheme (FSCH = b10)

31	30	29	28	0
FSCH		RTR Filter2	EXT ID Filter2	
Reserved		RTR Filter1	EXT ID Filter 1	

48.3.9.2 Enhanced RX FIFO under DMA operation

You can enable the DMA feature by writing 1 to both ERFCR[ERFEN] and MCR[DMA]. The DMA controller can read the received message by reading a message buffer structure at the enhanced FIFO output port at the address range defined in Enhanced RX FIFO structure.

NOTE

FlexCAN supports 32-bit access only for DMA transfers.

For proper FIFO engine operation, the CPU should not access the Enhanced FIFO output port address range during DMA operation. Before writing 1 to MCR[DMA], the CPU must service Enhanced RX FIFO status bits. Otherwise, these bits may show that the FIFO has data to be serviced, and mistakenly generate a DMA request. Before writing 0 to MCR[DMA], the CPU must first clear the ERFSR[ERFUFW], ERFSR[ERFOVF], ERFSR[ERFWMI], and ERFSR[ERFDA] flags. It must then clear the enhanced RX FIFO engine by writing one to ERFSR[ERFCLR].

When there is one frame available to be read from the Enhanced RX FIFO, FlexCAN sets ERFSR[ERFDA]. Upon receiving the request, the DMA controller can read the message in the Enhanced RX FIFO output. Each message reading process must end by the address defined in ERFCR[DMALW].

Follow these rules for Enhanced RX FIFO DMA operation:

- Because a DMA transfer cannot be changed dynamically, program ERFCR[DMALW] so the enhanced RX FIFO element can store the largest CAN message present on the CAN bus.
- Data bytes are valid according to the DLC field. See Table 388.

Each time the DMA controller reads one message from the FIFO, FlexCAN clears ERFSR[ERFDA]. If there is at least one message stored in the FIFO, FlexCAN sets it again.

Consider an example where the maximum number of bytes in the data field of a CAN frame for a certain application is eight, and high-resolution timestamp is enabled. In that case, the last enhanced RX FIFO address offset can be found in Table 398 and Table 399. Using this address offset, ERFCR[DMALW] can be determined in this way:

- Maximum number of data bytes = 8
- HR_TIME_STAMP enabled
- Last address offset = TS_OFF = 2014h
- DMALW = 5

48.3.9.3 Enhanced RX FIFO clear operation

When ERFCR[ERFEN] is 1, the CPU can clear the Enhanced RX FIFO by writing 1 to ERFSR[ERFCLR]. The clear operation resets the internal FIFO pointers, but the FIFO content stored in RAM is not changed. This operation can only be performed in Freeze mode; the module blocks the operation in other modes. This operation does not clear ERFSR[ERFUFW], ERFSR[ERFOVF], ERFSR[ERFDA], or ERFSR[ERFWMI]. The CPU must service all these fields before executing the clear FIFO operation.

48.3.10 Legacy RX FIFO

The Legacy RX FIFO is receive-only. To enable it, write 1 to MCR[RFEN]. To maintain software backward compatibility with previous versions of FlexCAN that did not have the Legacy FIFO feature, the reset value of this field is zero.

CAUTION

Do not enable Legacy RX FIFO when the CAN FD feature is enabled.

The Legacy FIFO is six messages deep. The memory region the Legacy FIFO structure occupies (both message buffers and Legacy FIFO engine) is described in Legacy RX FIFO structure. The CPU can read the received messages sequentially, in the order they were received, by repeatedly reading a message buffer structure at the output of the Legacy FIFO.

IFLAG1[BUF5I] (Frames Available in Legacy RX FIFO) is set when at least one frame is available to be read from the Legacy FIFO. If the corresponding mask bit enables it, an interrupt is generated. Upon receiving the interrupt, the CPU can read the message (accessing the output of the Legacy FIFO as a message buffer) and Legacy RX FIFO Information (RXFIR), then clear the interrupt. If there are more messages in the Legacy FIFO, clearing the interrupt:

1. Updates the output of the Legacy FIFO with the next message.
2. Updates RXFIR with the attributes of that message.
3. Reissues the interrupt to the CPU.

Otherwise, the flag remains cleared. The output of the Legacy FIFO is valid only when IFLAG1[BUF5I] is set.

IFLAG1[BUF6I] (Legacy RX FIFO Warning) is set when the Legacy RX FIFO receives a new message that increases the number of unread messages from four to five. This change means that the Legacy RX FIFO is almost full. The flag remains set until the CPU clears it.

IFLAG1[BUF7I] (Legacy RX FIFO Overflow) is set when an incoming message is lost because the Legacy RX FIFO is full. The flag is not set when the Legacy RX FIFO is full and a message buffer captures the message. The flag remains set until the CPU clears it.

Clearing one of the three flags above does not affect the state of the other two.

If an IFLAG flag is set and the corresponding mask bit is 1, an interrupt is generated.

A powerful filtering scheme is provided to accept only frames intended for the target application, reducing the interrupt servicing workload. The filtering criteria are specified by programming a table of up to 128 32-bit registers, according to CTRL2[RFFN]. This table can be configured to one of the following formats (see also Legacy RX FIFO structure):

- Format A: 128 Identifier Acceptance Filters (IDAFs) — extended or standard IDs including IDE and RTR
- Format B: 256 IDAFs — standard IDs or extended 14-bit ID slices including IDE and RTR
- Format C: 512 IDAFs — standard or extended 8-bit ID slices

NOTE

A chosen format is applied to all entries of the filter table. It is not possible to mix formats within the table.

Every frame available in the Legacy RX FIFO has a corresponding Identifier Acceptance Filter Hit Indicator (IDHIT). The IDHIT can be read in the IDHIT field in the Control and Status word, as shown in the Legacy RX FIFO Structure description. The CPU can also obtain this information by accessing Legacy RX FIFO Information (RXFIR). RXFIR[IDHIT] refers to the message at the output of the Legacy FIFO, and is valid when IFLAG1[BUF5I] is set. RXFIR must be read only before clearing the flag, guaranteeing that the information refers to the correct frame within the Legacy FIFO.

The Individual Mask Registers (RXIMR*n*) individually affect up to 32 elements of the filter table, according to the value of CTRL2[RFFN]. This configuration allows very powerful filtering criteria to be defined. If MCR[IRMQ] is 0, the Legacy RX FIFO filter table is affected by Legacy RX FIFO Global Mask (RXFGMASK).

NOTE

See Table 350 for information about the difference between FD and non-FD regarding this feature.

48.3.10.1 Legacy RX FIFO in DMA operation

The receive-only Legacy FIFO can support DMA. To enable this feature, write 1 to both MCR[RFEN] and MCR[DMA]. To maintain backward compatibility with previous versions of the module that did not have the DMA feature, the reset value of MCR[DMA] is zero.

The DMA controller can read the received message by reading a message buffer structure at the Legacy FIFO output port in the 80h–8Ch address range.

NOTE

FlexCAN supports 32-bit access only for DMA transfers.

When MCR[DMA] = 1, the CPU must not access the Legacy FIFO output port address range. Before writing 1 to MCR[DMA], the CPU must service the IFLAG flags set in the Legacy RX FIFO region. Otherwise, these flags may indicate that the FIFO has data to be serviced, and mistakenly generate a DMA request. Before writing 0 to MCR[DMA], the CPU must perform a clear Legacy FIFO operation.

When at least one frame available to be read from the FIFO, IFLAG1[BUF5I] (Frames available in Legacy RX FIFO) is set. A DMA request is generated simultaneously. Upon receiving the request, the DMA controller can read the message (accessing the output of the Legacy FIFO as a message buffer). The DMA reading process must end by reading address 8Ch. This read operation:

- Clears IFLAG1[BUF5I].
- Updates the FIFO output with the next message (if the FIFO is not empty).
- Updates Legacy RX FIFO Information (RXFIR) with the attributes of the new message.

If there are more messages stored in the FIFO, IFLAG1[BUF5I] is reasserted and another DMA request is issued. Otherwise, the flag remains cleared.

IFLAG1[BUF6I] and IFLAG1[BUF7I] are not used when the DMA feature is enabled.

When FlexCAN is working with DMA, the CPU does not receive any Legacy RX FIFO interruption and must not clear the related IFLAG flags. The related IMASK bits are not used to mask the generation of DMA requests.

NOTE

See Table 350 for information about the difference between FD and non-FD regarding this feature.

48.3.10.2 Clear legacy FIFO

When MCR[RFEN] = 1, you can use the clear Legacy FIFO operation to empty Legacy FIFO contents. When the CPU writes 1 to IFLAG1[BUF0I], the clear FIFO operation occurs. This operation can only be performed in Freeze mode; FlexCAN blocks it in other modes. This operation does not clear the FIFO IFLAG flags; the CPU must service all FIFO IFLAG flags before executing the clear FIFO operation.

When Legacy RX FIFO is working with DMA, the clear FIFO operation clears IFLAG1[BUF5I], and the DMA request is canceled.

CAUTION

The clear Legacy FIFO operation does not clear IFLAG flags, except when MCR[DMA] = 1; in this case, only IFLAG1[BUF5I] is cleared.

48.3.11 ACK suppression

FlexCAN does not send acknowledgment when connected through CAN HUB and ACK suppression is enabled by CTRL2[ASD]. When any of the on-chip CAN controllers (connected through CAN HUB) are transmitting, all the on-chip receivers do not send the acknowledgment of received frames. All the on-chip receivers accept the frames only when there is acknowledgment by external receivers. If there is no acknowledgment by external receivers, the frame is dropped and the BIT error is notified.

48.3.12 CAN protocol-related features

48.3.12.1 CAN FD ISO compliance

The CAN FD protocol has been improved to increase the failure-detection capability that was in the original CAN FD protocol. This original protocol is also called non-ISO CAN FD, by CAN in Automation (CiA). A three-bit stuff counter and a parity bit have been introduced in the improved CAN FD protocol, now called ISO CAN FD. The CRC calculation has also been modified. All these improvements make the ISO CAN FD protocol incompatible with the non-ISO CAN FD protocol. FlexCAN still supports non-ISO CAN FD, so it can be used during an intermediate phase, for evaluation and development purposes.

It is recommended that you configure FlexCAN with the ISO CAN FD protocol by writing 1 to CTRL2[ISOCANFDEN].

48.3.12.2 CAN FD frames

ISO 11898-1:2015 specifies the Classical Frame format compliant to ISO 11898-1:2003 (2003) and introduces the CAN Flexible Data Rate Frame format (CAN FD). The Classical Frame format allows bit rates up to one Mbit/s and payloads up to eight bytes per frame. The Flexible Data Rate Frame format allows bit rates faster than one Mbit/s and payloads longer than eight bytes per frame. FlexCAN can receive and transmit CAN FD messages interleaved with Classical CAN messages.

There are additional control bits in the CAN FD frame:

- The Extended Data Length (EDL) bit enables a longer data payload with different data length coding.
- The Bit Rate Switch (BRS) bit decides whether the bit rate is switched inside a CAN FD format frame.
- The Error State Indicator (ESI) flag is transmitted dominant by error active nodes, and recessive by error passive nodes.

There are no Remote Frames (see Remote frames) in the CAN FD format. A message configured to transmit a Remote Frame is always sent out in Classical CAN format. When an FD frame is received and matches a message buffer, the RTR bit in the receiving message buffer becomes 0. The RTR bit must be considered in classical frames only.

48.3.12.2.1 CAN FD messages

CAN FD messages may be formatted as long frames where the data field exceeds eight bytes, and may range from 12 up to 64 bytes. They can also be configured to support bit rate switching. In this case, the control field, data field, and CRC field of a CAN frame are transmitted with a higher bit rate than the beginning and end of the frame. Messages in the classical CAN format are limited to transport a maximum payload of eight bytes at nominal rate. Figure 186 illustrates the message formats for classical and FD frames with either standard or extended ID.

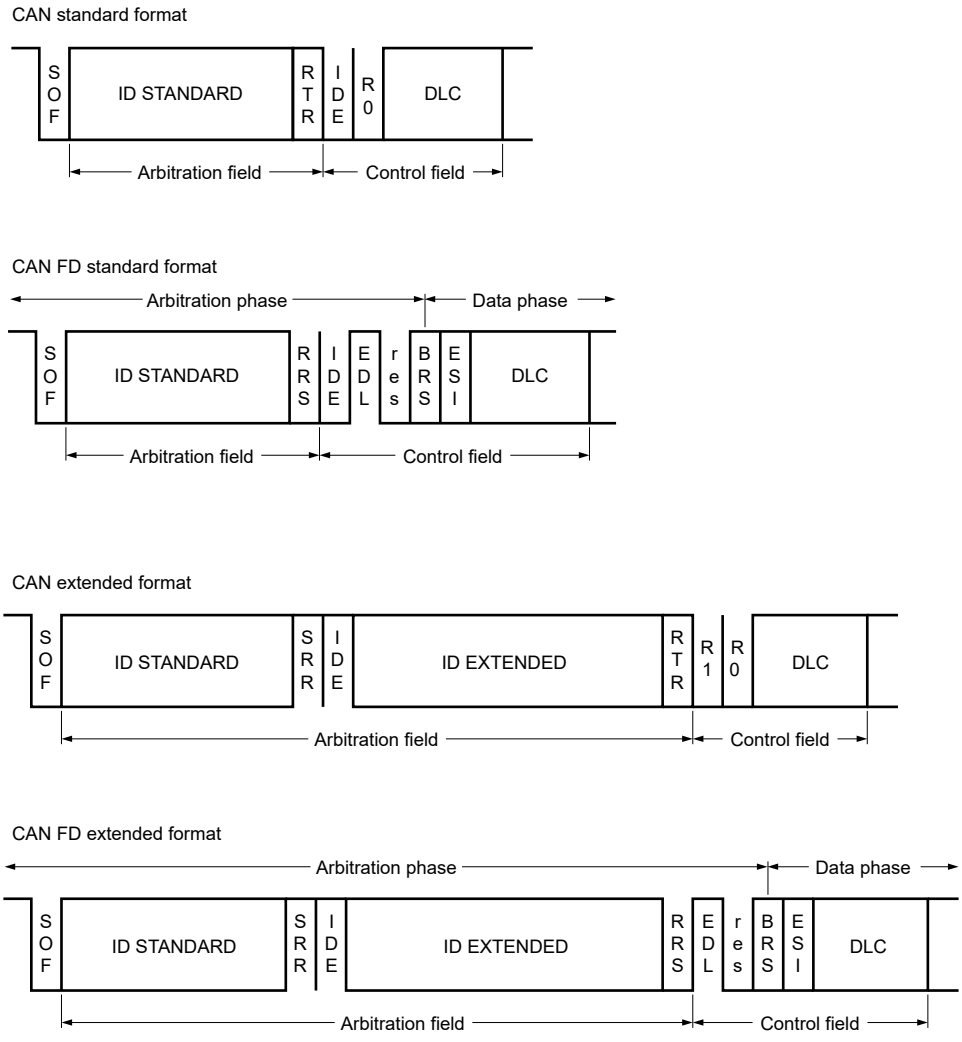

Figure 186. CAN message formats

MCR[FDEN] enables the ability to receive and transmit CAN FD messages. A recessive R0 bit in CAN frames with 11-bit identifiers, or a recessive R1 bit in CAN frames with 29-bit identifiers, is decoded as an EDL bit (not a reserved one). A recessive EDL bit identifies a CAN FD frame, and a dominant EDL bit identifies a Classical CAN frame. The BRS bit specifies whether this frame switches the bit rate in its data phase. A long frame is decoded according to the DLC field value (see DLC definition in Message buffer structure).

CAN FD messages can be transmitted with two different bit rates. The first part of a CAN FD frame, from the Start of Frame (SOF) bit until the Bit Rate Switch (BRS) bit is called the arbitration phase. This part is transmitted with the nominal bit rate based on a

set of nominal CAN bit timing configuration values. The second part, from the BRS bit until the CRC Delimiter bit, is called the data phase. When this second part is transmitted, a second set of CAN data bit timing configuration values determines the data bit rate. Finally, from the CRC delimiter until the Intermission bits, the transmission returns to nominal bit rate.

48.3.12.2.2 BRS in CAN FD

In CAN FD frames with bit rate switching, the bit timing changes inside the frame at the sample point of the BRS bit if this bit is recessive. Before the BRS bit, in the CAN FD arbitration phase, the nominal CAN bit timing is used as defined by CAN Bit Timing (CBT). (Control 1 (CTRL1) also defines this timing for backward compatibility.) Upon detecting a recessive BRS bit, the CAN data bit timing is used as defined by CAN FD Bit Timing (FDCBT).

NOTE

If the time quantum length in nominal bit timing and in the data bit timing are not identical, a quantization error of up to one time quantum of the arbitration phase may be present as a phase error. This situation can occur after the switch from arbitration to data phase, and it lasts until the next synchronization event. The length of the time quantum should be the same in nominal and data bit timing. This configuration minimizes the chance of error frames on the CAN bus, and optimizes the clock tolerance in networks that use FD frames.

If BRS = 1 in the selected TX MB, FDCTRL[FDRATE] enables the transmission of all frames with bit rate switching. If FDCTRL[FDRATE] = 0, the transmission is performed at nominal rate regardless of the BRS bit value. FDCTRL[FDRATE] can be written at any time but takes effect only for the next message transmitted or received.

Nominal bit timing is resumed at the sample point of the CRC Delimiter bit or when an error is detected, whichever occurs first. Figure 187 describes the mechanism for entering and leaving the data phase when the BRS bit is recessive.

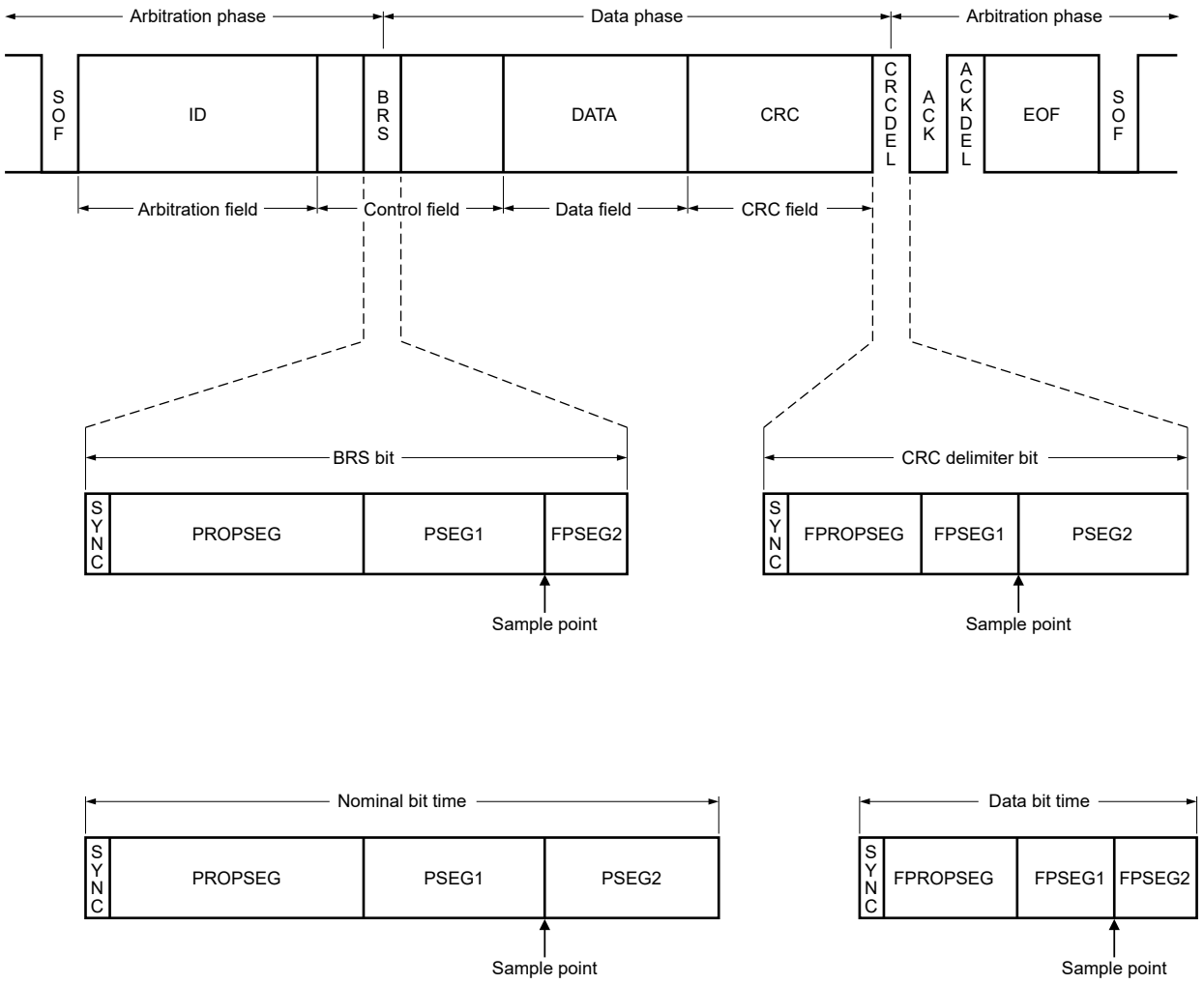

Figure 187. Bit rate switching mechanism for CAN FD messages

NOTE

In Classical CAN frames, the CRC delimiter is one recessive bit. In CAN FD frames, the CRC delimiter may consist of one or two recessive bits. FlexCAN sends only one recessive bit as the CRC delimiter. It accepts two recessive bits before the recessive-to-dominant edge that starts the acknowledge slot. As a receiver, FlexCAN sends its acknowledge bit after the first CRC delimiter bit. In CAN FD frames, FlexCAN accepts a two-bit dominant ACK slot as a valid ACK to compensate for phase shifts between the receivers.

The maximum configurable bit rate in the CAN FD data phase depends on the clock frequency of the CAN_PE subblock. For example, for a CAN_PE clock frequency of 40 MHz and the shortest configurable bit time of 5 time quanta, the bit rate in the data phase is 8 Mbit/s.

NOTE

The frequency used in this example may not be supported on this chip. It is shown only to demonstrate how the maximum configurable bit rate is calculated.

48.3.12.2.3 ESI in CAN FD

The value of the ESI field is determined by either of the following:

- The error state of the transmitter at the start of the transmission, if the frame is originated in the FlexCAN node
- The original transmitting node when FlexCAN is acting as a gateway for the message

If the transmitter is error-passive, ESI is transmitted recessive; otherwise, it is transmitted dominant. The permutations of the relationship between the written value and the transmitted value of the ESI are shown in Table 364.

Table 364. Written versus transmitted values of the ESI field

FlexCAN fault confinement status at start of frame	ESI field of TX MB	Transmitted ESI
Error active	0	0 (Error Active)
Error passive	0	1 (Error Passive)
Error active	1	1 (Error Passive)
Error passive	1	1 (Error Passive)

48.3.12.2.4 CRC calculations in CAN FD

Different CAN frame formats have different CRC polynomials. The first polynomial, CRC_15, is used for all frames in Classical CAN format. The second, CRC_17, is used for frames in CAN FD format with a data field up to 16 bytes long. The third, CRC_21, is used for frames in CAN FD format with a data field longer than 16 bytes. Each polynomial results in a Hamming distance of 6. At the start of the frame, all three CRC polynomials are calculated concurrently. The values of the EDL bit and the DLC field select the CRC sequence to be transmitted. When receiving a message, FlexCAN decodes EDL and DLC to select the adequate CRC polynomial to check for a CRC error.

In CAN FD format frames, stuff bits are included in the bit stream for CRC calculation. In Classical CAN format frames, stuff bits are not included. After the transmission of the last bit relevant to the CRC calculation, CAN FD CRC (FDCRC) stores the calculated CRC for the transmitted message. This storage is performed with adequate length for the type of message, for CAN FD and non-FD messages. Cyclic Redundancy Check (CRCR) reports a valid CRC for Classical CAN messages only.

In CAN FD format frames, the CAN bit stuffing method changes for the CRC sequence, so the stuff bits are inserted at fixed positions. When FlexCAN is transmitting a CAN FD frame, a fixed stuff bit is inserted just before the first bit of the CRC sequence. This insertion occurs even if the last bits of the preceding field do not fulfill the CAN stuff condition. Additional stuff bits are inserted after each fourth bit of the CRC sequence. The value of any fixed stuff bit is the inverse value of its preceding bit. When FlexCAN receives a CAN FD frame, it discards the fixed stuff bits from the bit stream for the CRC check. A stuff error is detected if the fixed stuff bit has the same value as its preceding bit.

48.3.12.2.5 CAN FD errors

FlexCAN detects errors in CAN FD frames the same way as in Classical CAN frames. The error counters ECR[RXERRCNT] and ECR[TXERRCNT] accumulate the counts of RX and TX errors, respectively, for both FD and non-FD frames indiscriminately. Two extra error counters, ECR[RXERRCNT_FAST] and ECR[TXERRCNT_FAST], accumulate RX and TX errors occurring in the data phase of CAN FD frames with BRS = 1 only. The rules for updating the error counters are the same for both CAN FD and non-FD frames (see Error Counter (ECR)).

These error flags report errors in both CAN FD and non-FD frames:

- ESR1[BIT1ERR]
- ESR1[BIT0ERR]
- ESR1[ACKERR]
- ESR1[CRCERR]
- ESR1[FRMERR]

- ESR1[STFERR]

If CTRL1[ERRMSK] = 1, they also generate the ERRINT interrupt.

These additional error flags indicate the occurrence of errors in the data phase of CAN FD frames with BRS = 1:

- ESR1[BIT1ERR_FAST]
- ESR1[BIT0ERR_FAST]
- ESR1[CRCERR_FAST]
- ESR1[FRMERR_FAST]
- ESR1[STFERR_FAST]

No ACKERR is detected in the data phase of a CAN FD frame. Fault confinement status reported in ESR1[FLTCONF] is the same for both CAN FD and Classical CAN frames, and is based on ECR[RXERRCNT] and ECR[TXERRCNT] only. Information in ECR[RXERRCNT_FAST] and ECR[TXERRCNT_FAST] may be considered as status to help detect the error nature related to the bit rate value.

When FlexCAN detects an error while transmitting or receiving a CAN FD message in the data phase, it immediately switches:

- Back to the arbitration phase, and
- Back to the nominal rate to start an error flag.

48.3.12.2.6 CAN FD synchronization

Resynchronization and hard synchronization occur in CAN FD frames in the same way as in Classical CAN ones. A hard synchronization is also performed at the recessive-to-dominant edge from EDL to R0 in CAN FD format frames. FlexCAN does not resynchronize when transmitting in the CAN FD data phase.

48.3.12.3 Transceiver delay compensation

The CAN FD protocol allows the transmission and reception of data at a higher bit rate than the nominal rate used in the arbitration phase, when BRS = 1 in the message. This feature enables the use of rates up to 8 Mbit/s.

During the data phase of a CAN FD frame, if the transmitter cannot receive its own latest transmitted bit at the sample point of that bit, it detects a bit error. When bit rate switching is enabled (BRS = 1), the CAN bit time in the data phase can become shorter than the loop delay of the transceiver. This condition impedes the correct comparison between the transmitted bit and the received bit within the current CAN bit time interval.

The transceiver delay compensation (TDC) process defines a secondary sample point where the transmitted bit is correctly compared to the received bit to check for bit errors.

You can enable the TDC mechanism via FDCTRL[TDCEN] or ETDC[ETDCEN]. The TDC mechanism is effective only during the data phase of FD frames with BRS = 1. It has no effect on either non-FD frames or FD frames transmitted at the normal bit rate. When the transmitted message has BRS = 1, TDC is active from the sample point of the BRS bit until the sample point of the CRC Delimiter bit. When TDC is active, the real received bit is compared to the delayed transmitted bit, where the delay is calculated based on the measured transceiver loop delay.

NOTE

The transmitters using TDC disregard the value of the CRC delimiter bit. A global error at the end of the CRC field causes the receivers to send error frames that the transmitter detects during Acknowledge or End of Frame.

For every transmitted FD frame with BRS = 1, the transition from the recessive EDL bit to the dominant R0 bit triggers the delay measurement (as shown in Figure 188). The loop delay is measured in Protocol Engine (PE) clock periods (CANCLK, see Protocol timing), from the transmitted EDL-R0 edge to the received EDL-R0 edge. The measured loop delay time added to an offset value specified in FDCTRL[TDCOFF] or ETDC[ETDCOFF] determines the position of the secondary sample point. FDCTRL[TDCVAL] or ETDC[ETDCVAL] stores the result of this calculation. The TDCVAL and ETDCVAL value saturates at its maximum value of 63 CANCLK and 255 CANCLK when the delay measurement is too long.

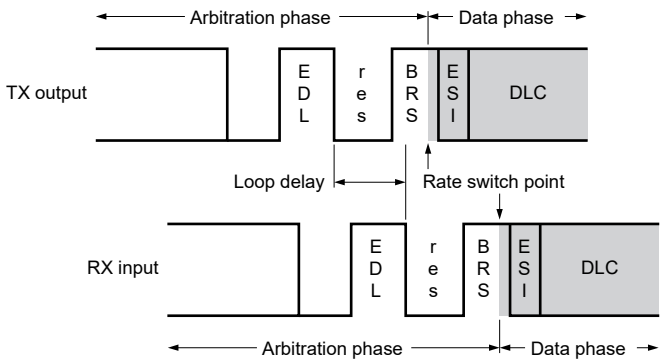

Figure 188. Transceiver loop delay measurement

The measured loop delay is not enough to define the secondary sample point, because it relates to the CAN bit edges. The transceiver delay compensation offset FDCTRL[TDCOFF] or ETDC[ETDCOFF] is used to shift the secondary sample point to an intermediate point inside the bit time, far away from its edges. The value of FDCTRL[TDCOFF] or ETDC[ETDCOFF] cannot be larger than the CAN bit duration in the data phase.

If the secondary sample point is set very near the CAN bit edge (SYNC field), problems may occur during the bit sampling in the data phase. For the TDC to work reliably, the offset must use optimal settings. To ensure that bit sampling is performed in the best region, configure the TDC offset as shown in this equation:

$$Offset = (FPSEG1 + FPROPSEG + 2) \times (FPRESDIV + 1)$$
$$or$$
$$Offset = (DTSEG1 + 2) \times (EDPRESDIV + 1), \ if \ ETDCEN$$

Equation 5. TDC offset calculation

Figure 189 shows the SSP position when these settings are used.

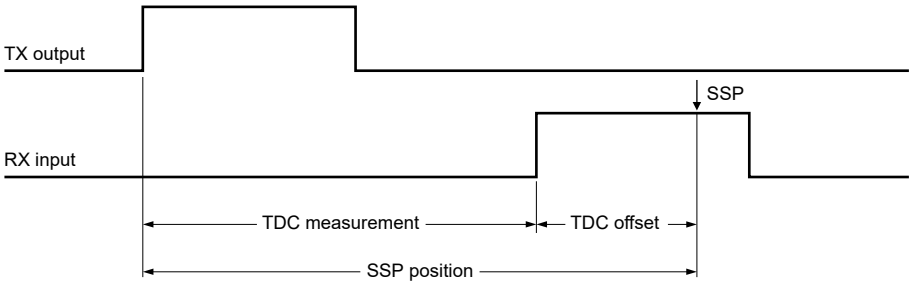

Figure 189. SSP position with optimal values

Alternatively, if CTRL2[BTE] and ETDC[ETDCEN] are 1, you can write 1 to ETDC[TDMDIS] to disable the transceiver delay measurement. In this case, only ETDC[ETDCOFF] defines the SSP position. Figure 190 shows the secondary sample point position when the transceiver delay measurement is disabled.

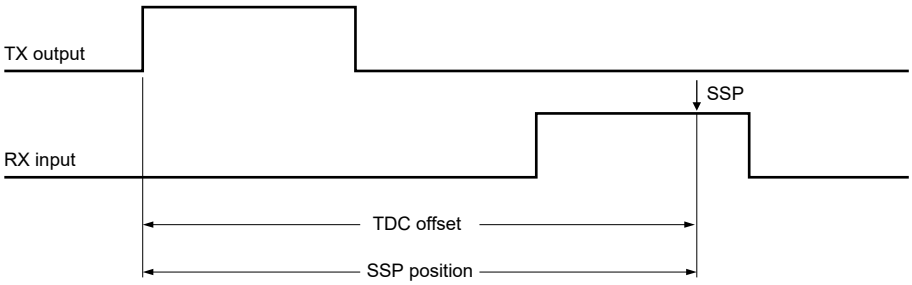

Figure 190. SSP position with TDC measurement disabled by ETDCEN and TDMDIS

During the data phase of CAN FD frames with bit rate switching enabled, at the onset of every TX CAN bit:

- The transmitted TX bit value is temporarily stored in a buffer.
- A time countdown based on FDCTRL[TDCVAL] or ETDC[ETDCVAL] is started. This countdown ends with the comparison of the received RX bit (delayed by the external loop delay plus the specified offset) to the stored TX bit.

If a bit error is detected at the secondary sample point, FlexCAN issues an error flag to the CAN bus at the next sample point.

During the arbitration phase, delay compensation is always disabled. During the data phase, the TDC mechanism of FlexCAN can compensate a maximum delay of 3 CAN bit times − 2 Tq. Beyond this limit, the FDCTRL[TDCFAIL] or ETDC[ETDCFAIL] flag is set. The flag indicates when the TDC mechanism is out of range and is unable to compensate the transceiver loop delay.

48.3.12.4 Remote frames

A remote frame is a special type of frame. You can program a message buffer to be a remote request frame by configuring the message buffer as Transmit with the RTR = 1. After the remote request frame is transmitted successfully, the message buffer becomes a receive message buffer, with the same ID as before.

When FlexCAN receives a remote request frame, the frame can be treated in different ways, depending on remote request storing (CTRL2[RRS]) and RX FIFO Enable (MCR[RFEN]):

- If RRS = 0, the ID of the frame is compared to the IDs of the transmit message buffers with the CODE field 1010b. If a matching ID exists, this message buffer frame is transmitted. If the matching message buffer has the RTR = 1, FlexCAN transmits a remote frame as a response. The received remote request frame is not stored in a receive buffer. It is only used to trigger a transmission of a frame in response.

  The mask registers are not used in remote frame matching, and all ID bits (except RTR) of the incoming received frame should match. If a remote request frame is received and matches a message buffer, this message buffer immediately enters the internal arbitration process. However, it is considered a normal TX message buffer, with no higher priority. The data length of this frame is independent of the DLC field in the remote frame that initiated its transmission.

- If CTRL2[RRS] = 1, the ID of the frame is compared to the IDs of the receive message buffers with the CODE field 0100b, 0010b, or 0110b. If a matching ID exists, this message buffer stores the remote frame in the same fashion as a data frame. No automatic remote response frame is generated. The mask registers are used in the matching process.
- If MCR[RFEN] = 1, FlexCAN does not generate an automatic response for remote request frames that match the Legacy FIFO filtering criteria. If the remote frame matches one of the target IDs, it is stored in the Legacy FIFO and presented to the CPU.

  For filtering formats A and B (see Legacy RX FIFO structure), it is possible to select whether remote frames are accepted or not. For format C, remote frames are always accepted if they match the ID. Remote request frames are considered as normal frames. They generate a Legacy FIFO overflow when a successful reception occurs and the Legacy FIFO is already full.

- If ERFCR[ERFEN] = 1, FlexCAN does not generate an automatic response for remote request frames that match the Enhanced RX FIFO filtering criteria. Remote Request Frames are considered normal frames. They generate an Enhanced RX FIFO overflow when a successful reception occurs and the enhanced RX FIFO is already full.

NOTE

There is no remote frame in the CAN FD format. A fixed dominant RRS bit replaces the RTR bit. FlexCAN receives and transmits remote frames in the Classical CAN format.

48.3.12.5 Overload frames

When a dominant bit is detected on the CAN bus in these locations, FlexCAN transmits overload frames:

- The first or second bit of Intermission.
- The seventh bit (last) of End of Frame field (RX frames).
- The eighth bit (last) of Error Frame Delimiter or Overload Frame Delimiter.

48.3.12.6 Message buffer timestamp

The value of the free-running timer is sampled at the beginning of the Identifier field on the CAN bus. This value is stored at the end of move-in in the TIME_STAMP field of a message buffer, providing network behavior regarding time.

When CTRL2[TIMER_SRC] = 1, an external time tick continuously clocks the free-running timer.

When CTRL2[TIMER_SRC] = 0, the FlexCAN bit clock clocks the free-running timer, which defines the baud rate on the CAN bus. During a message transmission or reception, it increments by one for each bit that is received or transmitted. When there is no message on the bus, it counts using the previously programmed baud rate.

The free-running timer is not incremented during Disable, Doze, Stop, and Freeze modes. It can be reset upon a specific frame reception, enabling network time synchronization. See CTRL1[TSYN].

Alternatively, by configuring CTRL2[MBTSBASE], the timestamp of the message buffer can capture the lower or higher 16 bits of the high-resolution dedicated counter. See the chip-specific FlexCAN timestamp implementation.

48.3.12.7 High-resolution timestamp

The high-resolution timestamp (HR_TIME_STAMP) uses a dedicated timer with a 32-bit counter operating in free-running mode. CTRL2[TSTAMPCAP] enables the high-resolution timestamp. When this field is not zero, the dedicated 32-bit counter value is captured during a valid CAN frame and stored in an HR_TIME_STAMP*n* register.

Each HR_TIME_STAMP*n* corresponds to a specific message buffer. For example, HR_TIME_STAMP0 stores the 32-bit timestamp associated with message buffer 0. HR_TIME_STAMP1 stores the 32-bit timestamp associated with message buffer 1, and so on.

The counter value is captured according to CTRL2[TSTAMPCAP]. For classical CAN frames, the capture points can be the start of frame bit or the point in time a CAN frame is considered valid. This valid point is the seventh bit of end of frame for transmission and the sixth bit of end of frame for reception.

For CAN FD frames, the capture points can be:

- The start of frame
- The point in time a CAN FD frame is considered valid
- The res bit of a CAN FD frame

The 16-bit timestamp of the message buffer can be configured to capture the lower or higher 16 bits of the high-resolution timer. This configuration is made by CTRL2[MBTSBASE]. See the chip-specific FlexCAN timestamp implementation.

48.3.12.8 Protocol timing

Figure 191 shows the structure of the clock generation circuitry that feeds the CAN Protocol Engine (PE) submodule.

NOTE

To identify the proper clock source, see the clock distribution chapter (module clocks table).

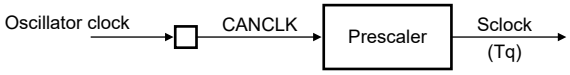

Figure 191. CAN engine clocking scheme

48.3.12.8.1 Bit timing configuration

FlexCAN supports various means to configure bit timing parameters required by the CAN protocol. Control 1 (CTRL1) has various fields to control bit timing parameters:

- CTRL1[PRESDIV]
- CTRL1[PROPSEG]
- CTRL1[PSEG1]
- CTRL1[PSEG2]
- CTRL1[RJW]

CAN Bit Timing (CBT) extends the range of the CAN bit timing variables in CTRL1. Enhanced Data Phase CAN Bit Timing (EDCBT) provides a second set of CAN bit timing variables to be applied at the data phase of CAN FD frames with the Bit Rate Switch (BRS) = 1.

Enhanced Nominal CAN Bit Timing (ENCBT) extends the range of CAN bit timing variables in CBT. Enhanced Nominal CAN Bit Timing (ENCBT) extends the range of CAN bit timing variables in FDCBT. When using ENCBT and EDCBT, you must program the nominal bit timing and data phase serial clock (Sclock) dividers in Enhanced CAN Bit Timing Prescalers (EPRS).

NOTE

When the CAN FD feature is enabled, always write 1 to CBT[BTF] or CTRL2[BTE] and specify the CAN bit timing variables in CBT or ENCBT. See CAN Bit Timing (CBT) or Enhanced Nominal CAN Bit Timing (ENCBT).

CTRL1[PRESDIV], and its extended range CBT[EPRESDIV] (or EPRS[ENPRESDIV]) and FDCBT[FPRESDIV] (or EPRS[EDPRESDIV]) for the data phase bits of CAN FD messages, defines the prescaler value that generates the serial clock (Sclock). (See Equation 6.) The period of Sclock defines the time quantum used to compose the CAN waveform. A time quantum (Tq) is the atomic unit of time managed by the CAN engine. It is the smallest time unit for all configuration values.

$$Tq = \frac{(PRESDIV + 1)}{f_{CANCLK}}$$

Equation 6. Time quantum

The bit rate, which defines the rate the CAN message is received or transmitted, is calculated with the formula:

$$CAN\ bit\ time = (Number\ of\ time\ quanta\ in\ 1\ bit\ time) \times Tq$$

$$Bit\ rate = \frac{1}{CAN\ bit\ time}$$

Equation 7. CAN bit time and baud rate

48.3.12.8.2 Bit time segments

A bit time is subdivided into three segments as shown in Figure 192. See also Figure 193 , Figure 194, and Table 365.

NOTE

For further explanation of the underlying concepts, see ISO 11898-1:2015. See also *CAN Specification Version 2.0, Part A and Part B* for bit timing.

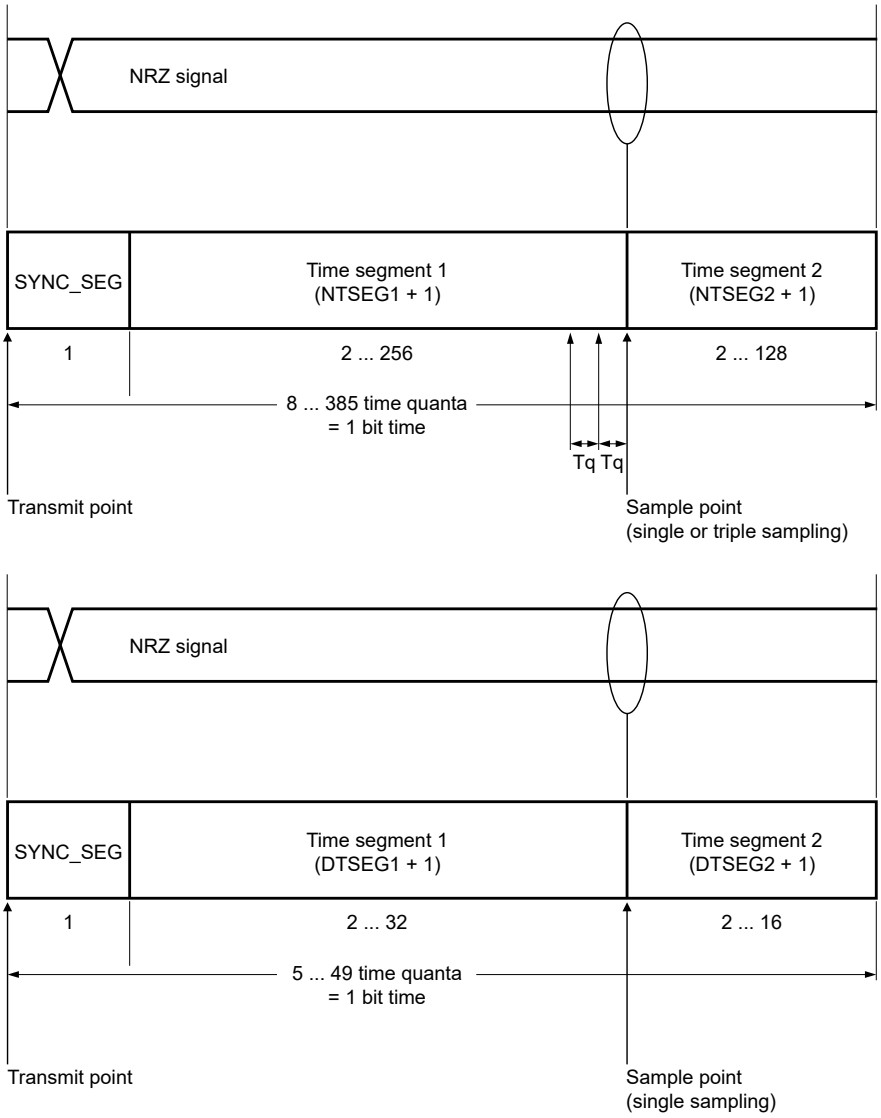

Figure 192. Segments within the bit timing (example using ENCBT and EDCBT bit timing variables)

The three bit time segments are:

- SYNC_SEG—this segment has a fixed length of one time quantum. Signal edges are expected to occur within this section.
- Time Segment 1—this segment includes the propagation segment and the phase segment 1 of the CAN standard.

  It can be programmed by configuring CTRL1[PROPSEG] and CTRL1[PSEG1] so that the sum (plus 2) is 2–16 time quanta. When CBT[BTF] = 1, FlexCAN uses CBT[EPROPSEG] and CBT[EPSEG1] so that the sum (plus 2) is 2–96 time quanta. For messages in CAN FD format with the BRS = 1, FlexCAN uses FDCBT[FPROPSEG] and FDCBT[FPSEG1] so that the sum (plus 1) is 2–39 time quanta.

  If CTRL2[BTE] = 1, FlexCAN uses ENCBT[NTSEG1] to configure time segment 1 to 2–256 time quanta. For the data phase in CAN FD messages with BRS = 1, EDCBT[DTSEG1] must be used for configuring time segment 1 to 2–32 time quanta.

- Time Segment 2—this segment represents the phase segment 2 of the CAN standard.

  It can be programmed by configuring CTRL1[PSEG2] (plus 1) to be 2–8 time quanta. When CBT[BTF] = 1, FlexCAN uses CBT[EPSEG2] so that its value (plus 1) is 2–32 time quanta. For messages in CAN FD format with the BRS = 1, FlexCAN uses FDCBT[FPSEG2] instead, so that its value (plus 1) is 2–8 time quanta. Time segment 2 cannot be smaller than the Information Processing Time (IPT), which is 2 time quanta in FlexCAN.

  If CTRL2[BTE] = 1, FlexCAN uses ENCBT[NTSEG2] to configure time segment 2 to 2–128 time quanta. For the data phase in CAN FD messages with BRS = 1, EDCBT[DTSEG2] must configure time segment 2 to 2–16 time quanta.

NOTE

The bit time defined by the above time segments must not be smaller than five time quanta. For bit time calculations, use an Information Processing Time (IPT) of two, which is the value implemented in the FlexCAN module.

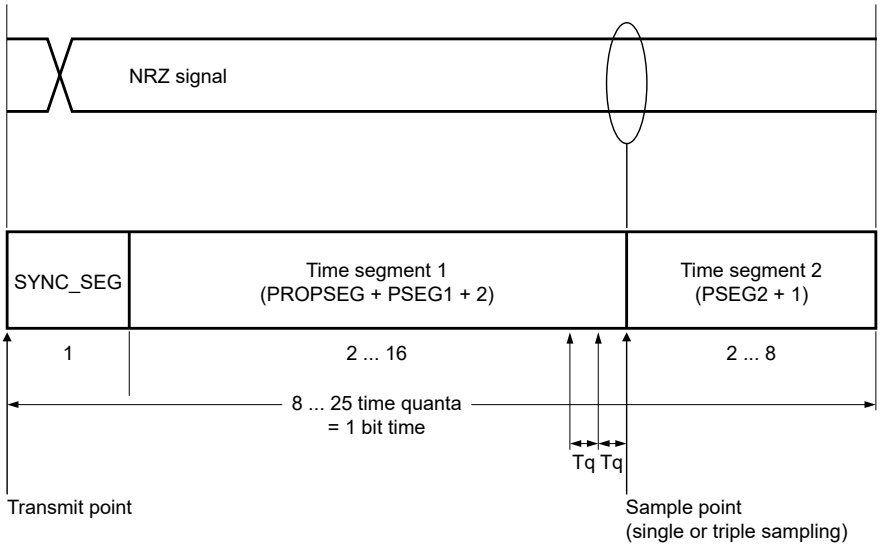

Figure 193. Segments within the bit time (example using CTRL1 bit timing variables for Classical CAN format)

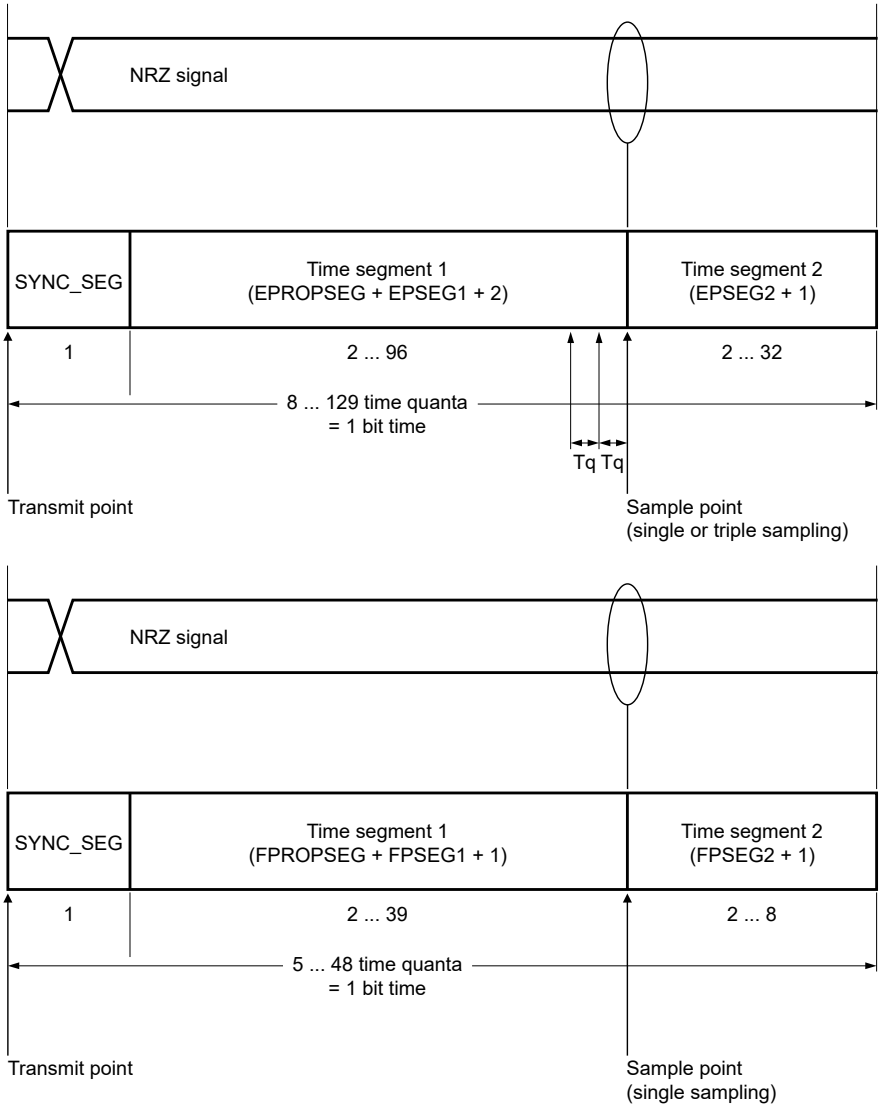

Figure 194. Segments within the bit time (example using CBT and FDCBT bit timing variables for CAN FD format)

Table 365. Time segment syntax

Syntax	Description
SYNC_SEG	Period during which the system expects transitions to occur on the bus
TSEG1	Period corresponding to the sum of PROPSEG and PSEG1
TSEG2	Period corresponding to the PSEG2 value
Transmit point	Point at which a node in Transmit mode transfers a new value to the CAN bus
Sample point	Point at which a node samples the bus. If the option of three samples per bit is selected, this point marks the position of the third sample.

Table 366 gives some examples of the CAN-compliant segment settings for Classical CAN format (Bosch CAN 2.0B) (non-FD) messages.

Table 366. Bosch CAN 2.0B standard compliant bit time segment settings

Time segment 1	Time segment 2	Resynchronization jump width
5 to 10	2	1 to 2
4 to 11	3	1 to 3
5 to 12	4	1 to 4
6 to 13	5	1 to 4
7 to 14	6	1 to 4
8 to 15	7	1 to 4
9 to 16	8	1 to 4

NOTE

You must ensure the bit time settings comply with the CAN Protocol standard ISO 11898-1:2015.

48.3.12.8.3 Calculating peripheral clocks

A CAN bit can be used as a measure of duration (for example, estimating the occurrence of a CAN bit event in a message). When a CAN bit is used in this way, the number of peripheral clocks in one CAN bit (NumClkBit) can be calculated as:

$$NumClkBit = \frac{f_{SYS}}{f_{CANCLK}} \times (PRESDIV + 1) \times (PROPSEG + PSEG1 + PSEG2 + 4)$$

Equation 8. Number of peripheral clocks per CAN bit when CTRL2[BTE] = 0

Or, if CTRL2[BTE] = 1:

$$NumClkBit = \frac{f_{SYS}}{f_{CANCLK}} \times (ENPRESDIV + 1) \times (NTSEG1 + NTSEG2 + 3)$$

Equation 9. Number of peripheral clocks per CAN bit when CTRL2[BTE] = 1

Where:

- NumClkBit is the number of peripheral clocks in one CAN bit.
- f_{CANCLK} is the Protocol Engine (PE) Clock (see Figure 191), in Hz.
- f_{SYS} is the frequency of operation of the system (CHI) clock, in Hz.
- PSEG1 is the value of CTRL1[PSEG1].
- PSEG2 is the value of CTRL1[PSEG2].
- PROPSEG is the value of CTRL1[PROPSEG].
- PRESDIV is the value in CTRL1[PRESDIV].
- ENPRESDIV is the value of EPRS[ENPRESDIV].
- NTSEG1 is the value of ENCBT[NTSEG1].
- NTSEG2 is the value of ENCBT[NTSEG2].

The formula above is also applicable to the alternative CAN bit timing variables described in:

- CAN Bit Timing (CBT)

- Enhanced Nominal CAN Bit Timing (ENCBT)
- CAN FD Bit Timing (FDCBT)
- Enhanced Nominal CAN Bit Timing (ENCBT)

For example, 180 CAN bits = (180 × NumClkBit) peripheral clock periods.

48.3.12.9 Arbitration and matching timing

During normal reception and transmission, the matching, arbitration, move-in, and move-out processes are executed during certain time windows inside the CAN frame. These windows are shown in the following figures.

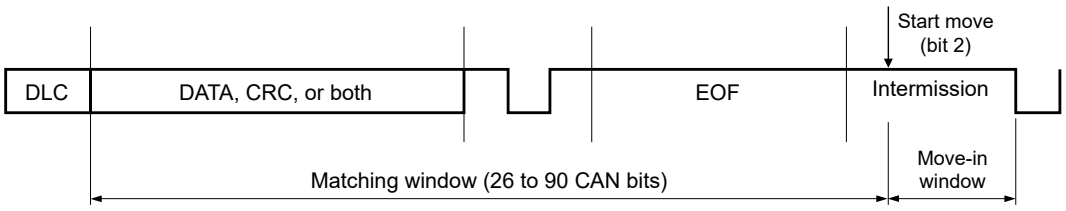

Figure 195. Matching and move-in time windows

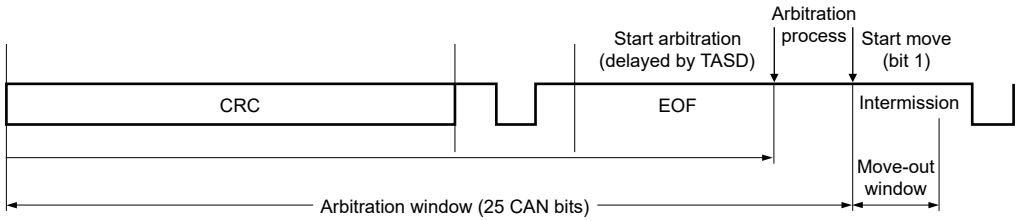

Figure 196. Arbitration and move-out time windows

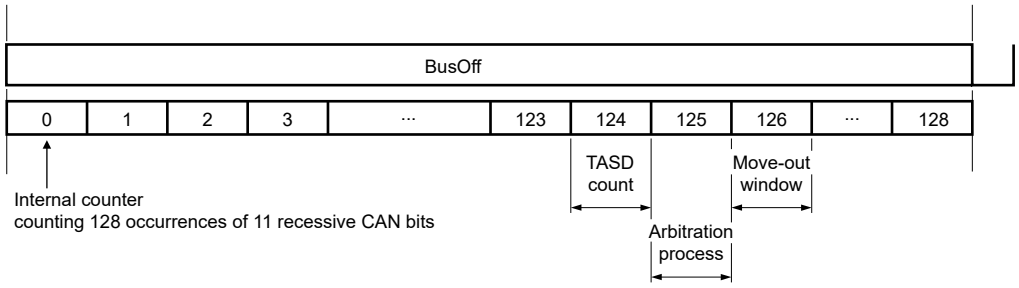

Figure 197. Arbitration at the end of bus off and move-out time windows

NOTE

In these figures, the matching and arbitration timing do not consider delays caused by concurrent memory access due to the CPU or other internal FlexCAN subblocks.

48.3.12.10 TX arbitration start delay

TX Arbitration Start Delay (CTRL2[TASD]) indicates the number of CAN bits that FlexCAN uses to delay the TX arbitration process starting point from the first bit of the CRC field of the current frame. This variable can be written only in Freeze mode; FlexCAN blocks it in other modes.

The ability of the CPU to reconfigure message buffers for transmission after the end of the internal arbitration process impacts transmission performance. In the arbitration process, FlexCAN finds the winner MB for transmission (see Arbitration process). If

the arbitration ends too early (before the first bit of the Intermission field) the CPU may reconfigure some TX message buffers. It is possible that the winning message buffer is no longer the best candidate to be transmitted.

TASD can optimize the transmission performance by defining the arbitration start point, as shown in Figure 198, based on factors such as:

- Peripheral-to-oscillator clock ratio
- CAN bit timing variables that determine the CAN bit rate
- Number of message buffers in use by the matching and arbitration processes

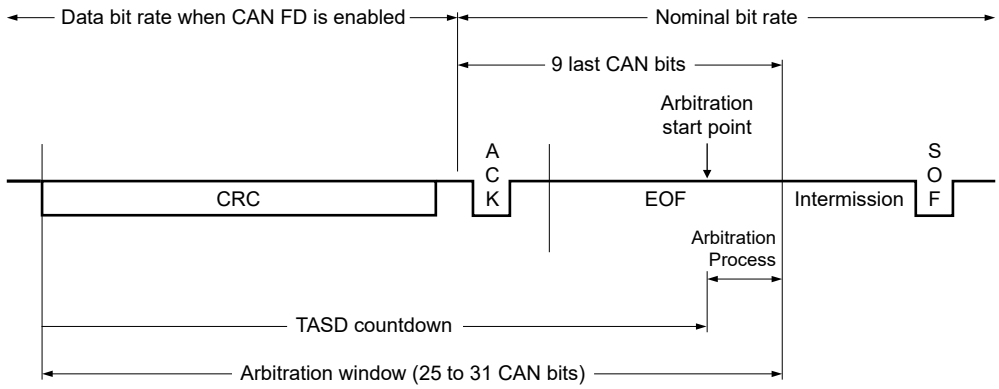

Figure 198. Optimal TX arbitration start point

The duration of an arbitration process, in terms of CAN bits, is:

- Directly proportional to the number of available message buffers
- Directly proportional to the CAN bit rate
- Inversely proportional to the peripheral clock frequency

The optimal arbitration timing occurs when the last message buffer is scanned immediately before the first bit of the Intermission field of a CAN frame. For instance, if the following are true:

- There are few message buffers.
- The peripheral-to-oscillator clock ratio is high.
- The CAN baud rate is low.

Then the arbitration can be placed closer to the end of the frame, adding more delay to its starting point, and vice versa.

If CTRL2[TASD] = 0, the arbitration start is not delayed, and more time is reserved for arbitration. Alternatively, if CTRL2[TASD] is close to 24, the CPU can configure a TX message buffer later, and less time is reserved for arbitration. If too little time is reserved for arbitration, FlexCAN may not be able to find a winner MB in time. The transmitted arbitration winner may not have the best chance to win the bus arbitration against external nodes on the CAN bus.

The optimal TASD value can be calculated as follows:

For CAN FD frames and (MAXMB + 1) ≤ NMB_{END}

$$TASD = 31 - \frac{2 * (MAXMB + 1) + 4}{CPCB_N}$$

For CAN FD frames and (MAXMB + 1) > NMB_{END}

$$TASD = 22 - \frac{2 * (MAXMB + 1) - NMB_{END}}{CPCB_F}$$

For non-FD frames

$$TASD = 25 - \frac{2 * (MAXMB + 1) + 4}{CPCB}$$

Equation 10. Optimal value for TASD

Where:

$$NMB_{END} = \frac{(9 \times CPCB_N) - 4}{2}$$

$$BITRATE_N = \left(\frac{f_{CANCLK}}{[1 + (EPSEG1 + 1) + (EPSEG2 + 1) + (EPROPSEG + 1)] \times (EPRESDIV + 1)} \right)$$

$$BITRATE_F = \left(\frac{f_{CANCLK}}{[1 + (FPSEG1 + 1) + (FPSEG2 + 1) + FPROPSEG] \times (FPRESDIV + 1)} \right)$$

$$CPCB_N = \frac{f_{SYS}}{BITRATE_N}$$

$$CPCB_F = \frac{f_{SYS}}{BITRATE_F}$$

$$CPCB = CPCB_N$$

Equation 11. Variables used in TASD calculation

- MAXMB is the value in MCR[MAXMB].
- NMB_{END} is the number of message buffers that the arbitration process can scan during the last nine CAN bits at the end of a frame. (See Equation 11.)
- $BITRATE_N$ is the CAN bit rate in bits per second calculated by the nominal CAN bit time variables.
- $BITRATE_F$ is the CAN bit rate in bits per second calculated by the data CAN bit time variables.
- $CPCB_N$ is the number of peripheral clocks per CAN bit in nominal bit rate for CAN FD frames.
- $CPCB_F$ is the number of peripheral clocks per CAN bit in data bit rate for CAN FD frames.
- CPCB is the number of peripheral clocks per CAN bit for non-FD frames.
- f_{CANCLK} is the oscillator clock, in Hz.
- f_{SYS} is the peripheral clock, in Hz.
- EPSEG1 is the value in CBT[EPSEG1] (CTRL1[PSEG1] can also be used).
- EPSEG2 is the value in CBT[EPSEG2] (CTRL1[PSEG2] can also be used).
- EPROPSEG is the value in CBT[EPROPSEG] (CTRL1[PROPSEG] can also be used).
- EPRESDIV is the value in CBT[EPRESDIV] (CTRL1[PRESDIV] can also be used).
- FPSEG1 is the value in FDCBT[FPSEG1].

- FPSEG2 is the value in FDCBT[FPSEG2].
- FPROPSEG is the value in FDCBT[FPROPSEG].
- FPRESDIV is the value in FDCBT[FPRESDIV].
- NTSEG1 is the value in ENCBT[NTSEG1].
- NTSEG2 is the value in ENCBT[NTSEG2].
- ENPRESDIV is the value in EPRS[ENPRESDIV].
- DTSEG1 is the value in EDCBT[DTSEG1].
- DTSEG2 is the value in EDCBT[DTSEG2].
- EDPRESDIV is the value in EPRS[EDPRESDIV].

If CTRL2[BTE] = 1, then:

$$BITRATE_N = \frac{f_{CANCLK}}{[1 + (NTSEG1 + 1) + (NTSEG2 + 1)] \times (ENPRESDIV + 1)}$$

Equation 12. Nominal baud rate when CTRL2[BTE] = 1

$$BITRATE_F = \frac{f_{CANCLK}}{[1 + (DTSEG1 + 1) + (DTSEG2 + 1)] \times (EDPRESDIV + 1)}$$

Equation 13. Fast baud rate when CTRL2[BTE] = 1

See also Protocol timing for more details.

48.3.12.10.1 TASD configuration examples

The following tables show the TASD value calculated for some configuration cases.

Case 1:

- Clock ratio = 2:1 (for example, peripheral clock 80 MHz and oscillator clock 40 MHz)
- Bit rate in arbitration phase = 1 Mbaud

Table 367. TASD values in Case 1

Number of message buffers	TASD value	Maximum bit rate in data phase (MBd)
16	24	Invalid
32	24	8.0

Case 2:

- Clock ratio = 1:1 (for example, peripheral clock 40 MHz and oscillator clock 40 MHz)
- Bit rate in arbitration phase = 1 Mbaud

Table 368. TASD values in Case 2

Number of message buffers	TASD value	Maximum bit rate in data phase (MBd)
16	24	Invalid
32	23	6.67

Case 3:

- Clock ratio = 2:1 (for example, peripheral clock 40 MHz and oscillator clock 20 MHz)

- Bit rate in arbitration phase = 1 Mbaud

Table 369. TASD values in Case 3

Number of message buffers	TASD value	Maximum bit rate in data phase (MBd)
16	24	Invalid
32	23	4.0

48.3.13 Clocks

The following table describes the clock sources for FlexCAN. See the chip clocking chapter for clock setting, configuration, and gating information.

Table 370. FlexCAN clocks

Clock name	Description
MODULE_CLK (system_clk)	Peripheral clock
MODULE_CLK_CHI (host_clock)	Control Host Interface (CHI) clock
MODULE_CLK_PE (protocol_engine_clock)	Protocol Engine (PE) clock
MODULE_CLK_PE_NOGATE (protocol_engine_clock_nogate)	Protocol Engine clock (no gating)
MODULE_CLK_S (system_clock_nogate)	Peripheral access clock

48.3.13.1 Clock domains and restrictions

FlexCAN has two clock domains asynchronous to each other:

- The bus domain feeds the Control Host Interface (CHI) submodule.
- The oscillator domain feeds the CAN Protocol Engine (PE) submodule.

When the two domains are connected to clocks with different frequencies or phases, the frequency relationship between the two clock domains is restricted. In asynchronous operation, the bus domain clock frequency must always be greater than the oscillator domain clock frequency.

NOTE

Asynchronous operation with a 1:1 ratio between peripheral and oscillator clocks is not allowed.

When performing matching and arbitration, FlexCAN must scan the whole message buffer memory during the time slot of one CAN frame, comprised of a number of CAN bits. To provide sufficient time for the scan, observe the following requirements:

- The peripheral clock frequency cannot be less than the oscillator clock frequency.
- There must be a minimum number of peripheral clocks per CAN bit, as specified in Table 371.

Table 371. Minimum number of peripheral clocks per CAN bit for Classical CAN format

Number of message buffers	Value of MCR[RFEN]	Value of ERFCR[ERFEN]	Minimum number of peripheral clocks per CAN bit
16	0	0	16
32	0	0	16

Table continues on the next page...

Table 371. Minimum number of peripheral clocks per CAN bit for Classical CAN format (continued)

Number of message buffers	Value of MCR[RFEN]	Value of ERFCR[ERFEN]	Minimum number of peripheral clocks per CAN bit
16	1	0	16
32	1	0	17
16	0	1	16
32	0	1	19

For classical frame format, the minimum number of peripheral clocks per CAN bit specified in Table 371 determines the minimum peripheral clock frequency for a given number of message buffers and for an expected CAN bit rate. The CAN bit rate depends on the number of time quanta in a CAN bit. This number can be defined by adjusting one or more of the bit timing values contained in:

- Control 1 (CTRL1)
- CAN Bit Timing (CBT)
- Enhanced Nominal CAN Bit Timing (ENCBT)

The time quantum (Tq) is defined in Protocol timing. The minimum number of time quanta per CAN bit must be eight, so the oscillator clock frequency should be at least eight times the CAN bit rate.

48.3.13.1.1 Clock restrictions for CAN FD

For CAN FD frame format, some constraints must be satisfied. The equation below calculates the number of peripheral clocks per CAN bit in nominal bit rate (NumClkNomBit).

$$NumClkNomBit = \frac{f_{SYS}}{f_{CANCLK}} \times (PRESDIV + 1) \times (PROPSEG + PSEG1 + PSEG2 + 4)$$

$$= \frac{f_{SYS}}{NomBitRate}$$

Equation 14. Number of peripheral clocks per nominal CAN bit

Where PRESDIV, PSEG1, and PSEG2 are CAN bit time values in Control 1 (CTRL1). Alternatively, EPRESDIV, EPSEG1, and EPSEG2 values in CAN Bit Timing (CBT) or the values of EPRS[ENPRESDIV], ENCBT[NTSEG1], and ENCBT[NTSEG2] can be used instead. NumClkNomBit can also be calculated as a function of the expected nominal bit rate used in the arbitration phase (NomBitRate), as shown in the equation above.

The number of CAN bits in the data phase of an FD frame with BRS = 1 (fast CAN bits) depends on the number of data bytes in the payload. The number of fast CAN bits (NumOfFastBits) can be determined in Table 372. Having fewer data bytes means having fewer fast CAN bits. It also means that less time is available for FlexCAN to scan the whole message buffer memory during the internal matching and arbitration processes.

Table 372. Number of fast CAN bits in a CAN FD frame

Minimum number of data bytes	DLC field	NumOfFastBits
0	0h	21
1	1h	29
2	2h	37
3	3h	45
4	4h	53

Table continues on the next page...

Table 372. Number of fast CAN bits in a CAN FD frame (continued)

Minimum number of data bytes	DLC field	NumOfFastBits
5	5h	61
6	6h	69
7	7h	77
8	8h	85
12	9h	117
16	Ah	149
20	Bh	186
24	Ch	218
32	Dh	282
48	Eh	410
64	Fh	538

The critical part of a CAN FD frame is during the data phase, where the CAN bit rate is faster than in the arbitration phase. The minimum number of peripheral clocks per fast CAN bit (MinNumClkFastBit) can be calculated to guarantee that enough time is available for FlexCAN to scan the message buffer memory during reception and transmission. The equation below calculates this constraint.

$$MinNumClkFastBit_A = \frac{(8.5 \times MaxNumOfMb) + [ERFEN \times (2 \times NFE + 4)] + 64 - (9 \times NumClkNomBit)}{NumOfFastBits}$$

Equation 15. Minimum number of peripheral clocks per fast CAN bit for FlexCAN scan process

Where MaxNumOfMb is the maximum number of available message buffers defined in MCR[MAXMB]. NFE and ERFEN are the fields defined in Enhanced RX FIFO Control (ERFCR).

The clock-domain-crossing circuit between the CHI and PE subblocks also imposes a minimum number of peripheral clocks per fast CAN bit. This minimum is required for the handshake mechanism to work properly without losing status information through the interface, as shown in the equation below.

$$MinNumClkFastBit_B = 3 \times \left(1 + \frac{f_{SYS}}{f_{CANCLK}}\right)$$

Equation 16. Minimum number of peripheral clocks per fast CAN bit for FlexCAN clock domain interface

Therefore, the larger of the two values calculated above determines the minimum number of peripheral clocks per fast CAN bit (MinNumClkFastBit).

$$MinNumClkFastBit = Maximum\ (MinNumClkFastBitA, MinNumClkFastBitB)$$

Equation 17. Minimum number of peripheral clocks per fast CAN bit

Then, the maximum CAN bit rate in the data phase of CAN FD frames (DataBitRateMAX) can be calculated as below.

$$DataBitrate_{MAX} = \frac{f_{CANCLK}}{ROUNDUP\left(\frac{MinNumClkFastBit \times f_{CANCLK}}{f_{SYS}}\right)}$$

Equation 18. Maximum achievable baud rate for data phase

These factors affect the maximum data bit rate attainable by FlexCAN in CAN FD mode:

- The peripheral and oscillator clock frequencies
- The maximum number of message buffers
- The expected nominal bit rate

Also, the data bit rate depends on the minimum payload size of FD frames used in a given application.

To illustrate how the configuration of FlexCAN variables affects the CAN FD bit rate, consider this application example:

- The peripheral clock frequency is set to 50 MHz
- The oscillator clock frequency is set to 40 MHz

1. Considering the nominal bit rate as 1 Mbit/s, the number of peripheral clocks per CAN bit in nominal bit rate is calculated as below.

$$NumClkNomBit = \frac{50 \times 10^6}{1 \times 10^6} = 50$$

Equation 19. Calculation example for number of peripheral clocks per nominal CAN bit

2. The number of fast CAN bits (NumOfFastBits) is determined in Table 372. For example, if the minimum payload in FD frames is 8 bytes, there are 85 CAN bits in the data phase.
3. Assuming the maximum number of message buffers is 96, and Enhanced RX FIFO is disabled, the minimum number of peripheral clocks per fast CAN bit (MinNumClkFastBit) can be calculated.

$$MinNumClkFastBit_A = \frac{(8.5 \times 96) + 64 - (9 \times 50)}{85} = 5.06$$

Equation 20. Calculation example for number of peripheral clocks per fast CAN bit for FlexCAN scan process

$$MinNumClkFastBit_B = 3 \times \left(1 + \frac{50}{40}\right) = 6.75$$

Equation 21. Calculation example for number of peripheral clocks per fast CAN bit for FlexCAN clock domain interface

$$MinNumClkFastBit = Maximum\ (\ 5.06, 6.75\ ) = 6.75$$

Equation 22. Calculation example for number of peripheral clocks per fast CAN bit

4. The maximum CAN bit rate in the data phase can finally be found.

$$DataBitRate_{MAX} = \frac{40 \times 10^6}{ROUNDUP\left(\frac{6.75 \times 40 \times 10^6}{50 \times 10^6}\right)} = 6.667\ Mbps$$

Equation 23. Calculation example for maximum achievable baud rate

Even though the oscillator clock frequency (40 MHz) is adequate to generate a data rate of 8 Mbit/s in CAN FD mode, the specific FlexCAN configuration limits this rate to 6.667 Mbit/s. This limitation is mainly due to the low peripheral clock frequency that imposes the MinNumClkFastBitB bound.

Table 373 shows the maximum data rate for CAN FD with Enhanced RX FIFO disabled according to clock frequencies, payload size, and number of available message buffers. For some cases, if the number of available message buffers is reduced, FlexCAN can then achieve a data rate up to 8 Mbit/s.

Table 373. Maximum CAN bit rate in data phase on CAN FD frames with Enhanced RX FIFO disabled

Peripheral clock frequency (MHz)	Minimum payload size	Number of available message buffers	Maximum data rate (Mbit/s)
40	8	94	6.667
40	8	114	>5.0
40	12	>117	6.667
40	12	128	5.714
50	12–64	128	6.667
60	8	126	8.0
60	12	128	8.0
67	6	128	8.0
80	3	128	8.0
100	0	128	8.0

48.3.14 Reset

You can reset FlexCAN in the following ways:

- Soft reset:
  - MCR[SOFTRST], which resets some of the memory-mapped registers synchronously. To see which registers soft reset affects, see Table 376.
  - The chip level soft reset input is not supported, use the MCR[SOFTRST] to trigger a soft reset.

Soft reset is synchronous and must follow an internal request-and-acknowledge procedure across clock domains. Therefore, it may take some time to propagate its effects fully. MCR[SOFTRST] remains 1 when soft reset is pending, so software can poll this field to identify when the reset has completed. Soft reset cannot be applied when clocks are shut down in a low-power mode. The low-power mode should be exited and the clocks resumed before applying soft reset.

When the module is enabled (MCR[MDIS] becomes 0), FlexCAN automatically enters Freeze mode. In Freeze mode:

1. FlexCAN is unsynchronized to the CAN bus.
2. MCR[HALT] and MCR[FRZ] become 1.
3. The internal state machines are disabled.
4. MCR[FRZACK] and MCR[NOTRDY] become 1.

The TX pin is in the recessive state and FlexCAN does not initiate any transmission or reception of CAN frames. Reset does not affect the message buffers and the RX Individual Mask registers, so they are not automatically initialized.

48.3.15 Interrupts

FlexCAN has many interrupt sources:

- Interrupts due to message buffers

- Interrupts due to interrupts combined via an OR operator from:
  - Message buffers
  - Bus Off
  - Bus Off Done
  - Error
  - Error Fast (errors detected in the data phase of CAN FD format messages with BRS = 1)
  - Wake Up
  - Wake Up Match
  - Wake Up Timeout
  - TX Warning
  - RX Warning

If its corresponding IMASK bit is 1, each message buffer can be an interrupt source. There is no distinction between TX and RX interrupts for a particular buffer, under the assumption that the buffer is initialized for either transmission or reception. Each buffer has an assigned flag bit in the IFLAG registers. When the corresponding buffer completes a successful transfer, the flag is set. When the CPU writes 1 to it, the flag is cleared (unless another interrupt is generated at the same time).

NOTE

The CPU must clear only the bit causing the current interrupt. For this reason, do not use bit manipulation instructions (BSET) to clear interrupt flags. These instructions may cause accidental clearing of interrupt flags which are set after entering the current interrupt handler.

If the Legacy RX FIFO is enabled (MCR[RFEN] = 1) and DMA is disabled (MCR[DMA] = 0), the interrupts corresponding to message buffers 0–7 have different meanings.

- Bit 7 of Interrupt Flags 1 (IFLAG1) becomes the Legacy FIFO Overflow flag
- Bit 6 becomes the Legacy FIFO Warning flag
- Bit 5 becomes the Frames Available in Legacy FIFO flag
- Bits 4–0 are unused.

See Interrupt Flags 1 (IFLAG1) for more information.

If both Legacy RX FIFO and DMA are enabled (MCR[RFEN] = 1 and MCR[DMA] = 1), FlexCAN does not generate any Legacy FIFO interrupt. Bit 5 of IFLAG1 still indicates Frames Available in Legacy FIFO and generates a DMA request. Bits 7, 6, and 4–0 are unused.

CAUTION

Legacy FIFO cannot be enabled when CAN FD is enabled.

When multiple message buffer interrupt sources are combined via an OR operator into a single interrupt, the interrupt is generated when any associated message buffer (or FIFO, if applicable) generates an interrupt. In this case, the CPU must read the IFLAG registers to determine which message buffer or FIFO source caused the interrupt.

These interrupt sources generate interrupts like the message buffer interrupt sources, and can be read from Error and Status 1 (ESR1):

- Bus Off
- Bus Off Done
- Error
- Error Fast
- Wake Up

- TX Warning
- RX Warning

The Bus Off, Error, TX Warning, and RX Warning interrupt masks are located in Control 1 (CTRL1); the wake-up interrupt mask is located in Module Configuration (MCR).

The interrupt sources for Pretended Networking (Wake-up by Match Flag and Wake-up by Timeout Flag) can be read in Pretended Networking Wake-Up Match (WU_MTC). The respective interrupt mask bits are located in Pretended Networking Control 1 (CTRL1_PN).

48.3.16 Bus interface

CPU access to FlexCAN registers is subject to the following rules:

- Read and write access to implemented reserved address space results in an access error.
- Write access to positions whose bits are all currently read-only results in an access error. If at least one of the bits is not read-only, no access error is issued. Write permission to specific positions or some of their bits can change depending on the mode of operation or transitory state. See register and field descriptions for details.
- Read and write access to unimplemented address space results in an access error.
- Read and write access to RAM-located positions during Low-Power mode results in an access error.
- The RXIMR memory region can be considered as general-purpose memory and available for access via these methods:
  - If you write 0 to MCR[IRMQ], the individual masks (RXIMR) are disabled. In this case, the RXIMR memory region is considered general-purpose memory.
  - If MCR[MAXMB] is programmed with a value smaller than the available number of message buffers, the unused memory space can be used as general-purpose RAM space. Reserved words within RAM cannot be used.
    For example, suppose the RAM in FlexCAN can support up to 16 message buffers, CTRL2[RFFN] = 0h, and MCR[MAXMB] = 0.
    - In this case, the maximum number of message buffers becomes one.
    - The RAM starts at 0080h, and the space 0080h–008Fh is used by the one message buffer.
    - The memory space 0090h–017Fh is available.
    - The space 0180h–087Fh is reserved.
    - The space 0880h–0883h is used by the one individual mask and the available memory in the mask register space is 0884h–08BFh.
    - In the space from 08C0h–09DFh, there are reserved words for internal use which cannot be used as general-purpose RAM.

    As a rule, free memory space for general purpose depends only on MCR[MAXMB].
  - If MCR[FDEN] = 1, general-purpose memory can be used only outside Freeze mode.

Table 374. Access permissions

Modes of operation	Normal	Freeze	Low-power
MCR	Bus error	Bus error	Bus error
CTRL1	Read and write	Read and write	Read and write
TIMER	Read and write	Read and write	Read and write
TCR	Bus error	Bus error	Bus error

Table continues on the next page...

Table 374. Access permissions (continued)

Modes of operation	Normal	Freeze	Low-power
RXMGMASK[1]	Bus error for write operation	Read and write	Bus error for write operation
RX14MASK[1]	Bus error for write operation	Read and write	Bus error for write operation
RX15MASK[1]	Bus error for write operation	Read and write	Bus error for write operation
ECR	Bus error for write operation	Read and write	Bus error for write operation
ESR1	Read and write	Read and write	Read and write
IMASK1	Read and write	Read and write	Read and write
IFLAG1	Read and write	Read and write	Read and write
CTRL2	Read and write	Read and write	Read and write
ESR2	Read and write	Read and write	Read and write
CRCR	Bus error for write operation	Bus error for write operation	Bus error for write operation
RXFGMASK[1]	Bus error for write operation	Read and write	Bus error for write operation
RXFIR[1]	Bus error for write operation	Bus error for write operation	Bus error for write operation
CBT	Bus error for write operation	Read and write	Bus error for write operation
DBG1	Bus error for write operation	Bus error for write operation	Bus error for write operation
DBG2	Bus error for write operation	Bus error for write operation	Bus error for write operation
MB[1] [2]	Read and write	Read and write	Read and write
Legacy FIFO header[1]	Read and write	Read and write	Read and write
Legacy FIFO reserved space[1]	Bus error	Bus error	Bus error
Legacy FIFO filters[1]	Read and write	Read and write	Read and write
RXIMR[1]	Bus error	Read and write	Bus error
CTRL1_PN	Read and write [3]	Read and write	Read and write [3]
CTRL2_PN	Read and write [3]	Read and write	Read and write [3]
WU_MTC	Read and write	Read and write	Read and write
FLT_ID1	Read and write [3]	Read and write	Read and write [3]
FLT_DLC	Read and write [3]	Read and write	Read and write [3]

Table continues on the next page...

Table 374. Access permissions (continued)

Modes of operation	Normal	Freeze	Low-power
PL1_LO	Read and write [3]	Read and write	Read and write [3]
PL1_HI	Read and write [3]	Read and write	Read and write [3]
FLT_ID2_IDMASK	Read and write [3]	Read and write	Read and write [3]
PL2_PLMASK_LO	Read and write [3]	Read and write	Read and write [3]
PL2_PLMASK_HI	Read and write [3]	Read and write	Read and write [3]
WMB0	Read and write [3]	Read and write [3]	Read and write [3]
WMB1	Read and write [3]	Read and write [3]	Read and write [3]
WMB2	Read and write [3]	Read and write [3]	Read and write [3]
WMB3	Read and write [3]	Read and write [3]	Read and write [3]
EPRS	Bus error for write operation	Read and write	Bus error for write operation
ENCBT	Bus error for write operation	Read and write	Bus error for write operation
EDCBT	Bus error for write operation	Read and write	Bus error for write operation
ETDC	Bus error for write operation	Read and write	Bus error for write operation
FDCTRL	Read and write	Read and write	Read and write
FDCBT	Centralize [3]	Read and write	Read and write [3]
FDCRC	Bus error for write operation	Bus error for write operation	Bus error for write operation
ERFCR	Centralize [3]	Read and write	Read and write [3]
ERFIER	Read and write	Read and write	Read and write
ERFSR	Read and write	Read and write	Read and write
HR_TIME_STAMP	Read and write	Read and write	Read and write
Enhanced Rx FIFO header[4]	Bus error for write operation	Bus error for write operation	Bus error for write operation
Enhanced Rx FIFO reserved space[4]	Bus error	Bus error	Bus error
ERFFEL	Bus error for write operation	Read and write	Bus error for write operation
General purpose RAM[1]	Read and write	Read and write	Read and write
Reserved space (used)[1]	Bus error	Bus error	Bus error
Reserved space (empty)[1]	Bus error	Bus error	Bus error

1. Access in low power is only possible if RAM_clk and MODULE_CLK are enabled.
2. If MCR[RFEN] = 1, see Legacy FIFO access rules below.
3. Write operation has no effect.

4. If MCR[RFEN] = 1, do not access Enhanced RX FIFO.

48.4 External signal descriptions

FlexCAN has two I/O signals connected to the external chip pins. These signals are summarized in Table 375 and described in the following subsections.

Table 375. FlexCAN signal descriptions

Signal	Description	I/O
CAN RX	CAN receive pin	Input
CAN TX	CAN transmit pin	Output

48.4.1 CAN RX

This pin is the receive pin from the CAN bus transceiver. Logic level 0 represents its dominant state. Logic level 1 represents its recessive state.

48.4.2 CAN TX

This pin is the transmit pin to the CAN bus transceiver. Logic level 0 represents its dominant state. Logic level 1 represents its recessive state.

48.5 Memory map and register definition

This section describes the registers and data structures in FlexCAN. The base address of the module depends on the particular memory map of the chip.

48.5.1 FlexCAN memory mapping

The address space occupied by FlexCAN has 128 bytes for registers starting at the module base address, followed by embedded RAM starting at address offset 0080h.

Each individual register is identified by its complete name and corresponding mnemonic.

NOTE

An invalid register access results in a bus error. Invalid accesses include reading a write-only register, writing a read-only register, and accessing an invalid address.

NOTE

To update the parity bits in memory properly, all FlexCAN memory must be initialized before reading registers which are implemented in memory. You must also initialize RX Message Buffers Global Mask (RXMGMASK), Receive 14 Mask (RX14MASK), Receive 15 Mask (RX15MASK) and Legacy RX FIFO Global Mask (RXFGMASK). MCR[RFEN] and ERFCR[ERFEN] must not be 1 during memory initialization.

Table 376. Register reset information

Register	Affected by soft reset
Module Configuration (MCR)	Yes
Control 1 (CTRL1)	No
Free-Running Timer (TIMER)	Yes

Table continues on the next page...

Table 376. Register reset information (continued)

Register	Affected by soft reset
RX Message buffers Global Mask (RXMGMASK)	No
RX Buffer 14 Mask (RX14MASK)	No
RX Buffer 15 Mask (RX15MASK)	No
Error Counter (ECR)	Yes
Error and Status 1 (ESR1)	Yes
Interrupt Masks 1 (IMASK1)	Yes
Interrupt Flags 1 (IFLAG1)	Yes
Control 2 (CTRL2)	No
Error and Status 2 (ESR2)	Yes
Cyclic Redundancy Check (CRCR)	Yes
RX FIFO Global Mask (RXFGMASK)	No
RX FIFO Information (RXFIR)	No
CAN Bit Timing (CBT)	No
Message buffers	No
RX Individual Masks	No
Pretended Networking Control 1 (CTRL1_PN)	Yes
Pretended Networking Control 2 (CTRL2_PN)	Yes
Pretended Networking Wake-Up Match (WU_MTC)	Yes
Pretended Networking ID Filter 1 (FLT_ID1)	Yes
Pretended Networking DLC Filter (FLT_DLC)	Yes
Pretended Networking Payload Low Filter 1 (PL1_LO)	Yes
Pretended Networking Payload High Filter 1 (PL1_HI)	Yes
Pretended Networking ID Filter 2 or ID Mask (FLT_ID2_IDMASK)	Yes
Pretended Networking Payload Low Filter 2 or Payload Low Mask (PL2_PLMASK_LO)	Yes
Pretended Networking Payload High Filter 2 or Payload High Mask (PL2_PLMASK_HI)	Yes

Table continues on the next page...

Table 376. Register reset information (continued)

Register	Affected by soft reset
Pretended Networking Wake Up Message Buffer 0 (WMB0)	No
Pretended Networking Wake Up Message Buffer 1 (WMB1)	No
Pretended Networking Wake-Up Message Buffer 2 (WMB2)	No
Pretended Networking Wake-Up Message Buffer 3 (WMB3)	No
Enhanced CAN Bit Timing Prescalers (EPRS)	No
Enhanced Nominal CAN Bit Timing (ENCBT)	No
Enhanced Data Phase CAN bit Timing (EDCBT)	No
Enhanced Transceiver Delay Compensation (ETDC)	No
CAN FD Control (FDCTRL)	No
CAN FD Bit Timing (FDCBT)	No
CAN FD CRC (FDCRC)	Yes
Enhanced RX FIFO Control (ERFCR)	Yes
Enhanced RX FIFO Interrupt Enable (ERFIER)	Yes
Enhanced RX FIFO Status (ERFSR)	Yes
High-Resolution Timestamp (HR_TIME_STAMP)	No
Enhanced RX FIFO	No
Enhanced RX FIFO Filter Element (ERFFEL)	No

FlexCAN can store CAN messages for transmission and reception using message buffers and RX FIFO structures.

48.5.2 FlexCAN register descriptions

The following table shows the FlexCAN memory map.

The address range from offset 80h–27Fh allocates the thirty-two 128-bit message buffers. The memory maps for the message buffers are in FlexCAN message buffer memory map.

The address range from offset 2000h–204Ch allocates the Enhanced RX FIFO output, and the address range from offset 2050h–23BCh allocates the rest of Enhanced RX FIFO 11 elements. The memory map for the Enhanced RX FIFO is in Enhanced RX FIFO structure.

48.5.2.1 FlexCAN memory map

CAN0 base address: 4003_B000h

CAN1 base address: 4004_F000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Module Configuration (MCR)	32	RW	D890_000Fh
4h	Control 1 (CTRL1)	32	RW	0000_0000h
8h	Free-Running Timer (TIMER)	32	RW	0000_0000h
10h	RX Message Buffers Global Mask (RXMGMASK)	32	RW	See section
14h	Receive 14 Mask (RX14MASK)	32	RW	See section
18h	Receive 15 Mask (RX15MASK)	32	RW	See section
1Ch	Error Counter (ECR)	32	RW	0000_0000h
20h	Error and Status 1 (ESR1)	32	RW	0000_0000h
28h	Interrupt Masks 1 (IMASK1)	32	RW	0000_0000h
30h	Interrupt Flags 1 (IFLAG1)	32	RW	0000_0000h
34h	Control 2 (CTRL2)	32	RW	00A0_0000h
38h	Error and Status 2 (ESR2)	32	R	0000_0000h
44h	Cyclic Redundancy Check (CRCR)	32	R	0000_0000h
48h	Legacy RX FIFO Global Mask (RXFGMASK)	32	RW	See section
4Ch	Legacy RX FIFO Information (RXFIR)	32	R	See section
50h	CAN Bit Timing (CBT)	32	RW	0000_0000h
880h - 8FCh	Receive Individual Mask (RXIMR0 - RXIMR31)	32	RW	See section
B00h	Pretended Networking Control 1 (CTRL1_PN)	32	RW	0000_0100h
B04h	Pretended Networking Control 2 (CTRL2_PN)	32	RW	0000_0000h
B08h	Pretended Networking Wake-Up Match (WU_MTC)	32	RW	0000_0000h
B0Ch	Pretended Networking ID Filter 1 (FLT_ID1)	32	RW	0000_0000h
B10h	Pretended Networking Data Length Code (DLC) Filter (FLT_DLC)	32	RW	0000_0008h
B14h	Pretended Networking Payload Low Filter 1 (PL1_LO)	32	RW	0000_0000h
B18h	Pretended Networking Payload High Filter 1 (PL1_HI)	32	RW	0000_0000h
B1Ch	Pretended Networking ID Filter 2 or ID Mask (FLT_ID2_IDMASK)	32	RW	0000_0000h
B20h	Pretended Networking Payload Low Filter 2 and Payload Low Mask (PL2_PLMASK_LO)	32	RW	0000_0000h
B24h	Pretended Networking Payload High Filter 2 and Payload High Mask (PL2_PLMASK_HI)	32	RW	0000_0000h
B40h	Wake-Up Message Buffer (WMB0_CS)	32	R	0000_0000h
B44h	Wake-Up Message Buffer for ID (WMB0_ID)	32	R	0000_0000h
B48h	Wake-Up Message Buffer for Data 0–3 (WMB0_D03)	32	R	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
B4Ch	Wake-Up Message Buffer Register Data 4–7 (WMB0_D47)	32	R	0000_0000h
B50h	Wake-Up Message Buffer (WMB1_CS)	32	R	0000_0000h
B54h	Wake-Up Message Buffer for ID (WMB1_ID)	32	R	0000_0000h
B58h	Wake-Up Message Buffer for Data 0–3 (WMB1_D03)	32	R	0000_0000h
B5Ch	Wake-Up Message Buffer Register Data 4–7 (WMB1_D47)	32	R	0000_0000h
B60h	Wake-Up Message Buffer (WMB2_CS)	32	R	0000_0000h
B64h	Wake-Up Message Buffer for ID (WMB2_ID)	32	R	0000_0000h
B68h	Wake-Up Message Buffer for Data 0–3 (WMB2_D03)	32	R	0000_0000h
B6Ch	Wake-Up Message Buffer Register Data 4–7 (WMB2_D47)	32	R	0000_0000h
B70h	Wake-Up Message Buffer (WMB3_CS)	32	R	0000_0000h
B74h	Wake-Up Message Buffer for ID (WMB3_ID)	32	R	0000_0000h
B78h	Wake-Up Message Buffer for Data 0–3 (WMB3_D03)	32	R	0000_0000h
B7Ch	Wake-Up Message Buffer Register Data 4–7 (WMB3_D47)	32	R	0000_0000h
BF0h	Enhanced CAN Bit Timing Prescalers (EPRS)	32	RW	0000_0000h
BF4h	Enhanced Nominal CAN Bit Timing (ENCBT)	32	RW	0000_0000h
BF8h	Enhanced Data Phase CAN Bit Timing (EDCBT)	32	RW	0000_0000h
BFCh	Enhanced Transceiver Delay Compensation (ETDC)	32	RW	0000_0000h
C00h	CAN FD Control (FDCTRL)	32	RW	8000_0100h
C04h	CAN FD Bit Timing (FDCBT)	32	RW	0000_0000h
C08h	CAN FD CRC (FDCRC)	32	R	0000_0000h
C0Ch	Enhanced RX FIFO Control (ERFCR)	32	RW	0000_0000h
C10h	Enhanced RX FIFO Interrupt Enable (ERFIER)	32	RW	0000_0000h
C14h	Enhanced RX FIFO Status (ERFSR)	32	RW	0000_0000h
C30h - CACh	High-Resolution Timestamp (HR_TIME_STAMP0 - HR_TIME_STAMP31)	32	RW	See section
3000h - 307Ch	Enhanced RX FIFO Filter Element (ERFFEL0 - ERFFEL31)	32	RW	See section

48.5.2.2 Module Configuration (MCR)

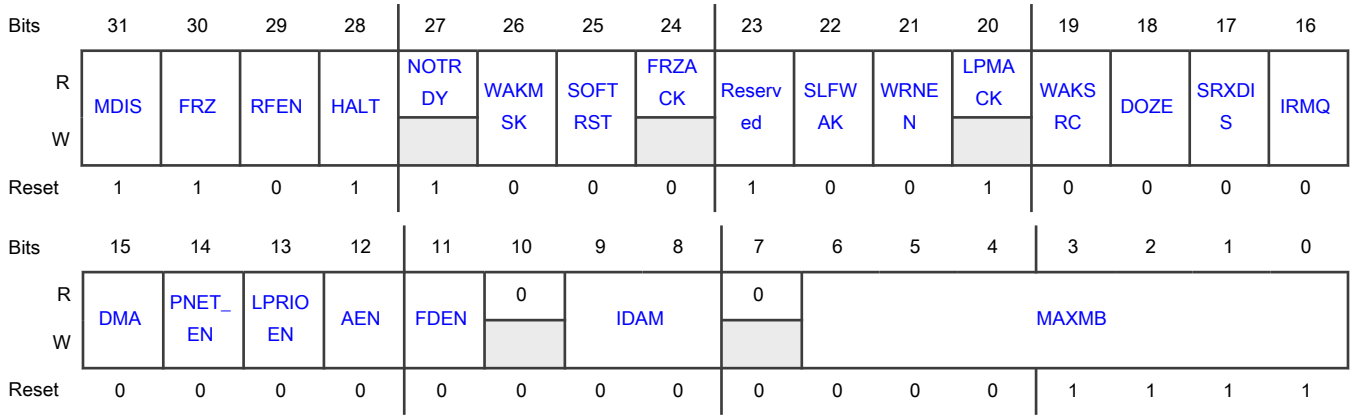
Offset

Register	Offset
MCR	0h

Function

Defines global system configurations, including the module operation modes and the maximum message buffer configuration.

Diagram



Fields

Field	Function
31 MDIS	Module Disable Disables FlexCAN. When disabled, FlexCAN disables the clocks to the CAN Protocol Engine and Controller Host Interface submodules. Soft reset does not affect this field. 0b - Enable 1b - Disable
30 FRZ	Freeze Enable Specifies FlexCAN behavior when MCR[HALT] = 1 or when Debug mode is requested at chip level. When this field becomes 1, FlexCAN can enter Freeze mode. Writing 0 to this field causes FlexCAN to exit from Freeze mode. 0b - Disable 1b - Enable
29 RFEN	Legacy RX FIFO Enable Enables the Legacy RX FIFO feature. When this field is 1, message buffers 0–5 cannot be used for normal reception and transmission. The corresponding memory region (80h–DCh) is used by the FIFO engine and additional message buffers (up to 32, depending on CTRL2[RFFN]). These message buffers are used as

Table continues on the next page...

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Field	Function
	Legacy RX FIFO ID filter table elements. This field also impacts the definition of the minimum number of peripheral clocks per CAN bit as described in Table 371. This field can be written in Freeze mode only; the module blocks it in other modes. **NOTE** When CAN FD operation is enabled (see MCR[FDEN]), you cannot write 1 to this field. **NOTE** This field must not be 1 if ERFCR[ERFEN] = 1. 0b - Disable 1b - Enable
28 HALT	Halt FlexCAN Puts FlexCAN into Freeze mode. The CPU should write 0 to this field after initializing the message buffers and Control 1 (CTRL1) and Control 2 (CTRL2). FlexCAN performs no reception or transmission before this field becomes 0. Freeze mode cannot be entered when FlexCAN is in a low-power mode. 0b - No request 1b - Enter Freeze mode, if MCR[FRZ] = 1.
27 NOTRDY	FlexCAN Not Ready Indicates whether FlexCAN is in Disable mode, Doze mode, Stop mode or Freeze mode. When FlexCAN has exited these modes, this field becomes 0. Soft reset does not affect this field. 0b - FlexCAN is in Normal mode, Listen-Only mode, or Loopback mode. 1b - FlexCAN is in Disable mode, Doze mode, Stop mode, or Freeze mode.
26 WAKMSK	Wake-up Interrupt Mask Enables the wake-up interrupt generation under the Self Wake-Up mechanism. 0b - Disabled 1b - Enabled
25 SOFTRST	Soft Reset Resets internal state machines of FlexCAN and some memory-mapped registers. The CPU can write 1 to this field directly. This field also becomes 1 when global soft reset is requested at the chip level. Because soft reset is synchronous and must follow a request-and-acknowledge procedure across clock domains, it may take some time to propagate its effect fully. When reset is pending, this field remains 1; it automatically becomes 0 when reset completes. You can poll this field to know when the soft reset has completed. Soft reset cannot be applied when clocks are shut down in a low-power mode. Transfer the module out of the low-power mode before applying soft reset. Soft reset does not affect this field. **NOTE** This field becomes 0 within 2 CAN bits after assertion of this bit.

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Field	Function
	0b - No reset 1b - Soft reset affects reset registers
24 FRZACK	Freeze Mode Acknowledge Indicates whether FlexCAN is in Freeze mode and its prescaler is stopped. The Freeze mode request cannot be granted until current transmission or reception processes have finished. Therefore, you can poll this field to know when FlexCAN has entered Freeze mode. If the Freeze mode request is negated, this field becomes 0 after the FlexCAN prescaler is running again. If Freeze mode is requested when FlexCAN is in a low-power mode, this field becomes 1 only when the low-power mode is exited. See Freeze mode. Soft reset does not affect this field. **NOTE** This field becomes 1 within 180 CAN bits if current transmission or reception is ongoing for classical frames and 730 CAN bits if current transmission or reception is ongoing for FD frames after the low-power mode requested by CPU. This field becomes 0 within 2 CAN bits after the Freeze mode request removal (see Protocol timing). 0b - Not in Freeze mode, prescaler running. 1b - In Freeze mode, prescaler stopped.
23 —	Reserved
22 SLFWAK	Self-Wake-Up Feature Enables the self-wake-up feature when FlexCAN is in a low-power mode other than Disable mode. When this feature is enabled, the FlexCAN module monitors the bus for a wake-up event (that is, a recessive-to-dominant transition). If a wake-up event is detected during Doze mode, FlexCAN requests to resume its clocks. If enabled to do so, it also generates a wake-up interrupt to the CPU. If a wake-up event is detected during Stop mode, FlexCAN generates, if enabled to do so, a wake-up interrupt to the CPU. The CPU can exit Stop mode globally and FlexCAN can request to resume the clocks. When FlexCAN is in a low-power mode other than Disable mode, this field cannot be written, as the module blocks it. When MCR[PNET_EN] = 1, this feature must be disabled. 0b - Disable 1b - Enable
21 WRNEN	Warning Interrupt Enable Enables the generation of the flags ESR1[TWRNINT] and ESR1[RWRNINT]. When this field is 1, TWRNINT and RWRNINT flags are set when the respective error counter transitions from less than 96 to greater than or equal to 96. When this field is 0, the TWRNINT and RWRNINT flags are always zero, independent of the values of the error counters. No warning interrupt is generated. This field can be written in Freeze mode only; the module blocks it in other modes.

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Field	Function
	0b - Disable 1b - Enable
20 LPMACK	Low-Power Mode Acknowledge Indicates whether FlexCAN is in a low-power mode (Disable mode, Doze mode, Stop mode). A low-power mode cannot be entered until all current transmission and reception processes have finished. The CPU can poll this field to know when FlexCAN has entered low-power mode. Soft reset does not affect this field. **NOTE** This field becomes 1 within 180 CAN bits if current transmission or reception is ongoing for classical frames and 730 CAN bits if current transmission or reception is ongoing for FD frames after the low-power mode requested by CPU. This field becomes 0 within 2 CAN bits after the low-power mode request removal (see Protocol timing). When FlexCAN is in Pretended Networking mode, this field becomes 0 within 180 CAN bits after the low-power mode request removal. 0b - Not in a low-power mode 1b - In a low-power mode
19 WAKSRC	Wake-Up Source Determines whether the integrated low-pass filter is applied to the RX input that FlexCAN uses to detect recessive-to-dominant edges on the CAN bus. This filter can protect the RX CAN input from spurious wake-up. This field can be written only in Freeze mode. The module blocks it in other modes. 0b - No filter applied 1b - Filter applied
18 DOZE	Doze Mode Enable Determines whether FlexCAN can enter low-power mode when Doze mode is requested at chip level. This field is automatically reset when FlexCAN wakes from Doze mode upon detecting activity on the CAN bus (self wake-up enabled). 0b - Disable 1b - Enable
17 SRXDIS	Self-Reception Disable Determines whether FlexCAN can receive frames transmitted by itself. If 1, frames transmitted by the module are not stored in any MB, regardless of whether the MB is programmed with an ID that matches the transmitted frame. No interrupt flag or interrupt signal is generated due to the frame reception. This field can be written only in Freeze mode; the module blocks it in other modes. 0b - Enable 1b - Disable
16 IRMQ	Individual RX Masking and Queue Enable

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Field	Function
	Indicates whether RX matching process is based on individual masking and queue, or based on a masking scheme with RX Message Buffers Global Mask (RXMGMASK), Receive 14 Mask (RX14MASK), Receive 15 Mask (RX15MASK), and Legacy RX FIFO Global Mask (RXFGMASK). When this field is disabled, for backward compatibility with legacy applications, reading the Control and Status word locks the MB even if it is empty. This field can be written in Freeze mode only. The module blocks it in other modes. 0b - Disable 1b - Enable
15 DMA	DMA Enable Enables DMA. The DMA feature can only be used in Legacy RX FIFO or Enhanced RX FIFO, so MCR[RFEN] or ERFCR[ERFEN] must be 1. When DMA and RFEN are 1, IFLAG1[BUF5I] generates the DMA request, and no RX FIFO interrupt is generated. This field can be written in Freeze mode only; the module blocks it in other modes. 0b - Disable 1b - Enable
14 PNET_EN	Pretended Networking Enable Enables Pretended Networking functionality. When in Doze mode or Stop mode, the PE subblock is kept operational. It can process RX message filtering as defined by the Pretended Networking configuration registers. See Receive process in Pretended Networking mode. This field can be written in Freeze mode only; the module blocks it in other modes. 0b - Disable 1b - Enable
13 LPRIOEN	Local Priority Enable Enables the local priority feature. It is used to expand the ID used during the arbitration process. With this expanded ID concept, the arbitration process is done based on the full 32-bit word. However, the actual transmitted ID is 11 bits for standard frames and 29 bits for extended frames. This field can be written only in Freeze mode; the module blocks it in other modes. This bit is provided for backward compatibility with legacy applications. 0b - Disable 1b - Enable
12 AEN	Abort Enable Enables the TX abort mechanism. This mechanism guarantees a safe procedure for aborting a pending transmission, so that no frame is sent in the CAN bus without notification. This field can be written only in Freeze mode; the module blocks it in other modes.

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Field	Function
	NOTE When this field is 1, only use the abort mechanism (see Transmission abort mechanism) to update message buffers configured for transmission. **CAUTION** Writing the abort code into RX message buffers can cause unpredictable results when this field is 1. 0b - Disabled 1b - Enabled
11 FDEN	CAN FD Operation Enable Enables the CAN with flexible data rate (CAN FD) operation. This field can be written in Freeze mode only. FlexCAN can receive and transmit messages in CAN 2.0 format. If this field is enabled, FlexCAN can also receive and transmit messages in CAN FD format. FlexCAN can transmit FD frame format according to ISO 11898-1:2015. **NOTE** If the value of this field is 1, the Legacy RX FIFO Enable (MCR[RFEN]) field cannot be 1. 0b - Disable 1b - Enable
10 —	Reserved
9-8 IDAM	ID Acceptance Mode Identifies the format of the Legacy RX FIFO ID filter table elements. This field configures all elements of the table at the same time; they are all the same format. See Legacy RX FIFO structure. This field can be written only in Freeze mode; the module blocks it in other modes. 00b - Format A: One full ID (standard and extended) per ID filter table element. 01b - Format B: Two full standard IDs or two partial 14-bit (standard and extended) IDs per ID filter table element. 10b - Format C: Four partial 8-bit standard IDs per ID filter table element. 11b - Format D: All frames rejected.
7 —	Reserved
6-0 MAXMB	Number of the Last Message Buffer Defines the number of the last message buffer that takes part in the matching and arbitration processes. The reset value (0Fh) is equivalent to a 16-MB configuration. This field can be written only in Freeze mode; the module blocks it in other modes.

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Field	Function
	NOTE You must write a value smaller than or equal to the number of available message buffers to this field, as described in FlexCAN memory partition for CAN FD. Additionally, the MAXMB value must consider the region of message buffers occupied by Legacy RX FIFO and its ID filters table space defined by CTRL2[RFFN]. MAXMB also impacts the definition of the minimum number of peripheral clocks per CAN bit, as described in Table 371.

48.5.2.3 Control 1 (CTRL1)

Offset

Register	Offset
CTRL1	4h

Function

Contains specific FlexCAN control features related to the CAN bus. These features include bit rate, programmable sampling point within an RX bit, Loopback mode, Listen-Only mode, Bus Off recovery behavior, and interrupt enabling (Bus-Off, Error, Warning). It also determines the division factor for the clock prescaler.

The CAN bit timing variables (CTRL1[PRESDIV], CTRL1[PROPSEG], CTRL1[PSEG1], CTRL1[PSEG2], and CTRL1[RJW]) can also be configured in CAN Bit Timing (CBT), which extends the range of all these variables. If CBT[BTF] = 1, CTRL1[PRESDIV], CTRL1[PROPSEG], CTRL1[PSEG1], CTRL1[PSEG2], and CTRL1[RJW] become read-only.

If CTRL2[BTE] = 1, CTRL1[PRESDIV], CTRL1[PROPSEG], CTRL1[PSEG1], CTRL1[PSEG2], and CTRL1[RJW] are not used by the module. Instead, these fields are read as zero, and a write operation to them has no effect.

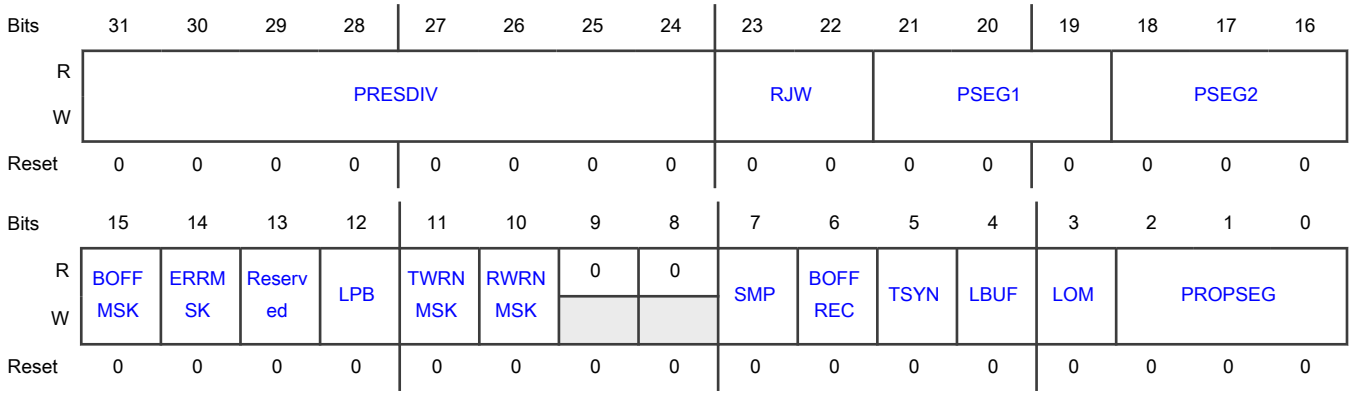
NOTE

When the CAN FD feature is enabled, do not use CTRL1[PRESDIV], CTRL1[PROPSEG], CTRL1[PSEG1], CTRL1[PSEG2], and CTRL1[RJW] for CAN bit timing. Instead use CBT[EPRESDIV], CBT[ERJW], CBT[EPSEG1], CBT[EPSEG2], and CBT[EPROPSEG].

The CAN bit variables in CTRL1 and in CBT are stored in the same internal register.

Soft reset does not affect the contents of this register.

Diagram



Fields

Field	Function
31-24 PRESDIV	Prescaler Division Factor Determines the ratio between the PE clock frequency and the serial clock (Sclock) frequency. The Sclock period defines the time quantum of the CAN protocol. For the reset value, the Sclock frequency is equal to the PE clock frequency. The maximum value of this field is FFh, which gives a minimum Sclock frequency equal to the PE clock frequency divided by 256. See Protocol timing for more information. This field can be written only in Freeze mode; the module blocks it in other modes. Sclock frequency = PE clock frequency ÷ (PRESDIV + 1).
23-22 RJW	Resync Jump Width Defines the maximum number of time quanta that one resynchronization can change a bit time. One time quantum is equal to one Sclock period. The valid programmable values are 0–3. See Protocol timing for more information. This field can be written only in Freeze mode; the module blocks it in other modes. Resync Jump Width = RJW + 1.
21-19 PSEG1	Phase Segment 1 Defines the length of phase segment 1 in the bit time. The valid programmable values are 0–7. See Protocol timing for more information. This field can be written only in Freeze mode; the module blocks it in other modes. Phase Buffer Segment 1 = (PSEG1 + 1) × Time Quanta.
18-16 PSEG2	Phase Segment 2 Defines the length of phase segment 2 in the bit time. The valid programmable values are 1–7. See Protocol timing for more information. This field can be written only in Freeze mode; the module blocks it in other modes. Phase Buffer Segment 2 = (PSEG2 + 1) × Time Quanta.
15 BOFFMSK	Bus Off Interrupt Mask Provides a mask for the Bus Off interrupt ESR1[BOFFINT]. 0b - Interrupt disabled

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Field	Function
	1b - Interrupt enabled
14 ERRMSK	Error Interrupt Mask Provides a mask for the Error interrupt ESR1[ERRINT]. 0b - Interrupt disabled 1b - Interrupt enabled
13 —	Reserved **NOTE** Writeable only if the module is disabled. Otherwise the access type is read-only.
12 LPB	Loopback Mode Configures FlexCAN to operate in Loopback mode. In this mode, FlexCAN performs an internal loopback that can be used for self-test operation. The bit stream output of the transmitter is fed back internally to the receiver input. The RX CAN input pin is ignored and the TX CAN output goes to the recessive state (logic 1). FlexCAN behaves as it normally does when transmitting, and treats its own transmitted message as a message received from a remote node. In this mode, FlexCAN ignores the bit sent during the ACK slot in the CAN frame acknowledge field. It generates an internal acknowledge bit to ensure proper reception of its own message. Both transmit and receive interrupts are generated. This field can be written only in Freeze mode; the module blocks it in other modes. **NOTE** In this mode, MCR[SRXDIS] cannot become 1, because it would impede the self-reception of a transmitted message. **NOTE** FDCTRL[TDCEN] and MCR[ETDCEN] must be 0 when this field is 1. 0b - Disabled 1b - Enabled
11 TWRNMSK	TX Warning Interrupt Mask Provides a mask for the TX Warning interrupt associated with the ESR1[TWRNINT] flag. When MCR[WRNEN] = 0, this field is read as 0. This field can be written only if MCR[WRNEN] = 1. 0b - Disabled 1b - Enabled
10 RWRNMSK	RX Warning Interrupt Mask Provides a mask for the RX Warning interrupt associated with the ESR1[RWRNINT] flag. When MCR[WRNEN] = 0, this field is read as 0. This field can be written only if MCR[WRNEN] = 1. 0b - Disabled

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Field	Function
	1b - Enabled
9 —	Reserved
8 —	Reserved
7 SMP	CAN Bit Sampling Determines the sampling mode of CAN bits at the RX input. This field can be written in Freeze mode only; the module blocks it in other modes. **NOTE** For proper operation, to write 1 to this field, you must guarantee a minimum value of two time quanta in CTRL1[PSEG1] (or CBT[EPSEG1]).This bit cannot become 1 when CAN FD is enabled (MCR[FDEN] = 1). 0b - One sample is used to determine the bit value. 1b - Three samples are used to determine the value of the received bit: the regular one (sample point) and two preceding samples. A majority rule is used.
6 BOFFREC	Bus Off Recovery Determines how FlexCAN recovers from Bus Off state. If 0, automatic recovering from Bus Off state occurs according to the CAN Specification 2.0B. If 1, automatic recovering from Bus Off is disabled. The module remains in Bus Off state until you write 1 to this field. If this field becomes 0 before 128 sequences of 11 recessive bits are detected on the CAN bus, Bus Off recovery happens as if this field had never become 1. If this field becomes 0 after 128 sequences of 11 recessive bits occurred, FlexCAN resynchronizes to the bus. It waits for 11 recessive bits before joining the bus. After this field becomes 0, it can become 1 again during Bus Off, but it will only be effective the next time the module enters Bus Off. If this field becomes 0 when the module is in Bus Off, writing 1 to this field is not effective for the current Bus Off recovery. **NOTE** See Bus Off in the CAN protocol standard ISO 11898-1:2015 for details. 0b - Enabled 1b - Disabled
5 TSYN	Timer Sync Enables a mechanism that resets the free-running timer each time a message is received in message buffer 0. This feature provides the means to synchronize multiple FlexCAN stations with a special "SYNC" message (that is, global network time). If MCR[RFEN] = 1 (Legacy RX FIFO enabled), the first available message buffer, according to CTRL2[RFFN], is used for timer synchronization instead of MB0. This field can be written in Freeze mode only; the module blocks it in other modes.

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Field	Function
	0b - Disable 1b - Enable
4 LBUF	Lowest Buffer Transmitted First Determines the ordering mechanism for message buffer transmission. When 1, MCR[LPRIOEN] does not affect the priority arbitration. This field can be written in Freeze mode only; the module blocks it in other modes. 0b - Buffer with highest priority is transmitted first. 1b - Lowest number buffer is transmitted first.
3 LOM	Listen-Only Mode Configures FlexCAN to operate in Listen-Only mode. In this mode, transmission is disabled, all error counters described in Error Counter (ECR) are frozen, and the module operates in CAN Error Passive mode. Only messages acknowledged by another CAN station are received. If FlexCAN detects an unacknowledged message, it flags a BIT0 error without changing the receive error counter (ECR[RXERRCNT]), as if it is trying to acknowledge the message. FlexCAN acknowledges Listen-Only mode when ESR1[FLTCONF] = 1, indicating the Error Passive state. There can be some delay between the Listen-Only mode request and its acknowledgment. This field can be written in Freeze mode only; the module blocks it in other modes. 0b - Listen-Only mode is deactivated. 1b - FlexCAN module operates in Listen-Only mode.
2-0 PROPSEG	Propagation Segment Defines the length of the propagation segment in the bit time. The valid programmable values are 0–7. This field can be written only in Freeze mode; the module blocks it in other modes. Propagation segment time = (PROPSEG + 1) × Time Quanta. One Time Quantum = one Sclock period.

48.5.2.4 Free-Running Timer (TIMER)

Offset

Register	Offset
TIMER	8h

Function

Represents a 16-bit free-running counter that the CPU can read and write. The timer starts from 0h after reset, counts linearly to FFFFh, and wraps around.

When CTRL2[TIMER_SRC] = 1, an external time tick continuously increments the timer. The time tick must be synchronous to the peripheral clock, with a minimum pulse width of one clock cycle.

When CTRL2[TIMER_SRC] = 0, the CAN bit clock increments the timer, which defines the baud rate on the CAN bus. During a message transmission or reception, it increments by one for each bit that is received or transmitted. When there is no message on the bus, it counts using the previously programmed baud rate. The timer is not incremented during Disable, Doze, Stop, Pretended Networking, and Freeze modes.

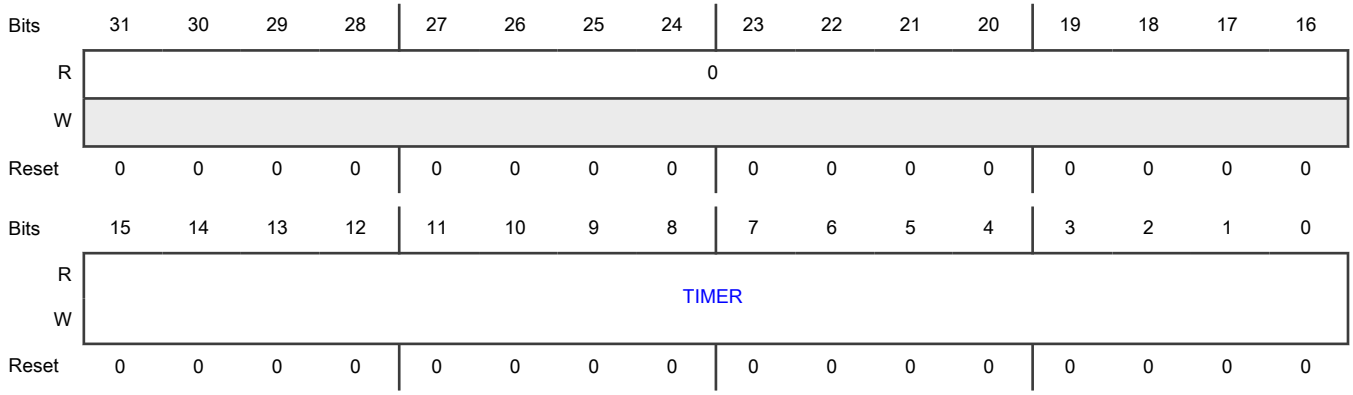
The timer value is captured when the second bit of the identifier field of any frame is on the CAN bus. This captured value is written into the timestamp entry in a message buffer after a successful reception or transmission of a message.

If CTRL1[TSYN] = 1, the timer is reset whenever a message is received in the first available message buffer, according to CTRL2[RFFN].

The CPU can write to this register anytime. However, if the write occurs simultaneously with the timer being reset by a reception in the first message buffer, the write value is discarded.

Reading this register affects the message buffer unlocking procedure (see Message buffer lock mechanism).

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 TIMER	Timer Value Contains the free-running counter value.

48.5.2.5 RX Message Buffers Global Mask (RXMGMASK)

Offset

Register	Offset
RXMGMASK	10h

Function

Masks the filter bits of all RX message buffers, excluding MB14 and MB15, which have individual mask registers.

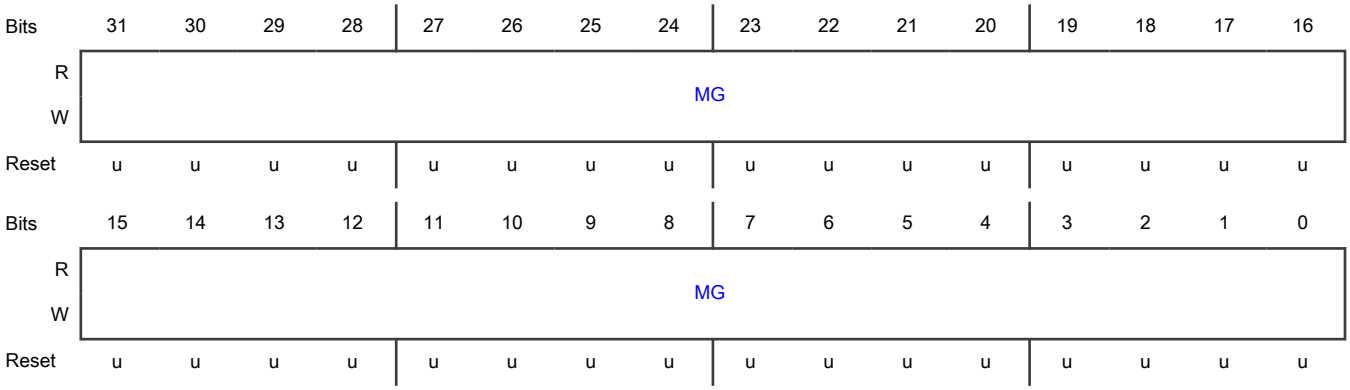
This register is located in RAM.

RXMGMASK is provided for legacy application support.

- When MCR[IRMQ] is 0, RXMGMASK is always in effect. The bits in RXMGMASK[MG] mask the MB filter bits.
- When MCR[IRMQ] is 1, RXMGMASK has no effect. The bits in RXMGMASK[MG] do not mask the MB filter bits.

This register can only be written in Freeze mode; the module blocks it in other modes.

Diagram



Fields

Field	Function
31-0 MG	Global Mask for RX Message Buffers Masks the message buffer filter bits. The alignment with the ID word of the message buffer is imperfect. The two most significant MG bits affect the fields RTR and IDE, which are located in the Control and Status word of the MB. The following table shows which MG bits mask each MB filter field.

SMB[RTR] [1]	CTRL2[RRS]	CTRL2[EACEN]	Message buffer filter fields			
			MB[RTR]	MB[IDE]	MB[ID]	Reserved
0	-	0	Note [2]	Note [3]	MG[28:0]	MG[31:29]
0	-	1	MG[31]	MG[30]	MG[28:0]	MG[29]
1	0	-	-	-	-	MG[31:0]
1	1	0	-	-	MG[28:0]	MG[31:29]
1	1	1	MG[31]	MG[30]	MG[28:0]	MG[29]

1. RTR bit of the incoming frame. It is saved into an auxiliary MB called RX serial message buffer (RX SMB).
2. If CTRL2[EACEN] is 0, the RTR bit of MB is never compared with the RTR bit of the incoming frame.
3. If CTRL2[EACEN] is 0, the IDE bit of MB is always compared with the IDE bit of the incoming frame.

0b - The corresponding bit in the filter is "don't care."

1b - The corresponding bit in the filter is checked.

48.5.2.6 Receive 14 Mask (RX14MASK)

Offset

Register	Offset
RX14MASK	14h

Function

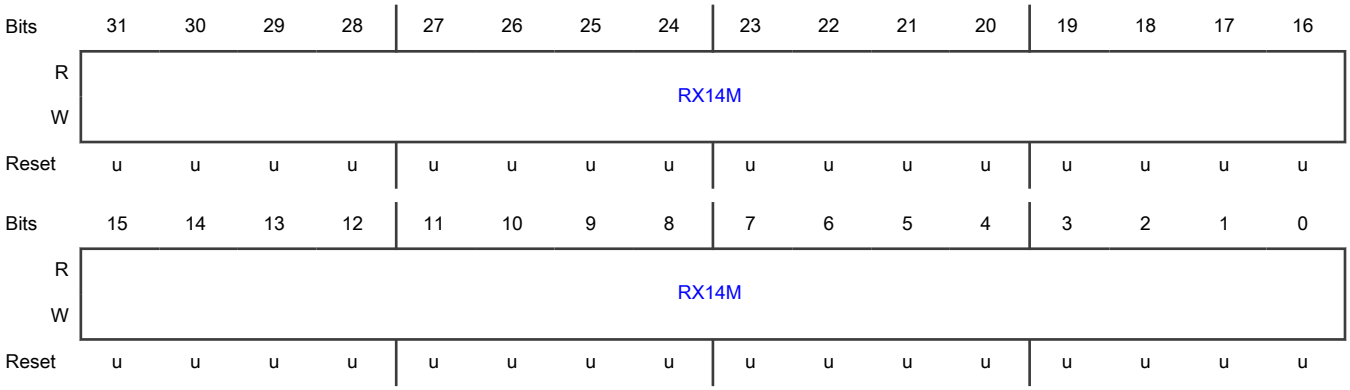
Masks the filter fields of MB14.

This register is located in RAM.

RX14MASK is provided for legacy application support. When MCR[IRMQ] = 1, RX14MASK has no effect.

This register can only be programmed when the module is in Freeze mode; the module blocks it in other modes.

Diagram



Fields

Field	Function
31-0 RX14M	RX Buffer 14 Mask Bits Masks the corresponding MB14 filter field in the same way that RX Message Buffers Global Mask (RXMGMASK) masks the filters of the other message buffers. 0b - The corresponding bit in the filter is "don't care." 1b - The corresponding bit in the filter is checked.

48.5.2.7 Receive 15 Mask (RX15MASK)

Offset

Register	Offset
RX15MASK	18h

Function

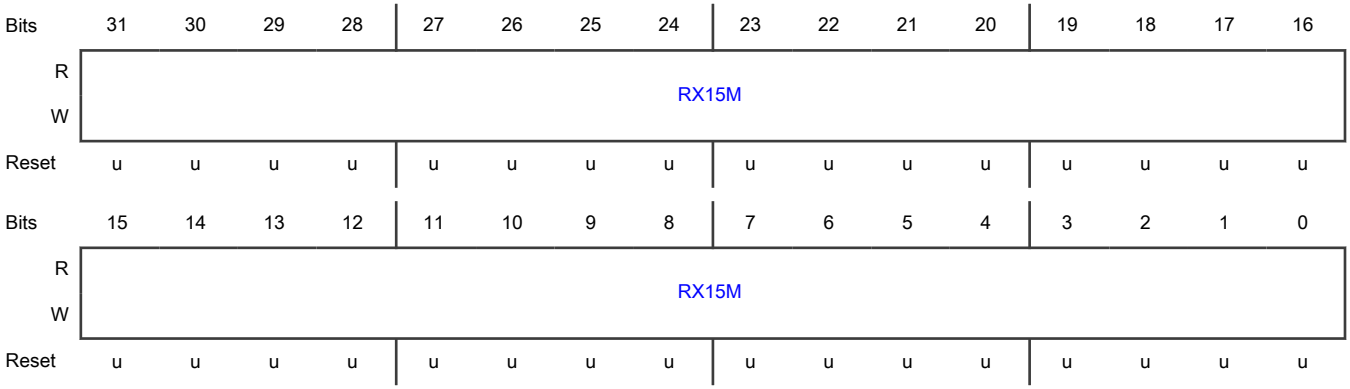
Masks the filter fields of MB15.

This register is located in RAM.

RX15MASK is provided for legacy application support. When MCR[IRMQ] = 1, RX15MASK has no effect.

This register can be programmed only when the module is in Freeze mode; the module blocks it in other modes.

Diagram



Fields

Field	Function
31-0 RX15M	RX Buffer 15 Mask Bits Masks the corresponding MB15 filter field in the same way that RX Message Buffers Global Mask (RXMGMASK) masks the filters of other message buffers. 0b - The corresponding bit in the filter is "don't care." 1b - The corresponding bit in the filter is checked.

48.5.2.8 Error Counter (ECR)

Offset

Register	Offset
ECR	1Ch

Function

Contains error counters for received and transmitted messages.

TXERRCNT and RXERRCNT consider all errors in both CAN FD and non-FD message formats. TXERRCNT_FAST and RXERRCNT_FAST count only the errors that occur in the data phase of CAN FD frames that have BRS = 1.

The Fault Confinement state (ESR1[FLTCONF]) is updated based on TXERRCNT and RXERRCNT counters only. The rules for increasing and decreasing these counters are described in the CAN protocol and are entirely implemented in FlexCAN.

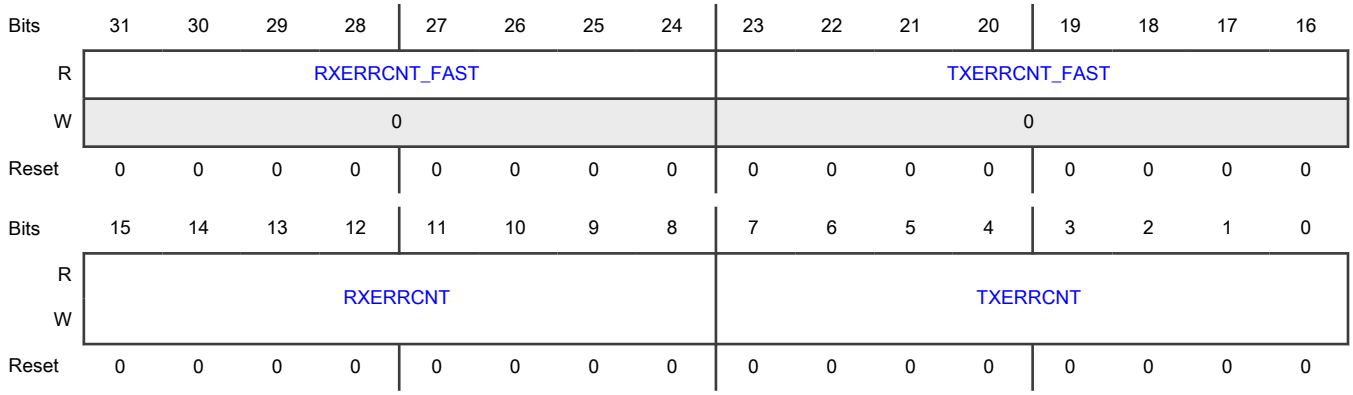
The basic rules for FlexCAN bus state transitions are:

- If the value of TXERRCNT or RXERRCNT becomes greater than or equal to 128, ESR1[FLTCONF] is updated to reflect Error Passive state.
- If the state of FlexCAN is Error Passive, and TXERRCNT or RXERRCNT decrements to a value less than 128 when the other already satisfies this condition, ESR1[FLTCONF] is updated to reflect Error Active state.
- If the value of TXERRCNT becomes greater than 255, ESR1[FLTCONF] is updated to reflect Bus Off state, and an interrupt may be issued. The value of TXERRCNT is then reset to zero.
- If FlexCAN is in Bus Off, TXERRCNT is cascaded with another internal counter to count the occurrences of 11 consecutive recessive bits on the bus. TXERRCNT is reset to zero. It counts in a manner where the internal counter counts 11 such bits and then wraps around when incrementing the TXERRCNT. When TXERRCNT reaches the value of 128, ESR1[FLTCONF] is updated to Error Active, and both error counters are reset to zero. Upon any instance of a dominant bit following a stream of less than 11 consecutive recessive bits, the internal counter resets itself to zero without affecting the TXERRCNT value. The TXERRCNT_FAST counter is frozen during Bus Off.
- If only one node is operating during system startup, its TXERRCNT increases upon each attempted message transmission, as a result of acknowledge errors (indicated by ESR1[ACKERR]). After the transition to Error Passive state, TXERRCNT no longer increments upon acknowledge errors. The chip never goes into the Bus Off state.
- If RXERRCNT increases to a value greater than 127, it is not incremented further, even if more errors are detected when being a receiver. At the next successful message reception, the counter is set to a value between 119 and 127 to return to the Error Active state.
- TXERRCNT_FAST and RXERRCNT_FAST error counter values increment and decrement based on errors detected only in the data phase of CAN FD frames that have BRS = 1. These counters follow the same increment and decrement rules as TXERRCNT and RXERRCNT. These counters do not wrap around and get stuck at their maximum value (255). They stop counting and keep their values frozen when FlexCAN is in the Bus Off state. They are reset when FlexCAN leaves the Bus Off state and resume counting after FlexCAN returns to the Error Active state.
- When FlexCAN is in Pretended Networking mode, RXERRCNT and RXERRCNT_FAST keep counting errors, and error flags are stored. TXERRCNT and TXERRCNT_FAST preserve their values and do not change, because no transmission occurs in Pretended Networking mode. Error counters and error flags that changed values in Pretended Networking mode are updated in this register and in Error and Status 1 (ESR1) when FlexCAN returns to Normal mode. If FlexCAN is in Pretended Networking mode, the FAST error flags in ESR1 are not set.

NOTE

See Fault confinement in the CAN Protocol standard ISO 11898-1:2015 for details.

Diagram



Fields

Field	Function
31-24 RXERRCNT_FAST	Receive Error Counter for Fast Bits Counts errors detected in the data phase of received CAN FD messages that have BRS = 1. This field is read-only except in Freeze mode, when the CPU can write an 8-bit zero value only.
23-16 TXERRCNT_FAST	Transmit Error Counter for Fast Bits Counts errors detected in the data phase of transmitted CAN FD messages that have BRS = 1. This field is read-only except in Freeze mode, when the CPU can write an 8-bit zero value only.
15-8 RXERRCNT	Receive Error Counter Counts all errors detected in received messages. This field is read-only except in Freeze mode, when the CPU can write to it.
7-0 TXERRCNT	Transmit Error Counter Counts all errors detected in transmitted messages. This field is read-only except in Freeze mode, when the CPU can write to it.

48.5.2.9 Error and Status 1 (ESR1)

Offset

Register	Offset
ESR1	20h

Function

Reports various error conditions detected in the reception and transmission of a CAN frame. This register provides status information about the chip, and is the source of some interrupts to the CPU. The reported error conditions are:

NOTE

Reading host can clear these fields.

- Errors detected in CAN frames of any format:
  - BIT1ERR
  - BIT0ERR
  - ACKERR
  - CRCERR
  - FRMERR
  - STFERR
- Errors detected in the data phase of CAN FD frames with the BRS bit set only:
  - BIT1ERR_FAST
  - BIT0ERR_FAST
  - CRCERR_FAST

— FRMERR_FAST

— STFERR_FAST

One or more error flags may report an error detected in a single CAN frame. To account for more error events occurring in subsequent frames when the CPU does not attempt to read this register, error reporting is cumulative.

Status flags:

- TXWRN
- RXWRN
- IDLE
- TX
- FLTCONF
- RX
- SYNCH

Interrupt flags:

- BOFFINT
- BOFFDONEINT
- ERRINT
- ERRINT_FAST
- WAKINT
- TWRNINT
- RWRNINT

The CPU should follow this procedure when servicing interrupt requests generated by these flags:

1. Read this register to capture all error condition and status flags. This action clears the respective flags that were set since the last read access.
2. Write 1 to clear the interrupt flag that triggered the interrupt request.
3. Write 1 to clear the ERROVR flag, if it is set.

Starting from all error flags cleared, a first error event sets either ERRINT or ERRINT_FAST (provided the corresponding mask bit is 1). If other error events in subsequent frames occur before the CPU serves the interrupt request, the ERROVR flag is set to indicate that errors from different frames have accumulated.

Table 377. CAN bus status

SYNCH	IDLE	TX	RX	FlexCAN state
0	0	0	0	Not synchronized to CAN bus
1	1	X	X	Idle
1	0	1	0	Transmitting
1	0	0	1	Receiving

NOTE

See Fault confinement in the CAN Protocol standard ISO 11898-1:2015 for details.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	BIT1ERR...	BIT0ERR...	0	CRCERR_...	FRMERR_...	STFERR_...	0		0	0	ERROVR	ERRINT_...	BOFFDON...	SYNCH	TWRNINT	RWRNINT
W											W1C	W1C	W1C		W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	BIT1ERR	BIT0ERR	ACKERR	CRCERR	FRMERR	STFERR	TXWRN	RXWRN	IDLE	TX	FLTCONF		RX	BOFFINT	ERRINT	WAKINT
W														W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 BIT1ERR_FAST	Fast Bit1 Error Flag Indicates when an inconsistency occurs between the transmitted and the received bit in the data phase of CAN FD frames that have BRS = 1. After a read operation, the field's value clears to 0. 0b - No such occurrence. 1b - At least one bit transmitted as recessive is received as dominant.
30 BIT0ERR_FAST	Fast Bit0 Error Flag Indicates when an inconsistency occurs between the transmitted and the received bit in the data phase of CAN FD frames that have BRS = 1. After a read operation, the field's value clears to 0. 0b - No such occurrence. 1b - At least one bit transmitted as dominant is received as recessive.
29 —	Reserved
28 CRCERR_FAST	Fast Cyclic Redundancy Check Error Flag Indicates that the receiver node has detected a CRC error in the CRC field of CAN FD frames that have BRS = 1. This error means that the calculated CRC is different from the received CRC. After a read operation, the field's value clears to 0. 0b - No such occurrence. 1b - A CRC error occurred since last read of this register.
27	Fast Form Error Flag

Table continues on the next page...

Table continued from the previous page...

Field	Function
FRMERR_FAST	Indicates whether the receiver node has detected a form error in the data phase of CAN FD frames that have BRS = 1. This error means that a fixed-form bit field contains at least one illegal bit. After a read operation, the field's value clears to 0. 0b - No such occurrence. 1b - A form error occurred since last read of this register.
26 STFERR_FAST	Fast Stuffing Error Flag Indicates that a stuffing error has been detected in the data phase of CAN FD frames that have BRS = 1. After a read operation, the field's value clears to 0. 0b - No such occurrence. 1b - A stuffing error occurred since last read of this register.
25-24 —	Reserved
23 —	Reserved
22 —	Reserved
21 ERROVR	Error Overrun Flag Indicates that an error condition occurred when any error flag is already set. 0b - No overrun 1b - Overrun
20 ERRINT_FAST	Fast Error Interrupt Flag Indicates that at least one error flag detected in the data phase of CAN FD frames that have BRS = 1 (BIT1ERR_FAST, BIT0ERR_FAST, CRCERR_FAST, FRMERR_FAST, or STFERR_FAST) is set. If CTRL2[ERRMSK_FAST] = 1, an interrupt is generated to the CPU. 0b - No such occurrence. 1b - Error flag set in the data phase of CAN FD frames that have BRS = 1.
19 BOFFDONEINT	Bus Off Done Interrupt Flag Indicates whether ECR[TXERRCNT] has finished counting 128 occurrences of 11 consecutive recessive bits on the CAN bus and is ready to leave Bus Off. If CTRL2[BOFFDONEMSK] = 1, an interrupt is generated to the CPU. 0b - No such occurrence 1b - FlexCAN module has completed Bus Off process.
18	CAN Synchronization Status Flag

Table continues on the next page...

Table continued from the previous page...

Field	Function
SYNCH	Indicates whether FlexCAN is synchronized to the CAN bus and able to participate in the communication process. FlexCAN sets and clears this flag. See the table in Error and Status 1 (ESR1). 0b - Not synchronized 1b - Synchronized
17 TWRNINT	TX Warning Interrupt Flag Indicates whether TX error counter changed from less than 96 to greater than or equal to 96. If MCR[WRNEN] = 1, this flag is set when the TXWRN flag transitions from 0 to 1, meaning that the TX error counters reached 96. If CTRL1[TWRNMSK] = 1, an interrupt is sent to the CPU. When MCR[WRNEN] = 0, this flag is masked. The CPU must clear this flag before writing 0 to MCR[WRNEN]. Otherwise, this flag is set when MCR[WRNEN] = 1 again. Writing 0 has no effect. This flag is not generated when in the Bus Off state. This flag is not updated during Freeze mode. When FlexCAN returns to Normal mode from Pretended Network mode (see Receive process in Pretended Networking mode), this bit is not updated. 0b - No such occurrence 1b - TX error counter changed from less than 96 to greater than or equal to 96.
16 RWRNINT	RX Warning Interrupt Flag Indicates whether the RX error counter changed from less than 96 to greater than or equal to 96. If MCR[WRNEN] = 1, this flag is set when the RXWRN flag transitions from 0 to 1, meaning that the RX error counters reached 96. If CTRL1[RWRNMSK] = 1, an interrupt is sent to the CPU. When MCR[WRNEN] = 0, this flag is masked. The CPU must clear this flag before writing 0 to MCR[WRNEN]. Otherwise, this flag is set when MCR[WRNEN] = 1 again. Writing 0 has no effect. This flag is not updated during Freeze mode. When FlexCAN returns to Normal mode from Pretended Network mode (see Receive process in Pretended Networking mode), this bit is updated to reflect the RX error counter state. 0b - No such occurrence 1b - RX error counter changed from less than 96 to greater than or equal to 96.
15 BIT1ERR	Bit1 Error Flag Indicates when an inconsistency occurs between the transmitted and the received bit in a non-CAN FD message or in the arbitration or data phase of a CAN FD message. This flag is updated when FlexCAN returns to Normal mode from Pretended Network mode. **NOTE** A transmitter does not set this flag for an arbitration field or ACK slot. It is not set for a node sending an error passive flag that detects dominant bits. After a read operation, the field's value clears to 0. 0b - No such occurrence. 1b - At least one bit sent as recessive is received as dominant.

Table continues on the next page...

Table continued from the previous page...

Field	Function
14 BIT0ERR	Bit0 Error Flag Indicates when an inconsistency occurs between the transmitted and the received bit in a non-CAN FD message or in the arbitration or data phase of a CAN FD message. This field is updated when FlexCAN returns to Normal mode from Pretended Network mode. After a read operation, the field's value clears to 0. 0b - No such occurrence. 1b - At least one bit sent as dominant is received as recessive.
13 ACKERR	Acknowledge Error Flag Indicates whether the transmitter node has detected an acknowledge error. This error means that a dominant bit has not been detected during the ACK SLOT. This flag is updated when FlexCAN returns to Normal mode from Pretended Network mode. After a read operation, the field's value clears to 0. 0b - No error 1b - Error occurred since last read of this register.
12 CRCERR	Cyclic Redundancy Check Error Flag Indicates whether the receiver node has detected a cyclic redundancy check (CRC) error either in a non-FD message or in the arbitration or data phase of a frame in CAN FD format. This error means that the calculated CRC is different from the received. This flag is updated when FlexCAN returns to Normal mode from Pretended Network mode. After a read operation, the field's value clears to 0. 0b - No error 1b - Error occurred since last read of this register.
11 FRMERR	Form Error Flag Indicates whether a form error has been detected in a non-FD message or in the arbitration or data phase of an FD message by the receiver node. This error means that a fixed-form field contains at least one illegal bit. This flag is updated when FlexCAN returns to Normal mode from Pretended Network mode. After a read operation, the field's value clears to 0. 0b - No error 1b - Error occurred since last read of this register.
10 STFERR	Stuffing Error Flag Indicates that a stuffing error has been detected in a non-FD message or in the arbitration or data phase of an FD message by the receiver node. This flag is updated when FlexCAN returns to Normal mode from Pretended Network mode. After a read operation, the field's value clears to 0.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - No error 1b - Error occurred since last read of this register.
9 TXWRN	TX Error Warning Flag Indicates when repetitive errors occur during message transmission. Only the value of ECR[TXERRCNT] affects this flag. This flag is not updated during Freeze mode. After a read operation, the field's value clears to 0. 0b - No such occurrence. 1b - TXERRCNT is 96 or greater.
8 RXWRN	RX Error Warning Flag Indicates when repetitive errors occur during message reception. Only the value of ECR[RXERRCNT] affects this flag. This flag is not updated during Freeze mode. Additionally, this flag is updated when FlexCAN returns to Normal mode from Pretended Networking mode. After a read operation, the field's value clears to 0. 0b - No such occurrence. 1b - RXERRCNT is greater than or equal to 96.
7 IDLE	Idle Indicates whether CAN bus is in IDLE state. See Table 377. 0b - Not IDLE 1b - IDLE
6 TX	FlexCAN In Transmission Indicates whether FlexCAN is transmitting a message. See Table 377. 0b - Not transmitting 1b - Transmitting
5-4 FLTCONF	Fault Confinement State Indicates the confinement state of FlexCAN. If CTRL1[LOM] = 1, after a delay that depends on the CAN bit timing, this field indicates Error Passive. The same delay affects the way that this field reflects an update to ECR register by the CPU. It may be necessary to wait up to one CAN bit time for coherence to be restored. Soft reset affects this field, but if CTRL1[LOM] = 1, its reset value lasts for only one CAN bit. After that time, this field reports Error Passive. 00b - Error Active 01b - Error Passive 1xb - Bus Off

Table continues on the next page...

Table continued from the previous page...

Field	Function
3 RX	FlexCAN in Reception Flag Indicates whether FlexCAN is receiving a message. See the table in Error and Status 1 (ESR1). 0b - Not receiving 1b - Receiving
2 BOFFINT	Bus Off Interrupt Flag Indicates whether FlexCAN has entered Bus Off state. If CTRL1[BOFFMSK]) = 1, an interrupt is generated to the CPU. Writing 0 to this field has no effect. 0b - No such occurrence. 1b - FlexCAN module entered Bus Off state.
1 ERRINT	Error Interrupt Flag Indicates that at least one of the error flags (ESR1[BIT1ERR], ESR1[BIT0ERR], ESR1[ACKERR], ESR1[CRCERR], ESR1[FRMERR], or ESR1[STFERR]) is set. If the corresponding mask CTRL1[ERRMSK] = 1, an interrupt is generated to the CPU. Writing 0 to this field has no effect. 0b - No such occurrence. 1b - Indicates setting of any error flag in the Error and Status register.
0 WAKINT	Wake-up Interrupt Flag Generates an interrupt to the CPU when a recessive-to-dominant transition is detected on the CAN bus and MCR[WAKMSK] = 1. This field applies when FlexCAN is in low-power mode during Self Wake-up: • Doze mode • Stop mode When MCR[SLFWAK] = 0, this flag is masked. The CPU must clear this flag before disabling the field. Otherwise, it is set when MCR[SLFWAK] becomes 1 again. Writing 0 has no effect. 0b - No such occurrence. 1b - Indicates that a recessive-to-dominant transition was received on the CAN bus.

48.5.2.10 Interrupt Masks 1 (IMASK1)

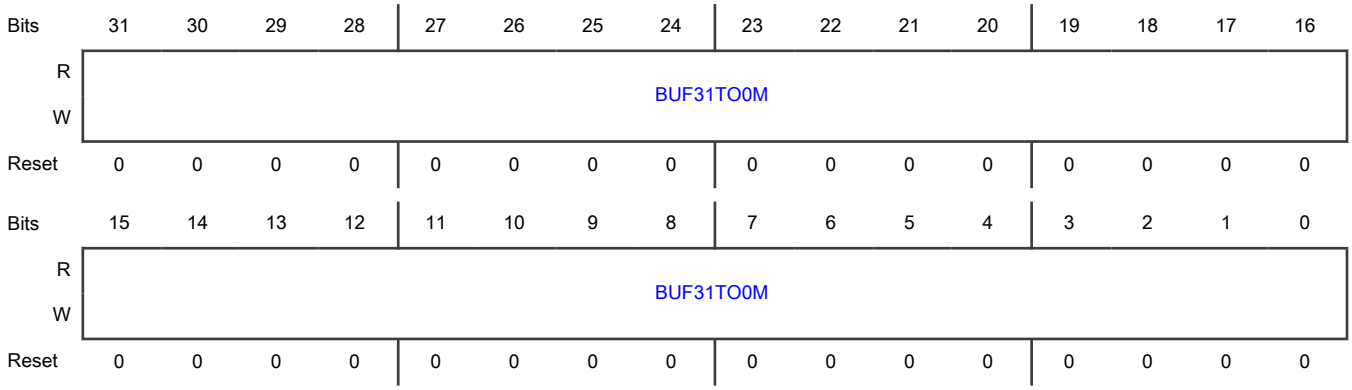
Offset

Register	Offset
IMASK1	28h

Function

Masks interrupt flags. This register allows any of the 32 message buffer interrupts to be enabled or disabled for MB31–MB0. It contains one interrupt mask bit per buffer. This configuration allows the CPU to determine which buffer generates an interrupt after a successful transmission or reception when the corresponding Interrupt Flags 1 (IFLAG1) flag is set.

Diagram



Fields

Field	Function
31-0 BUF31TO0M	Buffer MBi Mask Enables or disables the corresponding FlexCAN message buffer interrupt for MB31–MB0. **NOTE** If the corresponding Interrupt Flags 1 (IFLAG1) flag is set, writing 1 or 0 to a field in IMASK1 can set or clear an interrupt request. 0b - The corresponding buffer interrupt is disabled. 1b - The corresponding buffer interrupt is enabled.

48.5.2.11 Interrupt Flags 1 (IFLAG1)

Offset

Register	Offset
IFLAG1	30h

Function

Contains the flags for the 32 message buffer interrupts for MB31–MB0. It contains one interrupt flag bit per buffer. Each successful transmission or reception sets the corresponding IFLAG1 bit. If the corresponding Interrupt Masks 1 (IMASK1) bit is set, an interrupt is generated. There is an exception when DMA for Legacy RX FIFO is enabled, as described below.

The BUF7I–BUF5I flags also represent Legacy FIFO interrupts when the Legacy RX FIFO is enabled. When MCR[RFEN] is 1 and MCR[DMA] is 0, the function of the eight least significant interrupt flags changes:

- BUF7I, BUF6I, and BUF5I indicate operating conditions of the Legacy FIFO.
- BUF4I–BUF1I fields are reserved.
- BUF0I empties the Legacy FIFO.

Before writing 1 to MCR[RFEN], the CPU must service the IFLAG flags set in the Legacy RX FIFO region; see Legacy RX FIFO. Otherwise, these IFLAG flags mistakenly show the related message buffers now belonging to Legacy FIFO as having contents to be serviced. When MCR[RFEN] is 0, the Legacy FIFO flags must be cleared. The same care must be taken when a CTRL2[RFFN]

value is selected, extending Legacy RX FIFO filters beyond MB7. For example, when RFFN is 8h, Legacy RX FIFO filters occupy the MB23–MB0 range, and related IFLAG flags must be cleared.

When MCR[RFEN] and MCR[DMA] are 1 (DMA feature for Legacy RX FIFO enabled), the function of the eight least significant interrupt flags (BUF7I–BUF0I) changes to support DMA operation. BUF7I, BUF6I, and BUF4I–BUF1I are not used.

BUF5I indicates the operating condition of the Legacy FIFO, and BUF0I empties the Legacy FIFO. Moreover, BUF5I does not generate a CPU interrupt, but it does generate a DMA request. IMASK1 bits in the Legacy RX FIFO region are not considered when bit MCR[DMA] = 1. In addition, the CPU must not clear the BUF5I flag when DMA is enabled. Before writing 1 to MCR[DMA], the CPU must service the IFLAG flags set in the Legacy RX FIFO region. When MCR[DMA] is 0, the Legacy FIFO must be empty. Legacy FIFO must be disabled when MCR[FDEN] = 1.

Before updating MCR[MAXMB], the CPU must service the IFLAG1 flags whose MB value is greater than the MCR[MAXMB] to be updated. Otherwise, those flags remain set and are inconsistent with the number of message buffers available.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	BUF31TO8I															
W	W1C															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	BUF31TO8I								BUF7I	BUF6I	BUF5I	BUF4TO1I				BUF0I
W	W1C								W1C	W1C	W1C	W1C				W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-8 BUF31TO8I	Buffer MBi Interrupt Flags the corresponding FlexCAN message buffer interrupt for MB31–MB8. 0b - The corresponding buffer has no occurrence of successfully completed transmission or reception. 1b - The corresponding buffer has successfully completed transmission or reception.
7 BUF7I	Buffer MB7 Interrupt or Legacy RX FIFO Overflow Flags the interrupt for MB7 when MCR[RFEN] = 0 (Legacy RX FIFO disabled). **NOTE** When a CPU write changes the value of MCR[RFEN], FlexCAN clears this flag. When MCR[RFEN] = 1, this flag represents a Legacy RX FIFO overflow. In this case, the flag indicates that a message was lost because the Legacy RX FIFO is full. When the Legacy RX FIFO is full and a message buffer captures the message, this flag is not set. 0b - No occurrence of MB7 completing transmission or reception, or no FIFO overflow. 1b - MB7 completed transmission or reception, or FIFO overflow.

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Field	Function
6 BUF6I	Buffer MB6 Interrupt or Legacy RX FIFO Warning Flags the interrupt for MB6 when MCR[RFEN] = 0 (Legacy RX FIFO disabled). **NOTE** When a CPU write changes the value of MCR[RFEN], FlexCAN clears this flag. When MCR[RFEN] = 1, this flag represents a Legacy RX FIFO warning. In this case, the flag indicates when the number of unread messages within the Legacy RX FIFO is increased to five from four due to the reception of a new message. In other words, the Legacy RX FIFO is almost full. If this flag is cleared when there are more than four unread messages, it does not set again until the number of unread messages in the Legacy RX FIFO decreases to four or fewer. 0b - No occurrence of MB6 completing transmission or reception, or FIFO not almost full. 1b - MB6 completed transmission or reception, or FIFO almost full.
5 BUF5I	Buffer MB5 Interrupt or Frames available in Legacy RX FIFO Flags the interrupt for MB5 when MCR[RFEN] = 0 (Legacy RX FIFO disabled). **NOTE** When a CPU write changes the value of MCR[RFEN], FlexCAN clears this flag. When MCR[RFEN] = 1, the BUF5I flag represents frames available in Legacy RX FIFO. In this case, the flag indicates that at least one frame is available to be read from the Legacy RX FIFO. When MCR[DMA] = 1, this flag generates a DMA request. The CPU must not clear this field by writing 1 to BUF5I. 0b - No occurrence of completed transmission or reception, or no frames available 1b - MB5 completed transmission or reception, or frames available
4-1 BUF4TO1I	Buffer MBi Interrupt or Reserved Flags the interrupts for MB4–MB1 when MCR[RFEN] = 0 (Legacy RX FIFO disabled). **NOTE** When a CPU write changes the value of MCR[RFEN], FlexCAN clears these flags. When MCR[RFEN] = 1, the BUF4TO1I flags are reserved. 0b - The corresponding buffer has no occurrence of successfully completed transmission or reception. 1b - The corresponding buffer has successfully completed transmission or reception.
0 BUF0I	Buffer MB0 Interrupt or Clear Legacy FIFO bit Flags the interrupt for MB0 when MCR[RFEN] = 0 (Legacy RX FIFO disabled). If MCR[RFEN] = 1, this field is used to trigger the clear Legacy FIFO operation. This operation empties the Legacy FIFO contents. Before performing this operation, the CPU must service all Legacy FIFO-related IFLAG flags.

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Field	Function
	When MCR[DMA] = 1, this operation also clears the BUF5I flag, aborting the DMA request. The clear Legacy FIFO operation occurs when the CPU writes 1 to BUF0I. This operation is only allowed in Freeze mode; the module blocks it in other conditions. 0b - MB0 has no occurrence of successfully completed transmission or reception. 1b - MB0 has successfully completed transmission or reception.

48.5.2.12 Control 2 (CTRL2)

Offset

Register	Offset
CTRL2	34h

Function

Complements Control 1 (CTRL1), providing control bits for memory write-access in Freeze mode. This register extends Legacy FIFO filter quantity, and adjusts the operation of internal FlexCAN processes such as matching and arbitration.

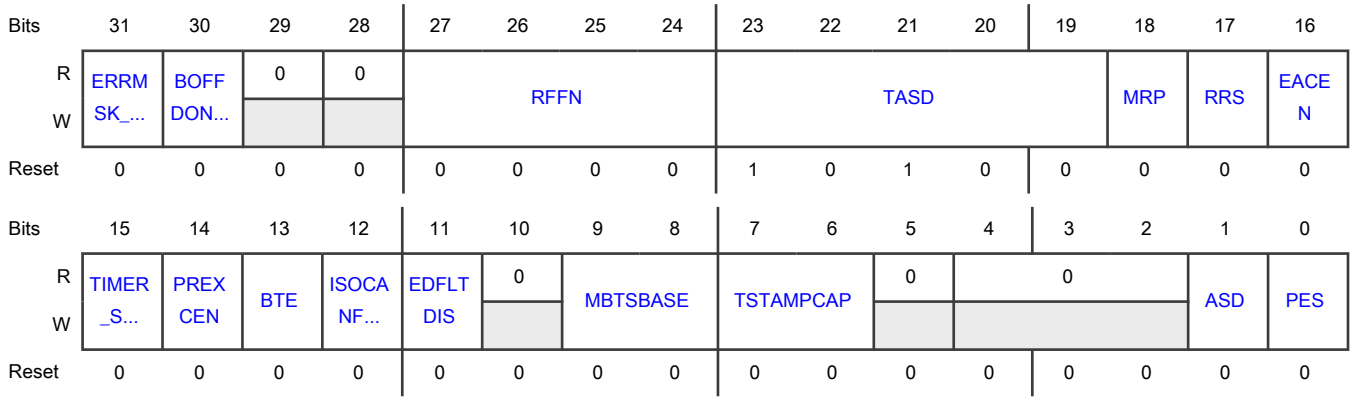
Soft reset does not affect the contents of this register.

Table 378 shows how the value of CTRL2[RFFN] determines the Legacy RX FIFO filter structure.

Table 378. Possible Legacy RX FIFO filter structures

RFFN[3:0]	Number of Legacy RX FIFO filter elements	Message buffers occupied by Legacy RX FIFO and ID filter table	Remaining available message buffers	Legacy RX FIFO ID filter table elements affected by RX individual masks	Legacy RX FIFO ID filter table elements affected by Legacy RX FIFO global mask
0h	8	MB 0–7	MB 8–31	Elements 0–7	None
1h	16	MB 0–9	MB 10–31	Elements 0–9	Elements 10–15
2h	24	MB 0–11	MB 12–31	Elements 0–11	Elements 12–23
3h	32	MB 0–13	MB 14–31	Elements 0–13	Elements 14–31
4h	40	MB 0–15	MB 16–31	Elements 0–15	Elements 16–39
5h	48	MB 0–17	MB 18–31	Elements 0–17	Elements 18–47
6h	56	MB 0–19	MB 20–31	Elements 0–19	Elements 20–55
7h	64	MB 0–21	MB 22–31	Elements 0–21	Elements 22–63
8h	72	MB 0–23	MB 24–31	Elements 0–23	Elements 24–71
9h	80	MB 0–25	MB 26–31	Elements 0–25	Elements 26–79
Ah	88	MB 0–27	MB 28–31	Elements 0–27	Elements 28–87
Bh	96	MB 0–29	MB 30–31	Elements 0–29	Elements 30–95
Ch	104	MB 0–31	none	Elements 0–31	Elements 32–103

Diagram



Fields

Field	Function
31 ERRMSK_FAST	Error Interrupt Mask for Errors Detected in the Data Phase of Fast CAN FD Frames Enables the ESR1[ERRINT_FAST] interrupt. 0b - Disable 1b - Enable
30 BOFFDONEMSK	Bus Off Done Interrupt Mask Enables the Bus Off Done interrupt, ESR1[BOFFDONEINT]. 0b - Disable 1b - Enable
29 —	Reserved
28 —	Reserved
27-24 RFFN	Number of Legacy Receive FIFO Filters Defines the number of Receive Legacy FIFO filters, as shown in Table 378. The chip determines the maximum selectable number of filters. Do not program this field with values that cause the number of message buffers occupied by Legacy RX FIFO and Legacy RX FIFO ID Filter to exceed MCR[MAXMB]. MCR[MAXMB] defines the number of message buffers present. This field can only be written in Freeze mode; the module blocks it in other modes. Each group of eight filters occupies a memory space equivalent to two message buffers. The more filters are implemented, the fewer message buffers are available. The Legacy RX FIFO occupies the memory space originally reserved for MB5–MB0. This field should be programmed with a value corresponding to a number of filters less than the number of available memory words. The number of available words can be calculated as follows: (SETUP_MB - 6) × 4

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Field	Function
	Where SETUP_MB is the smaller of the parameter NUMBER_OF_MB and MCR[MAXMB]. The number of remaining message buffers available is: (SETUP_MB - 8) - (RFFN × 2) If the number of Legacy RX FIFO filters programmed through RFFN exceeds the SETUP_MB value (memory space available), the exceeding ones are not functional. **NOTE** • The number of the last remaining available message buffers is the smaller of (NUMBER_OF_MB - 1) and MCR[MAXMB]. • If RX Individual Mask registers are not enabled, the Legacy RX FIFO Global Mask affects all Legacy RX FIFO filters.
23-19 TASD	Transmission Arbitration Start Delay Indicates by how many CAN bits the transmission arbitration process start point can be delayed from the first bit of CRC field on CAN bus. See TX arbitration start delay for details. This field can be written only in Freeze mode; the module blocks it in other modes.
18 MRP	Message Buffers Reception Priority Sets the priority for the matching process. This field can be written only in Freeze mode; the module blocks it in other modes. 0b - Matching starts from Legacy RX FIFO or Enhanced RX FIFO and continues on message buffers. 1b - Matching starts from message buffers and continues on Legacy RX FIFO or Enhanced RX FIFO.
17 RRS	Remote Request Storing Determines what the module does with a remote request. The remote request frame is submitted to a matching process. If this field is 1, the frame is stored in the corresponding message buffer in the same fashion as a data frame. No automatic remote response frame is generated. If this field is 0, an automatic remote response frame is generated if a message buffer with CODE = 1010b is found with the same ID. You can only write to this field in Freeze mode. The module blocks it in other modes. 0b - Generated 1b - Stored
16 EACEN	Entire Frame Arbitration Field Comparison Enable for RX Message Buffers Controls the comparison of IDE and RTR fields within RX message buffer filters with their corresponding bits in the incoming frame by the matching process. If enabled, the IDE and RTR fields of the RX message buffer are compared to their corresponding bits within the incoming frame (mask bits apply). If disabled, the IDE field of the RX message buffer filter is always compared and RTR is never compared despite mask bits.

Table continues on the next page...

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Field	Function
	This field does not affect matching for Legacy RX FIFO or Enhanced RX FIFO. You can only write to this field in Freeze mode; the module blocks it in other modes. 0b - Disable 1b - Enable
15 TIMER_SRC	Timer Source Selects the time tick source used for incrementing the free-running timer counter. If CAN bit clock is selected, it defines the baud rate on the CAN bus. If External time tick is selected, the period can be adjusted to match the baud rate on the CAN bus. It can also be adjusted to a different value as required. See the chip-specific section for details about the external time tick. You can only write to this field in Freeze mode. 0b - CAN bit clock 1b - External time tick
14 PREXCEN	Protocol Exception Enable Enables the protocol exception feature. You can only write to this field in Freeze mode. **NOTE** See Protocol exception event in the CAN Protocol standard ISO 11898-1:2015 for details. 0b - Disabled 1b - Enabled
13 BTE	Bit Timing Expansion Enable Enables the use of Enhanced CAN Bit Timing Prescalers (EPRS), Enhanced Data Phase CAN Bit Timing (EDCBT), and Enhanced Nominal CAN Bit Timing (ENCBT) to configure the CAN bit timing segments, instead of using the bit timing fields of CAN Bit Timing (CBT), CAN FD Bit Timing (FDCBT), and Control 1 (CTRL1). If this field is 1: • CTRL1[PRESDIV], CTRL1[PROPSEG], CTRL1[PSEG1], CTRL1[PSEG2], and CTRL1[RJW] are read as zero. A write operation to these fields has no effect. • CBT[EPRESDIV], CBT[ERJW], CBT[EPROPSEG], CBT[EPSEG1], and CBT[EPSEG2], and the corresponding fields in CAN FD Bit Timing (FDCBT), are read as zero. A write operation to these fields has no effect. • ETDC[ETDCOFF], ETDC[ETDCEN], ETDC[ETDCFAIL], and ETDC[ETDCVAL] are used by FlexCAN instead of FDCTRL[TDCOFF], FDCTRL[TDCEN], FDCTRL[TDCFAIL], and FDCTRL[TDCVAL]. These fields are read as zero, and a write operation to them has no effect. • ETDC[TDMDIS] can be used to disable transceiver delay measurement.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Disable 1b - Enable
12 ISOCANFDEN	ISO CAN FD Enable Enables the CAN FD protocol according to ISO specification ISO 11898-1:2015 (see CAN FD ISO compliance). When disabled, FlexCAN operates using the non-ISO CAN FD protocol. You can only write to this field in Freeze mode. **NOTE** FlexCAN is able to transmit FD frame format according to CAN Protocol standard ISO 11898-1:2015. 0b - Disable 1b - Enable
11 EDFLTDIS	Edge Filter Disable Disables the edge filter used during the Bus Integration state. When the Edge Filter is enabled, two consecutive nominal time quanta with dominant bus states are required to detect an edge that causes synchronization. When synchronization occurs, the counting of the sequence of 11 consecutive recessive bits is restarted. The edge filter prevents dominant pulses that are shorter than a nominal bit time (present during the data phase of an FD frame) from being mistaken for an idle condition. You can only write to this field in Freeze mode. **NOTE** See Bus Integration state in the CAN Protocol standard ISO 11898-1:2015 for details. 0b - Enabled 1b - Disabled
10 —	Reserved
9-8 MBTSBASE	Message Buffer Timestamp Base Selects the timebase used for capturing the 16-bit TIME_STAMP field of the message buffer register. This field can be written in Freeze Mode only. 00b - TIMER 01b - Lower 16 bits of high-resolution timer 10b - Upper 16 bits of high-resolution timer 11b - Reserved
7-6	Timestamp Capture Point

Table continues on the next page...

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Field	Function
TSTAMPCAP	Configures the point in time when a 32-bit timebase is captured during a CAN frame. This base is stored in the high-resolution timestamp register (HR_TIME_STAMP). For classical CAN frames, capture points can be the start-of-frame bit or the point when CAN frame is considered valid. This point is the seventh bit of the end-of-frame for transmission and the sixth bit of the end-of-frame for reception. For CAN FD frames, the high-resolution timestamp can be captured at the start of frame, when a CAN FD frame is considered valid, or the res bit. You can only write to this field in Freeze mode. 00b - Disabled 01b - End of the CAN frame 10b - Start of the CAN frame 11b - Start of frame for classical CAN frames; res bit for CAN FD frames
5 —	Reserved
4-2 —	Reserved
1 ASD	ACK Suppression Disable Disables the ACK suppression logic. You can only write to this field in Freeze mode. 0b - Enabled 1b - Disabled
0 PES	Payload Byte and Bit Order Selection Selects the byte order for the payload of transmit and receive frames. **NOTE** You can only write to this field in Freeze mode. 0b - Big-endian 1b - Little-endian

48.5.2.13 Error and Status 2 (ESR2)

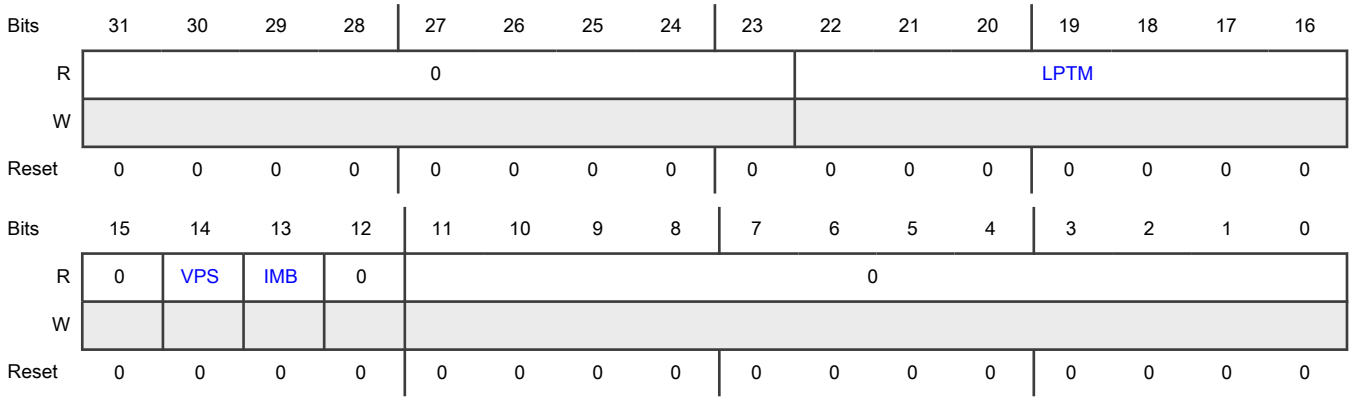
Offset

Register	Offset
ESR2	38h

Function

Reports general status information.

Diagram



Fields

Field	Function
31-23 —	Reserved
22-16 LPTM	Lowest Priority TX Message Buffer Indicates the lowest number inactive message buffer when ESR2[VPS] = 1 (see ESR2[IMB]). If no message buffer is inactive, the message buffer indicated depends on the value of CTRL1[LBUF]. If CTRL1[LBUF] = 0, the message buffer indicated is the one with the greatest arbitration value (see Highest-priority message buffer first). If CTRL1[LBUF] = 1, the message buffer indicated is the active TX message buffer with the highest number. If a TX message buffer is being transmitted, it is not considered in the LPTM calculation. If ESR2[IMB] is not 0 and a frame is transmitted successfully, the value of LPTM is updated with its message buffer number.
15 —	Reserved
14 VPS	Valid Priority Status Indicates whether the contents of ESR2[IMB] and ESR2[LPTM] are valid. It becomes 1 upon every complete TX arbitration process, unless the CPU writes to the Control and Status word of a message buffer already scanned. In other words, it is behind the TX Arbitration Pointer, during the TX arbitration process. If there is no inactive message buffer and only one TX message buffer that is being transmitted, this field remains 0. This field becomes 0 upon the start of every TX arbitration process or upon a write to the Control and Status word of any message buffer. **NOTE** No CPU write to the Control and Status of a message buffer that the abort mechanism blocks affects this field. When MCR[AEN] = 1, the abort code write to the Control and Status of an MB being transmitted (pending abort) is blocked. Any write attempt to a TX MB with its IFLAG flag set is also blocked. 0b - Invalid 1b - Valid

Table continues on the next page...

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Field	Function
13 IMB	Inactive Message Buffer Indicates whether any message buffer is inactive (CODE field is either 1000b or 0b) when ESR2[VPS] = 1. This field becomes 1 when: • A lowest-priority TX message buffer (ESR2[LPTM]) is found and it is inactive during arbitration. • This field is not 1, and a frame is transmitted successfully. This field always becomes 0 at the start of arbitration (see Arbitration process). If a message buffer is successfully transmitted and this field is 0 (no inactive message buffer), ESR2[VPS] and this field both become 1. The index related to the MB transmitted is loaded into ESR2[LPTM]. In this case, the value of ESR2[LPTM] is the number of the first inactive message buffer. 0b - Message buffer indicated by ESR2[LPTM] is not inactive. 1b - At least one message buffer is inactive.
12 —	Reserved
11-0 —	Reserved

48.5.2.14 Cyclic Redundancy Check (CRCR)

Offset

Register	Offset
CRCR	44h

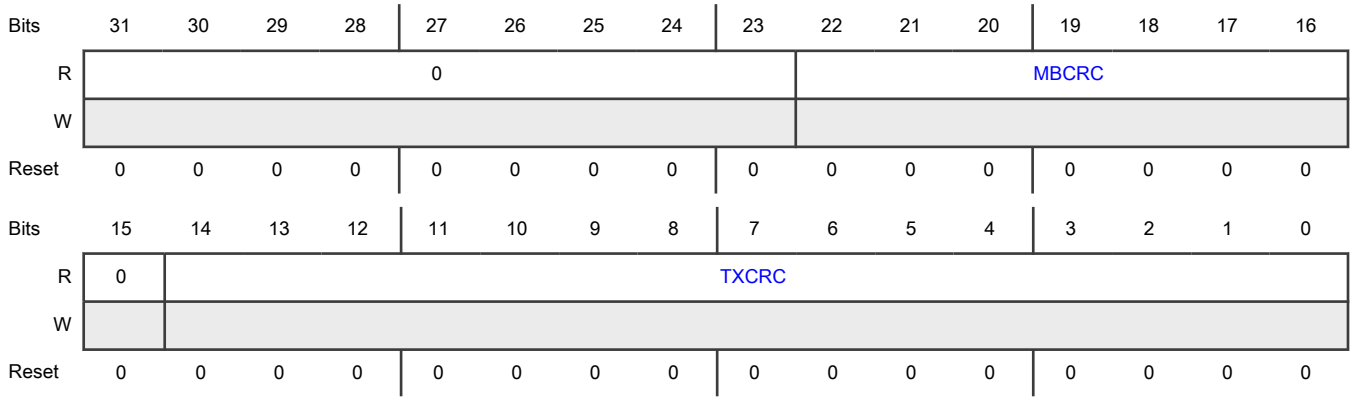
Function

Provides information about the CRC of transmitted messages for non-FD messages. This register only reports the 15 low-order bits of CRC calculations for messages in CAN FD format that require either 17 or 21 bits. For CAN FD format frames, you must use the CAN FD CRC (FDCRC). This register is updated at the same time that the TX interrupt flag is set.

NOTE

See CRC sequence calculation in the CAN Protocol standard ISO 11898-1:2015 for details.

Diagram



Fields

Field	Function
31-23 —	Reserved
22-16 MBCRC	CRC Message Buffer Indicates the number of the message buffer corresponding to the value in CRCR[TXCRC].
15 —	Reserved
14-0 TXCRC	Transmitted CRC value Indicates the CRC value of the last transmitted message for non-FD frames. For FD frames, CRC value is reported in CAN FD CRC (FDCRC).

48.5.2.15 Legacy RX FIFO Global Mask (RXFGMASK)

Offset

Register	Offset
RXFGMASK	48h

Function

Masks the Legacy RX FIFO ID filter table elements that do not have a corresponding RXIMR according to CTRL2[RFFN], when Legacy RX FIFO is enabled.

This register is located in RAM.

You can only write to this register in Freeze mode; the module blocks it in other modes.

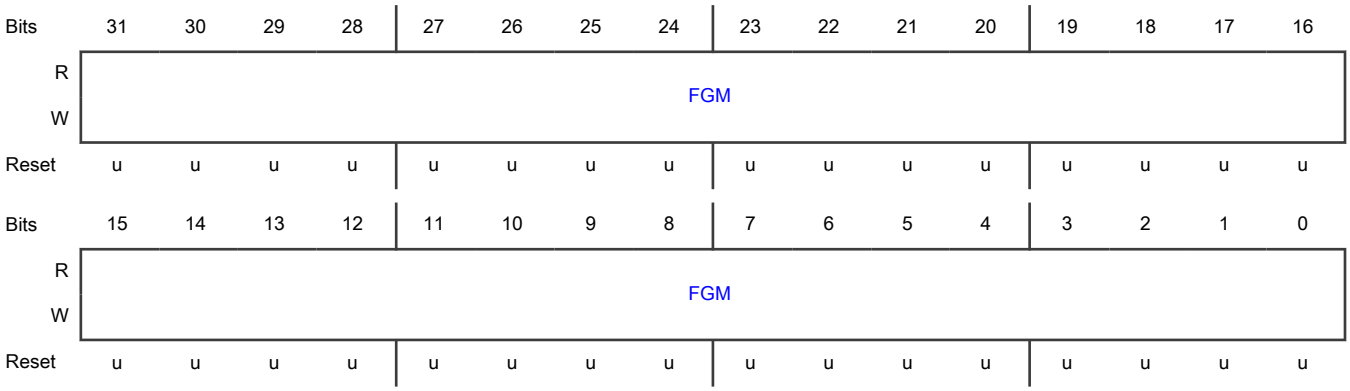
The following table shows how the FGM bits correspond to each IDAF field.

Table 379. Correspondence of Legacy RX FIFO global mask bits to IDF fields

Legacy RX FIFO ID filter table elements format (MCR[IDAM])	Identifier acceptance filter fields					
	RTR	IDE	RXIDA	RXIDB [1]	RXIDC [2]	Reserved
A	FGM[31]	FGM[30]	FGM[29:1]	—	—	FGM[0]
B	FGM[31], FGM[15]	FGM[30], FGM[14]	—	FGM[29:16], FGM[13:0]		—
C	—	—		—	FGM[31:24], FGM[23:16], FGM[15:8], FGM[7:0]	

1. If MCR[IDAM] is equivalent to format B, only the 14 most significant bits of the identifier of the incoming frame are compared with the Legacy RX FIFO filter.
2. If MCR[IDAM] is equivalent to format C, only the eight most significant bits of the identifier of the incoming frame are compared with the Legacy RX FIFO filter.

Diagram



Fields

Field	Function
31-0 FGM	Legacy RX FIFO Global Mask Bits Masks the ID filter table elements bits in a perfect alignment. 0b - The corresponding bit in the filter is "don't care." 1b - The corresponding bit in the filter is checked.

48.5.2.16 Legacy RX FIFO Information (RXFIR)

Offset

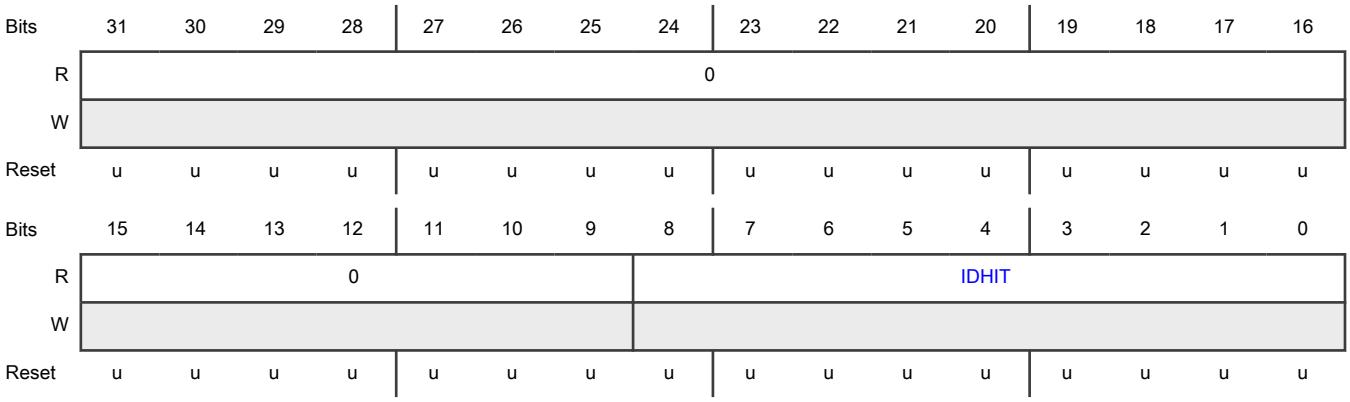
Register	Offset
RXFIR	4Ch

Function

Provides information about Legacy RX FIFO.

This register is the port through which the CPU accesses the output of the Legacy RXFIR FIFO located in RAM. FlexCAN writes to the Legacy RXFIR FIFO when a new message is moved into the Legacy RX FIFO. Also, its output is updated whenever the output of the Legacy RX FIFO is updated with the next message. See Legacy RX FIFO for instructions on reading this register.

Diagram



Fields

Field	Function
31-9 —	Reserved
8-0 IDHIT	Identifier Acceptance Filter Hit Indicator Indicates which Identifier Acceptance filter that the received message hit in the output of the Legacy RX FIFO. If multiple filters match the incoming message ID, the first matching IDAF found (lowest number) by the matching process is indicated. This field is valid only when IFLAG1[BUF5I] is set.

48.5.2.17 CAN Bit Timing (CBT)

Offset

Register	Offset
CBT	50h

Function

Provides an alternative way to store the CAN bit timing variables described in Control 1 (CTRL1). EPRESDIV, EPROPSEG, EPSEG1, EPSEG2, and ERJW are extended versions of CTRL1[PRESDIV], CTRL1[PROPSEG], CTRL1[PSEG1], CTRL1[PSEG2], and CTRL1[RJW] respectively.

NOTE

The CAN bit variables in CTRL1 and in CBT are stored in the same register.

CBT[BTF] selects the use of the timing variables defined in this register.

When the CAN FD feature is enabled (MCR[FDEN] = 1), always write 1 to CBT[BTF].

Soft reset does not affect the contents of this register.

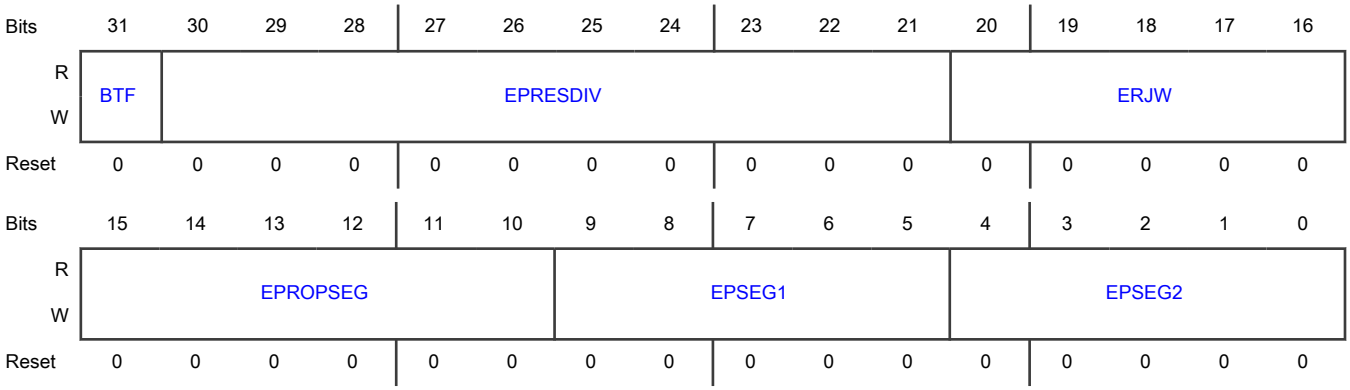
NOTE

Ensure that bit time settings and protocol engine tolerance are in compliance with the CAN Protocol standard ISO 11898-1:2015.

NOTE

If CTRL2[BTE] = 1, EPRESDIV, ERJW, EPROPSEG, EPSEG1, and EPSEG2 are read as zero. A write operation to them has no effect.

Diagram



Fields

Field	Function
31 BTF	Bit Timing Format Enable Enables the use of extended CAN bit timing fields EPRESDIV, EPROPSEG, EPSEG1, EPSEG2, and ERJW. These fields replace the CAN bit timing variables defined in Control 1 (CTRL1). This field can be written in Freeze mode only. 0b - Disable 1b - Enable
30-21 EPRESDIV	Extended Prescaler Division Factor Defines the ratio between the PE clock frequency and the serial clock (Sclock) frequency when CBT[BTF] = 1, otherwise it has no effect. It extends the CTRL1[PRESDIV] value range. The Sclock period defines the time quantum of the CAN protocol. For the reset value, the Sclock frequency is equal to the PE clock frequency (see Protocol timing). This field can be written only in Freeze mode; the module blocks it in other modes. Sclock frequency = PE clock frequency ÷ (EPRESDIV + 1)
20-16 ERJW	Extended Resync Jump Width Defines the maximum number of time quanta that one resynchronization can change a bit time when CBT[BTF] = 1. Otherwise, it has no effect. It extends the CTRL1[RJW] value range.

Table continues on the next page...

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Field	Function
	This field can be written only in Freeze mode; the module blocks it in other modes. Resync Jump Width = ERJW + 1. One Time Quantum = one Sclock period.
15-10 EPROPSEG	Extended Propagation Segment Defines the length of the propagation segment in the bit time when CBT[BTF] = 1, otherwise it has no effect. It extends the CTRL1[PROPSEG] value range. This field can be written only in Freeze mode; the module blocks it in other modes. Propagation Segment Time = (EPROPSEG + 1) × Time Quanta. One Time Quantum = one Sclock period.
9-5 EPSEG1	Extended Phase Segment 1 Defines the length of phase segment 1 in the bit time when CBT[BTF] = 1, otherwise it has no effect. It extends the CTRL1[PSEG1] value range. This field can be written only in Freeze mode; the module blocks it in other modes. Phase Buffer Segment 1 = (EPSEG1 + 1) × Time Quanta. One Time Quantum = one Sclock period.
4-0 EPSEG2	Extended Phase Segment 2 Defines the length of phase segment 2 in the bit time when CBT[BTF] = 1, otherwise it has no effect. It extends the CTRL1[PSEG2] value range. This field can be written only in Freeze mode; the module blocks it in other modes. Phase Buffer Segment 1 = (EPSEG2 + 1) × Time Quanta. One Time Quantum = one Sclock period.

48.5.2.18 Receive Individual Mask (RXIMR0 - RXIMR31)

Offset

For n = 0 to 31:

Register	Offset
RXIMRn	880h + (n × 4h)

Function

Stores the acceptance masks for ID filtering in RX message buffers and the Legacy RX FIFO.

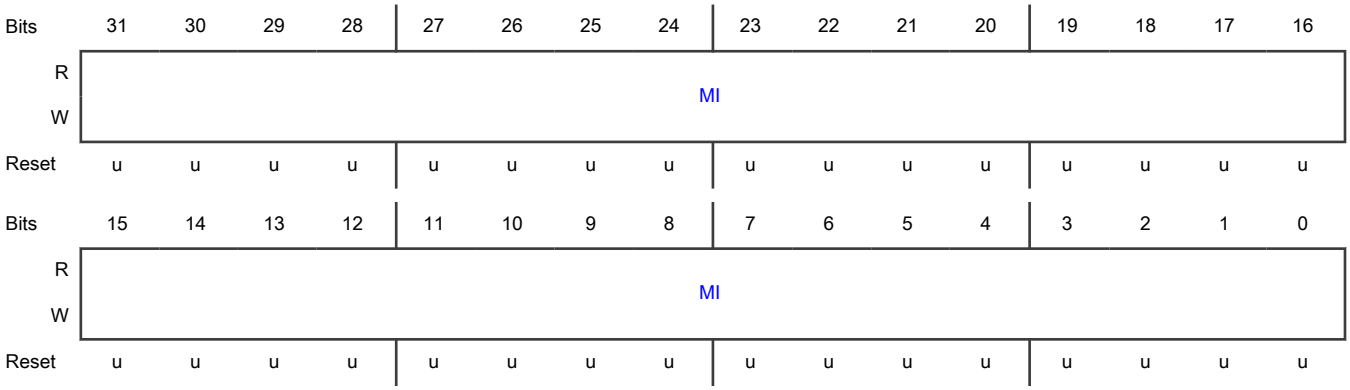
When the Legacy RX FIFO is disabled (MCR[RFEN] = 0), an individual mask is provided for each available RX message buffer on a one-to-one correspondence. When the Legacy RX FIFO is enabled (MCR[RFEN] = 1), an individual mask is provided for each Legacy RX FIFO ID filter table element on a one-to-one correspondence. This correspondence depends on the setting of CTRL2[RFFN] (see Legacy RX FIFO).

RXIMR0 stores the individual mask associated with either MB0 or ID filter table element 0. RXIMR1 stores the individual mask associated with either MB1 or ID filter table element 1, and so on.

The CPU can only access the RXIMR registers when the module is in Freeze mode; otherwise, the module blocks them. Reset does not affect these registers. They are located in RAM and must be explicitly initialized prior to any reception.

It is possible for the RXIMR memory region to be accessed as general-purpose memory. See Bus interface for more information.

Diagram



Fields

Field	Function
31-0 MI	Individual Mask Bits Masks the corresponding bit in both the message buffer filter and Legacy RX FIFO ID filter table element in distinct ways. For message buffer filters, see RX Message Buffers Global Mask (RXMGMASK). For Legacy RX FIFO ID filter table elements, see Legacy RX FIFO Global Mask (RXFGMASK). 0b - The corresponding bit in the filter is "don't care." 1b - The corresponding bit in the filter is checked.

48.5.2.19 Pretended Networking Control 1 (CTRL1_PN)

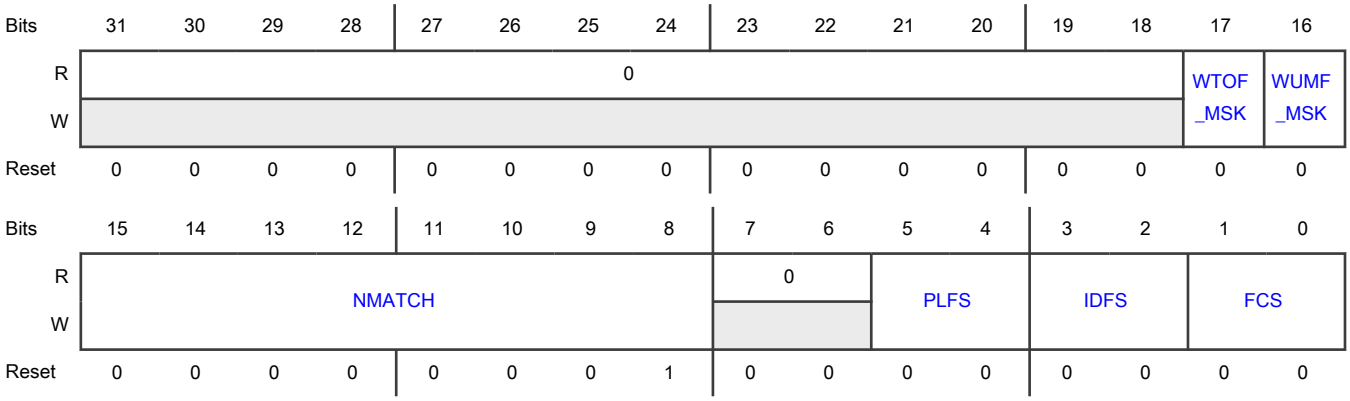
Offset

Register	Offset
CTRL1_PN	B00h

Function

Contains control bits for Pretended Networking mode filtering selection. Configure this register with the filter criteria to be used to receive wake-up messages. Fields in this register can be written in Freeze mode only, except for CTRL1_PN[WTOF_MSK] and CTRL1_PN[WUMF_MSK].

Diagram



Fields

Field	Function
31-18 —	Reserved
17 WTOF_MSK	Wake-up by Timeout Flag Mask Enables the generation of a wake-up event originated by a timeout. 0b - Disable 1b - Enable
16 WUMF_MSK	Wake-up by Matching Flag Mask Enables the generation of a wake-up event originated by a successful filtered RX message. 0b - Disable 1b - Enable
15-8 NMATCH	Number of Messages Matching the Same Filtering Criteria Defines the number of times a given message must match the predefined filtering criteria for ID or payload before generating a wake-up event. You can configure this quantity in the 1–255 range by using values 01h–FFh, respectively. 0000_0001b - Once 0000_0010b - Twice 1111_1111b - 255 times
7-6 —	Reserved
5-4 PLFS	Payload Filtering Selection Selects the level of payload filtering to be applied when FlexCAN is in Pretended Networking mode. When payload filtering is active, filtering does not accept remote messages (RTR = 1).

Table continues on the next page...

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Field	Function
	00b - Match payload contents to an exact target value 01b - Match a payload value greater than or equal to a specified target value 10b - Match a payload value smaller than or equal to a specified target value 11b - Match upon a payload value within a range of values, inclusive
3-2 IDFS	ID Filtering Selection Selects the level of ID filtering to be applied when FlexCAN is in Pretended Networking mode. In ID filtering, if FLT_ID2_IDMASK[IDE_MSK] = 1 and FLT_ID2_IDMASK[RTR_MSK] = 1, the IDE and RTR bits are considered part of the reception filter. 00b - Match ID contents to an exact target value 01b - Match an ID value greater than or equal to a specified target value 10b - Match an ID value smaller than or equal to a specified target value 11b - Match an ID value within a range of values, inclusive
1-0 FCS	Filtering Combination Selection Selects the filtering criteria to be applied when FlexCAN is in Pretended Networking mode. See Receive process in Pretended Networking mode for more details. 00b - Message ID filtering only 01b - Message ID filtering and payload filtering 10b - Message ID filtering occurring a specified number of times 11b - Message ID filtering and payload filtering a specified number of times

48.5.2.20 Pretended Networking Control 2 (CTRL2_PN)

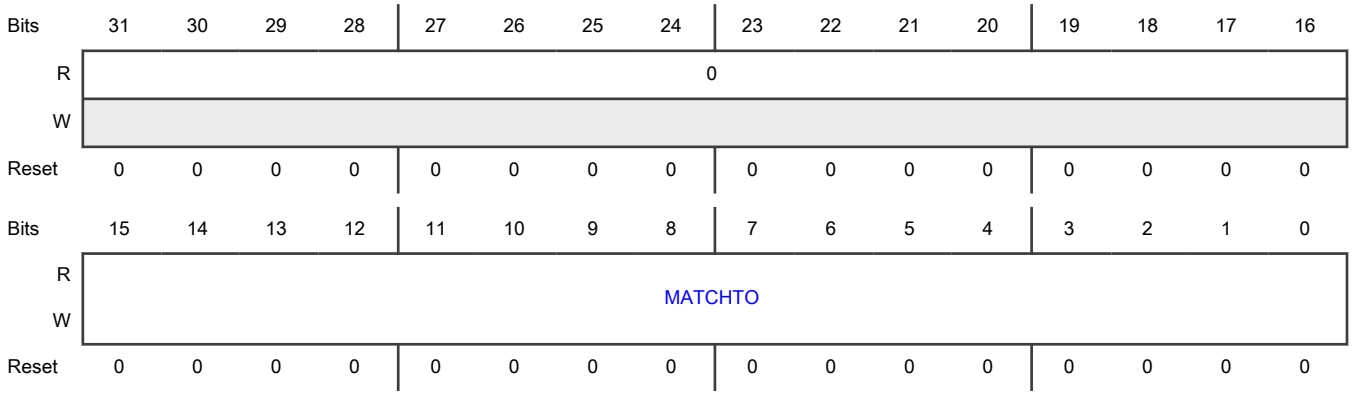
Offset

Register	Offset
CTRL2_PN	B04h

Function

Contains the configuration for the timeout value in Pretended Networking mode. You can only write to this register in Freeze mode.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 MATCHTO	Timeout for No Message Matching the Filtering Criteria Defines a timeout value that generates a wake-up event if MCR[PNET_EN] = 1. If the timeout counter reaches the target value when FlexCAN is in Pretended Networking mode, a wake-up event is generated. The timeout limit can be configured from 1 to 65535 to control an internal 16-bit incrementing timer to produce a trigger upon reaching this configured value. The internal timer is incremented based on periodic time ticks, where the period is 64 times the CAN Bit Time unit. Writing 0000h to this field disables the timeout.

48.5.2.21 Pretended Networking Wake-Up Match (WU_MTC)

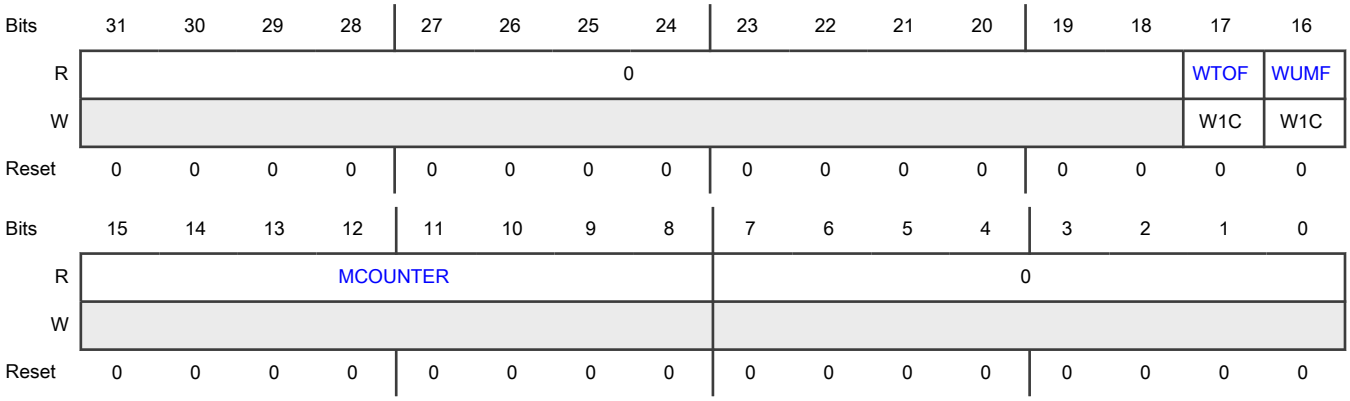
Offset

Register	Offset
WU_MTC	B08h

Function

Contains wake-up information related to the matching processes performed when FlexCAN receives frames in Pretended Networking mode.

Diagram



Fields

Field	Function
31-18 —	Reserved
17 WTOF	Wake-up by Timeout Flag Bit Identifies whether FlexCAN has detected a timeout event during a time interval defined by CTRL2_PN[MATCHTO]. If CTRL1_PN[WTOF_MSK] = 1, this flag generates a wake-up event. 0b - No event detected 1b - Event detected
16 WUMF	Wake-up by Match Flag Identifies whether FlexCAN has detected a matching RX incoming message that meets the filtering criteria specified in Pretended Networking Control 1 (CTRL1_PN). If CTRL1_PN[WUMF_MSK] = 1, this flag generates a wake-up event. 0b - No event detected 1b - Event detected
15-8 MCOUNTER	Number of Matches in Pretended Networking Contains the number of times a given message has matched the predefined filtering criteria for ID or payload before a wake-up event. When FlexCAN enters Pretended Networking mode, this register is reset; soft reset does not affect it.
7-0 —	Reserved

48.5.2.22 Pretended Networking ID Filter 1 (FLT_ID1)

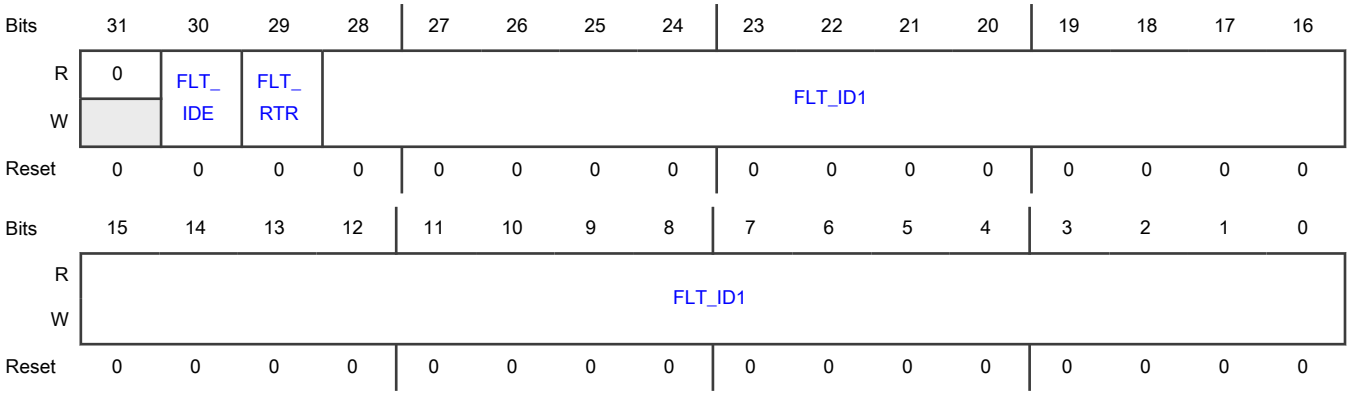
Offset

Register	Offset
FLT_ID1	B0Ch

Function

Contains FLT_ID1 target value, as well as IDE and RTR target values used to filter an incoming message ID. The FLT_ID1 is used for comparisons or as the lower limit value in an ID range detection. It can be written in Freeze mode only.

Diagram



Fields

Field	Function
31 —	Reserved
30 FLT_IDE	ID Extended Filter Identifies whether the frame format is standard or extended. It is used as part of the ID reception filter. 0b - Standard 1b - Extended
29 FLT_RTR	Remote Transmission Request Filter Identifies whether the frame is remote. It is used as part of the ID reception filter. 0b - Reject remote frame (accept data frame) 1b - Accept remote frame
28-0 FLT_ID1	ID Filter 1 for Pretended Networking filtering Defines either the 29 bits of an extended frame format, considering all bits, or the 11 bits of a standard frame format, considering only the leftmost 11 bits.

48.5.2.23 Pretended Networking Data Length Code (DLC) Filter (FLT_DLC)

Offset

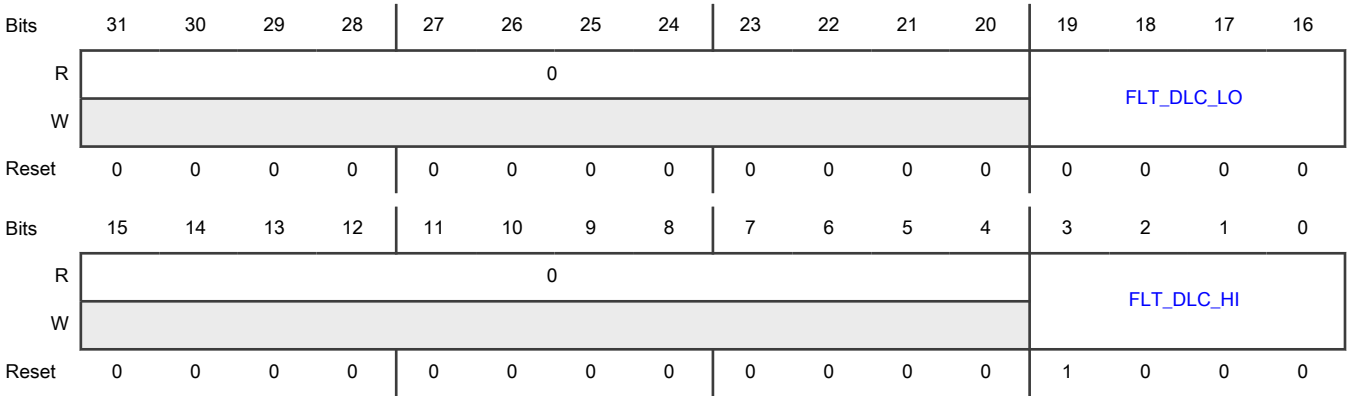
Register	Offset
FLT_DLC	B10h

Function

Contains the DLC inside a range of target values (FLT_DLC_LO and FLT_DLC_HI) used to filter an incoming message. The DLC range is used only for payload filtering. It can be written in Freeze mode only.

When a fixed quantity of data bytes is required, write the same value to FLT_DLC[FLT_DLC_LO] and FLT_DLC[FLT_DLC_HI]. See Receive process in Pretended Networking mode.

Diagram



Fields

Field	Function
31-20 —	Reserved
19-16 FLT_DLC_LO	Lower Limit for Length of Data Bytes Filter Specifies the lower limit for the number of data bytes considered valid for payload comparison. It is used as part of payload reception filter.
15-4 —	Reserved
3-0 FLT_DLC_HI	Upper Limit for Length of Data Bytes Filter Specifies the upper limit for the number of data bytes considered valid for payload comparison. It is used as part of payload reception filter.

48.5.2.24 Pretended Networking Payload Low Filter 1 (PL1_LO)

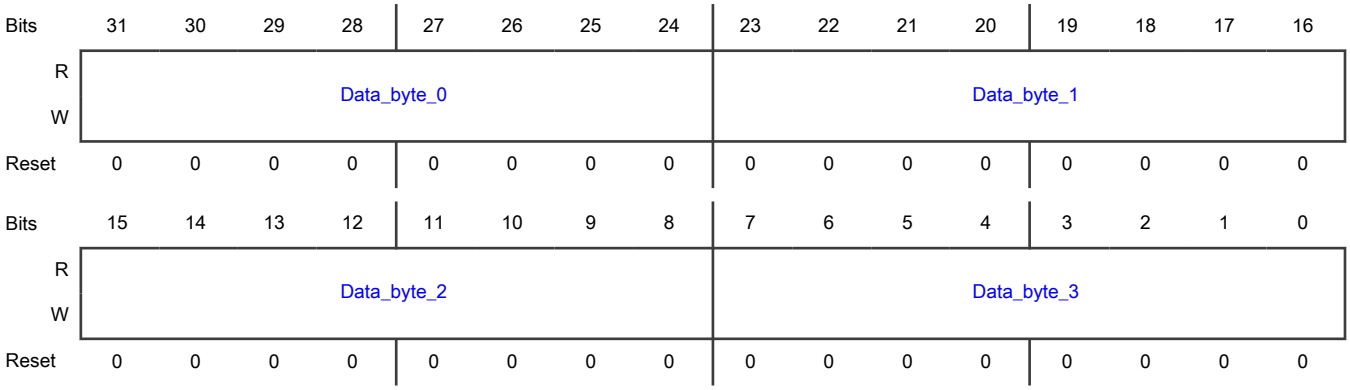
Offset

Register	Offset
PL1_LO	B14h

Function

Contains the low-order bits of the target value used to filter incoming message payload for payload filter 1. It is used for comparisons or as the lower limit value in a payload range detection. It can be written in Freeze mode only.

Diagram



Fields

Field	Function
31-24 Data_byte_0	Data byte 0 Contains payload filter 1 low-order bits for PN payload filtering corresponding to data byte 0.
23-16 Data_byte_1	Data byte 1 Contains payload filter 1 low-order bits for PN payload filtering corresponding to data byte 1.
15-8 Data_byte_2	Data byte 2 Contains payload filter 1 low-order bits for PN payload filtering corresponding to data byte 2.
7-0 Data_byte_3	Data byte 3 Contains payload filter 1 low-order bits for PN payload filtering corresponding to data byte 3.

48.5.2.25 Pretended Networking Payload High Filter 1 (PL1_HI)

Offset

Register	Offset
PL1_HI	B18h

Function

Contains the high-order bits of the target value used to filter incoming message payload for payload filter 1. It is used either for comparisons or as the lower limit value in a payload range detection. It can be written in Freeze mode only.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	Data_byte_4								Data_byte_5							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Data_byte_6								Data_byte_7							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 Data_byte_4	Data byte 4 Contains payload filter 1 high-order bits for PN payload filtering corresponding to data byte 4.
23-16 Data_byte_5	Data byte 5 Contains payload filter 1 high-order bits for PN payload filtering corresponding to data byte 5.
15-8 Data_byte_6	Data byte 6 Contains payload filter 1 high-order bits for PN payload filtering corresponding to data byte 6.
7-0 Data_byte_7	Data byte 7 Contains payload filter 1 high-order bits for PN payload filtering corresponding to data byte 7.

48.5.2.26 Pretended Networking ID Filter 2 or ID Mask (FLT_ID2_IDMASK)

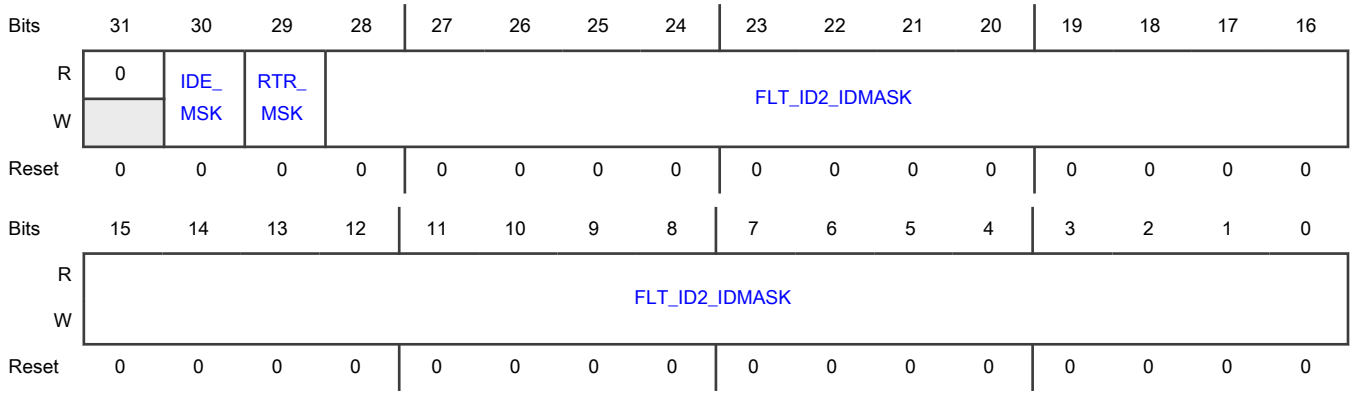
Offset

Register	Offset
FLT_ID2_IDMASK	B1Ch

Function

Contains FLT_ID2 target value used only as the upper limit value in ID range detection. When an exact ID filtering criterion is selected, this register stores the ID mask. IDE_MSK and RTR_MSK are used in both types of ID filtering (exact and range). These fields enable FLT_ID1[FLT_IDE] and FLT_ID1[FLT_RTR] to be used as part of the ID reception filter. This register can be written in Freeze mode only.

Diagram



Fields

Field	Function
31 —	Reserved
30 IDE_MSK	ID Extended Mask Indicates whether the frame format (standard or extended) is used as part of the ID reception filter. 0b - The corresponding bit in the filter is "don't care." 1b - The corresponding bit in the filter is checked.
29 RTR_MSK	Remote Transmission Request Mask Indicates whether the frame type (data or remote) is part of the ID reception filter. 0b - The corresponding bit in the filter is "don't care." 1b - The corresponding bit in the filter is checked.
28-0 FLT_ID2_IDMASK	ID Filter 2 for Pretended Networking Filtering or ID Mask Bits for Pretended Networking ID Filtering Defines filter values in range ID filtering: • Value in extended frame format (29 bits), considering FLT_ID2[28:0] • Value in standard frame format (11 bits), considering the FLT_ID2[28:18]. In this case, bits [17:0] are meaningless. Or, defines the mask values in exact ID filtering: • Values for extended frame format (29 bits), considering IDMASK[28:0] • Values for standard frame format (11 bits), considering IDMASK[28:18]. In this case, bits [17:0] are meaningless.

48.5.2.27 Pretended Networking Payload Low Filter 2 and Payload Low Mask (PL2_PLMASK_LO)

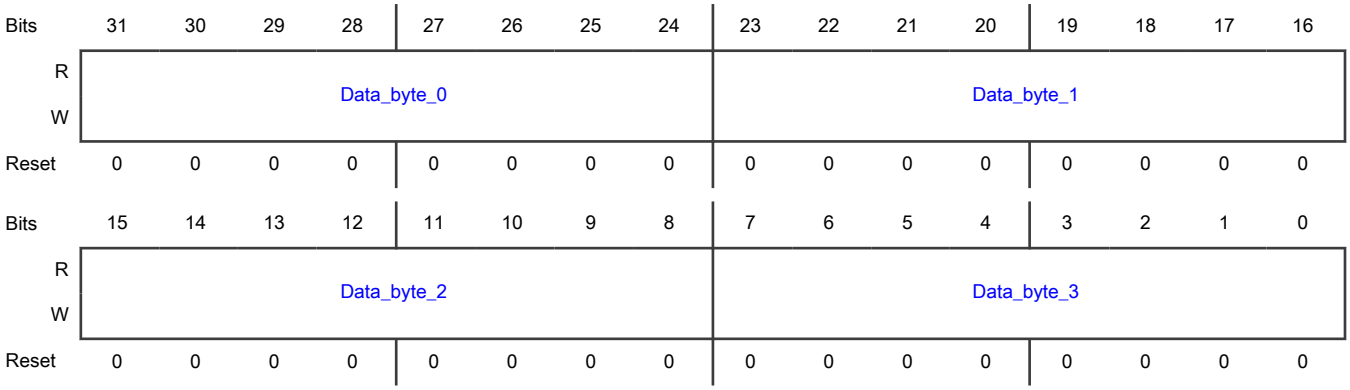
Offset

Register	Offset
PL2_PLMASK_LO	B20h

Function

Contains the low-order bits for Payload Filter 2, used only as the upper limit value in a payload range detection. Also, when an exact payload filtering criterion is selected, this register is used as payload mask for the low-order bits. Otherwise, this register is unused. It can be written in Freeze mode only.

Diagram



Fields

Field	Function
31-24 Data_byte_0	Data Byte 0 Contains payload filter 2 low-order bits, or Payload Mask low-order bits for PN payload filtering, corresponding to data byte 0
23-16 Data_byte_1	Data Byte 1 Contains payload filter 2 low-order bits, or Payload Mask low-order bits for PN payload filtering, corresponding to data byte 1
15-8 Data_byte_2	Data Byte 2 Contains payload filter 2 low-order bits, or Payload Mask low-order bits for PN payload filtering, corresponding to data byte 2
7-0 Data_byte_3	Data Byte 3 Contains payload filter 2 low-order bits, or Payload Mask low-order bits for PN payload filtering, corresponding to data byte 3

48.5.2.28 Pretended Networking Payload High Filter 2 and Payload High Mask (PL2_PLMASK_HI)

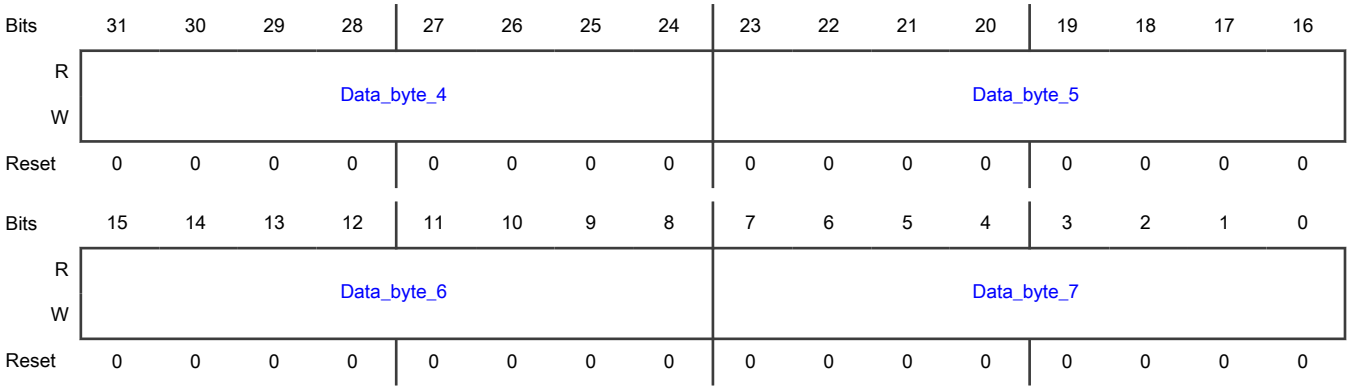
Offset

Register	Offset
PL2_PLMASK_HI	B24h

Function

Contains the high-order bits for the Payload Filter 2, used only as the upper limit value in a payload range detection. Also, when an exact payload filtering criterion is selected, this register is used as payload mask for the high-order bits. Otherwise, this register is unused. It can be written in Freeze mode only.

Diagram



Fields

Field	Function
31-24 Data_byte_4	Data Byte 4 Contains payload filter 2 high-order bits, or Payload Mask high-order bits for PN payload filtering, corresponding to data byte 4.
23-16 Data_byte_5	Data Byte 5 Contains payload filter 2 high-order bits, or Payload Mask high-order bits for PN payload filtering, corresponding to data byte 5.
15-8 Data_byte_6	Data Byte 6 Contains payload filter 2 high-order bits, or Payload Mask high-order bits for PN payload filtering, corresponding to data byte 6.
7-0 Data_byte_7	Data Byte 7 Contains payload filter 2 high-order bits, or Payload Mask high-order bits for PN payload filtering, corresponding to data byte 7.

48.5.2.29 Wake-Up Message Buffer (WMB0_CS - WMB3_CS)

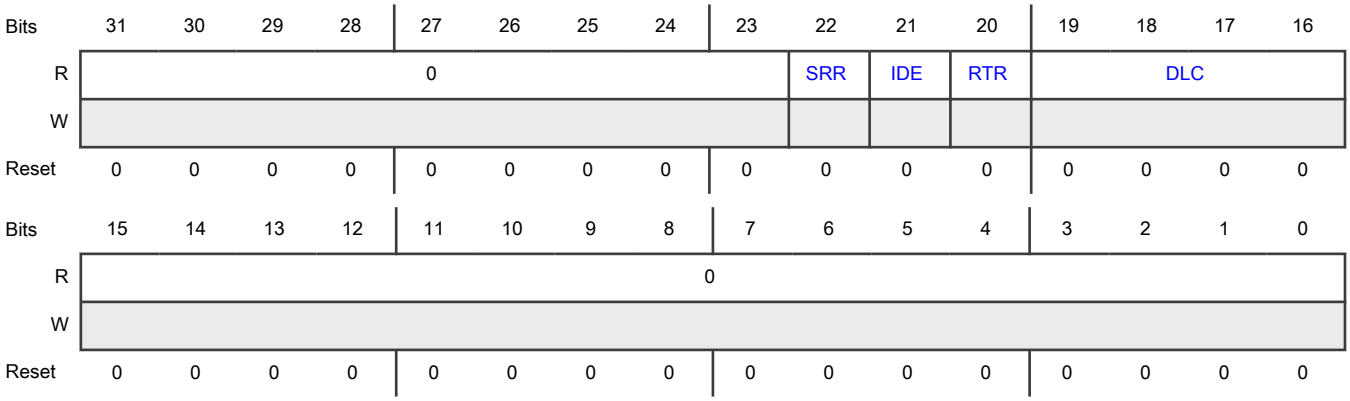
Offset

Register	Offset
WMB0_CS	B40h
WMB1_CS	B50h
WMB2_CS	B60h
WMB3_CS	B70h

Function

Stores the Control and Status information (IDE, RTR, and DLC fields) of an incoming RX message.

Diagram



Fields

Field	Function
31-23 —	Reserved
22 SRR	Substitute Remote Request Identifies whether the request is dominant or recessive. This field is used only in extended format. You must write 1 to this field for transmission buffers. The value of this field is stored with the value received on the CAN bus for receiving buffers. If FlexCAN receives this field as dominant, it is interpreted as an arbitration loss. 0b - Dominant 1b - Recessive
21 IDE	ID Extended Bit Identifies whether the frame format is standard or extended.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Standard 1b - Extended
20 RTR	Remote Transmission Request Identifies whether the frame is remote or data 0b - Data 1b - Remote
19-16 DLC	Length of Data in Bytes Contains the length (in bytes) of the RX data received when FlexCAN is in Pretended Networking mode. FlexCAN writes this field, copied from the DLC (Data Length Code) field of the received frame. The DLC field indicates which data bytes are valid.
15-0 —	Reserved

48.5.2.30 Wake-Up Message Buffer for ID (WMB0_ID - WMB3_ID)

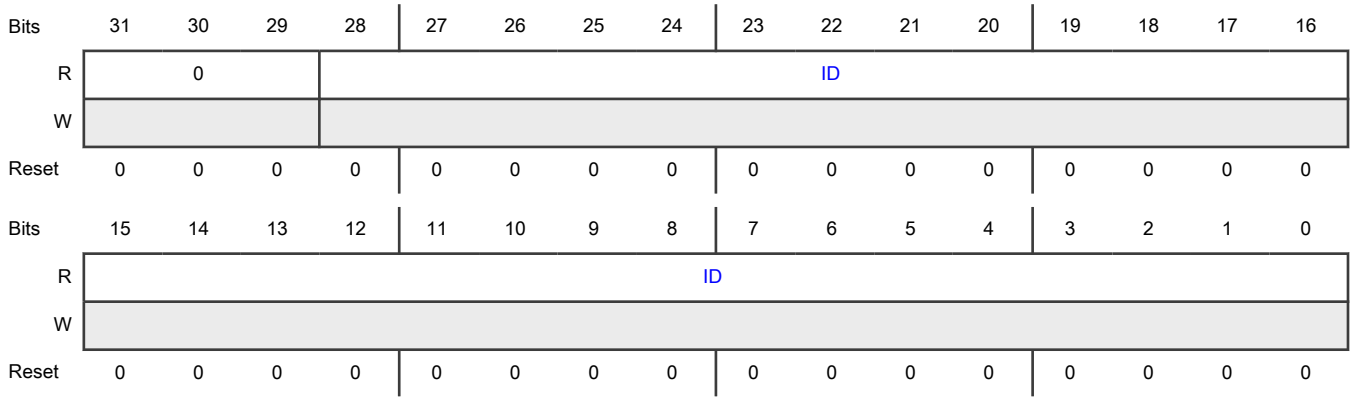
Offset

Register	Offset
WMB0_ID	B44h
WMB1_ID	B54h
WMB2_ID	B64h
WMB3_ID	B74h

Function

Stores the ID information of an incoming RX message.

Diagram



Fields

Field	Function
31-29 —	Reserved
28-0 ID	Received ID in Pretended Networking Mode Stores the received ID, which is: • The 29 bits of the extended frame format (considering ID[28:0]) • The 11 bits of the standard frame format (considering ID[28:18] only; the remaining bits in the ID[17:0] range are meaningless).

48.5.2.31 Wake-Up Message Buffer for Data 0–3 (WMB0_D03 - WMB3_D03)

Offset

Register	Offset
WMB0_D03	B48h
WMB1_D03	B58h
WMB2_D03	B68h
WMB3_D03	B78h

Function

Stores data bytes 0–3 of the payload information of an incoming RX message. The content of each register is cleared when the incoming matched message is either a remote frame (RTR = 1) or a data frame with DLC = 0.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	Data_byte_0								Data_byte_1							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Data_byte_2								Data_byte_3							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 Data_byte_0	Data Byte 0 Contains received payload corresponding to data byte 0 in Pretended Networking mode
23-16 Data_byte_1	Data Byte 1 Contains received payload corresponding to data byte 1 in Pretended Networking mode
15-8 Data_byte_2	Data Byte 2 Contains received payload corresponding to data byte 2 in Pretended Networking mode
7-0 Data_byte_3	Data Byte 3 Contains received payload corresponding to data byte 3 in Pretended Networking mode

48.5.2.32 Wake-Up Message Buffer Register Data 4–7 (WMB0_D47 - WMB3_D47)

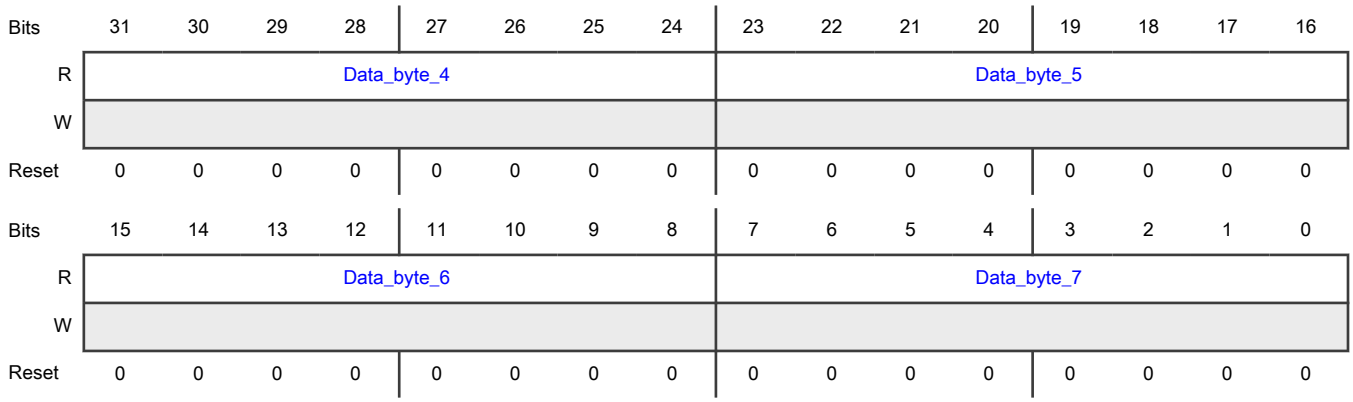
Offset

Register	Offset
WMB0_D47	B4Ch
WMB1_D47	B5Ch
WMB2_D47	B6Ch
WMB3_D47	B7Ch

Function

Stores the data bytes 4–7 of the payload information of an incoming RX message. The content of each register is cleared when the incoming matched message is either a remote frame (RTR = 1) or a data frame with DLC = 0.

Diagram



Fields

Field	Function
31-24 Data_byte_4	Data Byte 4 Contains received payload corresponding to data byte 4 in Pretended Networking mode
23-16 Data_byte_5	Data Byte 5 Contains received payload corresponding to data byte 5 in Pretended Networking mode
15-8 Data_byte_6	Data Byte 6 Contains received payload corresponding to data byte 6 in Pretended Networking mode
7-0 Data_byte_7	Data Byte 7 Contains received payload corresponding to data byte 7 in Pretended Networking mode

48.5.2.33 Enhanced CAN Bit Timing Prescalers (EPRS)

Offset

Register	Offset
EPRS	BF0h

Function

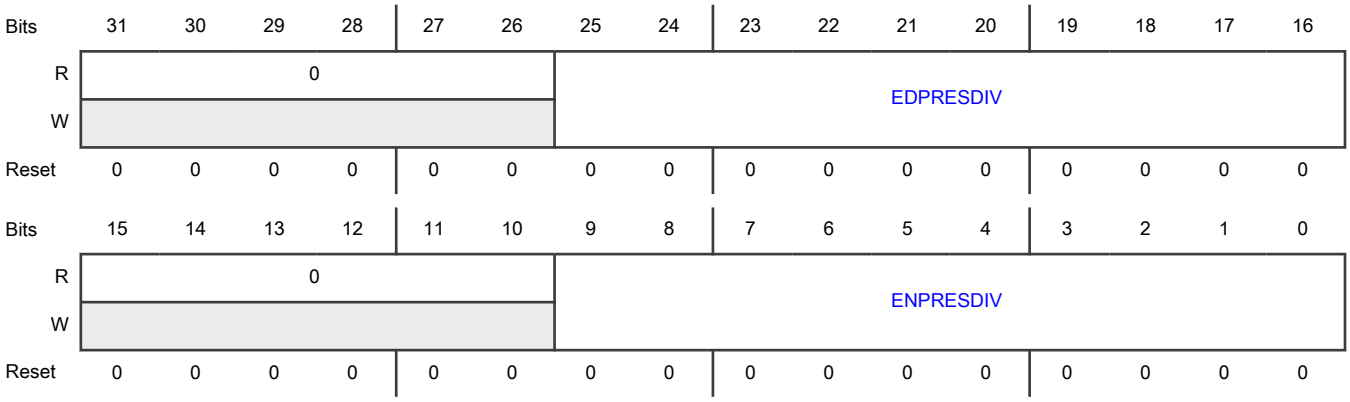
Defines the CAN bit timing prescalers for the nominal phase and data phase when CTRL2[BTE] = 1.

Used by the module only if CTRL2[BTE] = 1; otherwise, a write operation has no effect and all fields are read as zero.

This register can be written only in Freeze mode; the module blocks it in other modes.

Soft reset does not affect the contents of this register.

Diagram



Fields

Field	Function
31-26 —	Reserved
25-16 EDPRESDIV	Extended Data Phase Prescaler Division Factor Defines the ratio between the PE clock frequency and the Sclock frequency in the data phase of a CAN FD message when CTRL2[BTE] = 1. The Sclock period defines the time quantum of the CAN FD protocol for the data bit rate. Sclock frequency = PE clock frequency ÷ (EDPRESDIV + 1) **NOTE** To minimize errors when processing FD frames, use the same value for this field and for EPRS[ENPRESDIV]. See the first note in CAN FD frames for details.
15-10 —	Reserved
9-0 ENPRESDIV	Extended Nominal Prescaler Division Factor Defines the ratio between the PE clock frequency and the Sclock frequency when CTRL2[BTE] = 1. Otherwise, it reads as 0 and a write operation has no effect. The Sclock period defines the time quantum of the CAN protocol in the nominal phase. For the reset value, the Sclock frequency is equal to the PE clock frequency (see Protocol timing). Sclock frequency = PE clock frequency ÷ (ENPRESDIV + 1)

48.5.2.34 Enhanced Nominal CAN Bit Timing (ENCBT)

Offset

Register	Offset
ENCBT	BF4h

Function

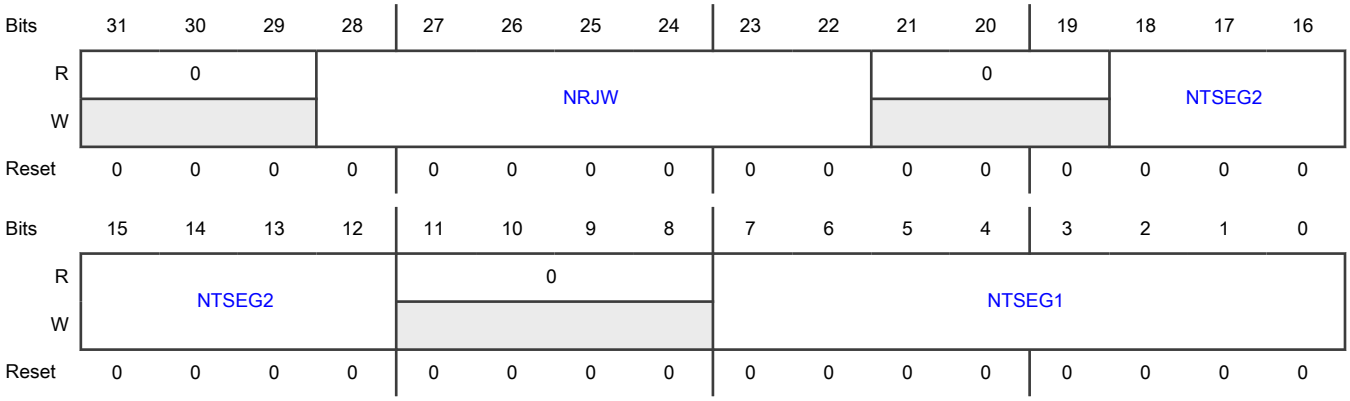
Provides an alternative way to store the CAN bit timing variables described in Control 1 (CTRL1) and CAN Bit Timing (CBT), to get higher CAN bit timing resolution.

This register is used by the module only if CTRL2[BTE] = 1. Otherwise, a write operation has no effect and all fields are read as zero.

Soft reset does not affect the contents of this register.

This register can be written only in Freeze mode; the module blocks it in other modes.

Diagram



Fields

Field	Function
31-29 —	Reserved
28-22 NRJW	Nominal Resynchronization Jump Width Defines the maximum number of time quanta that one resynchronization can change a nominal bit time when CTRL2[BTE] = 1. Otherwise, it has no effect. One time quantum = one Sclock period Nominal Resync Jump Width = NRJW + 1
21-19 —	Reserved
18-12 NTSEG2	Nominal Time Segment 2 Defines the length of Time Segment 2 in the nominal bit time when CTRL2[BTE] = 1. Otherwise, it has no effect. Nominal Time Segment 2 = (NTSEG2 + 1) × Time Quanta One time quantum = one Sclock period
11-8 —	Reserved
7-0 NTSEG1	Nominal Time Segment 1 Defines the length of Time Segment 1 in the bit time when CTRL2[BTE] = 1. Otherwise, it has no effect. Nominal Time Segment 1 = (NTSEG1 + 1) × Time Quanta One time quantum = one Sclock period

48.5.2.35 Enhanced Data Phase CAN Bit Timing (EDCBT)

Offset

Register	Offset
EDCBT	BF8h

Function

Provides an alternative way to store the data phase CAN bit timing variables described in CAN FD Bit Timing (FDCBT) to achieve higher CAN bit timing resolution.

This register is used by the module only if CTRL2[BTE] = 1; otherwise, a write operation has no effect and all fields are read as zero.

Soft reset does not affect the contents of this register.

This register can be written only in Freeze mode; the module blocks it in other modes.

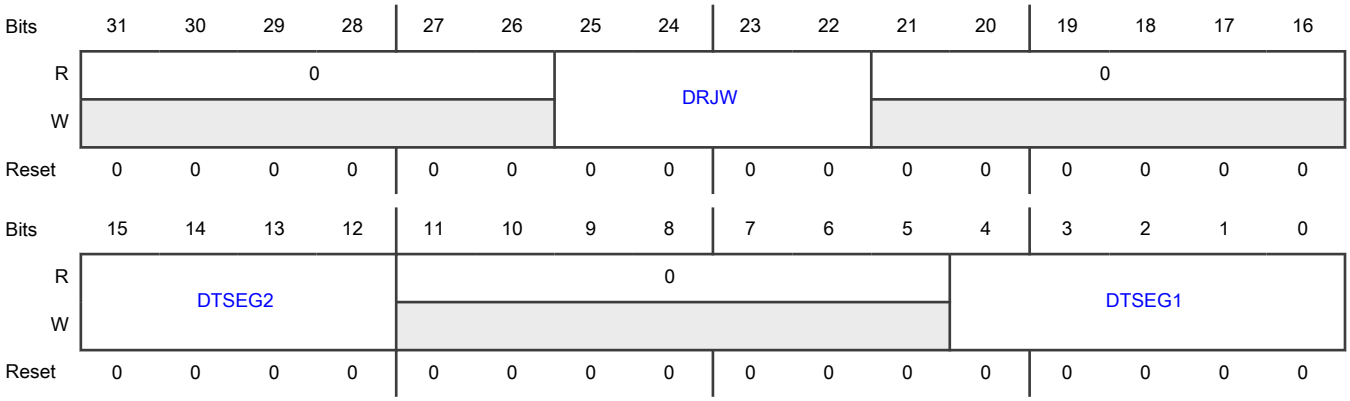
NOTE

Ensure that bit time settings and protocol engine tolerance are in compliance with the CAN Protocol standard ISO 11898-1:2015.

NOTE

DTSEG1 must be at least two time quanta.

Diagram



Fields

Field	Function
31-26 —	Reserved
25-22 DRJW	Data Phase Resynchronization Jump Width Defines the maximum number of time quanta that one resynchronization can change a data phase bit time when CTRL2[BTE] = 1. Otherwise, it has no effect.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	Data Phase Resync Jump Width = DRJW + 1.
21-16 —	Reserved
15-12 DTSEG2	Data Phase Time Segment 2 Defines the length of time segment 2 in the data phase bit time when CTRL2[BTE] = 1. Otherwise, it has no effect. Data Phase Time Segment 2 = (DTSEG2 + 1) × Time Quanta. One Time Quantum = one Sclock period.
11-5 —	Reserved
4-0 DTSEG1	Data Phase Segment 1 Defines the length of time segment 1 in the data phase bit time when CTRL2[BTE] = 1. Otherwise, it has no effect. Data Phase Time Segment 1 = (NTSEG1 + 1) × Time Quanta. One Time Quantum = one Sclock period.

48.5.2.36 Enhanced Transceiver Delay Compensation (ETDC)

Offset

Register	Offset
ETDC	BFCh

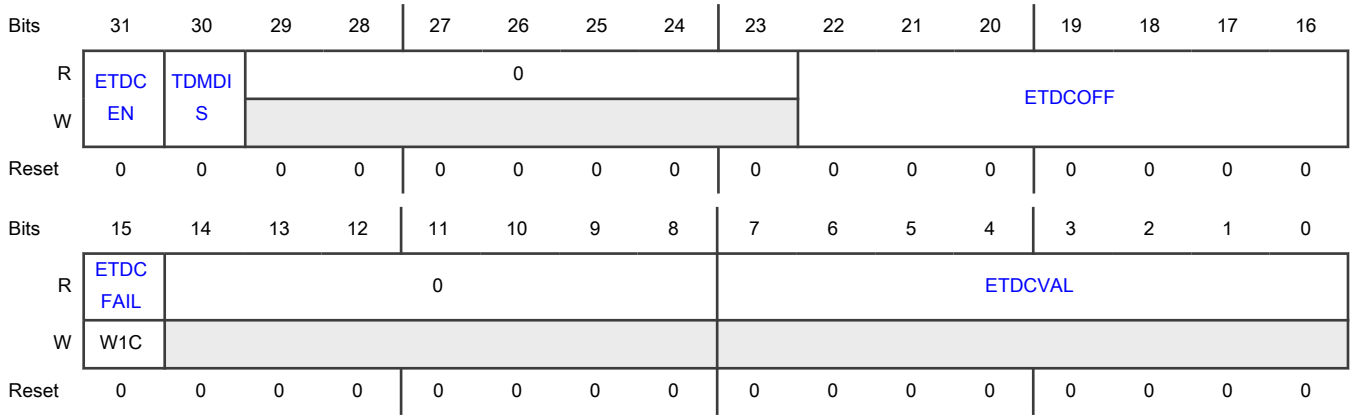
Function

Contains extended versions of FDCTRL[TDCOFF] and FDCTRL[TDCVAL]. This register is used by the module only if CTRL2[BTE] = 1. Otherwise, a write operation has no effect and all fields are read as zero.

NOTE

See Transmitter delay compensation in the CAN Protocol standard ISO 11898-1:2015 for details.

Diagram



Fields

Field	Function
31 ETDCEN	Transceiver Delay Compensation Enable Enables the TDC feature. It can be written in Freeze mode only. **NOTE** See Transmitter delay compensation in the CAN Protocol standard ISO 11898-1:2015 for details. **NOTE** TDC must be disabled when the Loop Back Mode is enabled. See CTRL1[LPB]. 0b - Disable 1b - Enable
30 TDMDIS	Transceiver Delay Measurement Disable Disables the transceiver delay measurement. When the TDC measurement is disabled, only ETDC[ETDCOFF] determines the secondary sample point position. If TCD measurement is enabled, the sum of the transceiver delay measurement plus the enhanced TDC offset determines the secondary sample point position. Soft reset does not affect this field. **NOTE** This bit can be enabled only if CTRL2[BTE] = 1. 0b - Enable 1b - Disable
29-23 —	Reserved
22-16	Enhanced Transceiver Delay Compensation Offset

Table continues on the next page...

Table continued from the previous page...

Field	Function
ETDCOFF	Contains the offset value to be added to the loop delay of the measured transceiver. This value defines the position of the delayed comparison point when bit rate switching is active. See Transceiver delay compensation for details on how the loop delay measurement is performed. This field can be written in Freeze mode only. Its value can be defined in protocol engine (PE) clock periods (CANCLK, see Protocol timing for more details). It must be smaller than the CAN bit duration in the data bit rate for proper operation. Do not write 0 to this field. **NOTE** If CTRL2[BTE] becomes 1 after a chip-level hard reset, this field is read as 1h.
15 ETDCFAIL	Transceiver Delay Compensation Fail Indicates whether the transceiver delay compensation (TDC) mechanism is out of range. In this case, it is unable to compensate the loop delay of the transceiver and successfully compare the delayed received bits to the transmitted ones. (See Transceiver delay compensation.) This field becomes 0 the first time FlexCAN detects the out of range condition. 0b - In range 1b - Out of range
14-8 —	Reserved
7-0 ETDCVAL	Enhanced Transceiver Delay Compensation Value Contains ETDC[ETDCOFF] added to the measured value of the transceiver loop delay in the latest transmitted CAN FD frame, with BRS = 1. The module only updates this field when ETDC[ETDCEN] = 1. Soft reset affects this field. **NOTE** If ETDC[TDMDIS] = 1, this field stores ETDC[ETDCOFF] only.

48.5.2.37 CAN FD Control (FDCTRL)

Offset

Register	Offset
FDCTRL	C00h

Function

Contains control bits for CAN FD operation. It also defines the data size of message buffers allocated in different partitions of RAM (memory blocks) as described in Table 380.

When an 8-byte payload is selected:

- Block R0 allocates MB0–MB31.
- Block R1 allocates MB32–MB63.

When a payload larger than eight bytes is selected, the maximum number of message buffers in a block is limited as described below.

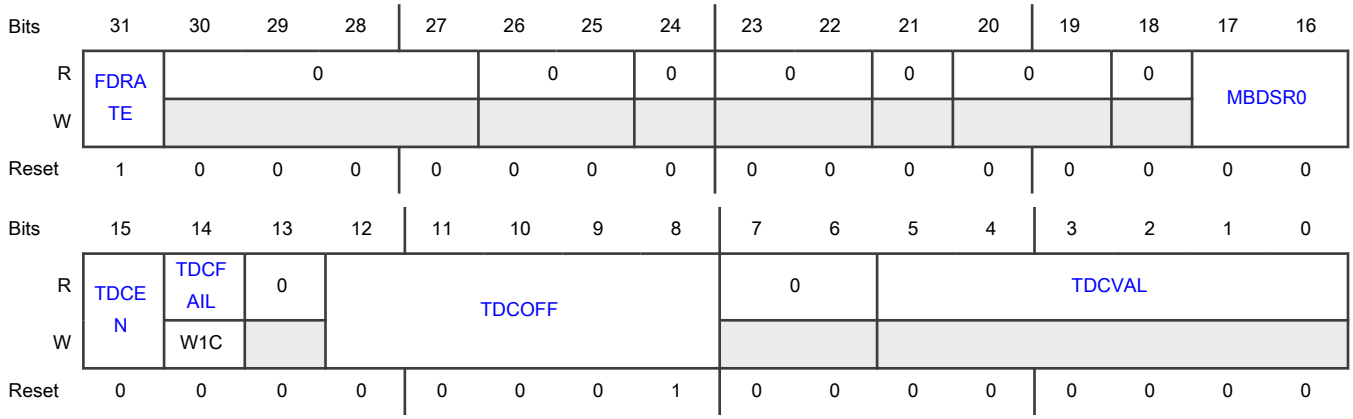
Table 380. Number of message buffers

Payload size	Maximum number of message buffers per RAM block
8 bytes	32
16 bytes	21
32 bytes	12
64 bytes	7

One memory block fits exactly 32 message buffers with an 8-byte payload. For other possible payload sizes, empty memory may exist between the last message buffer in a block and the beginning of the next block. This empty memory corresponds to less than one message buffer, and must not be used.

Soft reset does not affect the contents of this register.

Diagram



Fields

Field	Function
31 FDRATE	Bit Rate Switch Enable Enables the effect of the Bit Rate Switch (BRS bit) during the data phase of TX messages. When 1, if BRS = 1 in the TX message buffer, frames are transmitted with bit rate switching. When 0, frames are transmitted at a nominal rate, and the BRS bit in the TX MB has no effect. The CPU can write to this field at any time. However, its effect becomes active only under one of these conditions: • The CAN bus is in the Wait for Bus Idle state. • The CAN bus is in the Bus Idle state. • The CAN bus is in the Bus Off state.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	• The current frame under reception or transmission reaches the interframe space. By writing 0 to FDCTRL[FDRATE], the CPU can force all bits in CAN FD messages to be transmitted at nominal bit rate. This transmission occurs regardless of the value in the BRS bit of the TX message buffers. 0b - Disable 1b - Enable
30-27 —	Reserved
26-25 —	Reserved
24 —	Reserved
23-22 —	Reserved
21 —	Reserved
20-19 —	Reserved
18 —	Reserved
17-16 MBDSR0	Message Buffer Data Size for Region 0 Selects the data size per message buffer for region R0 of message buffers allocated in RAM. This field can be written in Freeze mode only. 00b - 8 bytes 01b - 16 bytes 10b - 32 bytes 11b - 64 bytes
15 TDCEN	Transceiver Delay Compensation Enable Enables the TDC feature. It can be written in Freeze mode only. See Transmitter delay compensation in the CAN Protocol standard ISO 11898-1:2015 for details. TDC must be disabled when Loopback mode is enabled (see CTRL1[LPB]).

Table continues on the next page...

Table continued from the previous page...

Field	Function
	NOTE If CTRL2[BTE] = 1, this field is read as 0 and a write operation has no effect. 0b - Disable 1b - Enable
14 TDCFAIL	Transceiver Delay Compensation Fail Indicates whether the Transceiver Delay Compensation (TDC) mechanism is out of range. In this case, the mechanism cannot compensate for the loop delay of the transceiver and successfully compare the delayed received bits to the transmitted ones (see Transceiver delay compensation). The first time that FlexCAN detects the out-of-range condition, this field becomes 1. **NOTE** If CTRL2[BTE] = 1, this field is read as 0 and a write operation has no effect. 0b - In range 1b - Out of range
13 —	Reserved
12-8 TDCOFF	Transceiver Delay Compensation Offset Contains the offset value to be added to the loop delay of the measured transceiver. This value defines the position of the delayed comparison point when bit rate switching is active. See Transceiver delay compensation for details about loop delay measurement. This field can be written in Freeze mode only. Its value can be defined in Protocol Engine Clock periods (CANCLK, see Protocol timing for more details). The value must be smaller than the CAN bit duration in the data bit rate for proper operation. **NOTE** If CTRL2[BTE] = 1, TDCOFF is read as 0 and a write operation has no effect. Do not write 0 to this field.
7-6 —	Reserved
5-0 TDCVAL	Transceiver Delay Compensation Value Contains the value of the transceiver loop delay measured from the transmitted EDL-to-R0 transition edge to the respective received one added to FDCTRL[TDCOFF]. This value is an integer multiple of the Protocol Engine Clock period (CANCLK). If CTRL2[BTE] = 1, this field is read as 0. See Protocol timing for details on the loop delay measurement.

48.5.2.38 CAN FD Bit Timing (FDCBT)

Offset

Register	Offset
FDCBT	C04h

Function

Stores the CAN bit timing variables used in the data phase of CAN FD messages when the FDCTRL[FDRATE] = 1, compatible with the CAN FD specification. Fields in this register define:

- The time quantum duration
- The number of time quanta per CAN bit
- The sample point position for the data bit rate portion of a CAN FD message with BRS = 1

Soft reset does not affect the contents of this register.

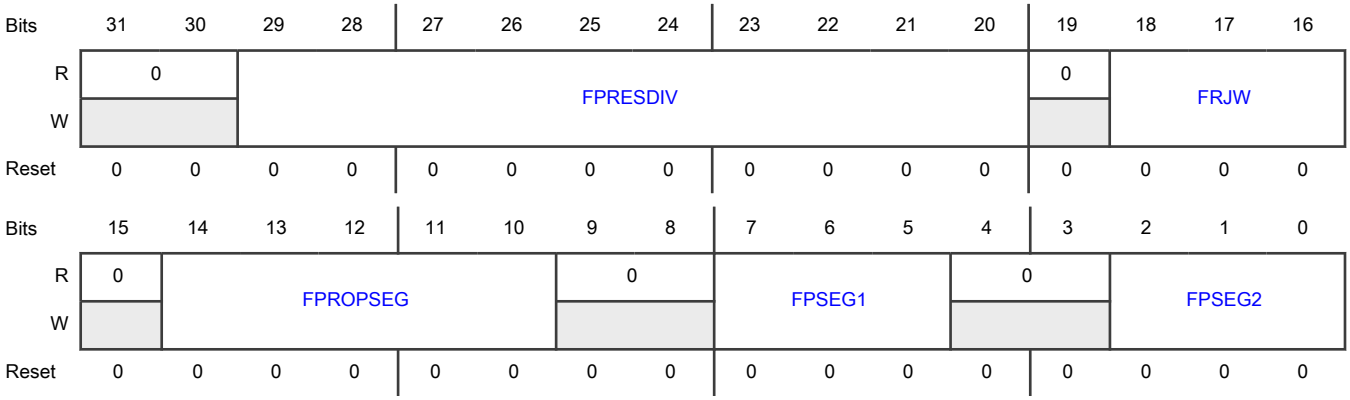
The sum of the Fast Propagation Segment (FPROPSEG) and Fast Phase Segment 1 (FPSEG1) must be at least two time quanta.

Ensure bit time settings and protocol engine tolerance are in compliance with the CAN Protocol standard ISO 11898-1:2015.

NOTE

If CTRL2[BTE] = 1, this register is read as zero and a write operation has no effect.

Diagram



Fields

Field	Function
31-30 —	Reserved
29-20 FPRESDIV	Fast Prescaler Division Factor Defines the ratio between the PE clock frequency and the serial clock (Sclock) frequency in the data bit rate portion of a CAN FD message with BRS = 1.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	The Sclock period defines the time quantum of the CAN FD protocol for the data bit rate. This field can be written only in Freeze mode; the module blocks it in other modes. Sclock frequency = PE clock frequency ÷ (FPRESDIV + 1). **NOTE** To minimize errors when processing FD frames, use the same value for this field and for CTRL1[PRESDIV] or CBT[EPRESDIV]. See the first note in CAN FD frames for details.
19 —	Reserved
18-16 FRJW	Fast Resync Jump Width Defines the maximum number of time quanta that one resynchronization can change a bit time in the data bit rate portion of a CAN FD message with BRS = 1. This field can be written only in Freeze mode; the module blocks it in other modes. Resync Jump Width = FSJW + 1. One Time Quantum = one Sclock period.
15 —	Reserved
14-10 FPROPSEG	Fast Propagation Segment Defines the length of the propagation segment in the bit time in the data bit rate portion of a CAN FD message with BRS = 1. This field can be written only in Freeze mode; the module blocks it in other modes. Propagation Segment Time = FPROPSEG × Time Quanta. One Time Quantum = one Sclock period.
9-8 —	Reserved
7-5 FPSEG1	Fast Phase Segment 1 Defines the length of phase segment 1 in the bit time in the data bit rate portion of a CAN FD message with BRS = 1. This field can be written only in Freeze mode; the module blocks it in other modes. Phase Segment 1 = (FPSEG1 + 1) × Time Quanta. One Time Quantum = one Sclock period.
4-3 —	Reserved
2-0 FPSEG2	Fast Phase Segment 2 Defines the length of phase segment 2 in the data bit rate portion of a CAN FD message with BRS = 1. This field can be written only in Freeze mode; the module blocks it in other modes.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	Phase Segment 2 = (FPSEG2 + 1) × Time Quanta. One Time Quantum = one Sclock period.

48.5.2.39 CAN FD CRC (FDCRC)

Offset

Register	Offset
FDCRC	C08h

Function

Provides information about the cyclic redundancy check (CRC) of transmitted messages.

FlexCAN uses different CRC polynomials for different frame formats.

- The CRC_15 polynomial is used for all frames in CAN format.
- The CRC_17 polynomial is used for frames in CAN FD format with a DATA FIELD up to 16 bytes.
- The CRC_21 polynomial is used for frames in CAN FD format with a DATA FIELD longer than 16 bytes.

Each polynomial shown below results in a Hamming distance of 6. This register is updated at the same time that the TX Interrupt flag is set.

$$\text{CRC_15} = \text{C599h}: \ (x^{15} + x^{14} + x^{10} + x^{8} + x^{7} + x^{4} + x^{3} + 1)$$

$$\text{CRC_17} = \text{3685Bh}: \ (x^{17} + x^{16} + x^{14} + x^{13} + x^{11} + x^{6} + x^{4} + x^{3} + x^{1} + 1)$$

$$\text{CRC_21} = \text{302899h}: \ (x^{21} + x^{20} + x^{13} + x^{11} + x^{7} + x^{4} + x^{3} + 1)$$

Equation 24. CRC polynomial used on CAN frame

NOTE

See CRC sequence calculation in the CAN Protocol standard ISO 11898-1:2015 for details.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	FD_MBCRC							0				FD_TXCRC			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	FD_TXCRC															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 —	Reserved
30-24 FD_MBCRC	CRC Message Buffer Number for FD_TXCRC Indicates the number of the message buffer corresponding to the value in FDCRC[FD_TXCRC], for both FD and non-FD frames. It reports the same information as in CRCR[MBCRC].
23-21 —	Reserved
20-0 FD_TXCRC	Extended Transmitted CRC value Contains the CRC value calculated over the most recent transmitted message. Different CRC polynomials are used for different frame formats. For CRC_15 and CRC_17, the six most significant bits and the four most significant bits are reported as zeroes, respectively. For CRC_15, this field has the same content as Cyclic Redundancy Check (CRCR).

48.5.2.40 Enhanced RX FIFO Control (ERFCR)

Offset

Register	Offset
ERFCR	C0Ch

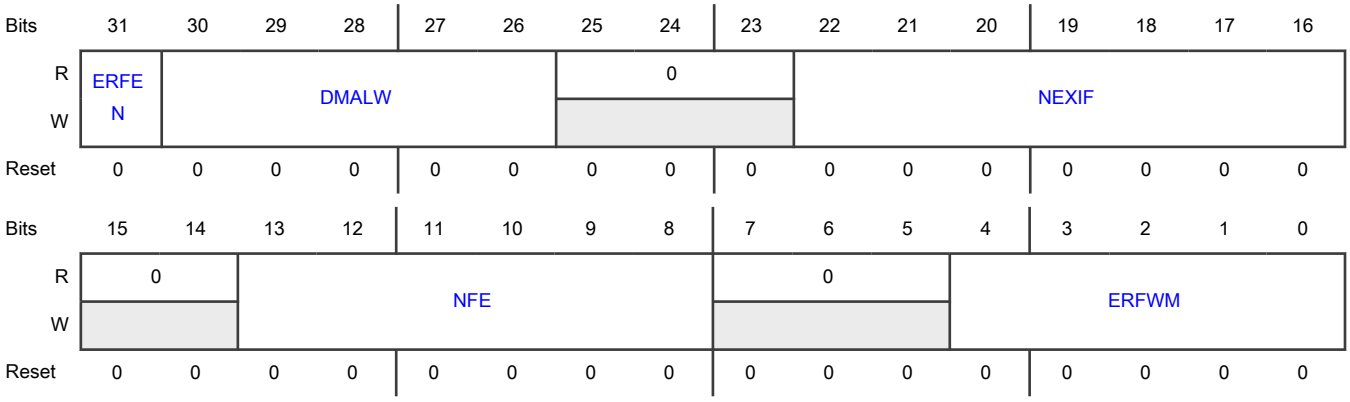
Function

Defines the Enhanced RX FIFO configuration.

This register can be written only in Freeze mode.

Soft reset does not affect any of the contents of this register.

Diagram



Fields

Field	Function
31 ERFEN	Enhanced RX FIFO enable Enables the Enhanced RX FIFO. **NOTE** If MCR[RFEN] = 1, do not write 1 to this field. 0b - Disable 1b - Enable
30-26 DMALW	DMA Last Word Defines the last DMA address for each Enhanced RX FIFO element. This table shows the number of elements and the last address for each Enhanced RX FIFO element according to the value of DMALW.

DMALW	Number of 32-bit words transferred	Last FIFO address
0	1	2000h
1	2	2004h
2	3	2008h
3	4	200Ch
4	5	2010h
5	6	2014h
6	7	2018h
7	8	201Ch
8	9	2020h

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td></td><td>
<table>
<tr><th>DMALW</th><th>Number of 32-bit words transferred</th><th>Last FIFO address</th></tr>
<tr><td>9</td><td>10</td><td>2024h</td></tr>
<tr><td>10</td><td>11</td><td>2028h</td></tr>
<tr><td>11</td><td>12</td><td>202Ch</td></tr>
<tr><td>12</td><td>13</td><td>2030h</td></tr>
<tr><td>13</td><td>14</td><td>2034h</td></tr>
<tr><td>14</td><td>15</td><td>2038h</td></tr>
<tr><td>15</td><td>16</td><td>203Ch</td></tr>
<tr><td>16</td><td>17</td><td>2040h</td></tr>
<tr><td>17</td><td>18</td><td>2044h</td></tr>
<tr><td>18</td><td>19</td><td>2048h</td></tr>
<tr><td>19</td><td>20</td><td>204Ch</td></tr>
</table>
NOTE
Undefined DMALW values in the table are reserved and must not be used.
</td></tr>
<tr><td>25-23
—</td><td>Reserved</td></tr>
<tr><td>22-16
NEXIF</td><td>Number of Extended ID Filter Elements
Defines the number of extended ID filter elements used during the Enhanced RX FIFO matching process.
The value of this field must be less than or equal to NFE + 1.
The number of standard ID filter elements is 2 × (NFE - NEXIF + 1).
This table shows the number of extended ID filters and standard ID filters available for Enhanced RX FIFO if all filter elements are used.
<table>
<tr><th>NEXIF</th><th>NFE</th><th>Number of Extended ID filter elements</th><th>Number of Standard ID filter elements</th></tr>
<tr><td>0</td><td>15</td><td>0</td><td>32</td></tr>
<tr><td>1</td><td>15</td><td>1</td><td>30</td></tr>
<tr><td>2</td><td>15</td><td>2</td><td>28</td></tr>
<tr><td>3</td><td>15</td><td>3</td><td>26</td></tr>
<tr><td>4</td><td>15</td><td>4</td><td>24</td></tr>
<tr><td>5</td><td>15</td><td>5</td><td>22</td></tr>
</table>
</td></tr>
</table>

Table continued from the previous page...

Field	Function

NEXIF	NFE	Number of Extended ID filter elements	Number of Standard ID filter elements
6	15	6	20
7	15	7	18
8	15	8	16
9	15	9	14
10	15	10	12
11	15	11	10
12	15	12	8
13	15	13	6
14	15	14	4
15	15	15	2
16	15	16	0

Field	Function
15-14 —	Reserved
13-8 NFE	Number of Enhanced RX FIFO Filter Elements Defines the total number of filter elements used during the enhanced RX FIFO matching process according to the table.

NFE	Maximum number of extended ID filter elements (NEXIF = NFE + 1)	Maximum number of standard ID filter elements (NEXIF = 0)
0	1	2
1	2	4
2	3	6
3	4	8
4	5	10
5	6	12
6	7	14
7	8	16
8	9	18
9	10	20

Table continues on the next page...

Table continued from the previous page...

Field	Function
	<table><tr><th>NFE</th><th>Maximum number of extended ID filter elements (NEXIF = NFE + 1)</th><th>Maximum number of standard ID filter elements (NEXIF = 0)</th></tr><tr><td>10</td><td>11</td><td>22</td></tr><tr><td>11</td><td>12</td><td>24</td></tr><tr><td>12</td><td>13</td><td>26</td></tr><tr><td>13</td><td>14</td><td>28</td></tr><tr><td>14</td><td>15</td><td>30</td></tr><tr><td>15</td><td>16</td><td>32</td></tr></table>
7-5 —	Reserved
4-0 ERFWM	Enhanced RX FIFO Watermark Defines the minimum number of CAN messages stored in the Enhanced RX FIFO. When that number is reached, ERFSR[ERFWMI] becomes 1. Minimum number of CAN messages = ERFWM + 1. **NOTE** If MCR[DMA] = 1, write 0h to this field.

48.5.2.41 Enhanced RX FIFO Interrupt Enable (ERFIER)

Offset

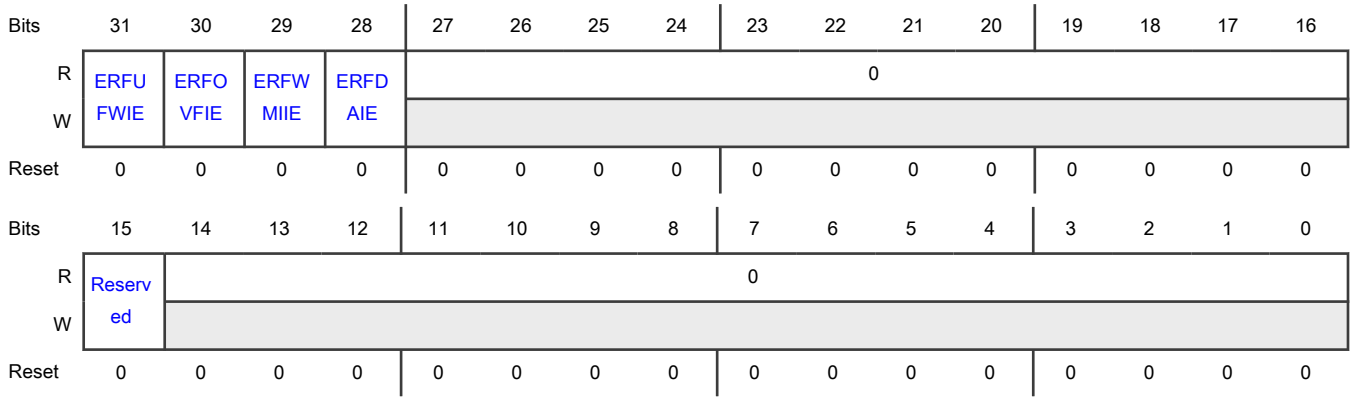
Register	Offset
ERFIER	C10h

Function

Contains the interrupt enables for the Enhanced RX FIFO.

Soft reset does not affect this register.

Diagram



Fields

Field	Function
31 ERFUFWIE	Enhanced RX FIFO Underflow Interrupt Enable Enables interrupt for ERFSR[ERFUFW]. 0b - Disable 1b - Enable
30 ERFOVFIE	Enhanced RX FIFO Overflow Interrupt Enable Enables interrupt for ERFSR[ERFOVF]. 0b - Disable 1b - Enable
29 ERFWMIIE	Enhanced RX FIFO Watermark Indication Interrupt Enable Enables interrupt for ERFSR[ERFWMI]. 0b - Disable 1b - Enable
28 ERFDAIE	Enhanced RX FIFO Data Available Interrupt Enable Enables interrupt for ERFSR[ERFDA]. 0b - Disable 1b - Enable
27-16 —	Reserved
15 —	Reserved
14-0 —	Reserved

48.5.2.42 Enhanced RX FIFO Status (ERFSR)

Offset

Register	Offset
ERFSR	C14h

Function

Contains the status fields of the Enhanced RX FIFO including error indications and a clear FIFO field.

Soft reset does not affect this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	ERFUFW	ERFOVF	ERFWMI	ERFDA	0	0									ERFE	ERFF
W	W1C	W1C	W1C	W1C	ERFCLR											
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved	0									ERFEL					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 ERFUFW	Enhanced RX FIFO Underflow Flag Indicates whether an underflow condition occurred in the enhanced RX FIFO. If ERFIER[ERFUFWIE] = 1, this field generates an interrupt. 0b - No such occurrence 1b - Underflow
30 ERFOVF	Enhanced RX FIFO Overflow Flag Indicates whether an overflow condition occurred in the Enhanced RX FIFO. If ERFIER[ERFOVFIE] = 1, this field generates an interrupt. 0b - No such occurrence 1b - Overflow
29	Enhanced RX FIFO Watermark Indication Flag

Table continues on the next page...

Table continued from the previous page...

Field	Function
ERFWMI	Indicates whether the number of messages available in the Enhanced RX FIFO is greater than the watermark defined in ERFCR[ERFWM]. If ERFIER[ERFWMIIE] = 1, this field generates an interrupt. 0b - No such occurrence 1b - Number of messages in FIFO is greater than the watermark
28 ERFDA	Enhanced RX FIFO Data Available Flag Indicates whether there is at least one message stored in the ERX FIFO. If ERFIER[ERFDAIE] = 1, this field generates an interrupt. 0b - No such occurrence 1b - At least one message stored in Enhanced RX FIFO
27 ERFCLR	Enhanced RX FIFO Clear Writing 1 to this field during Freeze mode resets the internal FIFO pointers, but the FIFO content stored in RAM is not changed. Writing to this field outside Freeze mode, or writing 0 to this field, has no effect. 0b - No effect 1b - Clear enhanced RX FIFO content
26-18 —	Reserved
17 ERFE	Enhanced RX FIFO Empty Flag Indicates whether Enhanced RX FIFO is empty. 0b - Not empty 1b - Empty
16 ERFF	Enhanced RX FIFO Full Flag Indicates whether enhanced RX FIFO is full. 0b - Not full 1b - Full
15 —	Reserved
14-6 —	Reserved
5-0	Enhanced RX FIFO Elements

Table continues on the next page...

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Field	Function
ERFEL	Indicates the number of CAN messages stored in the Enhanced RX FIFO.

48.5.2.43 High-Resolution Timestamp (HR_TIME_STAMP0 - HR_TIME_STAMP31)

Offset

For n = 0 to 31:

Register	Offset
HR_TIME_STAMPn	C30h + (n × 4h)

Function

Stores a copy of a 32-bit timer at the start or end of a CAN frame.

HR_TIME_STAMP0 stores the 32-bit timestamp associated with MB0, HR_TIME_STAMP1 stores the 32-bit timestamp associated with MB1, and so on.

Reset does not affect these registers.

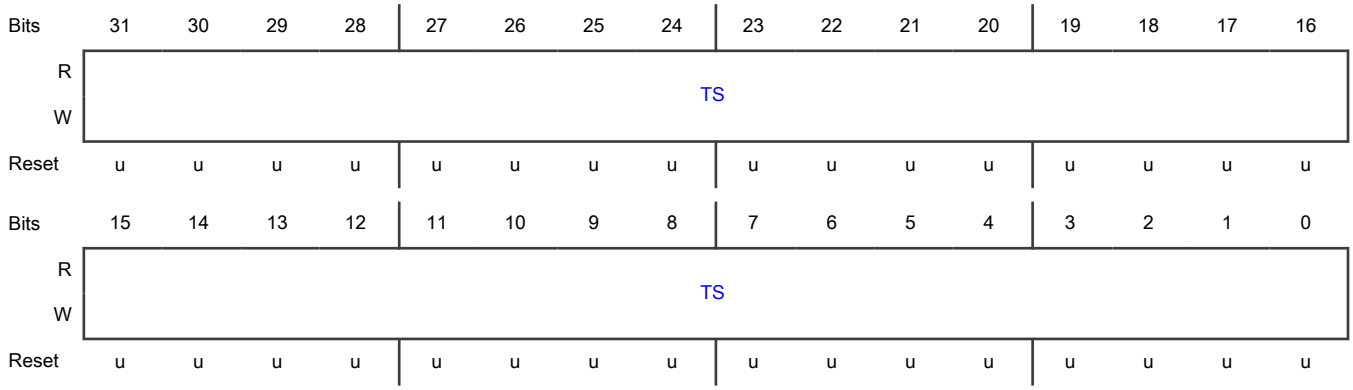
NOTE

Do not write to these registers outside Freeze mode.

Table 381. High-Resolution Timestamp register operation

TSTAMPCAP	Captured timebase	Capture point
b00	None	None
b01	32 bits of high-resolution on-chip timer	Seventh bit of the end-of-frame field for transmission and sixth bit of the end-of-frame field for reception.
b10	32 bits of high-resolution on-chip timer	Start of frame
b11	32 bits of high-resolution on-chip timer	Start of frame for classical CAN frame format and res bit for CAN FD frame format

Diagram



Fields

Field	Function
31-0 TS	High-Resolution Timestamp Captures the copy of the timestamp of corresponding message buffer. This field always captures a 32-bit timer value.

48.5.2.44 Enhanced RX FIFO Filter Element (ERFFEL0 - ERFFEL31)

Offset

For n = 0 to 31:

Register	Offset
ERFFELn	3000h + (n × 4h)

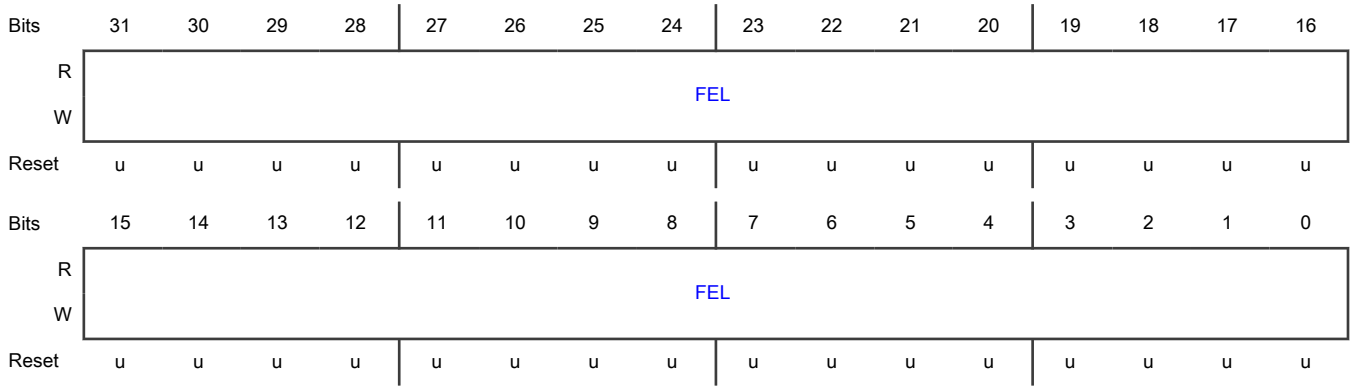
Function

Stores the filter elements of the Enhanced RX FIFO.

For standard ID filtering, each ERFFEL register stores one filter element. For extended ID filtering, each pair of ERFFEL registers stores one filter element.

ERFFEL registers can be written only in Freeze mode; otherwise, the module blocks them. Reset does not affect these registers. They are located in RAM and must be explicitly initialized prior to any reception.

Diagram



Fields

Field	Function
31-0 FEL	Filter Element Bits Stores filter elements. Each filter element is used during the match process. If the matching criteria are met, a message is stored in the Enhanced RX FIFO.

48.5.3 Message buffer structure

The message buffer structure used by FlexCAN is represented in the following figure. Both extended (29-bit identifier) and standard (11-bit identifier) frames used in the CAN specification (Version 2.0 Part B) are represented. Each individual message buffer is 16, 24, 40, or 72 bytes, depending on the quantity of data bytes allocated for the message payload: 8, 16, 32, or 64 data bytes, respectively.

The memory area 80h–27Fh is used by the message buffers. When CAN FD is enabled, the exact address for each message buffer depends on the size of its payload. See FlexCAN memory partition for CAN FD.

Table 382. Message buffer structure example with 64-byte payload

	31	30	29	28	27	24	23	22	21	20	19	18	17	16	15	8	7	0
0h	EDL	BRS	ESI		CODE			SRR	IDE	RTR	DLC				TIMESTAMP			
4h	PRIO				ID (standard/extended)										ID (extended)			
8h	Data byte 0						Data byte 1								Data byte 2		Data byte 3	
Ch	Data byte 4						Data byte 5								Data byte 6		Data byte 7	
10h	Data byte 8						Data byte 9								Data byte 10		Data byte 11	
14h	Data byte 12						Data byte 13								Data byte 14		Data byte 15	
18h	Data byte 16						Data byte 17								Data byte 18		Data byte 19	
1Ch	Data byte 20						Data byte 21								Data byte 22		Data byte 23	
20h	Data byte 24						Data byte 25								Data byte 26		Data byte 27	
24h	Data byte 28						Data byte 29								Data byte 30		Data byte 31	
28h	Data byte 32						Data byte 33								Data byte 34		Data byte 35	

Table continues on the next page...

Table 382. Message buffer structure example with 64-byte payload (continued)

2Ch	Data byte 36	Data byte 37	Data byte 38	Data byte 39
30h	Data byte 40	Data byte 41	Data byte 42	Data byte 43
34h	Data byte 44	Data byte 45	Data byte 46	Data byte 47
38h	Data byte 48	Data byte 49	Data byte 50	Data byte 51
3Ch	Data byte 52	Data byte 53	Data byte 54	Data byte 55
40h	Data byte 56	Data byte 57	Data byte 58	Data byte 59
44h	Data byte 60	Data byte 61	Data byte 62	Data byte 63
		= Unimplemented or reserved		

Table 383. Field descriptions

Mnemonic	Field	Description
EDL	Extended Data Length	Distinguishes between CAN format and CAN FD format frames. EDL must not be 1 for message buffers configured to RANSWER with code field 1010b (see Table 384).
BRS	Bit Rate Switch	Defines whether the bit rate is switched inside a CAN FD format frame.
ESI	Error State Indicator	Indicates whether the transmitting node is error-active or error-passive.
CODE	Message Buffer Code	Can be accessed (read or write) by the CPU and by the FlexCAN module itself, as part of the message buffer matching and arbitration process. The encoding is shown in Table 384 and Table 385. See Functional description.

Table 384. Message buffer code for RX buffers

CODE description	RX code BEFORE RX new frame	SRV[1]	RX code AFTER successful reception[2]	RRS[3]	Comment
0000b: INACTIVE. Message buffer is not active.	INACTIVE	—	—	—	Message buffer does not participate in the matching process.
0100b: EMPTY. Message buffer is active and empty.	EMPTY	—	FULL	—	When a frame is received successfully (after Move-in), CODE is automatically updated to FULL.
0010b: FULL. Message buffer is full.	FULL	Yes	FULL	—	The act of reading the Control and Status word followed by unlocking the message buffer (SRV) does not make CODE return to EMPTY. It remains FULL. If a new frame is moved to the message buffer after the message buffer

Table continues on the next page...

Table 384. Message buffer code for RX buffers (continued)

CODE description	RX code BEFORE RX new frame	SRV[1]	RX code AFTER successful reception[2]	RRS[3]	Comment
					is serviced, the code remains FULL. See Matching process for matching details related to FULL code.
		No	OVERRUN	—	If the message buffer is FULL and a new frame is moved to this message buffer before the CPU services it, CODE is automatically updated to OVERRUN. See Matching process for details about overrun behavior.
0110b: OVERRUN. Message buffer is being overwritten into a full buffer.	OVERRUN	Yes	FULL	—	If CODE indicates OVERRUN and the CPU has serviced the message buffer, when a new frame is moved to the message buffer, CODE returns to FULL.
		No	OVERRUN	—	If CODE already indicates OVERRUN, and another new frame must be moved, the message buffer is overwritten again, and CODE remains OVERRUN. See Matching process for details about overrun behavior.
1010b: RANSWER[4]. A frame was configured to recognize a Remote Request frame and transmit a Response frame in return.[5]	RANSWER	—	TANSWER (1110b)	0	A Remote Answer was configured to recognize a Remote Request frame received. After that, a message buffer is set to transmit a response frame. CODE is automatically changed to TANSWER (1110b). See Matching process for details. If CTRL2[RRS] = 0, transmit a response frame when a remote

Table continues on the next page...

Table 384. Message buffer code for RX buffers (continued)

CODE description	RX code BEFORE RX new frame	SRV[1]	RX code AFTER successful reception[2]	RRS[3]	Comment
					request frame with the same ID is received.
		—	—	1	This code is ignored during matching and arbitration process. See Matching process for details.
CODE[0] = 1: BUSY. FlexCAN is updating the contents of the message buffer. The CPU must not access the message buffer.	BUSY[6]	—	FULL	—	Indicates that the message buffer is being updated. It automatically becomes 0 and does not interfere with the next CODE.
		—	OVERRUN	—	

1. SRV: Serviced message buffer. Message buffer was read and unlocked by reading TIMER or another message buffer.
2. A frame is considered a successful reception after the frame is moved to a message buffer (move-in process). See Move-in.
3. Remote Request Stored field. See Control 2 (CTRL2).
4. Code 1010b is not considered TX and a message buffer with this code should not be aborted.
5. Code 1010b must be used in message buffers configured in CAN FD format, with EDL = 1.
6. For TX message buffers, the BUSY bit should be ignored upon read, except when MCR[AEN] = 1. If this field is 1, the corresponding message buffer does not participate in the matching process.

Table 385. Message buffer code for TX buffers

CODE Description	TX Code BEFORE TX frame	MB RTR	TX Code AFTER successful transmission	Comment
1000b: INACTIVE. Message buffer is not active.	INACTIVE	—	—	Message buffer does not participate in arbitration process.
1001b: ABORT. Message buffer is aborted.	ABORT	—	—	Message buffer does not participate in arbitration process.
1100b: DATA. Message buffer is a TX data frame (MB RTR must be 0).	DATA	0	INACTIVE	Transmit data frame unconditionally once. After transmission, the message buffer automatically returns to the INACTIVE state.
1100b: REMOTE. Message buffer is a Transmit Remote Request frame (MB RTR must be 1).	REMOTE	1	EMPTY	Transmit remote request frame unconditionally once. After transmission, the message buffer automatically becomes an RX Empty message buffer with the same ID.

Table continues on the next page...

Table 385. Message buffer code for TX buffers (continued)

CODE Description	TX Code BEFORE TX frame	MB RTR	TX Code AFTER successful transmission	Comment
1110b: TANSWER. Message buffer is a Transmit Response frame from an incoming Remote Request frame.	TANSWER	—	RANSWER	This intermediate code is automatically written to the message buffer by the CHI as a result of a match to a Remote Request frame. The Remote Response frame is transmitted unconditionally once, then the code automatically returns to RANSWER (1010b). The CPU can also write this code with the same effect. The Remote Response frame can be a data frame or another remote request frame, depending on the value of RTR. See Matching process and Arbitration process for details.

Table 386. RX and TX message buffer field descriptions

Mnemonic	Field	Description
SRR	Substitute Remote Request	Fixed recessive bit, used only in extended format. Write 1 to SRR for transmission (TX Buffers). SRR is stored with the value received on the CAN bus for RX receiving buffers. It can be received as either recessive or dominant. If FlexCAN receives this bit as dominant, it is interpreted as an arbitration loss. 1: Recessive value is compulsory for transmission in extended format frames. 0: Dominant is not a valid value for transmission in extended format frames.
IDE	ID Extended Bit	Identifies whether the frame format is standard or extended. 1: Frame format is extended 0: Frame format is standard
RTR	Remote Transmission Request	Affects the behavior of remote frames and is part of the reception filter. See Table 384, Table 385, and CTRL2[RRS]. If FlexCAN transmits this field as 1 (recessive) and receives it as 0 (dominant), it is interpreted as an arbitration loss. If this field is transmitted as 0 (dominant) and it is received as 1 (recessive), FlexCAN treats it as a bit error. If the value received matches the value transmitted, it is considered a successful bit transmission.

Table continues on the next page...

Table 386. RX and TX message buffer field descriptions (continued)

Mnemonic	Field	Description
		1: If message buffer is TX, indicates that the current message buffer may have a Remote Request frame to be transmitted. If the message buffer is RX, incoming remote request frames may be stored. 0: Indicates that the current message buffer has a Data frame to be transmitted. In an RX message buffer, it may be considered in matching processes. **NOTE** When configuring CAN FD frames, this field must be 0.
DLC	Data Length Code	Indicates the length (in bytes) of the RX or TX data, which is located in offset 8h–Fh of the message buffer space (see Table 382). In reception, this field is written by FlexCAN, copied from the DLC field of the received frame. In transmission, this field is written by the CPU and corresponds to the DLC field value of the frame to be transmitted. When RTR = 1, the frame to be transmitted is a remote frame and does not include the data field, regardless of the DLC field (see Table 388).
TIMESTAMP	Free-Running Counter Timestamp	Provides a copy of the Free-Running Timer, captured for TX and RX frames when the beginning of the Identifier field appears on the CAN bus. See Table 387 for Timestamp operation.
PRIO	Local priority	Used only when MCR[LPRIOEN] = 1, and only makes sense for transmit message buffers. These bits are not transmitted. They are appended to the regular ID to define the transmission priority. See Arbitration process.
ID	Frame Identifier	In standard frame format, only the 11 most significant bits (28 to 18) are used for frame identification in both receive and transmit cases. The 18 least significant bits are ignored. In extended frame format, all bits are used for frame identification in both receive and transmit cases.
DATA BYTE 0–63	Data Field	Up to 64 bytes can be used for a data frame, depending on the size of payload selected for the message buffers. For RX frames, the data is stored as it is received from the CAN bus. DATA BYTE (*n*) is valid only if *n* is less than DLC, as shown in Table 388.

Table 387. Timestamp operation

TSTAMPCAP	MBTSBASE	TIMER_SOURCE	Captured timebase	Capture point
b00	bxx	0	CAN_TIMER incremented by CAN bit clock	Second bit of identifier field
b00	bxx	1	CAN_TIMER incremented by on-chip timer clock	Second bit of identifier field
bxx	b00	0	CAN_TIMER incremented by CAN bit clock	Second bit of identifier field

Table continues on the next page...

Table 387. Timestamp operation (continued)

TSTAMPCAP	MBTSBASE	TIMER_SOURCE	Captured timebase	Capture point
bxx	b00	1	CAN_TIMER incremented by on-chip timer clock	Second bit of identifier field
b01	b01	x	Lower 16 bits of high-resolution on-chip timer	Seventh bit of the end of frame field for transmission and sixth bit of the end of frame field for reception
b01	b10	x	Upper 16 bits of high-resolution on-chip timer	Seventh bit of the end of frame field for transmission and sixth bit of the end of frame field for reception
b10	b01	x	Lower 16 bits of high-resolution on-chip timer	Start of frame
b10	b10	x	Upper 16 bits of high-resolution on-chip timer	Start of frame
b11	b01	x	Lower 16 bits of high-resolution on-chip timer	Start of frame for classical CAN frame format and res bit for CAN FD frame format
b11	b10	x	Upper 16 bits of high-resolution on-chip timer	Start of frame for classical CAN frame format and res bit for CAN FD frame format

Table 388. DATA BYTE validity

DLC	Valid data bytes
0	None
1	DATA BYTE 0
2	DATA BYTE 0–1
3	DATA BYTE 0–2
4	DATA BYTE 0–3
5	DATA BYTE 0–4
6	DATA BYTE 0–5
7	DATA BYTE 0–6
8	DATA BYTE 0–7
9	DATA BYTE 0–11
10	DATA BYTE 0–15
11	DATA BYTE 0–19
12	DATA BYTE 0–23
13	DATA BYTE 0–31

Table continues on the next page...

Table 388. DATA BYTE validity (continued)

DLC	Valid data bytes
14	DATA BYTE 0–47
15	DATA BYTE 0–63

48.5.4 FlexCAN memory partition for CAN FD

When CAN FD is enabled, FlexCAN RAM can be partitioned into blocks of 512 bytes each. Each block can accommodate a number of message buffers depending on the configuration provided by FDCTRL[MBDSR*n*] as shown in Table 389.

Table 389. RAM partition

RAM block	Number of MBs with 8 bytes (default range)	Size control field in FDCTRL	Number of MBs of different sizes, per block
0	0 to 31	MBDSR0	MBDSR0 = 00, 32 MBs with 8-byte payload MBDSR0 = 01, 21 MBs with 16-byte payload MBDSR0 = 10, 12 MBs with 32-byte payload MBDSR0 = 11, 7 MBs with 64-byte payload

Payload sizes of 16, 32, or 64 bytes may be configured in some or all of RAM blocks. In those cases, the total number of MBs and their respective number order may differ from the default configuration of 8 bytes. Consider an example where:

- Block0 is configured to an 8-byte payload
- Block1 is configured to a 16-byte payload

In this case, Table 390 indicates how the message buffers are arranged in RAM.

Table 390. RAM partition example

RAM block	Payload size	Number of MBs in the RAM block	Message buffer range
0	FDCTRL[MBDSR0] = 00, 8-byte payload	32	0 to 31

48.5.5 FlexCAN message buffer memory map

The FlexCAN memory buffers are allocated in memory according to the tables below.

Table 391. 8-byte message buffers

Address offset (hex)	MBDSR = b00 8-byte payload
0080	MB0
0090	MB1
00A0	MB2
00B0	MB3
00C0	MB4

Table continues on the next page...

Table 391. 8-byte message buffers (continued)

Address offset (hex)	MBDSR = b00 8-byte payload
00D0	MB5
00E0	MB6
00F0	MB7
0100	MB8
0110	MB9
0120	MB10
0130	MB11
0140	MB12
0150	MB13
0160	MB14
0170	MB15
0180	MB16
0190	MB17
01A0	MB18
01B0	MB19
01C0	MB20
01D0	MB21
01E0	MB22
01F0	MB23
0200	MB24
0210	MB25
0220	MB26
0230	MB27
0240	MB28
0250	MB29
0260	MB30
0270	MB31

Table 392. 16-byte message buffers

Address offset (hex)	MBDSR = b01 16-byte payload
0080	MB0
0098	MB1
00B0	MB2
00C8	MB3
00E0	MB4
00F8	MB5
0110	MB6
0128	MB7
0140	MB8
0158	MB9
0170	MB10
0188	MB11
01A0	MB12
01B8	MB13
01D0	MB14
01E8	MB15
0200	MB16
0218	MB17
0230	MB18
0248	MB19
0260	MB20

Table 393. 32-byte message buffers

Address offset (hex)	MBDSR = b10 32-byte payload
0080	MB0
00A8	MB1
00D0	MB2
00F8	MB3
0120	MB4
0148	MB5

Table continues on the next page...

Table 393. 32-byte message buffers (continued)

Address offset (hex)	MBDSR = b10 32-byte payload
0170	MB6
0198	MB7
01C0	MB8
01E8	MB9
0210	MB10
0238	MB11

Table 394. 64-byte message buffers

Address offset (hex)	MBDSR = b11 64-byte payload
0080	MB0
00C8	MB1
0110	MB2
0158	MB3
01A0	MB4
01E8	MB5
0230	MB6

48.5.6 Legacy RX FIFO structure

When MCR[RFEN] = 1, the memory area 80h–DCh (which is normally occupied by MBs 0–5) is used by the reception Legacy FIFO engine.

The region 80h–8Ch contains the output of the Legacy RX FIFO, which the CPU must read as a message buffer. This output contains the oldest message that has been received but not yet read. The region 90h–DCh is reserved for internal use of the Legacy RX FIFO engine.

An additional memory area, which starts at E0h and may extend up to 2DCh (normally occupied by MBs 6–37) depending on the value of CTRL2[RFFN], contains the ID filter table (configurable from 8 to 128 table elements) that specifies filtering criteria for accepting frames into the Legacy RX FIFO.

Out of reset, the ID filter table flexible memory area defaults to E0h and extends only to FCh, which corresponds to MBs 6 to 7 for RFFN = 0, for backward compatibility with previous versions of FlexCAN.

The following shows the Legacy RX FIFO data structure.

Table 395. Legacy RX FIFO structure

	31 28 24	23	22	21	20	19 18 17 16	15 8	7 0
80h	IDHIT		SRR	IDE	RTR	DLC	TIMESTAMP	
84h		ID standard				ID extended		

Table continues on the next page...

Table 395. Legacy RX FIFO structure (continued)

88h	Data byte 0	Data byte 1	Data byte 2	Data byte 3
8Ch	Data byte 4	Data byte 5	Data byte 6	Data byte 7
90h–DCh	Reserved			
E0h	ID filter table element 0			
E4h	ID filter table element 1			
E8h–2D4h	ID filter table elements 2 to 125			
2D8h	ID filter table element 126			
2DCh	ID filter table element 127			
		= Unimplemented or reserved		

NOTE

Due to the limitation of the maximum number of MBs, the additional memory area starting at E0h and depending on the value of CTRL2[RFFN] can only extend up to 270h (usually occupied by MB 6-31), which contains the ID filter table (configurable from 8 to 104 table elements).

Each ID filter table element occupies an entire 32-bit word. One, two, or four Identifier Acceptance Filters (IDAFs) can compound each element, depending on MCR[IDAM]. The following tables show the IDAF indexing.

Table 396 shows the three different formats of the ID table elements. All elements of the table must have the same format. See Legacy RX FIFO for more information.

Table 396. ID table structure

Format	31	30	29 24	23 16	15	14	13 8	7 1	0
A	RTR	IDE	RXIDA (standard = 29–19, extended = 29–1)						
B	RTR	IDE	RXIDB_0 (standard = 29–19, extended = 29–16)		RTR	IDE	RXIDB_1 (standard = 13–3, extended = 13–0)		
C	RXIDC_0 (std and ext = 31–24)		RXIDC_1 (std and ext = 23–16)		RXIDC_2 (std and ext = 15–8)		RXIDC_3 (std and ext = 7–0)		
			= Unimplemented or Reserved						

Table 397. Field descriptions

Mnemonic	Field	Description
RTR	Remote Frame	Specifies whether remote frames are accepted into the Legacy FIFO if they match the target ID. 1: Remote frames can be accepted and data frames are rejected.

Table continues on the next page...

Table 397. Field descriptions (continued)

Mnemonic	Field	Description
		0: Remote frames are rejected and data frames can be accepted.
IDE	Extended Frame	Specifies whether extended or standard frames are accepted into the Legacy FIFO if they match the target ID. 1: Extended frames can be accepted and standard frames are rejected. 0: Extended frames are rejected and standard frames can be accepted.
RXIDA	RX Frame Identifier (Format A)	Specifies an ID to be used as acceptance criteria for the Legacy FIFO. In the standard frame format, only the 11 most significant bits (29 to 19) are used for frame identification. In the extended frame format, all bits are used.
RXIDB_0, RXIDB_1	RX Frame Identifier (Format B)	Specifies an ID to be used as acceptance criteria for the Legacy FIFO. In the standard frame format, the 11 most significant bits (a full standard ID) (29 to 19 and 13 to 3) are used for frame identification. In the extended frame format, all 14 bits of the field are compared to the 14 most significant bits of the received ID.
RXIDC_0, RXIDC_1, RXIDC_2, RXIDC_3	RX Frame Identifier (Format C)	Specifies an ID to be used as acceptance criteria for the Legacy FIFO. In both standard and extended frame formats, all 8 bits of the field are compared to the 8 most significant bits of the received ID.
IDHIT	Identifier Acceptance Filter Hit Indicator	Indicates which identifier acceptance filter the received message in the output of the Legacy RX FIFO hit. See Legacy RX FIFO for more information.

48.5.7 Enhanced RX FIFO structure

When ERFCR[ERFEN] = 1, the Enhanced RX FIFO is enabled. The region 2000h–204Ch contains the output of the Enhanced RX FIFO, which the CPU must read as a message buffer. This output contains the oldest message that has been received but not yet read.

Table 398. Enhanced RX FIFO structure

	31	30	29	28 … 24	23	22	21	20	19	18	17	16	15 … 8	7	6 … 0
2000h	EDL	BRS	ESI	Reserved		SRR	IDE	RTR	DLC				TIMESTAMP LEGACY		
2004h	Reserved			ID (standard/extended)									ID (extended)		
2008h	Data byte 0					Data byte 1							Data byte 2		Data byte 3
200Ch	Data byte 4					Data byte 5							Data byte 6		Data byte 7
2010h	Data byte 8					Data byte 9							Data byte 10		Data byte 11
2014h	Data byte 12					Data byte 13							Data byte 14		Data byte 15
2018h	Data byte 16					Data byte 17							Data byte 18		Data byte 19
201Ch	Data byte 20					Data byte 21							Data byte 22		Data byte 23
2020h	Data byte 24					Data byte 25							Data byte 26		Data byte 27
2024h	Data byte 28					Data byte 29							Data byte 30		Data byte 31
2028h	Data byte 32					Data byte 33							Data byte 34		Data byte 35

Table continues on the next page...

Table 398. Enhanced RX FIFO structure (continued)

202Ch	Data byte 36	Data byte 37	Data byte 38	Data byte 39
2030h	Data byte 40	Data byte 41	Data byte 42	Data byte 43
2034h	Data byte 44	Data byte 45	Data byte 46	Data byte 47
2038h	Data byte 48	Data byte 49	Data byte 50	Data byte 51
203Ch	Data byte 52	Data byte 53	Data byte 54	Data byte 55
2040h	Data byte 56	Data byte 57	Data byte 58	Data byte 59
2044h	Data byte 60	Data byte 61	Data byte 62	Data byte 63
IH_OFF	Reserved			ID HIT
TS_OFF	HR TIMESTAMP			
2050h	11 Enhanced FIFO Elements (Reserved)			
...				
23BCh				

NOTE

ID HIT offset and high-resolution timestamp offset change dynamically according to data length code (DLC) as shown in Table 399.

Table 399. ID HIT offset and high-resolution timestamp offset

Data Length Code (DLC)	ID HIT offset (IH_OFF)	High-resolution timestamp offset (TS_OFF)
0	2008h	200Ch
1–4	200Ch	2010h
5–8	2010h	2014h
9	2014h	2018h
10	2018h	201Ch
11	201Ch	2020h
12	2020h	2024h
13	2028h	202Ch
14	2038h	203Ch
15	2048h	204Ch

Table 400. Field descriptions

Mnemonic	Field	Description
EDL	Extended Data Length	Distinguishes between classical CAN format and CAN FD format frames. 0: Classical CAN frame format 1: CAN FD frame format

Table continues on the next page...

Table 400. Field descriptions (continued)

Mnemonic	Field	Description
BRS	Bit Rate Switch	Defines whether the bit rate is switched inside a CAN FD format frame. 0: Bit rate is not switched in a CAN FD frame. 1: Bit rate is switched in a CAN FD frame.
ESI	Error State Indicator	Indicates whether the transmitting node is error-active or error-passive. This field is meaningful only if EDL = 1. 0: Error-active 1: Error-passive
SRR	Substitute Remote Request	Fixed recessive bit, used only in extended format. Transmitting nodes always send it as recessive and receiving nodes can receive it as either recessive or dominant. If FlexCAN receives this bit as dominant, it is interpreted as an arbitration loss.
IDE	ID Extended Bit	Identifies whether the frame format is standard or extended. 0: Standard 1: Extended
RTR	Remote Frame	Identifies whether the current frame is a data frame or a remote request. 0: Data frame 1: Remote request
DLC	Data Length Code	Defines the number of bytes in the data field of a CAN frame (Data byte 0 to Data byte 63). When RTR = 1, the frame is a remote request and does not include the data field, regardless of the DLC field. See Table 388 for more details.
LEGACY TIMESTAMP	16-bit Timestamp	Provides a copy of the Free-Running Timer, captured during the CAN frame. See Table 387 for details about legacy timestamp operation.
ID	Frame Identifier	In base frame format, only the 11 most significant bits are used for frame identification. The 18 least significant bits are ignored. In extended frame format, all bits are used for frame identification.
DATA BYTE 0–63	Data Field	Up to 64 bytes can be stored in the data field.
IDHIT	Identifier Acceptance Filter Hit Indicator	Indicates which Enhanced RX FIFO Filter Element (ERFFEL0 - ERFFEL31) the received message in the output of the Enhanced RX FIFO hit. For each filter region, standard-ID filter space, and extended-ID filter space, there is an independent index starting from zero. Table 401 shows how FlexCAN writes IDHIT according to each filter element.
HR TIMESTAMP	High-resolution Timestamp	32-bit timebase captured during the CAN frame. When CTRL2[TSTAMPCAP] is not zero, a 32-bit timebase is captured from a dedicated on-chip timer which operates in free-running mode. See CTRL2[TSTAMPCAP] for details about capture point configuration of the high-resolution timestamp.

Table 401. IDHIT for Enhanced RX FIFO

Enhanced RX FIFO filter element - ERFFEL	IDHIT value	Filter element type
ERFFEL0	0	Extended-ID
ERFFEL1	1	Extended-ID
. . .	. . .	Extended-ID
ERFFEL(m-1)	m-1	Extended-ID
ERFFEL(m)	0	Standard-ID
ERFFEL(m+1)	1	Standard-ID
. . .	. . .	Standard-ID
ERFFEL(2n-m+1)	2x(n-m)+1	Standard-ID

NOTE

Where m = NEXIF and n = NFE. If NEXIF = 0, only standard-ID filter elements exist. If NEXIF > NFE, only extended-ID filter elements exist.

48.6 Initialization and application information

48.6.1 FlexCAN initialization sequence

For any configuration change or initialization, you must put FlexCAN into Freeze mode (see Freeze mode). The module must be initialized after every reset. FlexCAN memory must be initialized before switching to functional mode.

The following is a generic initialization sequence applicable to FlexCAN:

1. Initialize Module Configuration (MCR).
    a. Enable the individual filtering per message buffer and reception queue features by writing 1 to MCR[IRMQ].
    b. Enable the warning interrupts by writing 1 to MCR[WRNEN].
    c. If required, disable frame self-reception by writing 1 to MCR[SRXDIS].
    d. Enable the Legacy RX FIFO by writing 1 to MCR[RFEN] or enable the Enhanced RX FIFO by writing 1 to ERFCR[ERFEN].
    e. If Legacy RX FIFO or Enhanced RX FIFO is enabled and DMA is required, write 1 to MCR[DMA].
    f. If Pretended Networking mode is required, write 1 to MCR[PNET_EN].
    g. Enable the abort mechanism by writing 1 to MCR[AEN].
    h. Enable the local priority feature by writing 1 to MCR[LPRIOEN].
2. Initialize Control 1 (CTRL1) and CAN FD Bit Timing (FDCBT). Optionally initialize CAN Bit Timing (CBT).
    a. Determine the bit timing parameters: CTRL1[PROPSEG], CTRL1[PSEG1], CTRL1[PSEG2], and CTRL1[RJW].

b. Optionally determine the bit timing parameters: CBT[EPROPSEG], CBT[EPSEG1], CBT[EPSEG2], and CBT[ERJW].

c. Determine the CAN FD bit timing parameters: FDCBT[FPROPSEG], FDCBT[FPSEG1], FDCBT[FPSEG2], and FDCBT[FRJW].

d. Determine the bit rate by programming CTRL1[PRESDIV] and optionally programming CBT[EPRESDIV].

e. Determine the CAN FD bit rate by programming FDCBT[FPRESDIV].

f. Determine the internal arbitration mode by programming CTRL1[LBUF].

3. Initialize the message buffers. (See Message buffer structure for message buffer details.)

   a. The control and status word of all message buffers must be initialized.

   b. If RX FIFO is enabled, the ID filter table must be initialized.

   c. Other entries in each message buffer should be initialized as required.

4. Initialize Receive Individual Mask (RXIMR0 - RXIMR31).

5. Write 1 to required interrupt mask bits in:

   - IMASK registers (for all message buffer interrupts)
   - Module Configuration (MCR) (for wake-up interrupt)
   - Control 1 (CTRL1) and Control 2 (CTRL2) (for Bus Off and Error interrupts)

6. If Pretended Networking mode is enabled, configure the necessary registers for selective wake-up.

7. Write 0 to MCR[HALT].

After the last step listed above, FlexCAN attempts to synchronize to the CAN bus.

48.7 Glossary

Active message buffer	A message buffer is active if it can participate in the current matching or arbitration process.
Bus interface unit	FlexCAN submodule responsible for the interface to the CPU.
Bus off	See CAN Specification.[4]
CAN	Controller Area Network, a serial communication protocol defined in CAN Specification[4] and ISO International Standard.[5]
CHI	Controller-host interface, a FlexCAN submodule responsible for message buffer matching and arbitration algorithms.
CRC	Cyclic redundancy check
Dominant bit	A dominant bit wins the arbitration on the CAN bus. It is transmitted as 0.
Doze mode	A system low-power mode where the CPU bus remains active and a global Doze mode request is sent to all peripherals asking them to enter low power mode.
Error active	See CAN Specification.[4]
Error frame	See CAN Specification.[4]
Error passive	See CAN Specification.[4]
Form error	See CAN Specification.[4]

[4] Controller Area Network - CAN Specification Version 2.0 Part A, Part B, Robert Bosch GmbH, 1991.
[5] ISO International Standard - ISO 11898 First Edition 1993 Road Vehicles - Interchange of Digital Information - Controller Area Network (CAN) for high-speed Communication.

Hard reset	A reset coming from an external pin and/or following power-on. It resets everything.
Idle	See CAN Specification.[4]
Information processing time	See CAN Specification.[4]
Intermission	See CAN Specification.[4]
Matching elements	Data used in the matching process, such as ID, filter, mask, etc.
MB	See Message buffer.
Message buffer	Internal FlexCAN data structure containing bytes received from, or to be transmitted to, the CAN line, as well as information about this data.
Overload frame	See CAN Specification.[4]
Phase buffer segment	See CAN Specification.[4]
Recessive bit	A recessive bit loses the arbitration on the CAN bus. It is transmitted as 1.
Sclock	Serial clock. Obtained by dividing the clock feeding the CAN engine (oscillator or bus clock) by a prescaler factor. The Sclock period defines the time quantum for CAN protocol timing.
Soft reset	Global reset typically used by peripherals to reinitialize some of its registers, but not all of them.
Stop mode	A system low-power mode in which all chip clocks are stopped for maximum power savings.
Stuffing error	See CAN Specification.[4]
Time quantum	This is equal to the Sclock period. It is the minimum time period used to compose the CAN protocol bit timing.

Chapter 49
Flexible I/O (FlexIO)

49.1 Chip-specific FLEXIO information

Table 402. Reference links to related information

Topic	Related module	Reference
Full description	FLEXIO	FLEXIO
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

49.1.1 Module instances

This device has one FlexIO module, FLEXIO0.

49.2 Overview

FLEXIO is a highly configurable module that provides:

- Emulation of various serial or parallel communication protocols.
- Flexible 16-bit timers with support for various trigger, reset, enable, and disable conditions.
- Programmable logic blocks that allow the implementation of digital logic functions on-chip and configurable interaction of internal and external modules.
- Programmable state machine for offloading basic system control functions from the CPU.

49.2.1 Block diagram

The following diagram provides a high-level overview of the FLEXIO timer and shifter configuration.

FLEXIO uses shifters, timers, and external triggers to shift data into or out of FLEXIO. As shown in the block diagram, timers control the timing of this data shift. You can configure the timers to use generic timer functions, external triggers, or various other conditions to determine the control.

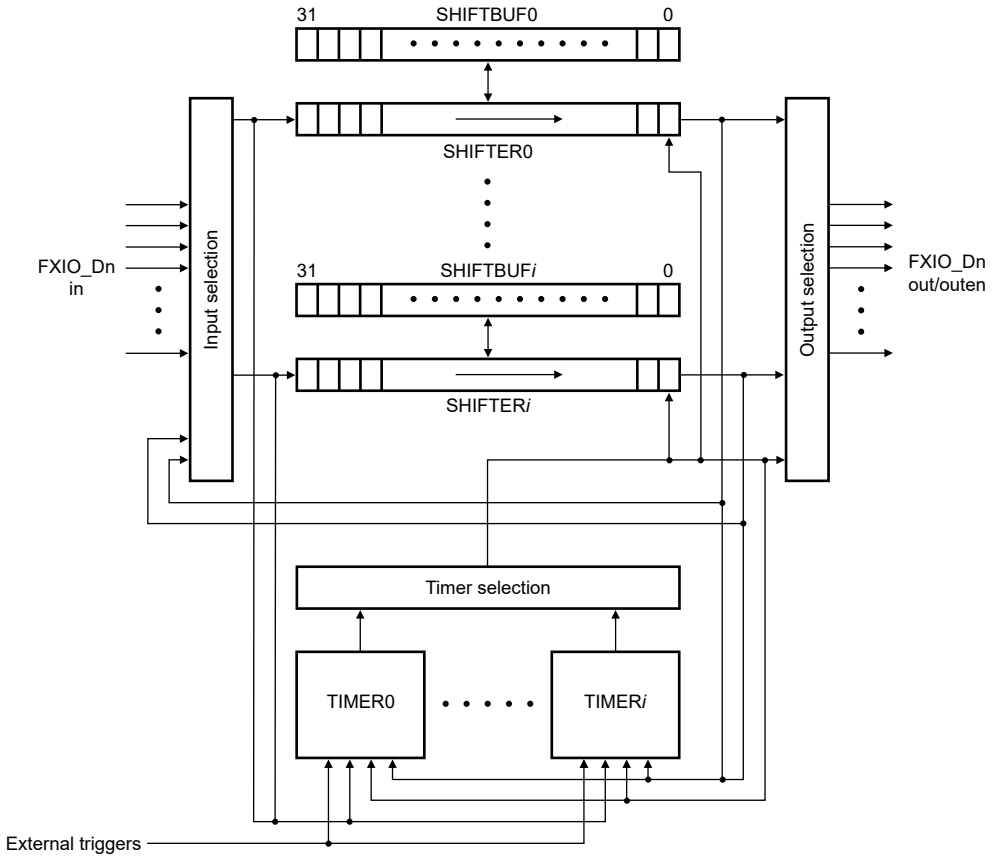


Figure 199. Block diagram

49.2.2 Features

- Array of 32-bit shift registers with transmit, receive, data match, logic, and state modes:
  - Double-buffered shifter operation for continuous data transfer
  - Shifter concatenation to support large transfer sizes
  - Automatic start and stop bit generation
  - 1, 2, 4, 8, 16, or 32 multi-bit shift widths for parallel interface support
  - Interrupt, DMA, or polled transmit and receive operation
- Highly flexible 16-bit timers with support for various internal or external triggers, reset, enable, and disable conditions:
  - Programmable baud rates independent of bus clock frequency, with support for asynchronous operation during Stop mode
  - Programmable logic mode for integrating external digital logic functions on-chip, or combining pin, shifter, or timer functions to generate complex outputs
  - Programmable state machine for offloading basic system control functions from CPU, with support for up to eight states, eight outputs, and three selectable inputs per state
- Integrated general-purpose I/O registers and pin rising or falling edge interrupts to simplify software support
- Support for a wide range of protocols, including but not limited to:
  - UART

— I2C

— SPI

— I2S

— Camera IF

— Motorola 68K or Intel 8080 bus

— PWM or waveform generation

— Input-capture (pulse-edge interval measurement), such as SENT

49.3 Functional description

49.3.1 Shifter operation

Shifters are responsible for buffering and shifting data into or out of FLEXIO. The timer assigned to the shifter controls the timing of shift, load, and store events via SHIFTCTL*n*[TIMSEL]. Shifters are designed to support either DMA, interrupt, or polled operations. The following figure provides a detailed view of the shifter microarchitecture.

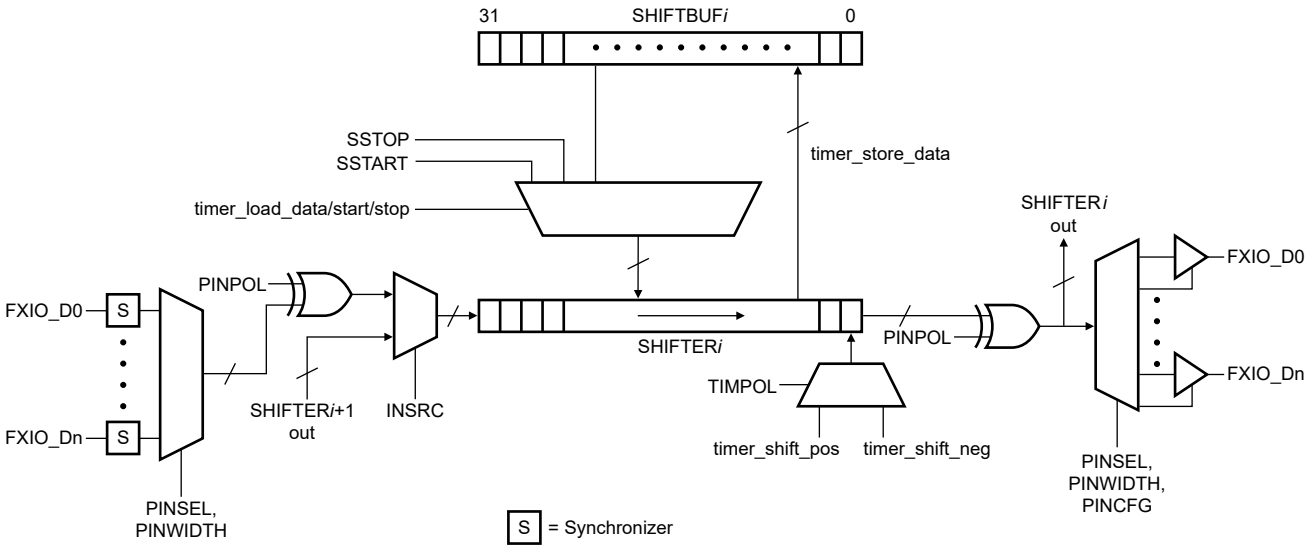


Figure 200. Shifter microarchitecture

49.3.1.1 Transmit mode

In Transmit mode (SHIFTCTL*n*[SMOD] = 010b), the shifter loads data from Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) and shifts data out when the assigned timer signals a load event. An optional start and stop bit can be automatically loaded before or after SHIFTBUF register data by configuring either SHIFTCFG[SSTART] and TIMCFG[TSTART], or SHIFTCFG[SSTOP] and TIMCFG[TSTOP] in the shifter and timer.

NOTE

If a stop bit is enabled, the shifter immediately loads a stop bit when it is initially configured for Transmit mode.

The shifter status flag (SHIFTSTAT[SSF]) and any enabled interrupts or DMA requests are set when data has either been loaded from the SHIFTBUF register into the shifter or when the shifter is initially configured for Transmit mode. To clear the flag, write 1 or write new data to SHIFTBUF. In Transmit mode, write any value to the SHIFTBUF register to clear the corresponding shifter status flag, which is cleared regardless of what is writing to the register (DMA or interrupt), or the state of the DMA or interrupt enables. See the functional description of SHIFTSTAT[SSF] for information on how the flag is set and cleared for each mode.

The shifter error flag (SHIFTERR[SEF]) and any enabled interrupts are set when an attempt to load data from an empty SHIFTBUF register occurs (buffer underrun). Clear the flag by writing 1.

49.3.1.2 Receive mode

When the assigned timer signals a store event in Receive mode (SHIFTCTL*n*[SMOD] = 001b), the shifter shifts and stores data in Shifter Buffer (SHIFTBUF0 - SHIFTBUF7). You can check for a start and stop bit before or after the shifter data is sampled by configuring either SHIFTCFG[SSTART] and TIMCFG[TSTART], or SHIFTCFG[SSTOP] and TIMCFG[TSTOP] in the shifter and timer.

The shifter status flag (SHIFTSTAT[SSF]) and any enabled interrupts or DMA requests are set when data is stored in the SHIFTBUF register from the shifter. To clear the flag, write 1 to or read the data from SHIFTBUF. Any read of the SHIFTBUF register clears the corresponding shifter status flag when the shifter is in Receive mode. The flag is cleared regardless of what is reading the register (DMA or interrupt) or the state of the DMA or interrupt enables. See the functional description of SHIFTSTAT[SSF] for information on how the flag is set or cleared for each mode.

The shifter error flag (SHIFTERR[SEF]) and any enabled interrupts are set either when an attempt to store data into a full SHIFTBUF register occurs (buffer overrun) or when a mismatch occurs on a start or stop bit check. Write 1 to clear the flag.

49.3.1.3 Match Store mode

In Match Store mode (SHIFTCTL*n*[SMOD] = 100b), the shifter shifts data in, checks for a match result, and stores matched data in Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) when the assigned timer signals a store event. By configuring either SHIFTCFG[SSTART], TIMCFG[TSTART], and SHIFTCFG[SSTOP], or TIMCFG[TSTOP] in the shifter and timer, you can check for a start and stop bit before or after the shifter data is sampled. You can compare up to 16 bits of data using SHIFTBUF[31:16] to configure the data to be matched and SHIFTBUF[15:0] to mask the match result.

The shifter status flag (SHIFTSTAT[SSF]) and any enabled interrupts or DMA requests are set when a match occurs and the matched data is stored in the SHIFTBUF register from the shifter. To clear the flag, read the matched data from the SHIFTBUF register or write 1 to the flag. Any read of the SHIFTBUF register clears the corresponding shifter status flag when the shifter is configured in Match Store mode. The flag is cleared regardless of what is reading the register (DMA or interrupt) or the state of the DMA or interrupt enables. See the functional description for SHIFTSTAT[SSF] to know how the flag is set or cleared for each mode.

The shifter error flag (SHIFTERR[SEF]) and any enabled interrupts are set when an attempt to store matched data into a full SHIFTBUF register occurs (buffer overrun), or when a mismatch occurs on a start or stop bit check. Write 1 to clear the flag.

49.3.1.4 Match Continuous mode

In Match Continuous mode (SHIFTCTL*n*[SMOD] = 101b), the shifter shifts data in and continuously checks for a match result whenever a shift event is signaled by the assigned timer. You can compare up to 16 bits of data using SHIFTBUF[31:16] to configure the data to be matched and SHIFTBUF[15:0] to mask the match result.

The shifter status flag (SHIFTSTAT[SSF]) and any enabled interrupts or DMA requests are set when a match occurs. The flag clears automatically as soon as no match exists between the shifter data and Shifter Buffer (SHIFTBUF0 - SHIFTBUF7).

You cannot clear the flag by reading the SHIFTBUF register.

The shifter error flag (SHIFTERR[SEF]) and any enabled interrupts are set when a match occurs. To clear the flag, write 1 or perform a read from the SHIFTBUF register.

49.3.1.5 State mode

State mode enables you to implement any state machine with up to eight states, eight outputs, and three selectable inputs per state. This feature allows basic control functions to be offloaded from the CPU, which can remain in a low-power mode.

In State mode (SHIFTCTL*n*[SMOD] = 110b), when the shifter is selected by the current state pointer (SHIFTSTATE[STATE]), use the SHIFTBUF register to drive the output and compute the next state values. The following figure provides a detailed view of the shifter microarchitecture when configured for State mode.

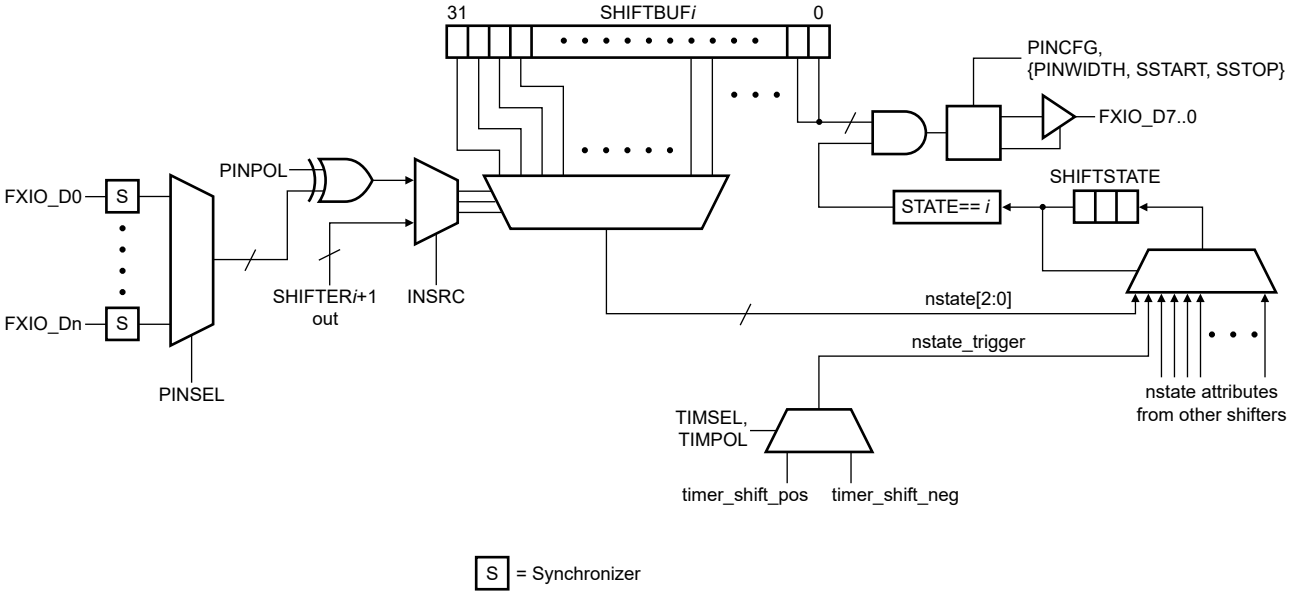


Figure 201. State microarchitecture

When the current state pointer selects a specific shifter (shifter *n*), output pins FXIO_D[7:0] are driven by SHIFTBUF*n*[31:24]; the configuration is defined by SHIFTCTL*n*[PINCFG]. Write 1 to Shifter Configuration (SHIFTCFG0 - SHIFTCFG7) {PWIDTH[3:0],SSTOP[1:0],SSTART[1:0]} to disable the output drive on pins FXIO_D[7:0] for state machine applications that require less than eight output pins.

Use the three input pins selected by SHIFTCTL*n*[PINSEL] and SHIFTBUF*n*[23:0] to compute the next state value.

NOTE

Each state can use a different set of three input pins.

The following table shows how the next state value is computed when the current state pointer is pointing to shifter *n*.

Table 403. Next state computation for SHIFTSTATE[STATE] = *n*

FXIO_D[PINSEL + 2]	FXIO_D[PINSEL + 1]	FXIO_D[PINSEL]	Next state value
0	0	0	SHIFTBUF*n*[2:0]
0	0	1	SHIFTBUF*n*[5:3]
0	1	0	SHIFTBUF*n*[8:6]
0	1	1	SHIFTBUF*n*[11:9]
...	...	...	...
1	1	1	SHIFTBUF*n*[23:21]

NOTE

You can configure other shifters and timers to drive the input pins of a given state, allowing you to create complex combinations of shifters and timers as needed. For example, the output of a shifter configured for Logic mode can be used to drive a state machine input.

The next state transition is triggered using the timer output selected by SHIFTCTL*n*[TIMSEL], with polarity controlled by SHIFTCTL*n*[TIMPOL].

NOTE

Each state can use a different timer to trigger each next state transition, allowing various internal or external trigger sources and clocking configurations to be used. See Timer section for more information.

The current state pointer defaults to shifter 0 at reset; however, you can write to select a different shifter for the initial state. If the current state pointer selects a shifter that is not configured for State mode, then outputs are not driven and the next state transition is never triggered.

The shifter status flag (SHIFTSTAT[SSF]) and any enabled interrupts or DMA requests are set when the shifter is selected by the current state pointer. The flag is cleared when the current state pointer is updated to a different shifter.

49.3.1.6 Logic mode

Logic mode enables you to implement a small amount of programmable digital logic within a FLEXIO shifter.

In Logic mode (SHIFTCTL*n*[SMOD] = 111b), use Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) to implement a 5-input, 32-bit programmable logic lookup table. The following figure provides a detailed view of shifter microarchitecture when configured for Logic mode.

Use the SHIFTBUF register to configure the lookup table for the four pin inputs. You can also use SHIFTER*n* to configure a feedback or delayed pin source as the fifth input to the lookup table.

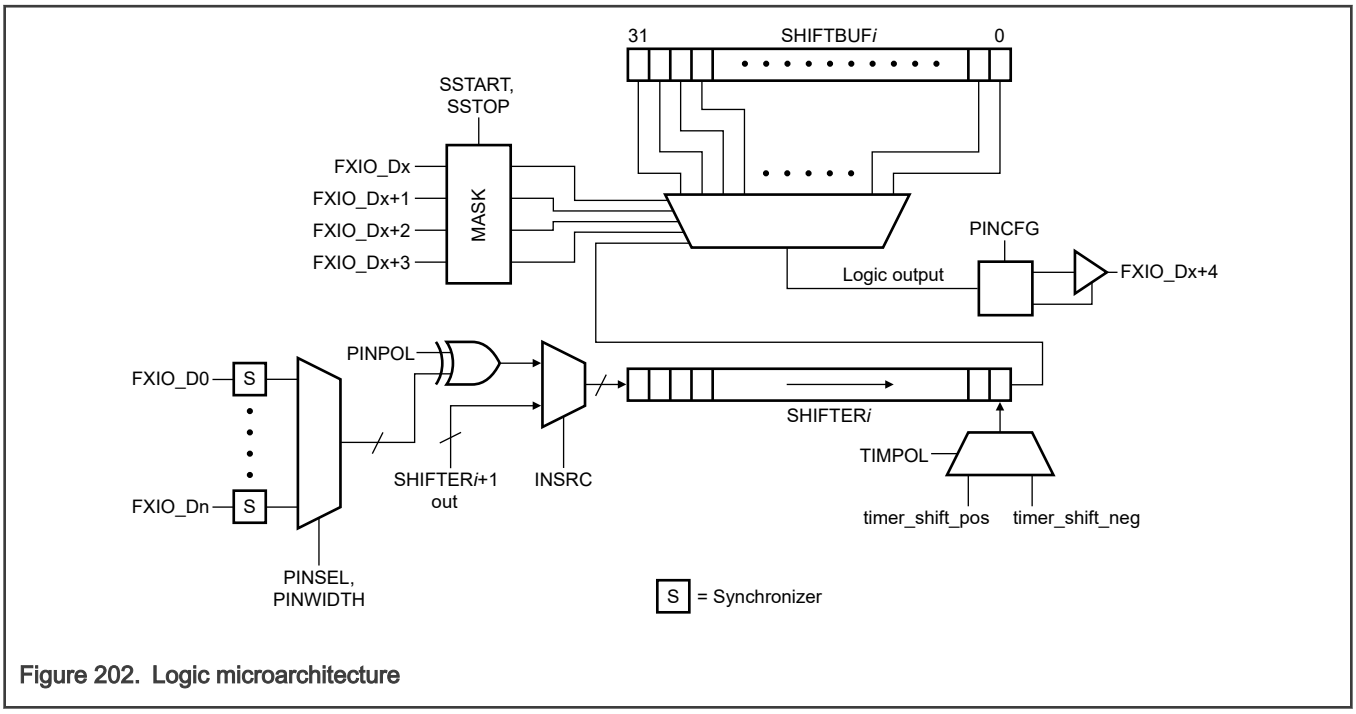


Figure 202. Logic microarchitecture

The lookup table is driven using four pin inputs (maskable using SHIFTCFG[SSTOP] and SHIFTCFG[SSTART]), plus one input from the internal shifter. It can be configured to drive an output pin using SHIFTCTL[PINCFG]. Pin inputs and outputs are fixed for each logic lookup table and are not selectable. The following table lists the logic output value selected by the lookup table for shifter *n*.

Table 404. Logic lookup table for shifter *n*

SHIFTER*n*[0]	FXIO_D[*x* + 3][1]	FXIO_D[*x* + 2]	FXIO_D[*x* + 1]	FXIO_D[*x*]	Logic output to FXIO_D[*x* + 4]
0	0	0	0	0	SHIFTBUF*n*[0]
0	0	0	0	1	SHIFTBUF*n*[1]

Table continues on the next page...

Table 404. Logic lookup table for shifter *n* (continued)

SHIFTER*n*[0]	FXIO_D[*x* + 3][1]	FXIO_D[*x* + 2]	FXIO_D[*x* + 1]	FXIO_D[*x*]	Logic output to FXIO_D[*x* + 4]
0	0	0	1	0	SHIFTBUF*n*[2]
0	0	0	1	1	SHIFTBUF*n*[3]
...	...	...	...	...	...
1	1	1	1	1	SHIFTBUF*n*[31]

1. for shifters *n* = 0...3, *x* = *n*

   for shifter *n* = 4...7, *x* = *n* + 4

To minimize output glitches, use SHIFTCFG*n*[SSTOP] and SHIFTCFG*n*[SSTART] to mask unused input pins. When these fields are 1, {SSTOP[1:0] and SSTART[1:0]} mask FXIO_D[*x* + 3]...FXIO_D[*x*] inputs respectively so that any transitions on these pins do not cause the logic output to glitch.

NOTE

You can configure other shifters and timers to drive the input pins of a given lookup table, allowing you to concatenate lookup tables or create complex combinations of shifters and timers as needed.

SHIFTCFG[PWIDTH] controls the number of delay stages introduced by the internal shifter input (SHIFTER*n*[0]). For example, when configured for a 1-bit shift (SHIFTCFG[PWIDTH] = 0), the internal shifter introduces a 32-shift clock delay before passing its input (selected by SHIFTCTL[PINSEL]) to the lookup table. When configured for a 32-bit shift (SHIFTCFG[PWIDTH] = 16...31), the internal shifter introduces a 1-shift clock delay to its input.

The shifter status flag (SHIFTSTAT[SSF]) and any enabled interrupts or DMA requests are set whenever the output pin allocated to the logic lookup table has a value of 1 after being synchronized with the FLEXIO clock. The flag clears when the output pin has a value of 0. This also allows SHIFTSTAT[SSF] to be used as a trigger to a timer if needed.

The shifter error flag (SHIFTERR[SEF]) and any enabled interrupts are set when the output pin allocated to the logic lookup table is asserted. Clear the flag by writing 1 to it.

The Logic mode input pins, including pins driven by other shifters and timers, are synchronized with the FLEXIO functional clock before they are input to the programmable logic lookup table.

49.3.2 Timer operation

The FLEXIO 16-bit timers control the loading, shifting, and storing of the shift registers. The counters load the contents of the compare register and decrement down to zero on the FLEXIO clock. The counters can perform generic timer functions such as generating a clock, select output, or a PWM waveform. You can configure these timers to perform any of the following functions:

- Enable in response to a trigger, pin, or shifter condition.
- Decrement always or only on a trigger or pin edge.
- Reset in response to a trigger or pin condition.
- Disable on a trigger or pin condition or on a timer compare.

Timers can optionally include a start condition and a stop condition.

Although each timer operates independently, you can configure a timer to enable or disable at the same time as the previous timer (for example, timer 1 can enable or disable at the same time as timer 0) and a timer output can be used to trigger any other timer. The trigger used by each timer is configured independently as a timer output, shifter status flag, pin input, or an external trigger input. The trigger configuration is separate from pin configuration; you can perform it to configure input, output data, or output enable. See the chip-specific FLEXIO information for information on external trigger connections.

You must configure Timer Configuration (TIMCFG0 - TIMCFG7) before writing 1 to TIMCTL*n*[TIMOD].

49.3.2.1 Timer 8-bit Baud Counter mode

In 8-bit Baud Counter mode, the 16-bit counter is divided into two 8-bit counters. The lower 8 bits are used to configure the baud rate of the shift clock and the upper 8 bits are used to configure the number of shift clock edges in the transfer. When the lower 8 bits decrement to zero, the timer output is toggled and the lower 8 bits reload from the compare register. The upper 8 bits decrement when the lower 8 bits become zero and decrement.

NOTE

A timer reset event in 8-bit Baud Counter mode only resets the lower 8-bit counter. The upper 8-bit counter is not affected and can decrement if the timer reset is configured to update the state of the timer output, which toggles as a result of the timer reset event.

A timer compare event occurs when the upper 8 bits equal zero and decrement. The timer status flag is set on a timer compare event.

49.3.2.2 Timer 8-bit High PWM mode

In 8-bit High PWM mode, the 16-bit counter is divided into two 8-bit counters. The lower 8 bits are used to configure the timer output high period and the upper 8 bits are used to configure the timer output low period. The lower 8 bits decrement when the output is high. When the lower 8 bits become zero and decrement, the timer output is cleared and the lower 8 bits are reloaded from the compare register. The upper 8 bits decrement when the output is low. When the upper 8 bits become zero and decrement, the timer output is set and the upper 8 bits are reloaded from the compare register.

A timer compare event occurs when the upper 8 bits become zero and decrement. The timer status flag is set on a timer compare event.

49.3.2.3 Timer 16-bit Counter mode

In 16-bit Counter mode, you can use the 16-bit counter to configure either the baud rate of the shift clock (for example, TIMDEC[1:0] ≠ 10 or 11) or the number of shift clock edges in the transfer (for example, TIMDEC[1:0] = 10 or 11). When the 16-bit counter equals zero and decrements, the timer output toggles and the counter reloads from the compare register.

A timer compare event occurs when the 16-bit counter equals zero and decrements. The timer status flag is set on a timer compare event.

49.3.2.4 Timer 16-bit Counter Disable mode

In 16-bit Counter Disable mode, the 16-bit counter can be used to configure either the baud rate of the shift clock (for example, TIMDEC[1:0] ≠ 10 or 11) or the number of shift clock edges in the transfer (for example, TIMDEC[1:0] = 10 or 11). When the 16-bit counter equals zero and decrements, the timer output toggles and the counter reloads from the compare register.

A timer compare event occurs when the 16-bit counter equals zero and decrements. The timer status flag is set on a timer disable event.

49.3.2.5 Timer 8-bit Word Counter mode

In 8-bit Word Counter mode, the 16-bit counter is divided into two 8-bit counters. The lower 8 bits are used to configure the number of shift clock edges in each word and the upper 8 bits are used to configure the number of words in the transfer. When the lower 8 bits decrement to zero, the timer output is toggled and the lower 8 bits reload from the compare register. The upper 8 bits only decrement when the lower 8 bits become zero and decrement.

A timer compare event occurs when the lower 8 bits become zero and decrement. The timer status flag is set when the upper 8 bits become zero and decrement.

49.3.2.6 Timer 8-bit Low PWM mode

In 8-bit Low PWM mode, the 16-bit counter is divided into two 8-bit counters. The lower 8 bits are used to configure the timer output low period and the upper 8 bits are used to configure the timer output high period. The lower 8 bits decrement when the output is low. When the lower 8 bits become zero and decrement, the timer output is set and the lower 8 bits are reloaded from the compare

register. The upper 8 bits decrement when the output is high. When the upper 8 bits become zero and decrement, the timer output is cleared and the upper 8 bits are reloaded from the compare register.

A timer compare event occurs when the upper 8 bits become zero and decrement. The timer status flag is set on a timer compare event.

49.3.2.7 Timer enable and start functions

The following events occur when you configure TIMCTL*n*[TIMOD] for the desired mode and the condition configured by the timer enable (TIMCFG*n*[TIMENA]) is detected. When TIMCTL*n*[ONETIM] is 1, the timer status flag must be clear to generate a timer enable event; otherwise, the timer enable event is blocked. You can use this to enforce software intervention after each timer iteration:

- The timer counter loads the current value of the compare register and starts decrementing, as configured by TIMCFG*n*[TIMDEC].
- The timer output may update to its initial state depending on the configuration of TIMCFG*n*[TIMOUT]. Shifters that are controlled by this timer do not see this as a rising edge on the timer shift clock.
- Transmit shifters controlled by this timer either output their start bit value or load the shift register from the shift buffer and output the first bit, as configured by SHIFTCFG*n*[SSTART].

If the timer start bit is enabled, the timer counter reloads with the compare register on the first rising edge of the shift clock after the timer starts decrementing. If there is no falling edge on the shift clock before the first rising edge (for example, when TIMCFG*n*[TIMOUT] = 1), a shifter that is configured to shift on the falling edge and load on the first shift does not load correctly.

49.3.2.8 Timer decrement and reset functions

The timer generates the timer output and timer shift clock depending on the fields, TIMCTL*n*[TIMOD] and TIMCFG*n*[TIMDEC]. The shifter clock is either equal to the timer output (when TIMCFG*n*[TIMDEC] ≠ 10 or 11) or equal to the decrement clock (when TIMCFG*n*[TIMDEC] = 10 or 11). If you configure TIMCFG*n*[TIMDEC] to decrement from a pin or trigger, the timer decrements on both rising and falling edges.

If a timer is configured to decrement on the FLEXIO functional clock divided by 16 or 256 (when TIMCFG*n*[TIMDEC] = 100 or 101), then a common prescaler that is shared by all timers is used to generate the two divide ratios. This prescaler is reset when all timers are either idle or configured not to use the prescaler (TIMCFG*n*[TIMDEC] ≠ 100 or 101).

If you configure the timer to reset as determined by TIMCFG*n*[TIMRST], then the timer counter loads the current value of the compare register again. You can configure the timer output and timer shift clock to update on timer reset, as configured by TIMCFG*n*[TIMOUT]. If the time output toggles as a result of the timer reset, this can result in a timer shift clock edge. In 8-bit Baud Counter mode, this also decrements the upper 8 bits of the counter.

In general, when the timer counter decrements to zero, a timer compare event is triggered. The timer compare event causes:

- The timer counter to load the contents of the timer compare register.
- The timer output to toggle.
- Any configured transmit shift registers to load.
- Any configured receive shift registers to store.

Depending on the timer mode, the timer status flag may also be set.

49.3.2.9 Timer disable and stop functions

When the timer is configured to add a stop bit on each compare, the following additional events occur:

- Transmit shifters controlled by this timer output their stop bit value (if configured by SHIFTCFG*n*[SSTOP]).
- Receive shifters controlled by this timer store the contents of the shift register in their shift buffer, as configured by SHIFTCFG*n*[SSTOP].

- The timer counter reloads the current value of the compare register on the first rising edge of the shifter clock after the compare.

If you configure the timer to insert a stop bit on each compare, you must configure the transmit shifters to load on the first shift.

When the condition configured by timer disable (TIMCFG*n*[TIMDIS]) is detected, the following events occur:

- Timer counter reloads the current value of the compare register and starts decrementing as configured by TIMCFG*n*[TIMDEC].
- Timer output clears. Shifters that are controlled by this timer do not see this as a falling edge on the timer shift clock, but can generate a shift event if the timer shift clock otherwise generates one.
- Transmit shifters controlled by this timer output their stop bit value (if configured by SHIFTCFG*n*[SSTOP]).
- Receive shifters controlled by this timer store the contents of the shift register in their shift buffer, as configured by SHIFTCFG*n*[SSTOP].

If the timer stop bit is enabled, the timer counter continues decrementing until the next rising edge of the shift clock is detected, at which point it finishes decrementing. Although the timer output is forced low during the stop bit, the timer shift clock can toggle during the stop bit. The timer output does not generate shift events during the stop bit.

A timer enable condition can be detected in the same cycle as a timer disable condition (if timer stop bit is disabled), or on the first rising edge of the shift clock after the disable condition (if stop bit is enabled). When TIMCTL*n*[ONETIM] is 1, the timer status flag must be clear before the next timer enable condition is detected. When the timer is in the stop state condition, receive shift registers with stop bit enabled store the contents of the shift register into the shift buffer and verify the state of the input data on the configured shift edge. If there is no configured edge between the timer disable and the next rising edge of the shift clock, then the final store and verify do not occur.

49.3.3 Pin operation

The pin configuration for each timer and shifter can be set to use any FLEXIO pin with either polarity. You can configure each timer and shifter as an input, output data, output enable, or bidirectional output. A pin configured for output enable can be used as an open drain (with inverted polarity because the output enable assertion causes logic zero to be output on the pin) or to control the enable on the bidirectional output. You can configure any timer or shifter to control the output enable for a pin where the bidirectional output data is driven by another timer or shifter.

When more than one shifter or timer is configured to use the same pin for output data, then the output data to the pin is combined using an OR function. This also applies if more than one timer or shifter is configured to use the same pin for output enable.

49.3.3.1 Parallel interface

You can configure shifters to use multiple FLEXIO pins simultaneously by using SHIFTCFG*n*[PWIDTH], which is used to configure the following settings of a shifter:

1. Number of bits shifted per shift clock.
2. Number of pins driven by the shifter per shift clock (only on shifters supporting parallel transmit—that is, SHIFTER0 and SHIFTER4.)
3. Number of pins sampled by the shifter per shift clock (only on shifters supporting parallel receive—that is, SHIFTER3 and SHIFTER7.)

When configured for parallel shift, either 4, 8, 16, or 32 bits can be shifted on every shift clock. If an adjacent shifter is selected as the input source (SHIFTCFG*n*[INSRC] = 1), the least significant 4, 8, 16, or 32 bits from the adjacent shifter are sampled on each shift clock.

For shifters supporting parallel receive (SHIFTER3, SHIFTER7), you can configure the shifter to sample multiple pins (INSRC = 0), with PWIDTH and PINSEL selecting the pins as FXIO_D[PINSEL+PWIDTH]:FXIO_D[PINSEL].

NOTE

If PWIDTH is less than the number of bits being shifted on each shift clock, then the most significant bits are masked with 0. For example, if PINSEL = 7 and PWIDTH = 6, then SHIFTER[31:24] samples {0,0,FXIO_D[12:7]} on each shift clock.

For shifters supporting parallel transmit (SHIFTER0, SHIFTER4), you can configure the shifter to drive multiple pins using SHIFTCTL*n*[PINCFG], with PWIDTH and PINSEL selecting the pins as follows: FXIO_D[PINSEL+PWIDTH]:FXIO_D[PINSEL].

NOTE

If PWIDTH is less than the number of bits being shifted on each shift clock, then the most significant pins are not driven. For example, if PINSEL = 7 and PWIDTH = 6, then SHIFTER[5:0] drives only FXIO_D[12:7] on each shift clock.

49.3.3.2 Pin synchronization

When you configure a pin as an input (this includes a timer trigger configured as a pin input), the input signal is first synchronized with the FLEXIO clock before a timer or shifter could use the signal. This introduces a small latency of 0.5–1.5 FLEXIO clock cycles when using an external pin input to generate an output or control a shifter. This sets the maximum setup time at 1.5 FLEXIO clock cycles.

If an input is used by more than one timer or shifter, then the synchronization occurs once to ensure any edge is seen on the same cycle by all timers and shifters using that input.

NOTE

FLEXIO pins are also connected internally. Configuring a FLEXIO shifter or timer to output data on an unused pin makes an internal connection that allows other shifters and timers to use this pin as an input. This allows a shifter output to trigger a timer or a timer output to be shifted into a shifter. This path is also synchronized with the FLEXIO clock and therefore incurs a one-cycle latency.

When using a pin input as a timer trigger, timer clock, or shifter data input, the following synchronization delays occur:

- 0.5–1.5 FLEXIO clock cycles for an external pin
- One FLEXIO clock cycle for an internally driven pin

See Application information for timing considerations such as output valid time and input setup time for specific applications (SPI controller, SPI target, I2C controller, I2S controller, and I2S target).

49.3.3.3 Pin override

You can change the state of any FLEXIO pin at any time. Pin Output Enable (PINOUTE) configures any pin as an output and drives that pin with the value in Pin Output Data (PINOUTD).

Alias registers for PINOUTE and data registers also exist. Writing a logic 1 to an alias register updates the corresponding register fields in both PINOUTE and PINOUTD as follows:

- Pin Output Disable (PINOUTDIS) clears Pin Output Enable (PINOUTE) and Pin Output Data (PINOUTD).
- Pin Output Clear (PINOUTCLR) sets Pin Output Enable (PINOUTE) and clears Pin Output Data (PINOUTD).
- Pin Output Set (PINOUTSET) sets Pin Output Enable (PINOUTE) and Pin Output Data (PINOUTD).
- Pin Output Toggle (PINOUTTOG) sets Pin Output Enable (PINOUTE) and toggles Pin Output Data (PINOUTD).

49.3.3.4 Pin interrupt

You can read the state of any FLEXIO pin at any time and also configure any pin to set a status flag when either a rising or falling edge is detected on that pin. Additionally, you can configure the pin status flag to generate an interrupt.

49.3.4 Low-power modes

FLEXIO remains functional during low-power modes, if CTRL[DOZEN] is 0 and the FLEXIO functional clock remains enabled.

The exception to this is in Deep Sleep mode. In this case, CTRL[DOZEN] is ignored and FLEXIO waits for all timers to complete any pending operation before acknowledging Deep Sleep mode entry.

49.3.5 Debug mode

FLEXIO remains functional in Debug mode, provided the value of CTRL[DBGE] is 1.

49.3.6 Clocking

Table 405. FLEXIO clocks

Clock	Description
Functional clock	Is asynchronous to the bus clock and can remain enabled in low-power modes. You must enable the FLEXIO functional clock before accessing any of the FLEXIO registers. Provided the FLEXIO functional clock is at least equal to the bus clock, you can configure CTRL[FASTACC] to support fast register accesses.
Bus clock	Is used only for bus accesses to the control and configuration registers.

49.3.7 Reset

Table 406. FLEXIO reset types

Reset	Description
Chip reset	Resets the FLEXIO logic and registers to their default states on chip reset.
Software reset	Resets, using CTRL[SWRST], all logic and registers to their default states, except for the Control register.

49.3.8 Interrupts and DMA requests

The following table shows the status flags that generate the FLEXIO interrupt and DMA requests.

Table 407. FLEXIO interrupts and DMA requests

Flag	Description	Interrupt	DMA request	Low-power wake-up
SHIFTSTAT[SSF]	Shifter status flag	Y	Y	Y
SHIFTERR[SEF]	Shifter error flag	Y	N	Y
TIMSTAT[TSF]	Timer status flag	Y	Y	Y
PINSTAT[PSF]	Pin status flag	Y	N	Y
TRGSTAT[ETSF]	External trigger status flag	Y	N	Y

49.3.9 Peripheral triggers

The connection between FLEXIO peripheral triggers and other peripherals is device-specific.

49.3.9.1 Output triggers

Each FLEXIO timer generates an output trigger equal to the timer output. The output trigger is not affected by the timer pin polarity configuration.

49.3.9.2 Input trigger

FLEXIO supports multiple external trigger inputs that can be used to trigger one or more FLEXIO timers. If a rising edge is detected on an external trigger when FLEXIO is enabled, then the external trigger status flag is set. The external triggers are synchronized to the FLEXIO functional clock and must assert for at least two cycles of the FLEXIO functional clock to be sampled correctly.

49.4 External signals

Table 408. External signals

Signal	Description	Direction
FXIO_D*n* (*n* = 0...31)	Bidirectional FLEXIO shifter and timer pin	Input or output

49.5 Initialization

Perform the following procedure to initialize FLEXIO registers:

1. Enable FLEXIO by writing 1 to CTRL[FLEXEN].
2. Configure shift registers for the given application. It is recommended to write to Shifter Configuration (SHIFTCFG0 - SHIFTCFG7) before writing to the corresponding register, Shifter Control (SHIFTCTL0 - SHIFTCTL7).
3. Configure timer registers for the given application. It is recommended to write to Timer Compare (TIMCMP0 - TIMCMP7) and Timer Configuration (TIMCFG0 - TIMCFG7) before writing to the corresponding register, Timer Control (TIMCTL0 - TIMCTL7).
4. Enable interrupts and/or DMA requests, as appropriate, for the given application.
5. Write transmit data to initiate a transfer (depending on the given application).

49.6 Application information

This section provides examples for a variety of FLEXIO module applications. See FLEXIO register descriptions for more information.

49.6.1 UART transmit

UART transmit can be supported using one timer, one shifter, and one pin (two pins, if supporting CTS). The start and stop bit insertion is handled automatically, and multiple transfers are supported using the DMA controller. The timer status flag is used to indicate when the stop bit of each word is transmitted.

Break and idle characters require software intervention. Before transmitting a break or idle character, you must modify SHIFTCFG*n*[SSTART] and SHIFTCFG*n*[SSTOP] to transmit the required state, and the data to transmit must equal FFh or 00h. Supporting a second stop bit requires the stop bit to be inserted into the data stream using software (and increasing the number of bits to transmit). When performing byte writes to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) (or Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7) for transmitting MSB first), the rest of the register remains unaltered. This allows an address mark bit or additional stop bit to remain undisturbed.

NOTE

FLEXIO does not support automatic insertion of parity bits.

Table 409. UART transmit configuration

Register	Value	Configuration
SHIFTCFG*n*	0000_0032h	Configure start bit of 0 and stop bit of 1.

Table continues on the next page...

Table 409. UART transmit configuration (continued)

Register	Value	Configuration
SHIFTCTL*n*	0003_0002h	Configure transmit using timer 0 on the positive edge of clock with output data on pin 0. You can configure the PINPOL field to invert output data, or support open-drain by writing 1h to the PINPOL and PINCFG fields.
TIMCMP*n*	0000_0F01h	Configure 8-bit transfer with baud rate of divide by 4 of the FLEXIO clock. Set TIMCMP[15:8] as (number of bits × 2) - 1, and set TIMCMP[7:0] as (baud rate divider ÷ 2) - 1.
TIMCFG*n*	0000_2222h	Configure start bit, stop bit, enable on trigger asserted and disable on compare. You can support CTS by configuring the TIMENA field as 3h.
TIMCTL*n*	01C0_0001h	Configure the dual 8-bit counter using the shifter 0 status flag as an inverted internal trigger source. To support CTS, configure the PINSEL (for pin 1) and PINPOL fields as 1h.
SHIFTBUF*n*	Data to transmit	Transmit data can be written to SHIFTBUF[7:0] to initiate an 8-bit transfer. Use the shifter status flag to indicate when data can be written using an interrupt or a DMA request. Write to SHIFTBUFBBS[7:0] instead to support MSB first transfer.

The following table shows an alternative configuration that supports slower baud rates. This configuration requires two timers.

Table 410. UART transmit configuration for slow baud rate

Register	Value	Configuration
SHIFTCFG*n*	0000_0032h	Configure start bit of 0 and stop bit of 1.
SHIFTCTL*n*	0003_0002h	Configure transmit using timer 0 on the positive edge of clock with output data on pin 0. Invert output data by writing 1 to the PINPOL field. Support open-drain by configuring the PINPOL and PINCFG fields as 1h.
TIMCMP*n*	0000_000Fh	Configure for 8-bit transfer, and configure TIMCMP[15:0] as (number of bits × 2) - 1.
TIMCFG*n*	0030_2622h	Configure start bit, stop bit, enable on trigger rising edge, decrement on trigger and disable on compare.

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Table 410. UART transmit configuration for slow baud rate (continued)

Register	Value	Configuration
TIMCTL*n*	0740_0003h	Configure the 16-bit counter using the timer 1 output as an internal trigger source.
TIMCMP(*n* + 1)	0000_0001h	Configure baud rate of divide by 4 of the FLEXIO clock, and configure TIMCMP[15:0] as (baud rate divider ÷ 2) - 1.
TIMCFG(*n* + 1)	0000_1200h	Configure enable on trigger asserted and disable on timer 0 disable. You can configure the TIMEN field as 3h to support CTS.
TIMCTL(*n* + 1)	01C0_0003h	Configure the 16-bit counter using the shifter 0 status flag as an inverted internal trigger source. You can support CTS by configuring the PINSEL (for pin 1) and PINPOL fields as 1h.
SHIFTBUF*n*	Data to transmit	Transmit data can be written to SHIFTBUF[7:0] to initiate an 8-bit transfer. Use the shifter status flag to indicate when data can be written using an interrupt or a DMA request. Write to SHIFTBUFBBS[7:0] instead to support MSB first transfer.

49.6.2 UART receive

UART receive can be supported using one timer, one shifter, and one pin (two timers and two pins, if supporting RTS). The start and stop bit verification is handled automatically and multiple transfers are supported using the DMA controller. The timer status flag is used to indicate when the stop bit of each word is received.

FLEXIO does not support triple voting of the received data, which is sampled only once in the middle of each bit. You can use a timer to implement a glitch filter on the incoming data and a different timer to detect an idle line of programmable length. Break characters cause the error flag to set, and the shifter buffer register returns 00h.

NOTE

FLEXIO does not support automatic verification of parity bits.

Table 411. UART receiver configuration

Register	Value	Configuration
SHIFTCFG*n*	0000_0032h	Configure start bit of 0 and stop bit of 1.
SHIFTCTL*n*	0080_0001h	Configure receive using timer 0 on the negative edge of clock with input data on pin 0. You can invert input data by writing 1 to the PINPOL field.
TIMCMP*n*	0000_0F01h	Configure 8-bit transfer with baud rate of divide by 4 of the FLEXIO clock. Set

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Table 411. UART receiver configuration (continued)

Register	Value	Configuration
		TIMCMP[15:8] as (number of bits × 2) - 1, and set TIMCMP[7:0] as (baud rate divider ÷ 2) - 1.
TIMCFG*n*	0204_2422h	Configure start bit, stop bit, enable on pin positive edge and disable on compare. Enable resynchronization to received data with TIMOUT = 2h and TIMRST = 4h.
TIMCTL*n*	0000_0081h	Configure the dual 8-bit counter using the inverted pin 0 input.
SHIFTBUF*n*	Data to receive	You can read received data from SHIFTBUFBYS[7:0]. Use the shifter status flag to indicate when data can be read using interrupt or DMA request. Read from SHIFTBUFBIS[7:0] instead to support MSB first transfer.

The UART receiver with RTS configuration uses a second timer to generate the RTS output. RTS asserts when the start bit is detected and negates when the data is read from the shifter buffer register. If no start bit is detected when the RTS is asserted, the received data is ignored.

Table 412. UART receiver with RTS configuration

Register	Value	Configuration
SHIFTCFG*n*	0000_0032h	Configure start bit of 0 and stop bit of 1.
SHIFTCTL*n*	0080_0001h	Configure receive using timer 0 on the negative edge of clock with input data on pin 0. Invert input data by writing 1 to the PINPOL field.
TIMCMP*n*	0000_0F01h	Configure 8-bit transfer with baud rate of divide by 4 of the FLEXIO clock. Set TIMCMP[15:8] as (number of bits × 2) - 1, and set TIMCMP[7:0] as (baud rate divider ÷ 2) - 1.
TIMCFG*n*	0204_2522h	Configure start bit, stop bit, enable on pin positive edge with trigger asserted and disable on compare. Enable resynchronization to received data with TIMOUT = 2h and TIMRST = 4h.
TIMCTL*n*	02C0_0081h	Configure dual 8-bit counter using the inverted pin 0 input. Trigger is internal using the inverted pin 1 input.
TIMCMP(*n* + 1)	0000_FFFFh	Never compare.

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Table 412. UART receiver with RTS configuration (continued)

Register	Value	Configuration
TIMCFG(*n* + 1)	0030_6100h	Enable on timer *n* enable and disable on the trigger falling edge. Decrement on trigger to ensure no compare.
TIMCTL(*n* + 1)	0143_0003h	Configure 16-bit counter and output on pin 1. Trigger is internal using the shifter 0 flag.
SHIFTBUF*n*	Data to receive	You can read received data using SHIFTBUFBYS[7:0]. Use the shifter status flag to indicate when data can be read using interrupt or DMA request. Read from SHIFTBUFBIS[7:0] instead to support MSB first transfer.

49.6.3 SPI controller

SPI Controller mode can be supported using two timers, two shifters, and four pins. Using the DMA controller, either CPHA = 0 or CPHA = 1 and transfers can be supported. For CPHA = 1, the chip select can remain asserted for multiple transfers and the timer status flag can be used to indicate the end of the transfer.

The stop bit is used to guarantee a minimum of one clock cycle between the target chip select negating and before the next transfer. To initiate each transfer, either the core or DMA writes to the transmit buffer.

NOTE

Because of synchronization delays, the setup time for the serial input data is 1.5 FLEXIO clock cycles. This means the maximum baud rate is divide by 4 of the FLEXIO clock frequency.

Table 413. SPI controller (CPHA = 0) configuration

Register	Value	Configuration
SHIFTCFG*n*	0000_0000h	Start and stop bit disabled.
SHIFTCTL*n*	0083_0002h	Configure transmit using timer 0 on the negative edge of clock with output data on pin 0.
SHIFTCFG(*n* + 1)	0000_0000h	Start and stop bit disabled.
SHIFTCTL(*n* + 1)	0000_0101h	Configure receive using timer 0 on the positive edge of clock with input data on pin 1.
TIMCMP*n*	0000_3F01h	Configure 32-bit transfer with baud rate of divide by 4 of the FLEXIO clock. Set TIMCMP[15:8] as (number of bits × 2) - 1, and set TIMCMP[7:0] as (baud rate divider ÷ 2) - 1.
TIMCFG*n*	0100_2222h	Configure start bit, stop bit, enable on trigger high and disable on compare; initial clock state is logic 0.

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Table 413. SPI controller (CPHA = 0) configuration (continued)

Register	Value	Configuration
TIMCTL*n*	01C3_0201h	Configure dual 8-bit counter using the pin 2 output (shift clock), with shifter 0 flag as the inverted trigger. Write 1 to the PINPOL field to invert the output shift clock.
TIMCMP(*n* + 1)	0000_FFFFh	Never compare.
TIMCFG(*n* + 1)	0000_1100h	Enable when timer 0 is enabled and disable when timer 0 is disabled.
TIMCTL(*n* + 1)	0003_0383h	Configure 16-bit counter (never compare) using the inverted pin 3 output as target select.
SHIFTBUF*n*	Data to transmit	You can write transmit data to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7). Use the shifter status flag to indicate when data can be written using interrupt or DMA request. Write to Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7) instead to support MSB first transfer.
SHIFTBUF(*n* + 1)	Data to receive	Received data can be read from Shifter Buffer (SHIFTBUF0 - SHIFTBUF7). Use the shifter status flag to indicate when data can be read using interrupt or DMA request. Read from Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7) instead to support MSB first transfer.

Table 414. SPI controller (CPHA = 1) configuration

Register	Value	Configuration
SHIFTCFG*n*	0000_0021h	Start bit loads data on first shift.
SHIFTCTL*n*	0003_0002h	Configure transmit using timer 0 on the positive edge of clock with output data on pin 0.
SHIFTCFG(*n* + 1)	0000_0000h	Start and stop bit disabled.
SHIFTCTL(*n* + 1)	0080_0101h	Configure receive using timer 0 on the negative edge of clock with input data on pin 1.
TIMCMP*n*	0000_3F01h	Configure 32-bit transfer with baud rate of divide by 4 of the FLEXIO clock. Set TIMCMP[15:8] as (number of bits x 2) - 1, and set TIMCMP[7:0] as (baud rate divider ÷ 2) - 1.

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Table 414. SPI controller (CPHA = 1) configuration (continued)

Register	Value	Configuration
TIMCFG*n*	0100_2222h	Configure start bit, stop bit, enable on trigger high and disable on compare; initial clock state is logic 0.
TIMCTL*n*	01C3_0201h	Configure dual 8-bit counter using pin 2 output (shift clock), with the shifter 0 flag as the inverted trigger. Write 1 to the PINPOL field to invert the output shift clock, and set the TIMDIS field as 3 to keep target select asserted for as long as there is data in the transmit buffer.
TIMCMP(*n* + 1)	0000_FFFFh	Never compare.
TIMCFG(*n* + 1)	0000_1100h	Enable when timer 0 is enabled and disable when timer 0 is disabled.
TIMCTL(*n* + 1)	0003_0383h	Configure 16-bit counter (never compare) using inverted pin 3 output (as target select).
SHIFTBUF*n*	Data to transmit	Transmit data can be written to SHIFTBUF. Use the shifter status flag to indicate when data can be written using interrupt or DMA request. Write to Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7) instead to support MSB first transfer.
SHIFTBUF(*n* + 1)	Data to receive	Received data can be read from Shifter Buffer (SHIFTBUF0 - SHIFTBUF7). Use the shifter status flag to indicate when data can be read using interrupt or DMA request. Read from Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7) instead to support MSB first transfer.

49.6.4 SPI target

SPI Target mode can be supported using one timer, two shifters, and four pins. Either CPHA = 0 or CPHA = 1 can be supported and transfers can be supported using the DMA controller. For CPHA = 1, the select can remain asserted for multiple transfers and the timer status flag can be used to indicate the end of the transfer.

You must write the transmit data to the transmit buffer register before the external target select asserts; otherwise, the shifter error flag is set.

NOTE

Because of synchronization delays, the output valid time for the serial output data is 2.5 FLEXIO clock cycles. This means the maximum baud rate is divide by 6 of the FLEXIO clock frequency.

Table 415. SPI target (CPHA = 0) configuration

Register	Value	Configuration
SHIFTCFG*n*	0000_0000h	Start and stop bit disabled.
SHIFTCTL*n*	0083_0002h	Configure transmit using timer 0 on the falling edge of shift clock with output data on pin 0.
SHIFTCFG(*n* + 1)	0000_0000h	Start and stop bit disabled.
SHIFTCTL(*n* + 1)	0000_0101h	Configure receive using timer 0 on the rising edge of shift clock with input data on pin 1.
TIMCMP*n*	0000_003Fh	Configure 32-bit transfer. Set TIMCMP[15:0] as (number of bits × 2) - 1.
TIMCFG*n*	0120_0600h	Configure enable on trigger rising edge. Initial clock state is logic 0 and decrements on pin input.
TIMCTL*n*	06C0_0203h	Configure 16-bit counter using pin 2 input (shift clock), with pin 3 input (target select) as the inverted trigger.
SHIFTBUF*n*	Data to transmit	Transmit data can be written to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7). Use the shifter status flag to indicate when data can be written using interrupt or DMA request. Write to Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7) instead to support MSB first transfer.
SHIFTBUF(*n* + 1)	Data to receive	Received data can be read from Shifter Buffer (SHIFTBUF0 - SHIFTBUF7). Use the shifter status flag to indicate when data can be read using interrupt or DMA request. Read from Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7) instead to support MSB first transfer.

Table 416. SPI target (CPHA = 1) configuration

Register	Value	Configuration
SHIFTCFG*n*	0000_0001h	Shifter configured to load on first shift and stop bit disabled.
SHIFTCTL*n*	0003_0002h	Configure transmit using timer 0 on rising edge of shift clock with output data on pin 0.
SHIFTCFG(*n* + 1)	0000_0000h	Start and stop bit disabled.

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Table 416. SPI target (CPHA = 1) configuration (continued)

Register	Value	Configuration
SHIFTCTL(*n* + 1)	0080_0101h	Configure receive using timer 0 on falling edge of shift clock with input data on pin 1.
TIMCMP*n*	0000_003Fh	Configure 32-bit transfer. Set TIMCMP[15:0] as (number of bits × 2) - 1).
TIMCFG*n*	0120_6602h	Configure start bit, enable on trigger rising edge, disable on trigger falling edge. Initial clock state is logic 0 and decrements on pin input.
TIMCTL*n*	06C0_0203h	Configure 16-bit counter using pin 2 input (shift clock), with pin 3 input (target select) as the inverted trigger.
SHIFTBUF*n*	Data to transmit	Transmit data can be written to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7). Use the shifter status flag to indicate when data can be written using interrupt or DMA request. Write to Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7) instead to support MSB first transfer.
SHIFTBUF(*n* + 1)	Data to receive	Received data can be read from Shifter Buffer (SHIFTBUF0 - SHIFTBUF7). Use the shifter status flag to indicate when data can be read using interrupt or DMA request. Read from Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7) instead to support MSB first transfer.

49.6.5 I2C controller

I2C Controller mode can be supported using two timers, two shifters, and two pins. One timer is used to generate the SCL output and another one is used to control the shifters. The two shifters that are used to transmit and receive for every word, when receiving the transmitter, must transmit FFh to 3-state the output. FLEXIO inserts a stop bit after every word to generate and verify the ACK or NACK. FLEXIO waits for the first write to the transmit data buffer before enabling SCL generation. Data transfers can be supported using the DMA controller and the shifter error flag sets on transmit underrun or receive overflow.

The first timer generates the bit clock for the entire packet (start to repeated start or stop condition), so you must program the compare register with the total number of clock edges in the packet (minus one). The timer supports clock stretching using the reset counter when pin is equal to output. However, this increases both the clock high and clock low periods by at least one FLEXIO clock cycle each. The second timer uses the SCL input pin to control the transmit and receive shift registers. This enforces an SDA data hold time by an extra two FLEXIO clock cycles.

Both the transmit and receive shifters must be serviced for each word in the transfer. The transmit shifter must transmit FFh when receiving, and the receive shifter returns the data present on the SDA pin. The transmit shifter loads one additional word on the last falling edge of the SCL pin. When generating a stop condition or a repeated start condition, this word must be 00h and FFh, respectively. During the last word of a controller-receiver transfer, you must set the transmit SHIFTCFG*n*[SSTOP] field to generate a NACK.

The receive shift register asserts an error interrupt if a NACK is detected, but you are responsible for generating the stop or repeated start condition. If a NACK is detected during controller-transmit, the interrupt routine must immediately write 00h (when generating a stop condition) or FFh (when generating a repeated start condition) to the transmit shifter register. You must wait for the next rising edge on SCL before disabling both timers. The transmit shifter must be disabled after the setup delay for a repeated start or stop condition.

NOTE

Because of synchronization delays, the data valid time for the transmit output is two FLEXIO clock cycles. This means the maximum baud rate is divide by 6 of the FLEXIO clock frequency.

To guarantee SDA hold time, the I2C controller data valid is delayed by two cycles because the clock output is passed through a synchronizer before clocking the transmit or receive shifter. Because the SCL output is synchronous with FLEXIO clock, the synchronization delay is one cycle, and then an additional cycle is involved to generate the output.

Table 417. I2C controller configuration

Register	Value	Configuration
SHIFTCFG*n*	0000_0032h	Start bit enabled (logic 0) and stop bit enabled (logic 1).
SHIFTCTL*n*	0101_0082h	Configure transmit using timer 1 on the rising edge of clock with inverted output enable (open-drain output) on pin 0.
SHIFTCFG(*n* + 1)	0000_0020h	Start bit disabled and stop bit enabled (logic 0) for ACK or NACK detection.
SHIFTCTL(*n* + 1)	0180_0001h	Configure receive using timer 1 on the falling edge of clock with input data on pin 0.
TIMCMP*n*	0000_2501h	Configure 2 word transfer with baud rate of divide by 4 of the FLEXIO clock. Set TIMCMP[15:8] as (number of words × 18) + 1, and set TIMCMP[7:0] as (baud rate divider ÷ 2) - 1.
TIMCFG*n*	0102_2222h	Configure start bit, stop bit, enable on trigger high, disable on compare, reset if output equals pin. Initial clock state is logic 0 and is not affected by reset.
TIMCTL*n*	01C1_0101h	Configure dual 8-bit counter using pin 1 output enable (SCL open-drain), with the shifter 0 flag as the inverted trigger.
TIMCMP(*n* + 1)	0000_000Fh	Configure 8-bit transfer. Set TIMCMP[15:0] as (number of bits x 2) - 1.
TIMCFG(*n* + 1)	0020_1112h	Enable when timer 0 is enabled; disable when timer 0 is disabled. Enable start bit and stop bit at the end of each word and decrement on pin input.
TIMCTL(*n* + 1)	01C0_0183h	Configure 16-bit counter using inverted pin 1 input (SCL).

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Table 417. I2C controller configuration (continued)

Register	Value	Configuration
SHIFTBUF*n*	Data to transmit	Transmit data can be written to SHIFTBUFBBS[7:0]. Use the shifter status flag to indicate when data can be written using interrupt or DMA request.
SHIFTBUF(*n* + 1)	Data to receive	Received data can be read from SHIFTBUFBIS[7:0]. Use the shifter status flag to indicate when data can be read using interrupt or DMA request.

49.6.6 I2S controller

I2S Controller mode can be supported using two timers, two shifters, and four pins. One timer is used to generate the bit clock and control the shifters and another timer is used to generate the frame sync. FLEXIO waits for the first write to the transmit data buffer before enabling bit clock and frame sync generation. Data transfers are supported using the DMA controller and the shifter error flag sets on transmit underrun or receive overflow.

The bit clock frequency is an even integer divide of the FLEXIO clock frequency. The initial frame sync assertion occurs at the same time as the first bit clock edge. The timer uses the start bit to ensure that the frame sync is generated one clock cycle before the first output data.

NOTE

Because of synchronization delays, the setup time for the receiver input is 1.5 FLEXIO clock cycles. This means that the maximum baud rate is divide by 4 of the FLEXIO clock frequency.

Table 418. I2S controller configuration

Register	Value	Configuration
SHIFTCFG*n*	0000_0001h	Load transmit data on first shift and stop bit disabled.
SHIFTCTL*n*	0003_0002h	Configure transmit using timer 0 on the rising edge of clock with output data on pin 0.
SHIFTCFG(*n* + 1)	0000_0000h	Start and stop bit disabled.
SHIFTCTL(*n* + 1)	0080_0101h	Configure receive using timer 0 on the falling edge of clock with input data on pin 1.
TIMCMP*n*	0000_3F01h	Configure 32-bit transfer with baud rate of divide by 4 of the FLEXIO clock. Set TIMCMP[15:8] as (number of bits × 2) - 1, and set TIMCMP[7:0] as (baud rate divider ÷ 2) - 1.
TIMCFG*n*	0000_0202h	Configure start bit, enable on trigger high and never disable. Initial clock state is logic 1.
TIMCTL*n*	01C3_0281h	Configure dual 8-bit counter using inverted pin 2 output (bit clock), with

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Table 418. I2S controller configuration (continued)

Register	Value	Configuration
		shifter 0 flag as the inverted trigger. Write 0 to the PINPOL field to invert the polarity of the output shift clock.
TIMCMP(*n* + 1)	0000_007Fh	Configure 32-bit transfer with baud rate of divide by 4 of the FLEXIO clock. Set TIMCMP[15:0] as (number of bits × baud rate divider) ÷ 1.
TIMCFG(*n* + 1)	0000_0100h	Enable when timer 0 is enabled and never disable.
TIMCTL(*n* + 1)	0003_0383h	Configure 16-bit counter using inverted pin 3 output (as frame sync). Write 0 to the PINPOL field to invert the polarity of the output frame sync.
SHIFTBUF*n*	Data to transmit	Transmit data can be written to Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7). Use the shifter status flag to indicate when data can be written using interrupt or DMA request. Write to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) instead to support LSB first transfer.
SHIFTBUF(*n* + 1)	Data to receive	Received data can be read from Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7). Use the shifter status flag to indicate when data can be read using interrupt or DMA request. Read from Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) instead to support LSB first transfer.

49.6.7 I2S target

I2S Target mode can be supported using three timers, two shifters, and four pins. For single transmit and single receive, other combinations of transmit and receive are possible.

The transmit data must be written to the transmit buffer register before the external frame sync asserts, otherwise the shifter error flag is set.

NOTE

Because of synchronization delays, the output valid time for the serial output data is 2.5 FLEXIO clock cycles. This means the maximum baud rate is divide by 6 of the FLEXIO clock frequency.

The output valid time of I2S target is maximum 2.5 cycles because there is a maximum 1.5 cycle delay on the clock synchronization, plus one cycle to output the data.

Timer 2 detects the falling edge of frame sync (start of new frame) and asserts output until the rising edge of bit clock (when the frame sync is normally sampled). Timer 0 detects the rising edge of bit clock with timer 2 output asserted and asserts output for length of frame. Timer 1 detects the falling edge of bit clock with timer 0 output asserted and controls shift registers for 32-bit transfers.

Table 419. I2S target configuration

Register	Value	Configuration
SHIFTCFG*n*	0000_0000h	Start and stop bit disabled.
SHIFTCTL*n*	0103_0002h	Configure transmit using timer 1 on the rising edge of shift clock with output data on pin 0.
SHIFTCFG(*n* + 1)	0000_0000h	Start and stop bit disabled.
SHIFTCTL(*n* + 1)	0180_0101h	Configure receive using timer 1 on the falling edge of shift clock with input data on pin 1.
TIMCMP*n*	0000_007Fh	Configure two 32-bit transfers per frame. Set TIMCMP[15:0] as (number of bits × 4) - 1.
TIMCFG*n*	0020_2500h	Configure enable on pin rising edge (inverted bit clock) with trigger high (timer 2) and disable on compare. Initial clock state is logic 1 and decrements on pin input (bit clock).
TIMCTL*n*	0B40_0203h	Configure 16-bit counter using pin 2 input (bit clock), with timer 2 output as the trigger.
TIMCMP(*n* + 1)	0000_003Fh	Configure 32-bit transfers. Set TIMCMP[15:0] as (number of bits × 2) - 1.
TIMCFG(*n* + 1)	0020_2500h	Configure enable on pin (bit clock) rising edge with trigger (timer 0) high and disable on compare. Initial clock state is logic 1 and decrement on pin input (bit clock).
TIMCTL(*n* + 1)	0340_0283h	Configure 16-bit counter using inverted pin 2 input (bit clock), with timer 0 output as the trigger.
TIMCMP(*n* + 2)	0000_0000h	Compare on zero (first edge).
TIMCFG(*n* + 2)	0020_6400h	Configure enable on inverted pin (frame sync) rising edge and disable on trigger falling edge (bit clock). Initial clock state is logic 1 and decrement on inverted pin input (frame sync).
TIMCTL(*n* + 2)	04C0_0383h	Configure 16-bit counter using inverted pin 3 input (frame sync), with pin 2 inverted input (bit clock) as the trigger.
SHIFTBUF*n*	Data to transmit	Transmit data can be written to Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7). Use the shifter status flag to indicate when data can be written

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Table 419. I2S target configuration (continued)

Register	Value	Configuration
		using interrupt or DMA request. Write to the SHIFTBUF register instead to support LSB first transfer.
SHIFTBUF(*n* + 1)	Data to receive	Received data can be read from Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7). Use the shifter status flag to indicate when data can be read using interrupt or DMA request. Read from the SHIFTBUF register instead to support LSB first transfer.

49.6.8 SENT receiver

The SENT receiver can be supported by using one timer and one pin. The timer is configured as Input-Capture mode, and captures the counter value at the falling edge of the pin input. After the counter value is captured, the counter is automatically restarted from counter value 0. Therefore, the captured value always indicates the period between the previous falling edge and current falling edge. You can configure the CPU interrupt or DMA trigger at each capture of the counter. The CPU software performs the entire SENT frame decoding with the latest tick width adjustment.

Table 420. SENT receiver configuration

Register	Value	Configuration
TIMCMP*n*	—	Stores counter value at the falling edge of the pin.
TIMCFG*n*	0000_6000h	Timer is always enabled. It is disabled on trigger falling edge, decrement counter on FLEXIO clock.
TIMCTL*n*	0040_0007h	Single 16-bit input capture mode. The PINSEL field selects the timer pin input and output. Timer pin output disabled, internal trigger selected, select pin 0 as trigger.

49.6.9 Camera interface

Camera interface can be supported using one timer, one or more shifters, and multiple pins. Multiple transfers can be supported using the DMA controller.

The example configuration shown in the following table describes the FLEXIO configuration for interfacing with an 8-bit CMOS sensor with PCLK, VSYNC, HREF, and D[7:0] outputs. The example uses a 128-bit buffer to capture 16 pixels of image data before an interrupt or DMA transfer. You can use a bigger or smaller buffer depending on system DMA performance and FLEXIO resource usage by other applications.

NOTE

You can use additional timers to track the number of pixels per row and number of rows per frame, or HREF or VSYNC can be assigned as GPIO interrupts for software tracking.

Table 421. Camera interface configuration for 8-bit CMOS sensor

Register	Value	Configuration
SHIFTCFG*n*...*n*+2[1]	0007_0100h	Configure 8-bit parallel shift in from adjacent shifter.
SHIFTCFG*n*+3	0007_0000h	Configure 8-bit parallel shift in from pins FXIO_D[7:0] (D[7:0]).
SHIFTCTL*n*...*n*+3	0080_0001h	Configure receive using timer 0 on the negative edge of clock.
TIMCMP*n*	0000_001Fh	Configure 16 pixel (8 bits/pixel × 16 pixels = 128 bits) transfer. Set TIMCMP[15:0] as (number of pixels × 2) - 1.
TIMCFG*n*	0120_6600h	Configure enable on trigger (HREF) rising edge and disable on trigger falling edge. Initial shift clock state is logic 0 and decrement on PCLK input.
TIMCTL*n*	12C0_0803h	Configure 16-bit counter using FXIO_D[8] input (PCLK), with FXIO_D[9] input (HREF) as the inverted trigger.
SHIFTBUF*n*...*n*+3	Data to receive	Received data can be read from SHIFTBUF*n*...*n*+3. Use the shifter status flag to indicate when data can be read using interrupt or DMA request.

1. *n* = 0 or 4

49.6.10 Motorola 68K and Intel 8080 bus interface

Motorola 68K and Intel 8080 bus are two parallel interfaces commonly used by smart and asynchronous LCD controllers. With GPIO, FLEXIO can drive these interfaces using one timer and one shifter. Additional shifters can be used to support large transfers via the DMA controller.

Example configurations are provided for 1-beat and 16-beat transfers. Other lengths are also supported.

The following table provides an example of how to drive a 16-bit 68K or 8080 bus. For an 8080 bus, two GPIOs are used to drive the nCS and RS pins. For a 68K bus, an additional GPIO is required to drive the RDWR pin.

Table 422. Motorola 68K and Intel 8080 write configuration

Register	Value	Configuration
SHIFTCFG0...7	000F_0100h	Configure 16-bit parallel shift in from adjacent shifter.
SHIFTCTL0	0003_0002h	Configure transmit using timer 0 on the positive edge of clock with data output to FXIO_D[15:0].
SHIFTCTL1...7	0000_0002h	Configure transmit using timer 0 on the positive edge of clock.

Table continues on the next page...

Table 422. Motorola 68K and Intel 8080 write configuration (continued)

Register	Value	Configuration
TIMCMP0	0000_0101h (1 beat) 0000_1F01h (16 beats)	Configure 1 or 16-beat transfer with baud rate of divide by 4 of the FLEXIO clock. Set TIMCMP[15:8] as (number of beats × 2) - 1, and set TIMCMP[7:0] as (baud rate divider ÷ 2) - 1.
TIMCFG0	0000_2200h	Configure enable on trigger high and disable on compare. Timer output high on enable.
TIMCTL0	01C3_1001h (Motorola 68K, 1 beat) 1DC3_1001h (Motorola 68K, 16 beats) 01C3_1081h (Intel 8080, 1 beat) 1DC3_1081h (Intel 8080, 16 beats)	Configure dual 8-bit counter using FXIO_D[16] output (EN pin for 68K, nWR pin for 8080), with shifter 0 (1-beat) or shifter 7 (16 beats) flag as the inverted trigger.
SHIFTBUF0...7	Data to transmit	Transmit data can be written to SHIFTBUF0 (1 beat) or SHIFTBUF0...7 (16-beats) to initiate a transfer; use the shifter status flag to indicate when data can be written using interrupt or DMA request.

Table 423. Motorola 68K and Intel 8080 read configuration

Register	Value	Configuration
SHIFTCFG0...6	000F_0100h	Configure 16-bit parallel shift in from the adjacent shifter.
SHIFTCFG7	000F_0000h	Configure 16-bit parallel shift in from pin.
SHIFTCTL0...7	0080_0001h	Configure receive using timer 0 on the negative edge of clock with data input from FXIO_D[15:0].
TIMCMP0	0000_0101h (1 beat) 0000_1F01h (16 beats)	Configure 1 or 16-beat transfer with baud rate of divide by 4 of the FLEXIO clock. Set TIMCMP[15:8] = (number of beats × 2) - 1, and set TIMCMP[7:0] = (baud rate divider ÷ 2) - 1.
TIMCFG0	0000_2220h	Configure stop_bit. Enable on trigger high and disable on compare. Timer output high on enable.
TIMCTL0	1DC3_1001h (Motorola 68K, 1 beat) 01C3_1001h (Motorola 68K, 16 beats) 1DC3_1181h (Intel 8080, 1 beat) 01C3_1181h (Intel 8080, 16 beats)	Configure dual 8-bit counter using either FXIO_D[16] output (EN pin for 68K) or FXIO_D[17] output (nRD pin for 8080), with shifter 7 flag (1-beat) or shifter 0 flag (16 beats) as the inverted trigger.

Table continues on the next page...

Table 423. Motorola 68K and Intel 8080 read configuration (continued)

Register	Value	Configuration
SHIFTBUF0...7	Data received	Received data can be read from SHIFTBUF0 (1 beat) or SHIFTBUF0...7 (16 beats). Use the shifter status flag to indicate when data can be read using interrupt or DMA request.

In general, any operation to a 68K or 8080 bus target begins with a register write cycle followed by one or more data read or write cycles. To accomplish this, perform the following procedure:

1. Configure FLEXIO with 1-beat write configuration.
2. Configure GPIO to assert the nCS and RS pins (and deassert the RDWR pin for 68K).
3. Write register index data to SHIFTBUF0[15:0].
4. Configure GPIO to deassert the RS pin (and assert the RDWR pin for 68K data read).
5. Configure FLEXIO with the desired read or write configuration (1 or 16 beats).
6. Use the shifter status flag to trigger interrupt or DMA driven data transfers to and from Shifter Buffer (SHIFTBUF0 - SHIFTBUF7).
7. Configure GPIO to deassert the nCS pin.

49.6.11 Low-power state machine

Table 424 shows an example of a hypothetical state machine to illustrate the flexibility allowed in Shifter State mode.

In this example, FLEXIO waits for the FXIO_D[2] pin to assert and then drives a complementary square wave output at a frequency of FLEXIO_CLK/131072 on the FXIO_D[1:0] pins while the comparator output is asserted. This assumes that the comparator is connected to external trigger 15. See the chip-specific FLEXIO information for actual FLEXIO trigger mappings. Throughout this operation, the CPU can be kept in a stop or VLPS mode by writing 0 to CTRL[DOZEN] and ensuring that FLEXIO_CLK is enabled. Figure 203 shows the states and transitions implemented by this example.

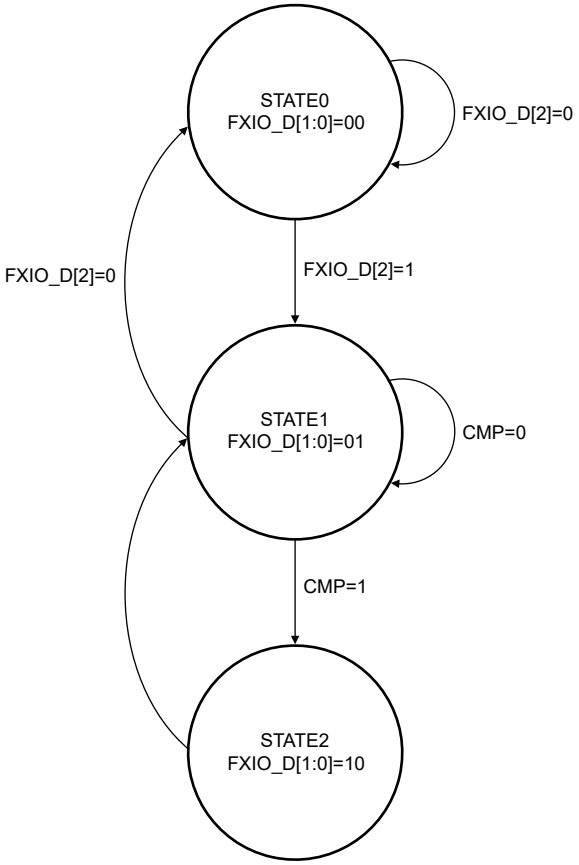

Figure 203. State diagram

Table 424. State machine configuration

Register	Value	Configuration
SHIFTCFG0...2	0000_0003h	Enable FXIO_D[1:0] as outputs.
SHIFTCTL0	0080_0206h	Configure for State mode using FXIO_D[4:2] as inputs to select next state and timer 0 output low to trigger next state.
SHIFTBUF0	0020_8208h	State0: Drive FXIO_D[1:0] = 00; transition to state0 if FXIO_D[2] = 0, state1 if FXIO_D[2] = 1.
SHIFTCTL1	0000_0206h	Configure for State mode using FXIO_D[4:2] as inputs to select next state and timer 0 output high to trigger next state.
SHIFTBUF1	0140_8408h	State1: Drive FXIO_D[1:0]=01; transition to state0 if FXIO_D[2]=0, state1 if CMP = 0, state2 if CMP = 1 (FXIO_D[3]=1).

Table continues on the next page...

Table 424. State machine configuration (continued)

Register	Value	Configuration
SHIFTCTL2	0080_0206h	Configure for State mode using FXIO_D[4:2] as inputs to select next state and timer 0 output low to trigger next state.
SHIFTBUF2	0224_9249h	State2: Drive FXIO_D[1:0] = 10, transition to state1 with timer 0 output low.
TIMCMP0	0000_FFFFh	Configure baud rate of divide by 131072 of the FLEXIO clock. Set TIMCMP[7:0] as (baud rate divider ÷ 2) - 1.
TIMCFG0	0000_0000h	Configure timer always enabled.
TIMCTL0	0000_0003h	Configure single 16-bit counter.
TIMCFG1	0010_7600h	Configure timer enabled on trigger rising edge, disabled on trigger falling edge, decrement on trigger edge.
TIMCTL1	0F03_0303h	Configure timer output enabled on FXIO_D[3], external trigger 15 (comparator output) selected.

49.6.12 Keypad interface

The keypad interface can support a 3 × 4 keypad matrix using three timers and three shifters, although a larger matrix can be supported using additional shifters. The configuration is designed for four columns configured as active low open-drain pins and three rows configured as input pins with pull-up resistors enabled.

One shifter is configured in Logic mode to assert its output when any of the row inputs are low, indicating a key is pressed. Use a timer to filter the shifter output to ensure that the key is pressed for a minimum amount of time before performing the column scan.

A different shifter is configured for parallel transmit. Use this shifter to scan each column when a keypress is detected. When not scanning, the shifter output is configured to assert all active low open-drain column outputs to detect any keypress. Use a dedicated timer to control the transmit shifter.

The last shifter is configured for parallel receive. Use this shifter to capture the result of the column scanning so that you can decode which key (or keys) was pressed. This configuration captures the state of both row and column pins for each scan, although the row state can also be deduced by the shift order. Use a dedicated timer to control the receive shifter, which shifts at half the frequency of the transmit shifter.

When the result of the key scan is available in the receive shifter register, FLEXIO continues to monitor the row inputs and can trigger multiple scans from a single keypress. To support debouncing, you can decide how many consecutive scans must be considered as a single keypress.

NOTE

Because the pins used in Logic mode are fixed per shifter and the shifters that support parallel shifts are limited, this configuration is restricted to what pins and shifters it can use. Increasing the matrix beyond four-row inputs requires multiple shifters in Logic mode. Increasing beyond four-column outputs requires concatenating transmit shifters to create a larger shift register.

Table 425. Keypad interface configuration

Register	Value	Configuration
SHIFTCFG0	0003_0032h	Start bit enabled (logic 0) and stop bit enabled (logic 1), configured for 4-bit shift.
SHIFTCTL0	0101_0402h	Configure transmit using timer 1 on the rising edge of clock generating open-drain output on pins[7:4] (column outputs).
SHIFTBUF0	0804_0201h	Static data containing the column scan pattern; each column is scanned one-hot with dead time in between.
SHIFTCFG1	0000_0020h	In Logic mode, mask input 3.
SHIFTCTL1	0000_0007h	Configure Logic mode.
SHIFTBUF1	07FF_07FFh	Static data configuring Logic mode LUT. Output asserts if pins [3:1] are logic 0.
SHIFTCFG3	0007_0000h	Configured for 8-bit shift.
SHIFTCTL3	0280_0001h	Configure receive using timer 2 on falling edge of clock with input data on pins [7:0] (both rows and columns; pin 0 is don't care).
TIMCMP0	0000_00ffh	Configure prescanning glitch filter to 256 FLEXIO clock cycles. For different filter cycles, configure TIMCMP[15:0] as (filter cycles) - 1.
TIMCFG0	0103_6600h	Configure enable on trigger rising edge and disable on trigger falling edge. Initial clock state is logic 0 and is not affected by reset.
TIMCTL0	0540_0003h	Configure 16-bit counter using the shifter 1 flag (logic state) as trigger.
TIMCMP1	0000_0F3Fh	Configure eight shifts (twice for each column) at column scan rate of divide by 128. For a different scan frequency, define TIMCMP[7:0] as (scan divider ÷ 2) - 1.
TIMCFG1	0020_2622h	Enable on trigger rising edge, disable on compare. Start and stop bits are enabled.
TIMCTL1	0340_0001h	Configure dual 8-bit counter using timer 0 output as the trigger.
TIMCMP2	0000_0801h	Configure four shifts at half the frequency of the timer 1 trigger.

Table continues on the next page...

Table 425. Keypad interface configuration (continued)

Register	Value	Configuration
TIMCFG2	0110_2100h	Enable on timer 1 enable, disable on compare, decrement on trigger input with output initially negated, and not affected by reset.
TIMCTL2	0740_0001h	Configure dual 8-bit counter using timer 1 output as the trigger.
SHIFTBUF3	Keypad scan result	Keypad scan result can be read from SHIFTBUF3. Each byte is the result of one scan with both row and column pin state from the scan (pin 0 is not used). Use the shifter status flag to indicate when data can be written using interrupt or DMA request.

49.7 Memory map and registers

49.7.1 FLEXIO register descriptions

NOTE

Invalid register accesses, which include reading a write-only register, writing to a read-only register, or accessing an invalid address, result in a bus error.

49.7.1.1 FLEXIO memory map

FLEXIO0 base address: 4003_A000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VERID)	32	R	0201_0003h
4h	Parameter (PARAM)	32	R	0420_0808h
8h	FLEXIO Control (CTRL)	32	RW	0000_0000h
Ch	Pin State (PIN)	32	R	0000_0000h
10h	Shifter Status (SHIFTSTAT)	32	RW	0000_0000h
14h	Shifter Error (SHIFTERR)	32	RW	0000_0000h
18h	Timer Status Flag (TIMSTAT)	32	RW	0000_0000h
20h	Shifter Status Interrupt Enable (SHIFTSIEN)	32	RW	0000_0000h
24h	Shifter Error Interrupt Enable (SHIFTEIEN)	32	RW	0000_0000h
28h	Timer Interrupt Enable (TIMIEN)	32	RW	0000_0000h
30h	Shifter Status DMA Enable (SHIFTSDEN)	32	RW	0000_0000h
38h	Timer Status DMA Enable (TIMERSDEN)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
40h	Shifter State (SHIFTSTATE)	32	RW	0000_0000h
48h	Trigger Status (TRGSTAT)	32	RW	0000_0000h
4Ch	External Trigger Interrupt Enable (TRIGIEN)	32	RW	0000_0000h
50h	Pin Status (PINSTAT)	32	RW	0000_0000h
54h	Pin Interrupt Enable (PINIEN)	32	RW	0000_0000h
58h	Pin Rising Edge Enable (PINREN)	32	RW	0000_0000h
5Ch	Pin Falling Edge Enable (PINFEN)	32	RW	0000_0000h
60h	Pin Output Data (PINOUTD)	32	RW	0000_0000h
64h	Pin Output Enable (PINOUTE)	32	RW	0000_0000h
68h	Pin Output Disable (PINOUTDIS)	32	RW	0000_0000h
6Ch	Pin Output Clear (PINOUTCLR)	32	RW	0000_0000h
70h	Pin Output Set (PINOUTSET)	32	RW	0000_0000h
74h	Pin Output Toggle (PINOUTTOG)	32	RW	0000_0000h
80h - 9Ch	Shifter Control (SHIFTCTL0 - SHIFTCTL7)	32	RW	0000_0000h
100h - 11Ch	Shifter Configuration (SHIFTCFG0 - SHIFTCFG7)	32	RW	0000_0000h
200h - 21Ch	Shifter Buffer (SHIFTBUF0 - SHIFTBUF7)	32	RW	0000_0000h
280h - 29Ch	Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7)	32	RW	0000_0000h
300h - 31Ch	Shifter Buffer Byte Swapped (SHIFTBUFBYS0 - SHIFTBUFBYS7)	32	RW	0000_0000h
380h - 39Ch	Shifter Buffer Bit Byte Swapped (SHIFTBUFBBS0 - SHIFTBUFBBS7)	32	RW	0000_0000h
400h - 41Ch	Timer Control (TIMCTL0 - TIMCTL7)	32	RW	0000_0000h
480h - 49Ch	Timer Configuration (TIMCFG0 - TIMCFG7)	32	RW	0000_0000h
500h - 51Ch	Timer Compare (TIMCMP0 - TIMCMP7)	32	RW	0000_0000h
680h - 69Ch	Shifter Buffer Nibble Byte Swapped (SHIFTBUFNBS0 - SHIFTBUFNBS7)	32	RW	0000_0000h
700h - 71Ch	Shifter Buffer Halfword Swapped (SHIFTBUFHWS0 - SHIFTBUFHWS7)	32	RW	0000_0000h
780h - 79Ch	Shifter Buffer Nibble Swapped (SHIFTBUFNIS0 - SHIFTBUFNIS7)	32	RW	0000_0000h
800h - 81Ch	Shifter Buffer Odd Even Swapped (SHIFTBUFOES0 - SHIFTBUFOES7)	32	RW	0000_0000h
880h - 89Ch	Shifter Buffer Even Odd Swapped (SHIFTBUFEOS0 - SHIFTBUFEOS7)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
900h - 91Ch	Shifter Buffer Halfword Byte Swapped (SHIFTBUFHBS0 - SHIFTBUFHBS7)	32	RW	0000_0000h

49.7.1.2 Version ID (VERID)

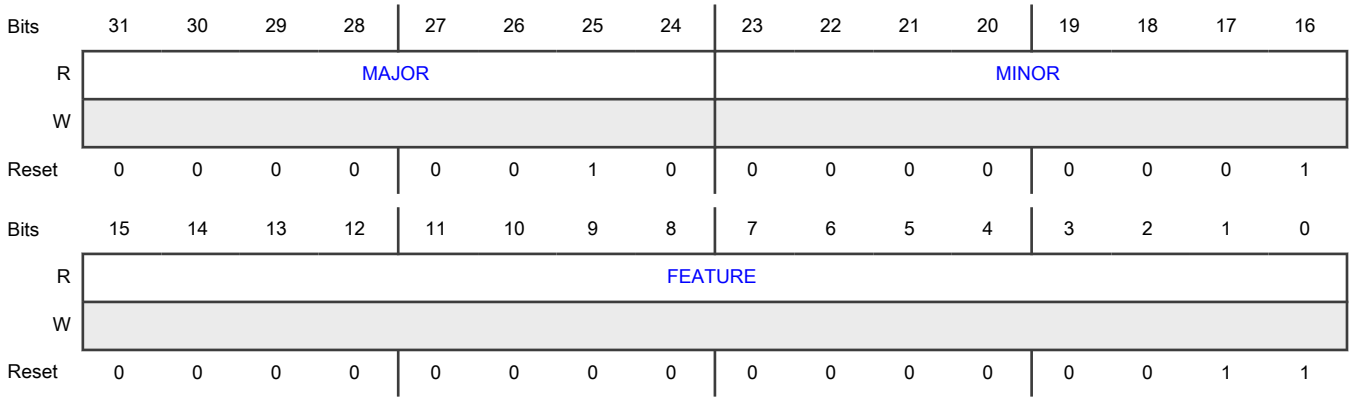
Offset

Register	Offset
VERID	0h

Function

Indicates the version of FLEXIO.

Diagram



Fields

Field	Function
31-24 MAJOR	Major Version Number Indicates the major version number of the module specification.
23-16 MINOR	Minor Version Number Indicates the minor version number of the module specification.
15-0 FEATURE	Feature Specification Number Indicates the feature set number. 0000_0000_0000_0000b - Standard features implemented

Table continues on the next page...

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Field	Function
	0000_0000_0000_0001b - State, logic, and parallel modes supported 0000_0000_0000_0010b - Pin control registers supported 0000_0000_0000_0011b - State, logic, and parallel modes, plus pin control registers supported

49.7.1.3 Parameter (PARAM)

Offset

Register	Offset
PARAM	4h

Function

Contains the number of shifters, timers, pins, and triggers.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	TRIGGER								PIN							
W																
Reset	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	TIMER								SHIFTER							
W																
Reset	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0

Fields

Field	Function
31-24 TRIGGER	Trigger Number Indicates the number of external triggers implemented.
23-16 PIN	Pin Number Indicates the number of pins implemented.
15-8 TIMER	Timer Number Indicates the number of timers implemented.
7-0 SHIFTER	Shifter Number Indicates the number of shifters implemented.

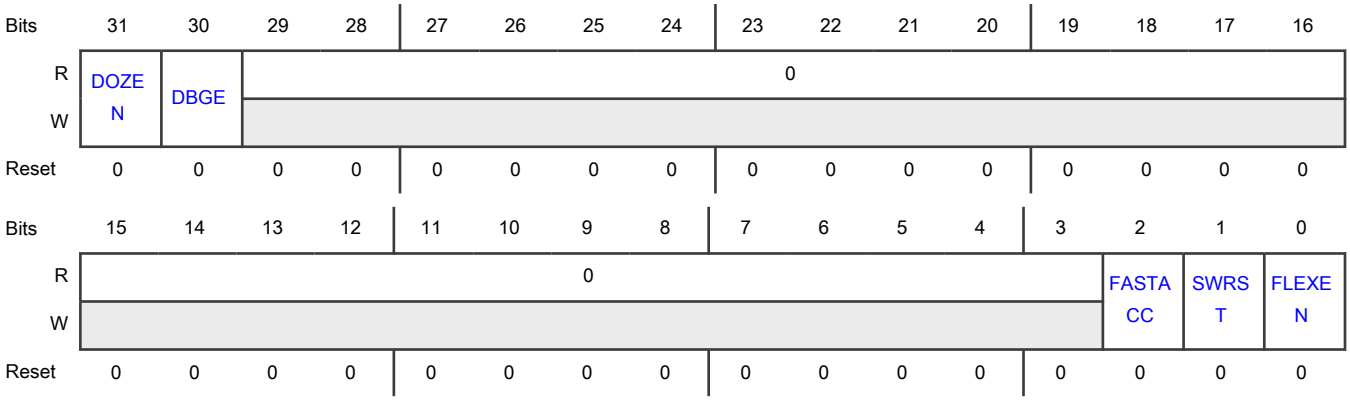
49.7.1.4 FLEXIO Control (CTRL)

Offset

Register	Offset
CTRL	8h

Function
Controls various aspects of the FLEXIO operation.

Diagram



Fields

Field	Function
31 DOZEN	Doze Enable Disables FLEXIO operation in Doze modes. 0b - Enable 1b - Disable
30 DBGE	Debug Enable Enables the FLEXIO operation in Debug mode. 0b - Disable 1b - Enable
29-3 —	Reserved
2 FASTACC	Fast Access Configures fast or normal register accesses to FLEXIO registers, but requires the FLEXIO functional clock to be at least equal to the frequency of the bus clock.

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Field	Function
	0b - Normal 1b - Fast
1 SWRST	Software Reset Specifies whether software reset is enabled. The software reset does not affect this register but it affects all other logic in FLEXIO. All other register accesses are ignored until this field is cleared. The field remains 1 until software clears it and the reset has cleared in the FLEXIO clock domain. If you write 1 to this field, all FLEXIO registers except the Control register are reset. 0b - Disabled 1b - Enabled
0 FLEXEN	FLEXIO Enable Enables FLEXIO. 0b - Disable 1b - Enable

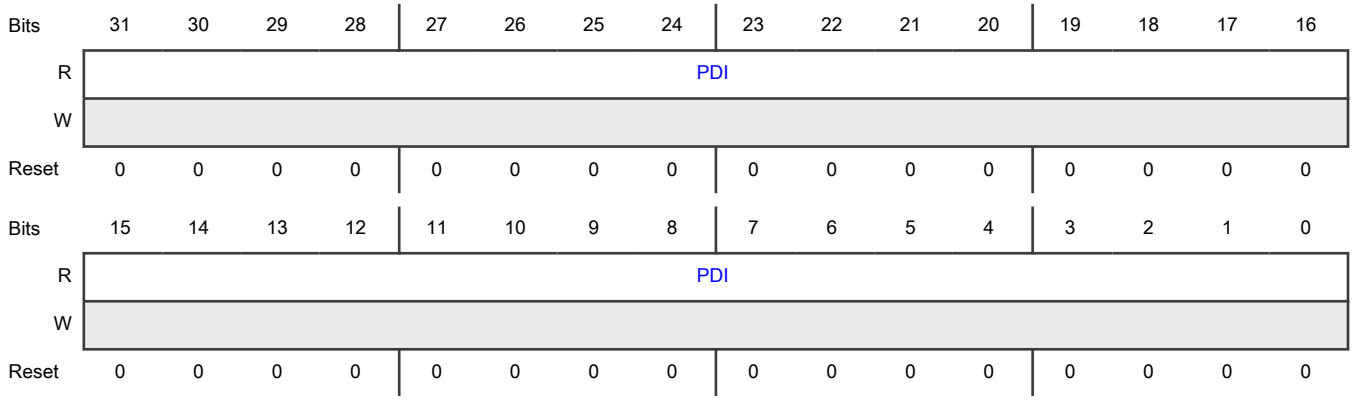
49.7.1.5 Pin State (PIN)

Offset

Register	Offset
PIN	Ch

Function
Indicates the status of the pin data input.

Diagram



Fields

Field	Function
31-0 PDI	Pin Data Input Indicates the input data on each of the FLEXIO pins.

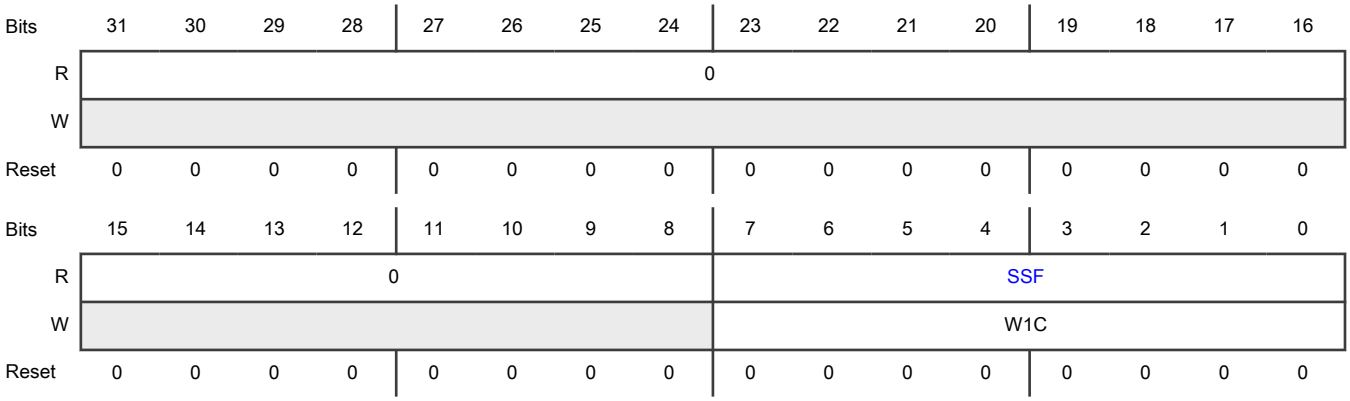
49.7.1.6 Shifter Status (SHIFTSTAT)

Offset

Register	Offset
SHIFTSTAT	10h

Function
Contains shifter status flags.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 SSF	Shifter Status Flag Indicates the shifter status. This flag is updated in one of the following cases: • If SHIFTCTL*n*[SMOD] = 001b (Receive mode), the status flag is set when SHIFTBUF is loaded with data from the shifter (SHIFTBUF is full). The status flag is cleared when you read Shifter Buffer (SHIFTBUF0 - SHIFTBUF7).

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Field	Function
	• If SHIFTCTL*n*[SMOD] = 010b (Transmit mode), the status flag is set when SHIFTBUF data is transferred to the shifter (SHIFTBUF is empty) or when SHIFTCTL*n*[SMOD] is initially configured as 010b (Transmit mode). The status flag is cleared when you write to the SHIFTBUF register. • If SHIFTCTL*n*[SMOD] = 100b (Match Store mode), the status flag is set when a match occurs between SHIFTBUF and the shifter. The status flag is cleared when you read the SHIFTBUF register. • If SHIFTCTL*n*[SMOD] = 101b (Match Continuous mode), the status flag returns the current match result between SHIFTBUF and the shifter. You cannot clear the status flag by reading the SHIFTBUF register. • If SHIFTCTL*n*[SMOD] = 110b (State mode), the status flag for a shifter sets when it is selected by the current state pointer. • If SHIFTCTL*n*[SMOD] = 111b (Logic mode), the status flag returns the current value of the programmable logic block output. You can clear this status flag by writing a logic one to the flag for all modes except Match Continuous mode, State mode, and Logic mode. **NOTE** This field behaves differently for register reads and writes. When reading 0000_0000b - Clear 0000_0001b - Set When writing 0000_0000b - No effect 0000_0001b - Clear the flag

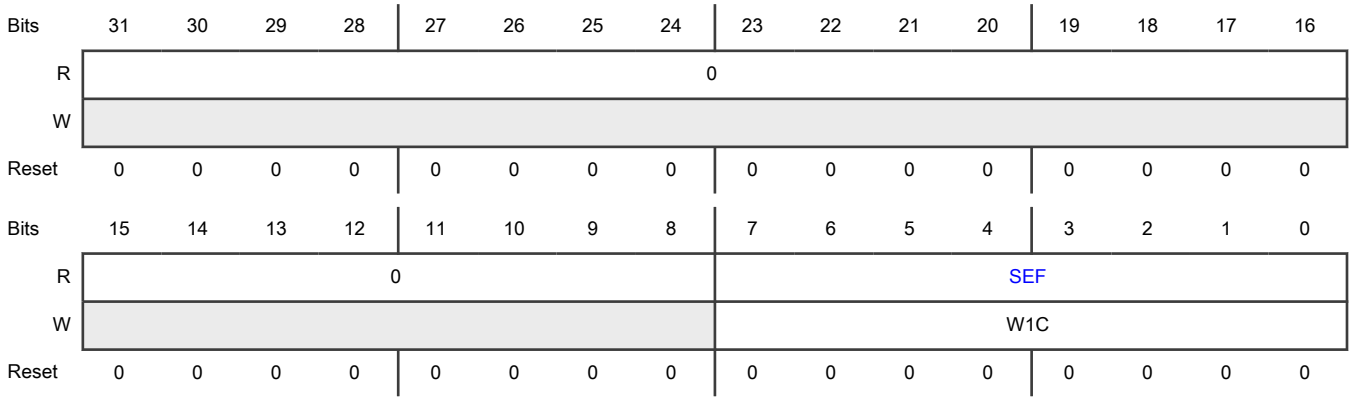
49.7.1.7 Shifter Error (SHIFTERR)

Offset

Register	Offset
SHIFTERR	14h

Function
Reports shifter errors.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 SEF	Shifter Error Flag Indicates shifter error flag status. This flag is set when one of the following events occurs: • If SHIFTCTL*n*[SMOD] = 001b (Receive mode), it indicates that either the shifter is ready to store new data into SHIFTBUF before the previous data is read from SHIFTBUF (SHIFTBUF overrun), or the received start or stop bit does not match the expected value. • If SHIFTCTL*n*[SMOD] = 010b (Transmit mode), it indicates that the shifter is ready to load new data from SHIFTBUF before new data is written into SHIFTBUF (SHIFTBUF underrun). • If SHIFTCTL*n*[SMOD] = 100b (Match Store mode), it indicates the occurrence of a match event before the previous match data is read from SHIFTBUF (SHIFTBUF overrun). • If SHIFTCTL*n*[SMOD] = 101b (Match Continuous mode), the error flag is set when a match occurs between SHIFTBUF and the shifter. • If SHIFTCTL*n*[SMOD] = 111b (Logic mode), the error flag is set when the output of the programmable logic block is asserted. For SHIFTCTL*n*[SMOD] = 101b (Match Continuous mode), the flag can also be cleared when you read Shifter Buffer (SHIFTBUF0 - SHIFTBUF7). **NOTE** This field behaves differently for register reads and writes. When reading 0000_0000b - Clear 0000_0001b - Set When writing 0000_0000b - No effect 0000_0001b - Clear the flag

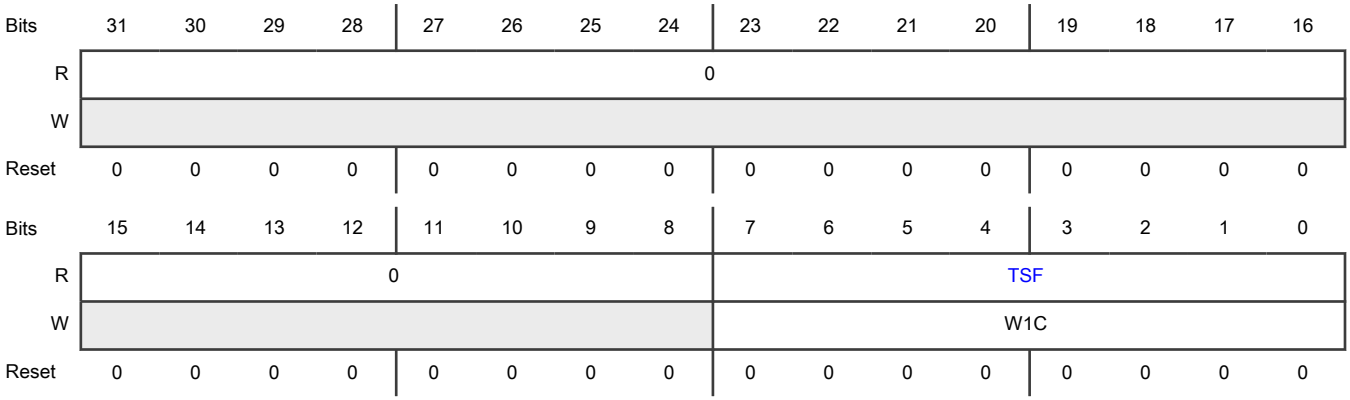
49.7.1.8 Timer Status Flag (TIMSTAT)

Offset

Register	Offset
TIMSTAT	18h

Function
Reports timer status.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 TSF	Timer Status Flag Indicates timer status. This flag is set depending on Timer mode: • In 8-bit baud counter mode, this flag is set when the upper 8-bit counter equals zero and decrements. • In 8-bit high PWM mode, this flag is set when the upper 8-bit counter equals zero and decrements. • In 16-bit counter mode, this flag is set when the 16-bit counter equals zero and decrements. • In 16-bit counter disable mode, TSF is set when a timer disable event is detected. • In 8-bit word counter mode, TSF is set when the upper 8-bit counter equals zero and decrements. • In 8-bit low PWM mode, TSF is set when the upper 8-bit counter equals zero and decrements. • In 16-bit input capture mode, TSF is set when a timer disable event is detected and the flag is clear. In this mode, you must read Timer Control (TIMCTL0 - TIMCTL7) only when TSF is set. **NOTE** This field behaves differently for register reads and writes.

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Field	Function
	When reading 0000_0000b - Clear 0000_0001b - Set When writing 0000_0000b - No effect 0000_0001b - Clear the flag

49.7.1.9 Shifter Status Interrupt Enable (SHIFTSIEN)

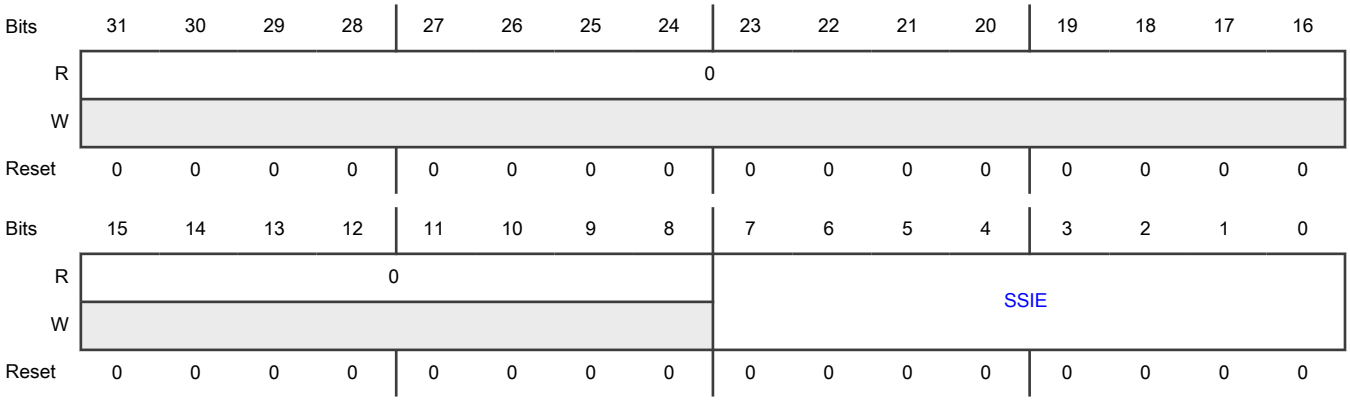
Offset

Register	Offset
SHIFTSIEN	20h

Function

Enables shifter status interrupts.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 SSIE	Shifter Status Interrupt Enable Enables interrupt generation when the corresponding SHIFTSTAT[SSF] flag is set. If you write 0 to this field, SHIFTSTAT[SSF] is disabled; and if you write 1 to this field, SHIFTSTAT[SSF] is enabled.

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Field	Function
	0b - Disable 1b - Enable

49.7.1.10 Shifter Error Interrupt Enable (SHIFTEIEN)

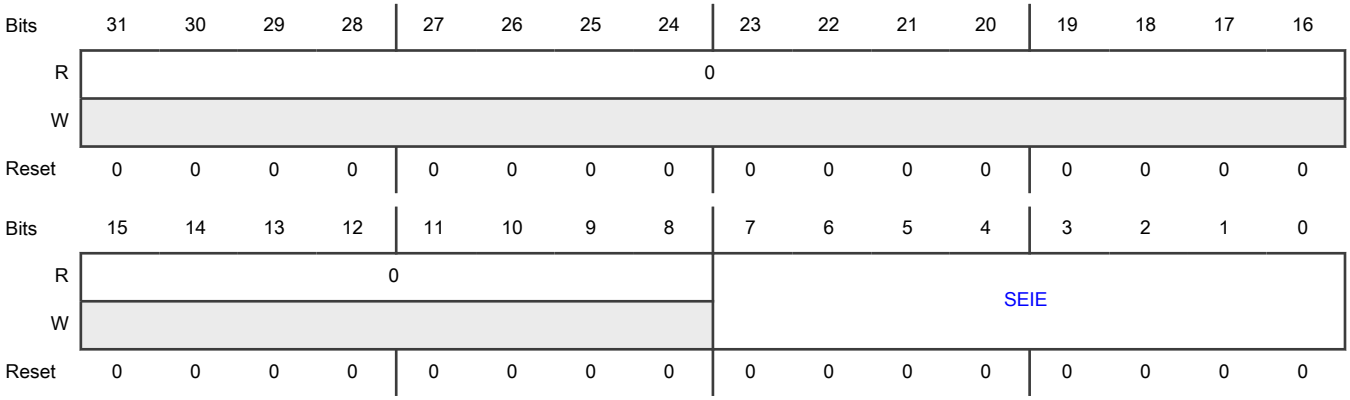
Offset

Register	Offset
SHIFTEIEN	24h

Function

Enables shifter error interrupts.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 SEIE	Shifter Error Interrupt Enable Enables interrupt generation when the corresponding SHIFTERR[SEF] flag is set. If you write 0 to this field, SHIFTERR[SEF] is disabled; and if you write 1 to this field, SHIFTERR[SEF] is enabled. 0b - Disable 1b - Enable

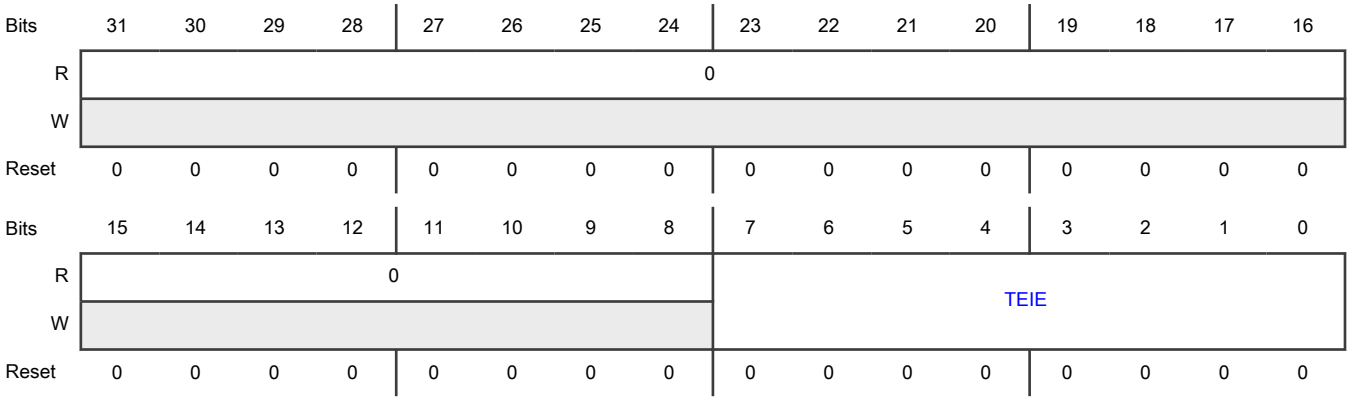
49.7.1.11 Timer Interrupt Enable (TIMIEN)

Offset

Register	Offset
TIMIEN	28h

Function
Enables timer status interrupts.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 TEIE	Timer Status Interrupt Enable Enables interrupt generation when the corresponding TIMSTAT[TSF] flag is set. If you write 0 to this field, TIMSTAT[TSF] is disabled; and if you write 1 to this field, TIMSTAT[TSF] is enabled. 0b - Disable 1b - Enable

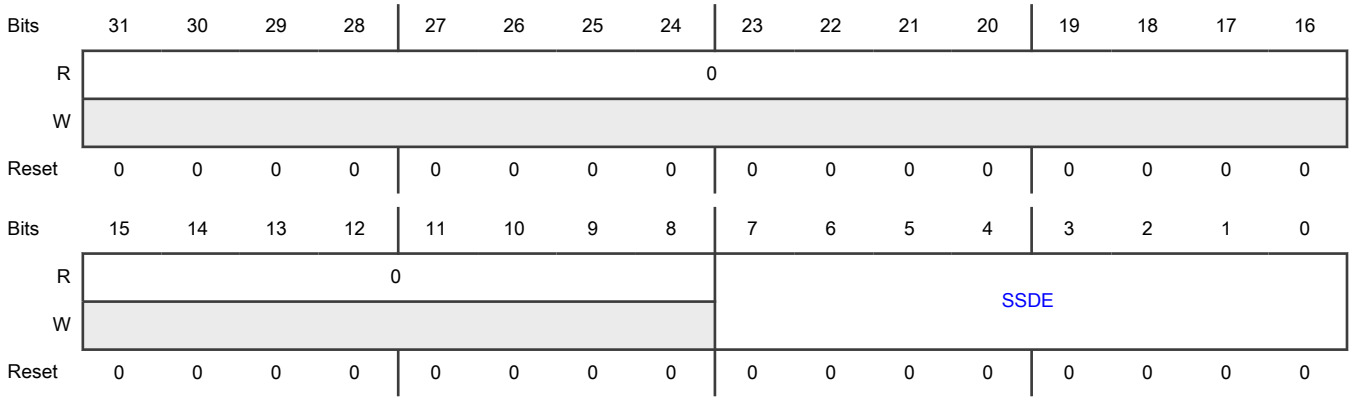
49.7.1.12 Shifter Status DMA Enable (SHIFTSDEN)

Offset

Register	Offset
SHIFTSDEN	30h

Function
Enables shifter DMA requests.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 SSDE	Shifter Status DMA Enable Enables DMA request generation when the corresponding SHIFTSTAT[SSF] flag is set. If you write 0 to this field, SHIFTSTAT[SSF] is disabled; and if you write 1 to this field, SHIFTSTAT[SSF] is enabled. 0b - Disable 1b - Enable

49.7.1.13 Timer Status DMA Enable (TIMERSDEN)

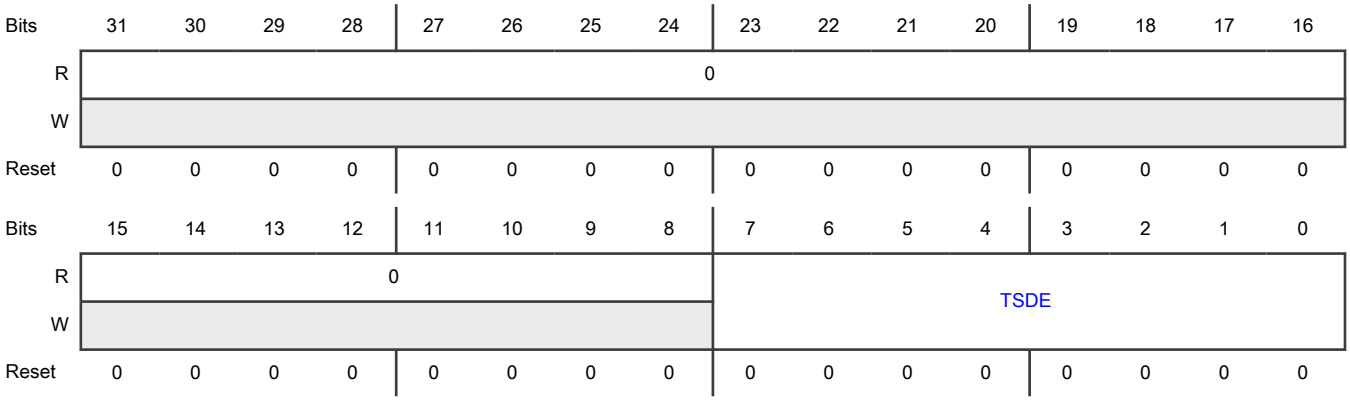
Offset

Register	Offset
TIMERSDEN	38h

Function

Enables DMA requests when the timer status flag is set.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 TSDE	Timer Status DMA Enable Enables DMA request generation when the corresponding TIMSTAT[TSF] flag is set. When the timer status DMA request is enabled, reading or writing to a timer compare register clears the corresponding timer status register. The DMA must therefore read or write to the timer compare register as part of the DMA transfer; otherwise, the DMA request remains asserted. 0b - Disable 1b - Enable

49.7.1.14 Shifter State (SHIFTSTATE)

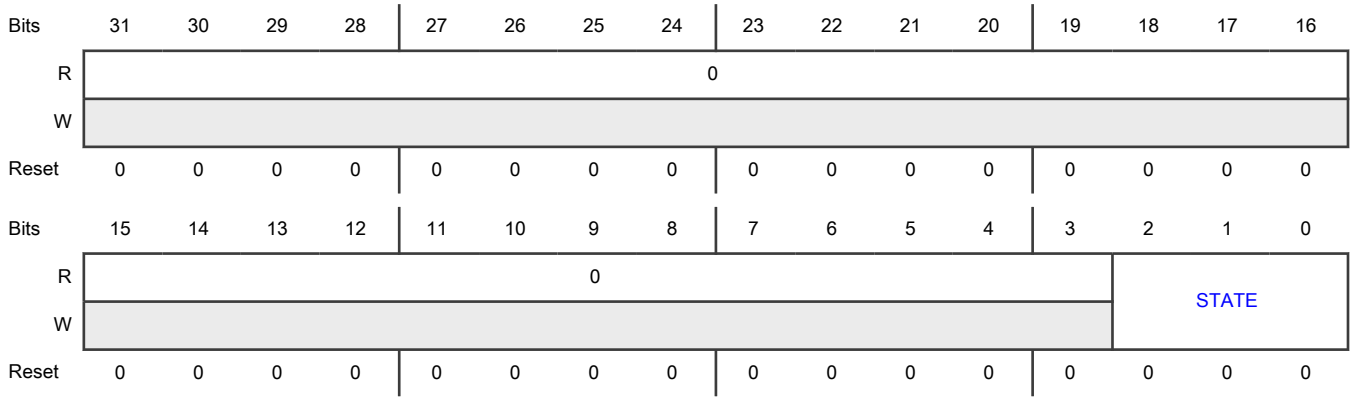
Offset

Register	Offset
SHIFTSTATE	40h

Function

Contains a pointer to track the current shifter.

Diagram



Fields

Field	Function
31-3 —	Reserved
2-0 STATE	Current State Pointer Maintains a pointer to track the current shifter (configured for State mode) enabled to drive outputs and compute the next state. Reading this register when the state pointer is updating can result in the return of an incorrect state. The value that you write to this field overrides the current state.

49.7.1.15 Trigger Status (TRGSTAT)

Offset

Register	Offset
TRGSTAT	48h

Function

Contains external trigger status flags.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												ETSF			
W													W1C			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-4 —	Reserved
3-0 ETSF	External Trigger Status Flag Specifies whether the external trigger status flag is set when a rising edge is detected on the corresponding external trigger input. **NOTE** This field behaves differently for register reads and writes. When reading 0000b - Clear 0001b - Set When writing 0000b - No effect 0001b - Clear the flag

49.7.1.16 External Trigger Interrupt Enable (TRIGIEN)

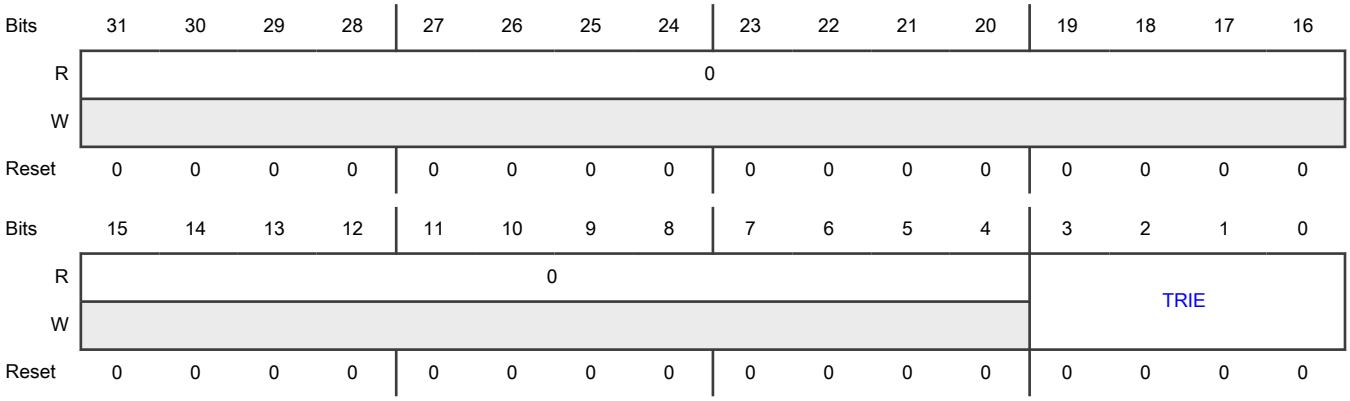
Offset

Register	Offset
TRIGIEN	4Ch

Function

Enables external trigger interrupts.

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 TRIE	External Trigger Interrupt Enable Enables interrupt generation when the corresponding TRGSTAT[ETSF] flag is set. If you write 0 to this field, TRGSTAT[ETSF] is disabled, and if you write 1 to this field, TRGSTAT[ETSF] is enabled. 0b - Disable 1b - Enable

49.7.1.17 Pin Status (PINSTAT)

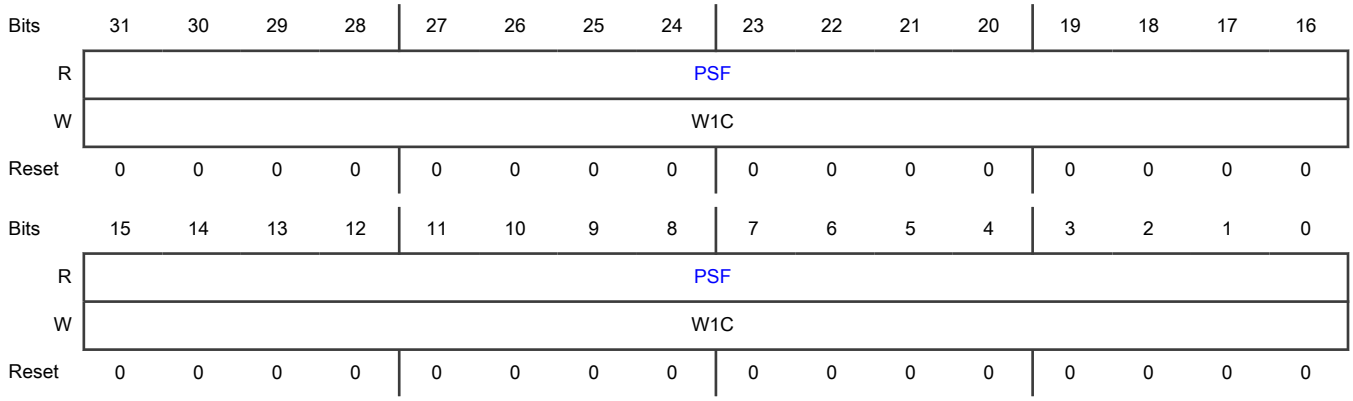
Offset

Register	Offset
PINSTAT	50h

Function

Contains pin status flags.

Diagram



Fields

Field	Function
31-0 PSF	Pin Status Flag Indicates whether the pin status flag is set when a rising edge or falling edge (if configured) is detected on the corresponding pin, as configured by the pin. **NOTE** This field behaves differently for register reads and writes. When reading 0000_0000_0000_0000_0000_0000_0000_0000b - Clear 0000_0000_0000_0000_0000_0000_0000_0001b - Set When writing 0000_0000_0000_0000_0000_0000_0000_0000b - No effect 0000_0000_0000_0000_0000_0000_0000_0001b - Clear the flag

49.7.1.18 Pin Interrupt Enable (PINIEN)

Offset

Register	Offset
PINIEN	54h

Function

Enables pin status interrupts.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	PSIE															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	PSIE															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 PSIE	Pin Status Interrupt Enable Enables interrupt generation when the corresponding PINSTAT[PSF] flag is set. If you write 0 to this field, PINSTAT[PSF] is disabled, and if you write 1 to this field, PINSTAT[PSF] is enabled. 0b - Disable 1b - Enable

49.7.1.19 Pin Rising Edge Enable (PINREN)

Offset

Register	Offset
PINREN	58h

Function
Enables the pin status flag on a rising edge.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	PRE															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	PRE															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 PRE	Pin Rising Edge Specifies whether the pin status flag is set whenever a rising edge is detected on the pin. 0b - Not set 1b - Set

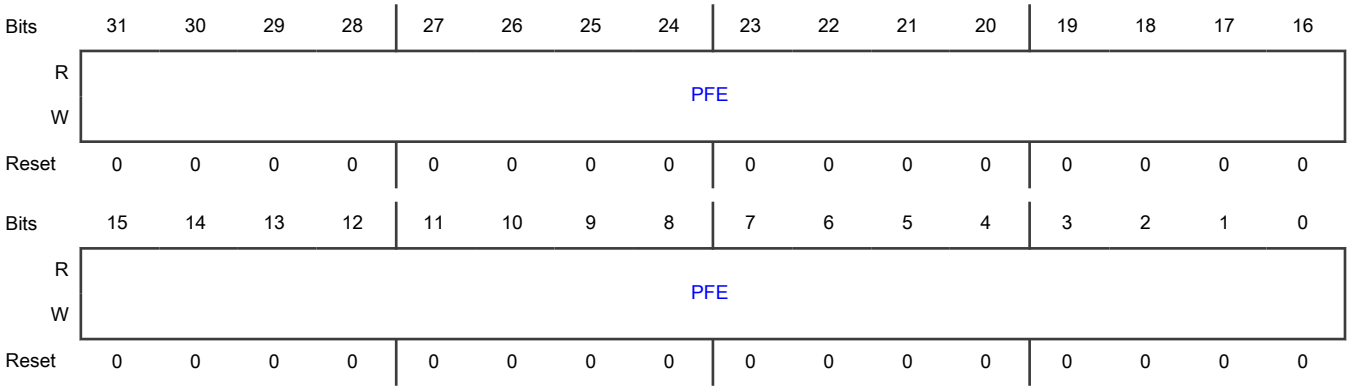
49.7.1.20 Pin Falling Edge Enable (PINFEN)

Offset

Register	Offset
PINFEN	5Ch

Function
Enables the pin status flag on a falling edge.

Diagram



Fields

Field	Function
31-0 PFE	Pin Falling Edge Specifies whether the pin status flag is set whenever a falling edge is detected on the pin. 0b - Not set 1b - Set

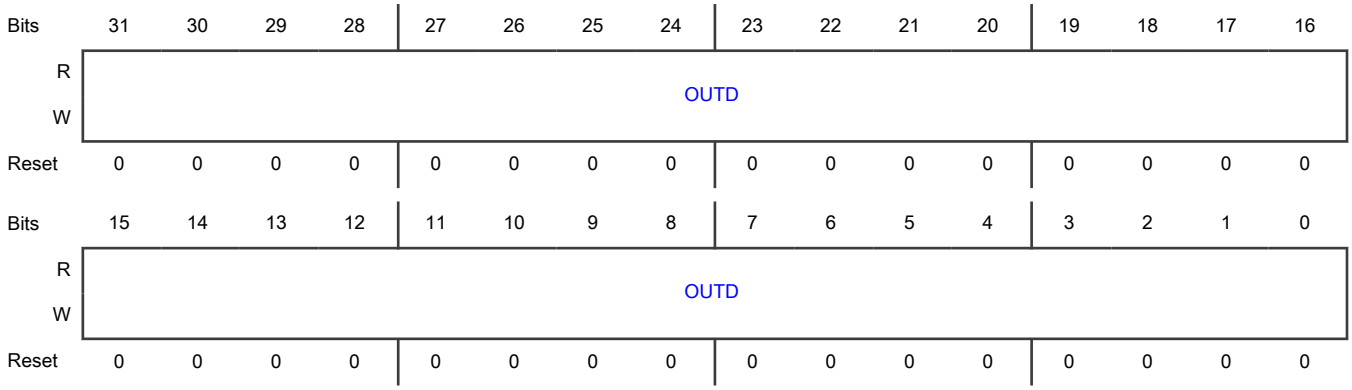
49.7.1.21 Pin Output Data (PINOUTD)

Offset

Register	Offset
PINOUTD	60h

Function
Contains data output when direct pin output is enabled.

Diagram



Fields

Field	Function
31-0 OUTD	Output Data Configures the value driven on the corresponding pin when direct pin output is enabled. 0b - Logic zero 1b - Logic one

49.7.1.22 Pin Output Enable (PINOUTE)

Offset

Register	Offset
PINOUTE	64h

Function
Enables pin output.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	OUTE															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	OUTE															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 OUTE	Output Enable Enables direct output on the corresponding pin. If this field is 0, the pin is controlled by timer/shifter configuration, and if this field is 1, pin is an output and driven with the value of Pin Output Data (PINOUTD). 0b - Controlled by timer/shifter configuration 1b - Output; driven with value of PINOUTD

49.7.1.23 Pin Output Disable (PINOUTDIS)

Offset

Register	Offset
PINOUTDIS	68h

Function
Disables pin output.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W	OUTDIS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W	OUTDIS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 OUTDIS	Output Disable Configures the corresponding pins to disable direct output. If this field is 1, the corresponding fields in Pin Output Data (PINOUTD) and Pin Output Enable (PINOUTE) become 0. 0b - No effect 1b - Corresponding fields become 0

49.7.1.24 Pin Output Clear (PINOUTCLR)

Offset

Register	Offset
PINOUTCLR	6Ch

Function
Clears pin output.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W	OUTCLR															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W	OUTCLR															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 OUTCLR	Output Clear Configures the corresponding pins to output zero. If this field is 1, the corresponding field in Pin Output Data (PINOUTD) becomes 0 and the one in Pin Output Enable (PINOUTE) becomes 1. 0b - No effect 1b - Corresponding field in PINOUTD becomes 0; corresponding field in PINOUTE becomes 1

49.7.1.25 Pin Output Set (PINOUTSET)

Offset

Register	Offset
PINOUTSET	70h

Function
Sets pin output.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W	OUTSET															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W	OUTSET															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 OUTSET	Output Set Configures the corresponding pins to output logic one. If this field is 1, the corresponding fields in Pin Output Data (PINOUTD) and Pin Output Enable (PINOUTE) become 1. 0b - No effect 1b - Corresponding fields become 1

49.7.1.26 Pin Output Toggle (PINOUTTOG)

Offset

Register	Offset
PINOUTTOG	74h

Function
Toggles pin output.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W	OUTTOG															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W	OUTTOG															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 OUTTOG	Output Toggle Configures the corresponding pins to toggle. If this field is 1, the corresponding field in Pin Output Data (PINOUTD) is inverted and the one in Pin Output Enable (PINOUTE) becomes 1. 0b - No effect 1b - Corresponding field in PINOUTD is inverted; corresponding field in PINOUTE becomes 1

49.7.1.27 Shifter Control (SHIFTCTL0 - SHIFTCTL7)

Offset

For n = 0 to 7:

Register	Offset
SHIFTCTLn	80h + (n × 4h)

Function

Provides shifter controls.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				TIMSEL				TIMPOL	0			PINCFG			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				PINSEL				PINPOL	0			SMOD			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-27 —	Reserved
26-24 TIMSEL	Timer Select Selects which timer is used for controlling the logic or shift register and generating the shift clock. TIMSEL = i selects TIMERi.
23 TIMPOL	Timer Polarity Determines whether the shift occurs on the positive edge or negative edge of the shift clock. 0b - Positive edge 1b - Negative edge
22-18 —	Reserved
17-16 PINCFG	Shifter Pin Configuration Specifies shifter pin configuration. For pins configured as an output (PINCFG = 11b), this field takes effect when you write to the register. **NOTE** When initially configuring PINCFG as 11b, FLEXIO may briefly drive the pin low. To avoid this, you can configure PINCFG as 10b along with the rest of the Control register and then perform a subsequent write to set PINCFG as 11b. Likewise, when changing the value of PINCFG from 11b to 00b, you must perform an initial write to set PINCFG as 10b and then perform a subsequent write to update the rest of the Control register with the value of PINCFG as 00b. 00b - Shifter pin output disabled 01b - Shifter pin open-drain or bidirectional output enable 10b - Shifter pin bidirectional output data 11b - Shifter pin output
15-13 —	Reserved
12-8 PINSEL	Shifter Pin Select Selects the pin that is used by the shifter input or output. PINSEL = i selects the FXIO_Di pin. For pins configured as an output (PINCFG = 11b), this field takes effect when you write to the register.
7 PINPOL	Shifter Pin Polarity Specifies the shifter pin polarity. For pins configured as an output (PINCFG = 11b), this field takes effect when you write to this register.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Active high 1b - Active low
6-3 —	Reserved
2-0 SMOD	Shifter Mode Configures the mode of the shifter. 000b - Disable 001b - Receive mode; capture the current shifter content into SHIFTBUF on expiration of the timer 010b - Transmit mode; load SHIFTBUF contents into the shifter on expiration of the timer 011b - Reserved 100b - Match Store mode; shifter data is compared to SHIFTBUF content on expiration of the timer 101b - Match Continuous mode; shifter data is continuously compared to SHIFTBUF contents 110b - State mode; SHIFTBUF contents store programmable state attributes 111b - Logic mode; SHIFTBUF contents implement programmable logic lookup table

49.7.1.28 Shifter Configuration (SHIFTCFG0 - SHIFTCFG7)

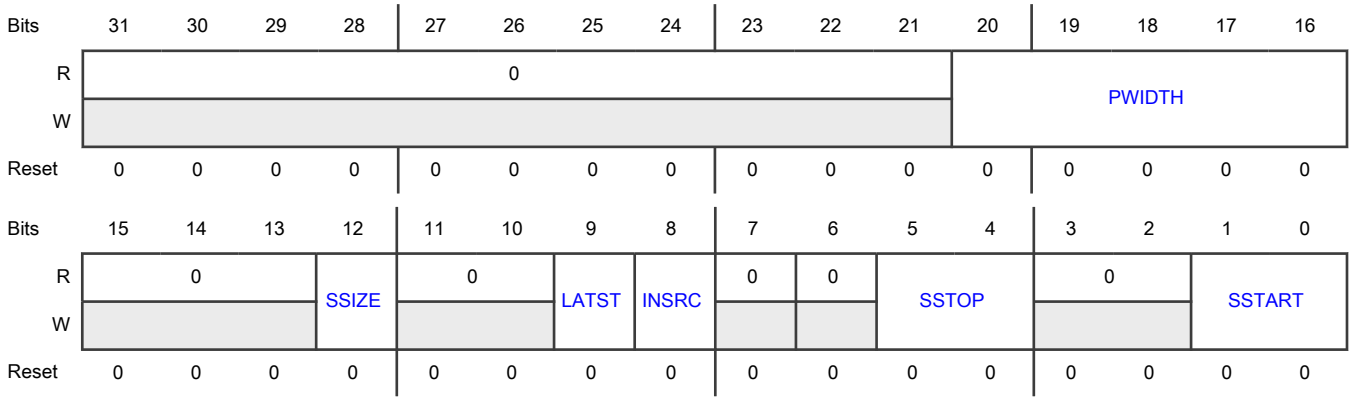
Offset

For n = 0 to 7:

Register	Offset
SHIFTCFGn	100h + (n × 4h)

Function
Provides fields for shifter configuration.

Diagram



Fields

Field	Function
31-21 —	Reserved
20-16 PWIDTH	Parallel Width Configures the number of bits to be shifted on each shift clock for all shifters: • 1-bit shift for PWIDTH = 0 • 2-bit shift for PWIDTH = 1 • 4-bit shift for PWIDTH = 2...3 • 8-bit shift for PWIDTH = 4...7 • 16-bit shift for PWIDTH = 8...15 • 32-bit shift for PWIDTH = 16...31 For shifters that support parallel transmit (SHIFTER0, SHIFTER4, ...) or parallel receive (SHIFTER3, SHIFTER7, ...), this field, together with PINSEL, also selects the pins to be driven or sampled on each shift clock: FXIO_D[PINSEL+PWIDTH]:FXIO_D[PINSEL]. Shifters that do not support parallel transmit or parallel receive only support parallel shift when SHIFTCFG*n*[INSRC] = 1. If SHIFTCTL*n*[SMOD] = 110b (State mode), use this field to disable state outputs (see State mode).
15-13 —	Reserved
12 SSIZE	Shifter Size Configures the size of the Shift registers. A 24-bit Shift register shifts data only into bits [23:0] and does not update bits [31:24] during shift operations. When the Shift register is configured for a 24-bit shift, configuring PWIDTH as 8..15 performs a 12-bit shift and PWIDTH as 16..31 performs a 24-bit shift.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - 32-bit 1b - 24-bit
11-10 —	Reserved
9 LATST	Late Store Configures what happens when a receive or match Shift register is configured to both shift and store on the same cycle. 0b - Store the pre-shift register state 1b - Store the post-shift register state
8 INSRC	Input Source Selects the input source for the shifter. Configuring this field as 1 is not supported for the last shifter. 0b - Pin 1b - Shifter n+1 output
7 —	Reserved
6 —	Reserved
5-4 SSTOP	Shifter Stop Allows automatic stop bit insertion, if the selected timer has also enabled a stop bit, when SHIFTCTL*n*[SMOD] is 10b (Transmit mode). If SHIFTCTL*n*[SMOD] is 1b or 100b (Receive mode or Match Store mode), this field allows automatic stop bit checking if the selected timer has also enabled a stop bit. If SHIFTCTL*n*[SMOD] is 110b (State mode), this field disables state outputs (see State mode). If SHIFTCTL*n*[SMOD] is 111b (Logic mode), this field masks logic pin inputs (see Logic mode). 00b - Stop bit disabled for Transmitter, Receiver, and Match Store modes 01b - Stop bit disabled for Transmitter, Receiver, and Match Store modes; when timer is in stop condition, Receiver and Match Store modes store receive data on the configured shift edge 10b - Transmitter mode outputs stop bit value 0 in Match Store mode; if stop bit is not 0, Receiver and Match Store modes set error flag (when timer is in stop condition, these modes also store receive data on the configured shift edge) 11b - Transmitter mode outputs stop bit value 1 in Match Store mode; if stop bit is not 1, Receiver and Match Store modes set error flag (when timer is in stop condition, these modes also store receive data on the configured shift edge)
3-2	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
1-0 SSTART	Shifter Start Allows automatic start bit insertion, if the selected timer has also enabled a start bit, when SHIFTCTL*n*[SMOD] is 10b (Transmit mode). If SHIFTCTL*n*[SMOD] = 1b (Receive mode) or 100b (Match Store mode), this field allows automatic start bit checking if the selected timer has also enabled a start bit. If SHIFTCTL*n*[SMOD] is 110b (State mode), this field disables state outputs (see State mode). If SHIFTCTL*n*[SMOD] = 111b (Logic mode), this field masks logic pin inputs (see Logic mode). 00b - Start bit disabled for Transmitter, Receiver, and Match Store modes; Transmitter mode loads data on enable 01b - Start bit disabled for Transmitter, Receiver, and Match Store modes; Transmitter mode loads data on first shift 10b - Transmitter mode outputs start bit value 0 before loading data on first shift; if start bit is not 0, Receiver and Match Store modes set error flag 11b - Transmitter mode outputs start bit value 1 before loading data on first shift; if start bit is not 1, Receiver and Match Store modes set error flag

49.7.1.29 Shifter Buffer (SHIFTBUF0 - SHIFTBUF7)

Offset

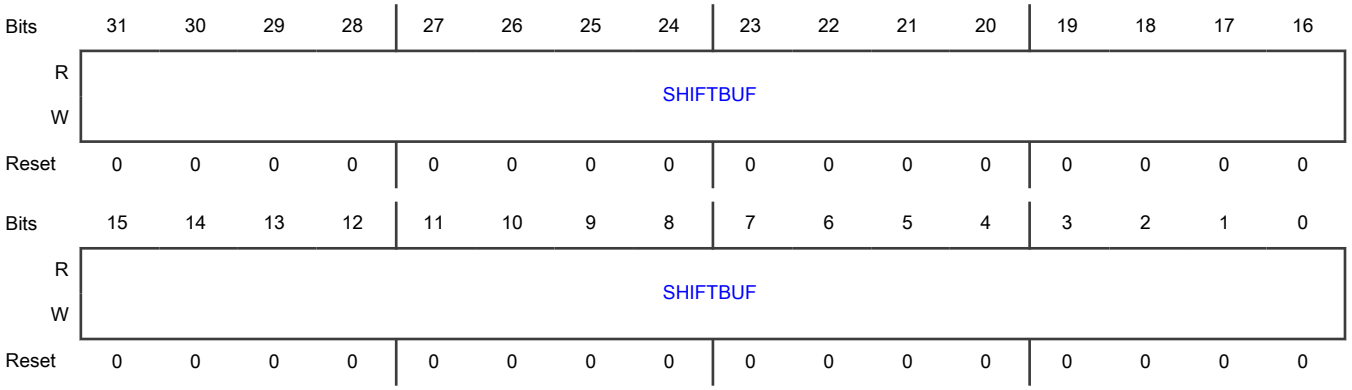
For n = 0 to 7:

Register	Offset
SHIFTBUFn	200h + (n × 4h)

Function

Contains shift buffer data.

Diagram



Fields

Field	Function
31-0 SHIFTBUF	Shift Buffer Contains the data to be matched with the shifter contents and is used for various other functions, depending on the setting of SHIFTCTL*n*[SMOD]: • If SHIFTCTL0[SMOD] is 1b (Receive mode), shifter data is transferred into SHIFTBUF at the expiration of the timer. You must read this register only when the corresponding SHIFTSTAT[SSF] flag is set, indicating that new shifter data is available. • If SHIFTCTL0[SMOD] is 10b (Transmit mode), SHIFTBUF data is transferred into the shifter before the timer begins. • If SHIFTCTL0[SMOD] is 100b (Match Store mode), SHIFTBUF[31:16] contains the data to be matched with the shifter contents and SHIFTBUF[15:0] can be used to mask the match result (1 = mask, 0 = no mask). The match is checked when the timer expires. Shifter data [31:16] is written to SHIFTBUF[31:16] whenever a match event occurs. You must read this register only when the corresponding shifter status flag is set, indicating that new shifter data is available. • If SHIFTCTL0[SMOD] is 101b (Match Continuous mode), SHIFTBUF[31:16] contains the data to be matched with the shifter contents, and SHIFTBUF[15:0] can be used to mask the match result (1 = mask, 0 = no mask). • If SHIFTCTL0[SMOD] is 111b (Logic mode), SHIFTBUF[31:0] implements a 5-input, 32-bit programmable logic lookup table (see Logic mode). • If SHIFTCTL0[SMOD] is 110b (State mode), use SHIFTBUF[31:24] to drive the output value when this shifter is selected by the current state pointer and use SHIFTBUF[23:0] to configure the value of the next state transition (see State mode).

49.7.1.30 Shifter Buffer Bit Swapped (SHIFTBUFBIS0 - SHIFTBUFBIS7)

Offset

For n = 0 to 7:

Register	Offset
SHIFTBUFBISn	280h + (n × 4h)

Function

Contains Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) content, but it is bit-swapped.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SHIFTBUFBIS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SHIFTBUFBIS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 SHIFTBUFBIS	Shift Buffer Acts as an alias to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7), but reads or writes to this register are bit-swapped. Reads return SHIFTBUF[0:31].

49.7.1.31 Shifter Buffer Byte Swapped (SHIFTBUFBYS0 - SHIFTBUFBYS7)

Offset

For n = 0 to 7:

Register	Offset
SHIFTBUFBYSn	300h + (n × 4h)

Function

Contains Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) content, but it is byte-swapped.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SHIFTBUFBYS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SHIFTBUFBYS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 SHIFTBUFBYS	Shift Buffer Acts as an alias to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7), but reads or writes to this register are byte-swapped. Reads return {SHIFTBUF[7:0], SHIFTBUF[15:8], SHIFTBUF[23:16], SHIFTBUF[31:24]}.

49.7.1.32 Shifter Buffer Bit Byte Swapped (SHIFTBUFBBS0 - SHIFTBUFBBS7)

Offset

For n = 0 to 7:

Register	Offset
SHIFTBUFBBSn	380h + (n × 4h)

Function

Contains the register data for Shifter Buffer (SHIFTBUF0 - SHIFTBUF7), but it is bit-swapped within each byte.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SHIFTBUFBBS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SHIFTBUFBBS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 SHIFTBUFBBS	Shift Buffer Acts as an alias to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7), except that reads or writes to this register are bit-swapped within each byte. Reads return {SHIFTBUF[24:31], SHIFTBUF[16:23], SHIFTBUF[8:15], SHIFTBUF[0:7]}.

49.7.1.33 Timer Control (TIMCTL0 - TIMCTL7)

Offset

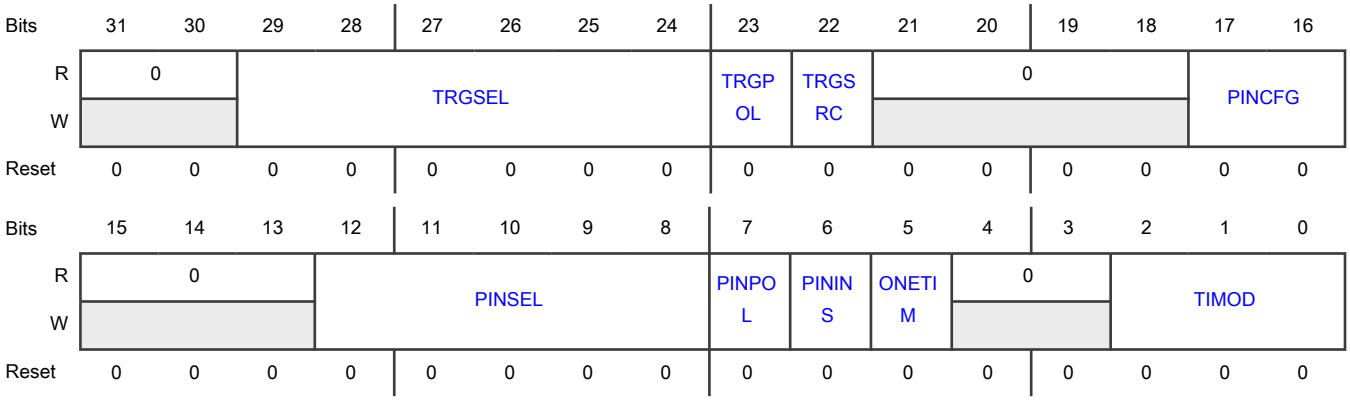
For n = 0 to 7:

Register	Offset
TIMCTLn	400h + (n × 4h)

Function

Controls various settings for timer *n*.

Diagram



Fields

Field	Function
31-30 —	Reserved
29-24 TRGSEL	Trigger Select Selects the trigger. The valid values for TRGSEL depend on the configuration of Parameter (PARAM): • If TRGSRC = 1, the valid values for *n* depend on the settings of PARAM[PIN], PARAM[TIMER], and PARAM[SHIFTER]. • If TRGSRC = 0, the valid values for *n* depend on PARAM[TRIGGER]. See the chip-specific FLEXIO information for external trigger selection. **NOTE** For a pin, *n* = 0 to 31, for a shifter, *n* = 0 to 7, and for a timer, *n* = 0 to 7. If TRGSRC = 0, configure the trigger selection as *n* = external trigger *n* input. If TRGSRC = 1, you can configure the internal trigger to select an input pin as 2×*n* = pin *n* input. If TRGSRC = 1, you can configure the internal trigger to select a shifter or timer signal as: • 4×*n* + 1 = shifter *n* status flag • 4×*n* + 3 = timer *n* trigger output Following are the values for expanded internal trigger selection (TRGSRC = 1):

Table continues on the next page...

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Field	Function
	• 0000 = Pin 0 • 0001 = Shifter 0 flag • 0010 = Pin 1 • 0011 = Timer 0 trigger • 0100 = Pin 2 • 0101 = Shifter 1 flag • 0110 = Pin 3 • 0111 = Timer 1 trigger • ... • This continues up to pin 31, shifter 7, and timer 7.
23 TRGPOL	Trigger Polarity Specifies whether the trigger is active high or active low. 0b - Active high 1b - Active low
22 TRGSRC	Trigger Source Specifies whether the selected trigger source is external or internal. 0b - External 1b - Internal
21-18 —	Reserved
17-16 PINCFG	Timer Pin Configuration Configures the direction of the timer pin. For pins configured as an output (PINCFG = 11b), this field takes effect when you write to the register. **NOTE** When you initially configure PINCFG as 11b, FLEXIO may briefly drive the pin low. To avoid this, configure PINCFG as 10b along with the rest of the Control register and then perform a subsequent write to set the value of PINCFG as 11b. Likewise, when changing the value of PINCFG from 11b to 00b, you must perform an initial write to set PINCFG as 10b, and then perform a subsequent write to update the rest of the Control register with PINCFG as 00b. 00b - Timer pin output disabled 01b - Timer pin open-drain or bidirectional output enable 10b - Timer pin bidirectional output data 11b - Timer pin output

Table continues on the next page...

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Field	Function
15-13 —	Reserved
12-8 PINSEL	Timer Pin Select Selects the pin that is used by the timer input or output. PINSEL = i selects the FXIO_Di pin. For pins configured as an output (PINCFG = 11b), this field takes effect when you write to the register.
7 PINPOL	Timer Pin Polarity Specifies the timer pin polarity. For pins configured as an output (PINCFG = 11b), this field takes effect when you write to the register. 0b - Active high 1b - Active low
6 PININS	Timer Pin Input Select Specifies what selects the timer pin input. If this field is 1, the timer input pin is different from the timer output pin. PINSEL must select an even-numbered pin when this field is 1, which means that the output pin is even-numbered and input pin is odd-numbered. 0b - PINSEL selects timer pin input and output 1b - PINSEL + 1 selects the timer pin input; timer pin output remains selected by PINSEL
5 ONETIM	Timer One Time Operation Configures the timer to perform a single enable or disable iteration. Clear the timer status flag for the timer to be enabled again. 0b - Generate the timer enable event as normal 1b - Block the timer enable event unless the timer status flag is clear
4-3 —	Reserved
2-0 TIMOD	Timer Mode Specifies the timer mode: • In 8-bit baud counter mode, the lower 8 bits of the counter and compare register are used to configure the baud rate of the timer shift clock. The upper 8 bits are used to configure the shifter bit count. • In 8-bit PWM high mode, the lower 8 bits of the counter and compare register are used to configure the high period of the timer shift clock. The upper 8 bits are used to configure the low period of the timer shift clock. The shifter bit count is configured using another timer or external signal. • In 16-bit counter mode, the full 16 bits of the counter and compare register are used to configure either the baud rate of the shift clock or the shifter bit count. • In 16-bit counter disable mode, the full 16 bits of the counter and compare register are used to configure either the baud rate of the shift clock or the shifter bit count.

Table continues on the next page...

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Field	Function
	• In 8-bit word counter mode, the lower 8 bits of the counter and compare register are used to configure the shifter bit count. The upper 8 bits are used to configure the shifter word count. • In 8-bit PWM low mode, the lower 8 bits of the counter and compare register are used to configure the low period of the timer shift clock. The upper 8 bits are used to configure the high period of the timer shift clock. Use another timer or external signal to configure the shifter bit count. • In 16-bit input capture mode, the inverted value of the 16-bit counter is latched into the compare register when a timer counter disable condition is detected (as configured by TIMCFG*n*[TIMDIS]). This also sets the timer status flag. The timer counter is immediately restarted from FFFFh. 000b - Timer disabled 001b - Dual 8-bit counters baud mode 010b - Dual 8-bit counters PWM high mode 011b - Single 16-bit counter mode 100b - Single 16-bit counter disable mode 101b - Dual 8-bit counters word mode 110b - Dual 8-bit counters PWM low mode 111b - Single 16-bit input capture mode

49.7.1.34 Timer Configuration (TIMCFG0 - TIMCFG7)

Offset

For n = 0 to 7:

Register	Offset
TIMCFGn	480h + (n × 4h)

Function

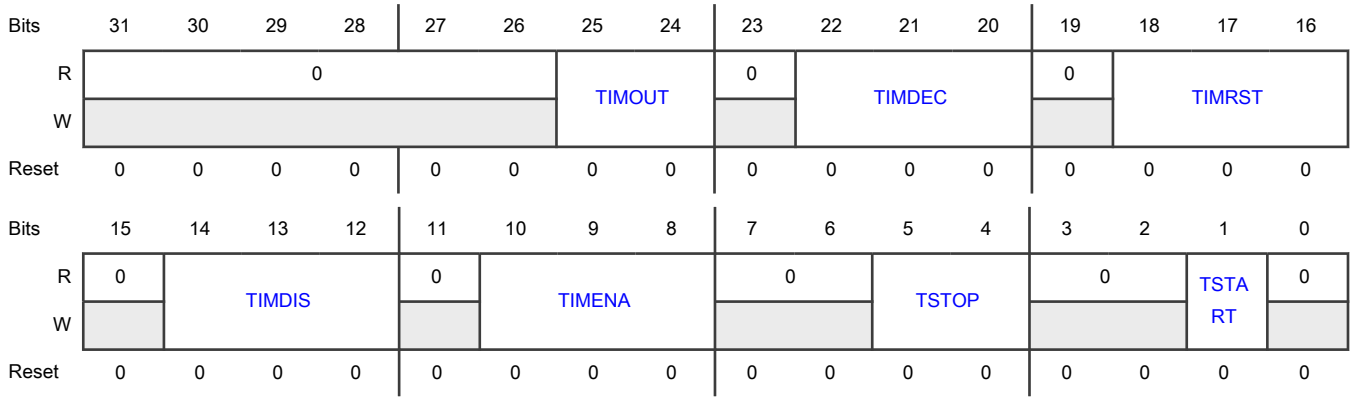
Controls various aspects of timer configuration.

The options to enable or disable the timer using the timer *n* - 1 enable or disable are reserved when *n* is evenly divisible by 4 (timer 0, for example).

NOTE

The pin and trigger level and edges specified in this register refer to the signal state after being modified by the settings of TIMCTL*n*[PINPOL] and TIMCTL*n*[TRGPOL]. For example, "trigger low" means that a trigger is actually at logic level 1 if TIMCTL*n*[TRGPOL] is 1 (active low).

Diagram



Fields

Field	Function
31-26 —	Reserved
25-24 TIMOUT	Timer Output Configures the initial state of the timer output and whether it is affected by the timer reset. 00b - Logic one when enabled; not affected by timer reset 01b - Logic zero when enabled; not affected by timer reset 10b - Logic one when enabled and on timer reset 11b - Logic zero when enabled and on timer reset
23 —	Reserved
22-20 TIMDEC	Timer Decrement Configures the source of the timer decrement and that of the shift clock. 000b - Decrement counter on FLEXIO clock; shift clock equals timer output 001b - Decrement counter on trigger input (both edges); shift clock equals timer output 010b - Decrement counter on pin input (both edges); shift clock equals pin input 011b - Decrement counter on trigger input (both edges); shift clock equals trigger input 100b - Decrement counter on FLEXIO clock divided by 16; shift clock equals timer output 101b - Decrement counter on FLEXIO clock divided by 256; shift clock equals timer output 110b - Decrement counter on pin input (rising edge); shift clock equals pin input 111b - Decrement counter on trigger input (rising edge); shift clock equals trigger input
19 —	Reserved

Table continues on the next page...

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Field	Function
18-16 TIMRST	Timer Reset Configures the condition that causes the timer counter (and optionally the timer output) to be reset. In 8-bit counter mode, the timer reset only resets the lower 8 bits that configure the baud rate. In all other modes, the timer reset resets full 16 bits of the counter. 000b - Never reset timer 001b - Timer reset on timer output high. 010b - Timer reset on timer pin equal to timer output 011b - Timer reset on timer trigger equal to timer output 100b - Timer reset on timer pin rising edge 101b - Reserved 110b - Timer reset on trigger rising edge 111b - Timer reset on trigger rising or falling edge
15 —	Reserved
14-12 TIMDIS	Timer Disable Configures the condition that causes the timer to be disabled and stop decrementing. 000b - Timer never disabled 001b - Timer disabled on timer n-1 disable 010b - Timer disabled on timer compare (upper 8 bits match and decrement) 011b - Timer disabled on timer compare (upper 8 bits match and decrement) and trigger low 100b - Timer disabled on pin rising or falling edge 101b - Timer disabled on pin rising or falling edge provided trigger is high 110b - Timer disabled on trigger falling edge 111b - Reserved
11 —	Reserved
10-8 TIMENA	Timer Enable Configures the condition that causes the timer to be enabled and start decrementing. 000b - Timer always enabled 001b - Timer enabled on timer n-1 enable 010b - Timer enabled on trigger high 011b - Timer enabled on trigger high and pin high

Table continues on the next page...

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Field	Function
	100b - Timer enabled on pin rising edge 101b - Timer enabled on pin rising edge and trigger high 110b - Timer enabled on trigger rising edge 111b - Timer enabled on trigger rising or falling edge
7-6 —	Reserved
5-4 TSTOP	Timer Stop Specifies whether the stop bit is enabled. The stop bit can be added on a timer compare (between each word) or on a timer disable. When stop bit is enabled, configured shifters output the contents of the stop bit when the timer is disabled. When stop bit is enabled on timer disable, the timer remains disabled until the next rising edge of the shift clock. If configured for both timer compare and timer disable, only one stop bit is inserted on timer disable. 00b - Disabled 01b - Enabled on timer compare 10b - Enabled on timer disable 11b - Enabled on timer compare and timer disable
3-2 —	Reserved
1 TSTART	Timer Start Specifies whether the start bit is enabled. If it is enabled, configured shifters output the contents of the start bit when the timer is enabled. The timer counter reloads from the compare register on the first rising edge of the shift clock. 0b - Disabled 1b - Enabled
0 —	Reserved

49.7.1.35 Timer Compare (TIMCMP0 - TIMCMP7)

Offset

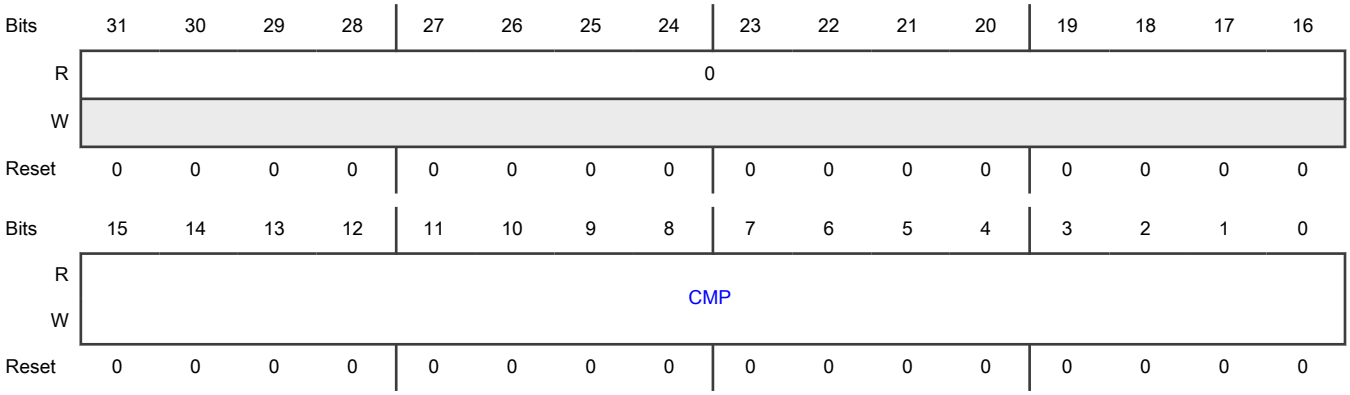
For n = 0 to 7:

Register	Offset
TIMCMPn	500h + (n × 4h)

Function

Contains the timer compare value.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 CMP	Timer Compare Value Loads into the timer counter when the timer is first enabled, when the timer is reset, and when the timer decrements down to zero. In 8-bit baud counter mode, the lower 8 bits configure the baud rate divider as (CMP[7:0] + 1) × 2. The upper 8 bits configure the number of bits in each word as (CMP[15:8] + 1) ÷ 2. In 8-bit PWM high mode, the lower 8 bits configure the high period of the output to (CMP[7:0] + 1) and the upper 8 bits configure the low period of the output to (CMP[15:8] + 1). In 16-bit counter mode, the compare value can be used to generate the baud rate divider (if shift clock source is timer output) as (CMP[15:0] + 1) × 2. When the shift clock source is a pin or trigger input, the compare register is used to set the number of bits in each word as (CMP[15:0] + 1) ÷ 2. In 16-bit counter disable mode, the compare value can be used to generate the baud rate divider (if shift clock source is timer output) as (CMP[15:0] + 1) × 2. When the shift clock source is a pin or trigger input, the compare register is used to set the number of bits in each word as (CMP[15:0] + 1) ÷ 2. In 8-bit word counter mode, the lower 8 bits configure the number of bits in each word as (CMP[7:0] + 1) ÷ 2. The upper 8 bits configure the number of words to transfer equal to (CMP[15:8] + 1) ÷ 2. In 8-bit PWM low mode, the lower 8 bits configure the low period of the output to (CMP[7:0] + 1) and the upper 8 bits configure the high period of the output to (CMP[15:8] + 1). In 16-bit input capture mode, the compare register is updated with the inverse of the timer counter value whenever the timer status flag is set. You must read this register only when the timer status flag is set.

49.7.1.36 Shifter Buffer Nibble Byte Swapped (SHIFTBUFNBS0 - SHIFTBUFNBS7)

Offset

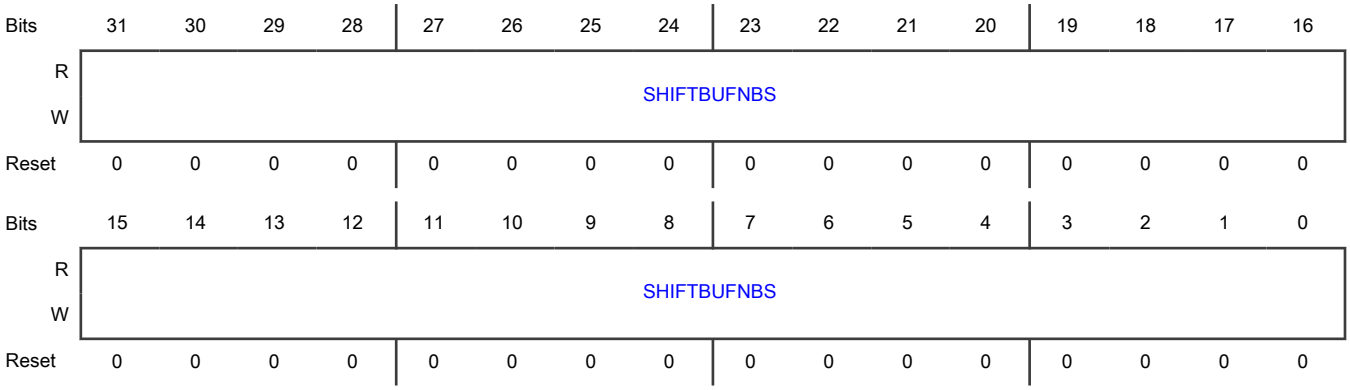
For n = 0 to 7:

Register	Offset
SHIFTBUFNBSn	680h + (n × 4h)

Function

Contains Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) content, but it is nibble-swapped within each byte.

Diagram



Fields

Field	Function
31-0 SHIFTBUFNBS	Shift Buffer Acts as an alias to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7), but reads or writes to this register are nibble-swapped within each byte. Reads return {SHIFTBUF[27:24], SHIFTBUF[31:28], SHIFTBUF[19:16], SHIFTBUF[23:20], SHIFTBUF[11:8], SHIFTBUF[15:12], SHIFTBUF[3:0], SHIFTBUF[7:4]}.

49.7.1.37 Shifter Buffer Halfword Swapped (SHIFTBUFHWS0 - SHIFTBUFHWS7)

Offset

For n = 0 to 7:

Register	Offset
SHIFTBUFHWSn	700h + (n × 4h)

Function

Contains Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) content, but it is halfword-swapped.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SHIFTBUFHWS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SHIFTBUFHWS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 SHIFTBUFHWS	Shift Buffer Acts as an alias to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7), but reads or writes to this register are halfword-swapped. Reads return {SHIFTBUF[15:0], SHIFTBUF[31:16]}.

49.7.1.38 Shifter Buffer Nibble Swapped (SHIFTBUFNIS0 - SHIFTBUFNIS7)

Offset

For n = 0 to 7:

Register	Offset
SHIFTBUFNISn	780h + (n × 4h)

Function

Contains Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) content, but it is nibble-swapped.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SHIFTBUFNIS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SHIFTBUFNIS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 SHIFTBUFNIS	Shift Buffer Acts as an alias to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7), but reads or writes to this register are nibble-swapped. Reads return {SHIFTBUF[3:0], SHIFTBUF[7:4], SHIFTBUF[11:8], SHIFTBUF[15:12], SHIFTBUF[19:16], SHIFTBUF[23:20], SHIFTBUF[27:24], SHIFTBUF[31:28]}.

49.7.1.39 Shifter Buffer Odd Even Swapped (SHIFTBUFOES0 - SHIFTBUFOES7)

Offset

For n = 0 to 7:

Register	Offset
SHIFTBUFOESn	800h + (n × 4h)

Function

Contains Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) content, but it has odd and even bits partitioned separately.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SHIFTBUFOES															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SHIFTBUFOES															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 SHIFTBUFOES	Shift Buffer Acts as an alias to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7), but reads or writes to this register have the odd and even bits partitioned separately. Only 32-bit accesses are supported for this register. Reads return {SHIFTBUF[31], SHIFTBUF[29], SHIFTBUF[27],SHIFTBUF[25],SHIFTBUF[23],SHIFTBUF[21],SHIFTBUF[19],SHIFTBUF[17],SHIFTBUF[15],SHIFTBUF[13],SHIFTBUF[11],SHIFTBUF[9], SHIFTBUF[7], SHIFTBUF[5], SHIFTBUF[3], SHIFTBUF[1], SHIFTBUF[30], SHIFTBUF[28], SHIFTBUF[26], SHIFTBUF[24], SHIFTBUF[22], SHIFTBUF[20], SHIFTBUF[18], SHIFTBUF[16], SHIFTBUF[14], SHIFTBUF[12], SHIFTBUF[10], SHIFTBUF[8], SHIFTBUF[6], SHIFTBUF[4], SHIFTBUF[2], SHIFTBUF[0]}.

49.7.1.40 Shifter Buffer Even Odd Swapped (SHIFTBUFEOS0 - SHIFTBUFEOS7)

Offset

For n = 0 to 7:

Register	Offset
SHIFTBUFEOSn	880h + (n × 4h)

Function

Contains Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) content, with even and odd bits partitioned separately.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SHIFTBUFEOS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SHIFTBUFEOS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 SHIFTBUFEOS	Shift Buffer Acts as an alias to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7), but reads or writes to this register have the even and odd bits partitioned separately. Only 32-bit accesses are supported for this register. Reads return {SHIFTBUF[30], SHIFTBUF[28], SHIFTBUF[26], SHIFTBUF[24], SHIFTBUF[22], SHIFTBUF[20], SHIFTBUF[18], SHIFTBUF[16], SHIFTBUF[14], SHIFTBUF[12], SHIFTBUF[10], SHIFTBUF[8], SHIFTBUF[6], SHIFTBUF[4], SHIFTBUF[2], SHIFTBUF[0], SHIFTBUF[31], SHIFTBUF[29], SHIFTBUF[27],SHIFTBUF[25],SHIFTBUF[23],SHIFTBUF[21],SHIFTBUF[19],SHIFTBUF[17],SHIFTBUF[15],SHIFTBUF[13],SHIFTBUF[11],SHIFTBUF[9], SHIFTBUF[7], SHIFTBUF[5], SHIFTBUF[3], SHIFTBUF[1]}.

49.7.1.41 Shifter Buffer Halfword Byte Swapped (SHIFTBUFHBS0 - SHIFTBUFHBS7)

Offset

For n = 0 to 7:

Register	Offset
SHIFTBUFHBSn	900h + (n × 4h)

Function

Contains Shifter Buffer (SHIFTBUF0 - SHIFTBUF7) content, but it is halfword byte-swapped.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SHIFTBUFHBS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SHIFTBUFHBS															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 SHIFTBUFHBS	Shift Buffer Acts as an alias to Shifter Buffer (SHIFTBUF0 - SHIFTBUF7), but reads or writes to this register are halfword byte-swapped. Reads return {SHIFTBUF[23:16], SHIFTBUF[31:24], SHIFTBUF[7:0], SHIFTBUF[15:8]}.

Chapter 50
Semaphores2 (SEMA42)

50.1 Chip-specific SEMA42 information

Table 426. Reference links to related information

Topic	Related module	Reference
Full description	SEMA42	SEMA42
System memory map		System memory map
Clocking		Clock distribution
Signal multiplexing	Port control	Signal multiplexing

50.1.1 Module instances

This device has one instance of the SEMA42 module.

50.1.2 Domain ID

The following table lists modules assigned to each domain.

Table 427. SEMA42 domain ID assignment

Domain ID	Modules
M0	CM33 Code and Data in normal function mode
M1	CM33 Code and Data in debug mode
M2	eDMA
M3	EdgeLock Secure Enclave
M4	Data Stream
M5	Radio NBU
M6	DSP

50.2 Overview

SEMA42 is a memory-mapped module that provides robust hardware support needed in multi-core systems for implementing semaphores and provides a simple mechanism to achieve "lock and unlock" operations via a single - write access. The hardware semaphore module provides hardware-enforced gates as well as other useful system functions related to the gating mechanisms.

NOTE

Terminology in this chapter has been updated as follows:

Table 428. Updated terms

Updated term	Deprecated term
Initiator	Master
Target	Slave
Stop	Abort

50.2.1 Block diagram

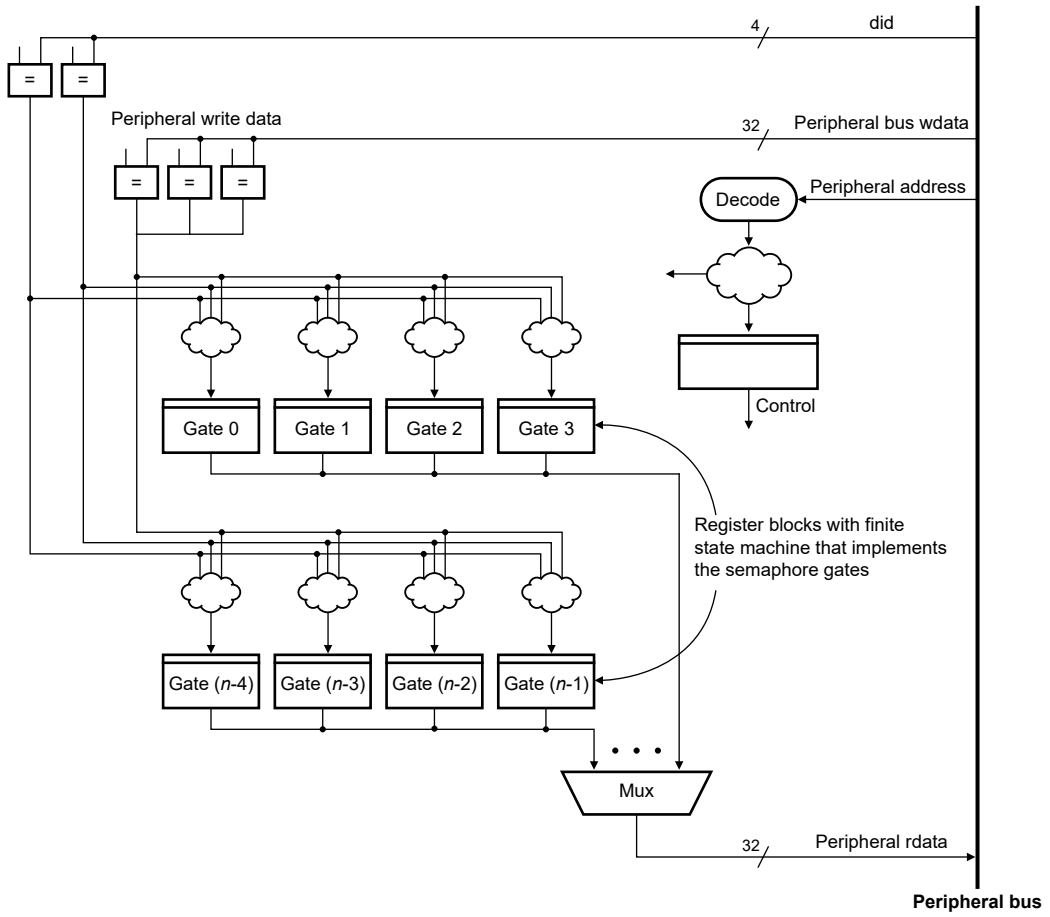


Figure 204. SEMA42 block diagram

50.2.2 Features

SEMA42 implements hardware-enforced semaphores as an IPS-mapped target peripheral device. The feature set includes:

- Support for 16 hardware-enforced gates in a multi-domain configuration that supports up to 15 domains.
- Each hardware gate appears as a 16-state, 4-bit state machine.
- Support for secure reset mechanisms to clear the contents of individual gates, as well as a clear-all capability.
- Memory-mapped target peripheral that offers programming-model accesses.

50.3 Memory map/register definition

You can access these registers only in Supervisor mode. User accesses terminate with an error.

50.3.1 SEMA42 register descriptions

50.3.1.1 SEMA42 memory map

SEMA42 base address: 4003_F000h

Offset	Register	Width (In bits)	Access	Reset value
0h - Fh	Gate (GATE0 - GATE15) [1]	8	RW	00h
42h	Reset Gate Read (RSTGT_R)	16	R	0000h
42h	Reset Gate Write (RSTGT_W)	16	W	See section

1. In this array, the index and offset values of the registers do not increment in direct alignment. For details, see the register description.

50.3.1.2 Gate (GATE0 - GATE15)

Offset

For n = 0 to 15:

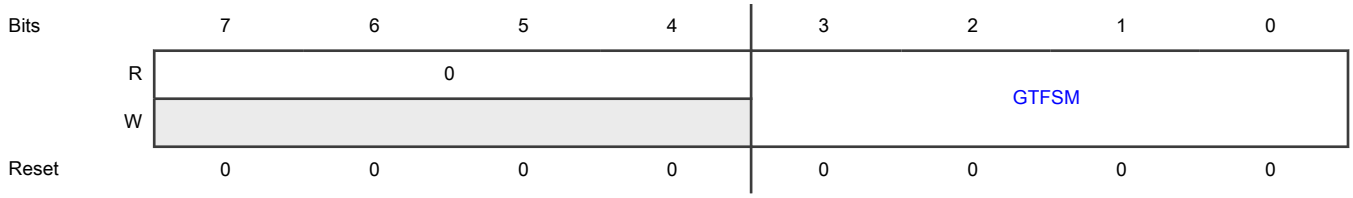
Register	Offset
GATEn	0h + (n + 3 - 2 × (n mod 4))

Function

Implements each semaphore gate in a 4-bit finite state machine, right-justified in a byte data structure. The hardware uses the logical domain-identifier number in conjunction with the data patterns to validate all attempted write operations. Only domain initiators can modify the gate registers. After a gate locks, only the locking domain must open (unlock) the gate.

You can read multiple gate values in a single access. However, you can update only a single gate at a time, via a write operation. If you attempt to write a byte-wide value that is neither the unlock value (00h) nor the appropriate lock value (domainID_number + 1), SEMA42 considers this as "no operation" and does not change any gate state. Attempts to write multiple gates in a single-aligned access with a size larger than 8 bits (byte) generate an error termination and do not allow any gate state changes.

Diagram



Fields

Field	Function
7-4 —	Reserved
3-0 GTFSM	Gate Finite State Machine Indicates the state of the gate for the last domain that locked the gate. This can be useful during system debug.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	The hardware gate has a 16-state implementation, defined as: 0000b - The gate is unlocked (free). 0001b - Domain 0 locked the gate. 0010b - Domain 1 locked the gate. 0011b - Domain 2 locked the gate. 0100b - Domain 3 locked the gate. 0101b - Domain 4 locked the gate. 0110b - Domain 5 locked the gate. 0111b - Domain 6 locked the gate. 1000b - Domain 7 locked the gate. 1001b - Domain 8 locked the gate. 1010b - Domain 9 locked the gate. 1011b - Domain 10 locked the gate. 1100b - Domain 11 locked the gate. 1101b - Domain 12 locked the gate. 1110b - Domain 13 locked the gate. 1111b - Domain 14 locked the gate.

50.3.1.3 Reset Gate Read (RSTGT_R)

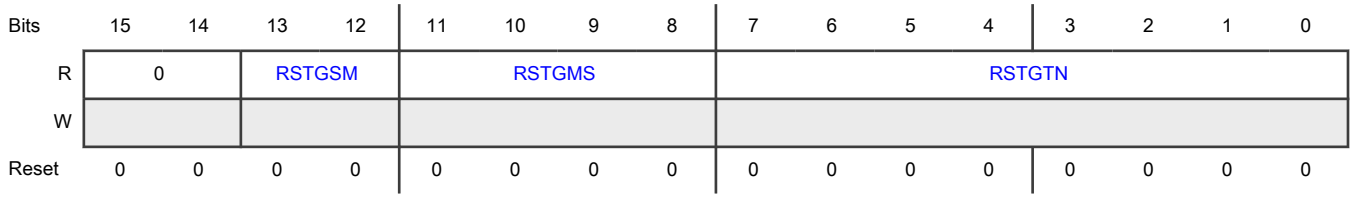
Offset

Register	Offset
RSTGT_R	42h

Function

Describes the specific hardware gate to be reset and records the logic number of domain. Reset Gate Write (RSTGT_W) also describe the same register showing the fields when you write it.

Diagram



Fields

Field	Function
15-14 —	Reserved
13-12 RSTGSM	Reset Gate Finite State Machine Indicates the encoded state machine value when you read the register. RSTGSM = 10b is valid for only a single machine cycle, so a read can never return this value. SEMA42 maintains the reset state machine in a 2-bit, 3-state implementation, defined as follows: 00b - Idle, waiting for the first data pattern write. 01b - Waiting for the second data pattern write 10b - The 2-write sequence has completed. Generate the specified gate reset(s). After the reset is performed, this machine returns to the idle (waiting for first data pattern write) state. 11b - This state encoding is never used and therefore reserved.
11-8 RSTGMS	Reset Gate Domain Records the logical number of the domain performing the gate reset function. To succeed, this function requires that the same domain initiate the two consecutive writes to this register. SEMA42 updates the field each time a write to this register occurs.
7-0 RSTGTN	Reset Gate Number Specifies the specific hardware gate to be reset. The second write updates this field. If RSTGTN < 64, SEMA42 resets the single gate defined by RSTGTN. Otherwise, SEMA42 resets all the gates.

50.3.1.4 Reset Gate Write (RSTGT_W)

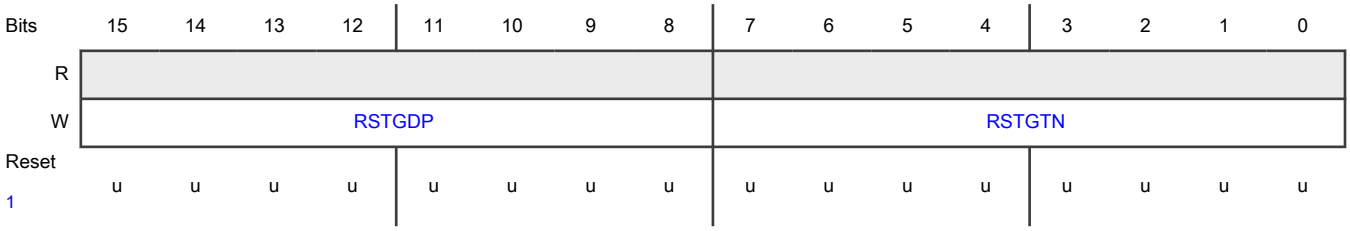
Offset

Register	Offset
RSTGT_W	42h

Function

Specifies the hardware gate to reset when data patterns are specified.

Diagram



1. Reset value is not applicable for writes.

Fields

Field	Function
15-8 RSTGDP	Reset Gate Data Pattern You access this field with the specified data patterns on the two consecutive writes to enable the gate-reset mechanism. For the first write, RSTGDP must be E2h. For the second write, RSTGDP must be 1Dh.
7-0 RSTGTN	Reset Gate Number Specifies the specific hardware gate to be reset. The second write updates this field. If RSTGTN < 64, SEMA42 resets the single gate defined by RSTGTN. Otherwise, SEMA42 resets all the gates.

50.4 Functional description

The intent of the hardware gate implementation is to specify a protocol where the locking domain must unlock the gate. However, some systems may require a reset function to re-initialize the state of any gate(s) without requiring a system-level reset. To support this special gate reset requirement, SEMA42 implements a secure reset mechanism that allows you to initialize a hardware gate (or all the gates) by following a specific dual-write access pattern. The secure-gate reset:

- Uses a technique similar to that required for the servicing of a software watchdog timer
- Requires two consecutive writes with pre-defined data patterns from the same domain

You must do this to force the clearing of the specified gate(s). The required access pattern as follows:

1. A domain performs a 16-bit write to the RSTGT memory location. The most significant byte (RSTGT_W[RSTGDP]) must be E2h. The value of least significant byte is irrelevant for this reference and can be anything.
2. The same domain then performs a second 16-bit write to the RSTGT location. For this write, the upper byte (RSTGT_W[RSTGDP]) is the logical complement of the first data pattern (1Dh) and the lower byte (RSTGT_W[RSTGTN]) specifies the gate(s) to be reset. This gate field can specify a single gate or all gates to be cleared. If the same domain writes incorrect data on the second access or another domain performs the second write access, SEMA42 stops the special gate reset sequence and does not assert an error signal.
3. Reads of the RSTGT location return information on the 2-bit reset state machine (RSTGT_R[RSTGSM]) that implements these functions:
   - The domain performing the reset (RSTGT_R[RSTGMS])
   - The last-cleared gate number(s) (RSTGT_R[RSTGTN])

   Reads of the RSTGT register do not affect the secure-reset finite state machine in any manner.

50.4.1 Multi-core programming: software gates

Multi-processor systems require a function that can be used to safely and easily provide a locking mechanism for system software to control access to shared data structures, shared hardware resources, and so on. The software uses the gating mechanisms to serialize (and synchronize) accesses to shared data and/or resources to prevent race conditions and preserve memory coherency between different processes and domains.

Consider the following description of a typical use-case: domain*X* enters a section of code, where shared data values are to be updated. The domain must first acquire a semaphore. Think of this as the locking (or closing) of a software gate. After the gate locks, a properly-architected software system does not allow other processes (or domains) to execute the same code segment or modify the shared data structure protected by the gate. In other words, the system locks out other processes/domains. Many software implementations include a spin-wait loop within the lock function until the gate locks. After domain X obtains the lock, domain X continues execution and updates the data values protected by the particular lock. After domain X completes the updates, it unlocks (or opens) the software gate, allowing other processes/domains access to the updated data values.

A correctly-implemented system solution must follow these important rules:

- A gate variable must protect all writes to shared data values or shared hardware resources.
- After a domain locks a gate, the system must block other processes/domains from accessing the shared data or resources. Software conventions enforce this.
- The domain that locks a particular gate is the only domain that can open (unlock) that gate.

Information in the hardware gate identifying the locking domain can be extremely useful for system-level debugging.

50.4.2 16 Hardware-enforced gates

Gates appear as a 16-entry byte-size array with read and write accesses.

Domains lock gates by writing "domainID_number+1" to the appropriate gate and must read back the gate value to verify that the lock operation succeeded.

After the gate locks, the locking domain unlocks the gate by writing zeroes.

- 16-state implementation

  If gate = 0h, then state = unlocked

  if gate = 1h, then state = locked by domain (initiator) 0

  if gate = 2h, then state = locked by domain (initiator) 1

  …

  if gate = Fh, then state = locked by domain (initiator) 14

SEMA42 uses the logical domain number and the specified data patterns as reference attributes to validate all write operation.

After a gate locks, the locking domain must unlock the gate by writing zeroes.

50.4.3 State machine of the GATE*n* registers

This section describes more about the SEMA42 functional operation and specific details of the state machines of the GATE*n* registers.

As described previously, each of the GATE*n* registers implements a 4-bit, 16-state machine. The following figure shows a simplified diagram of the state transitions for each gate.

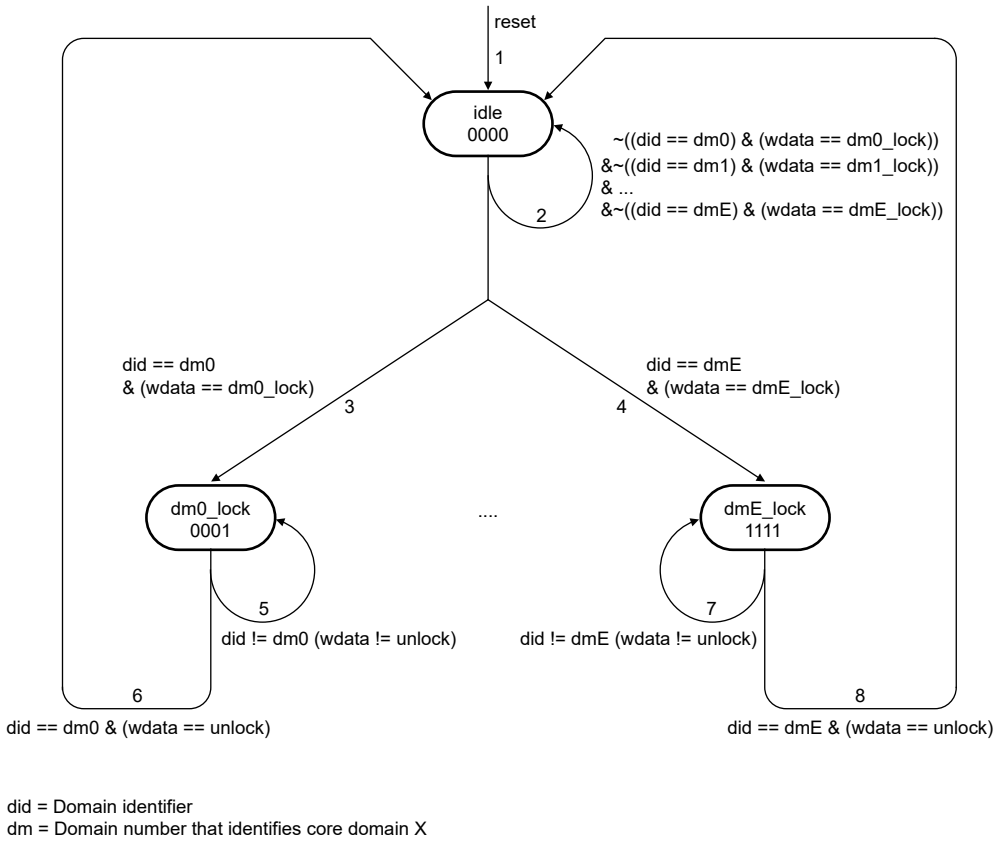


Figure 205. GATE*n* state machine

In the figure above, "dmE" represents domain 14 (E in hexadecimal). The platform passes the domain number to SEMA42.

The following table defines the GATE*n* state transitions.

Table 429. GATE*n* state transitions

Current state	Next state	Transition	Description
–	idle	1	Any reset, whether a system reset or a software-initiated gate reset, unconditionally forces the gate into the idle state.
idle	idle	2	Unless a write of the appropriate lock value from the corresponding domain occurs, the gate remains in the idle state.
idle	dm0_lock	3	When domain 0h initiates a write of the dm0_lock data value, the gate transitions into the dm0_lock state.
idle	dmE_lock	4	When domain Eh initiates a write of the dmE_lock value, the gate transitions into the dmE_lock state.
dm0_lock	dm0_lock	5	When in this state, the gate remains here if any attempted write is not from domain 0h with the unlock data value.
dm0_lock	idle	6	The gate returns to the idle (unlocked) state after a write from domain 0h with the unlock data value occurs.

Table continues on the next page...

Table 429. GATE*n* state transitions (continued)

Current state	Next state	Transition	Description
dmE_lock	dmE_lock	7	When in this state, the gate remains here if any attempted write is not from domain Eh with the unlock data value.
dmE_lock	idle	8	The gate returns to the idle (unlocked) state after a write from domain Eh with the unlock data value occurs.

SEMA42 uses these gate data values:

- The lock data value is (domain number) + 1.
- The unlock data value is 00h.

50.4.4 Clocking

Type of clock	Description
Module clock (clk)	Functions the module and controls the access to the registers.

50.4.5 Interrupts

This module has no interrupts.

50.5 External signals

This module has no external signals.

50.6 Initialization

This module does not require initialization.

Chapter 51
Messaging Unit (MU)

51.1 Chip-specific MU information

Table 430. Reference links to related information

Topic	Related module	Reference
Full description	MU	MU
Peripheral memory map		Memory map overview
Clocking		Clock overview Clock controller
Power management	PMC	Power overview

51.1.1 Module instances

This device has three instances of the MU module.

Table 431. MU instances connections

MU instances	Connections	Related SEMA42 instances
MU0_MUA	CPU0	SEMA42
MU0_MUB	LCE	
S200_MUA	CPU0/CPU1	
S200_MUB	S200	

NOTE

Radio has custom implementation of MU core.

51.2 Overview

MU enables two processors on a chip to communicate and coordinate by passing messages (for example, data, status, and control) through the MU interface. MU also allows one processor to signal the other processor using interrupts.

MU must synchronize the accesses from one side to the other because MU can manage messaging between processors using different clocks. MU accomplishes synchronization using two sets of matching registers: processor A-facing and processor B-facing.

51.2.1 Block diagram

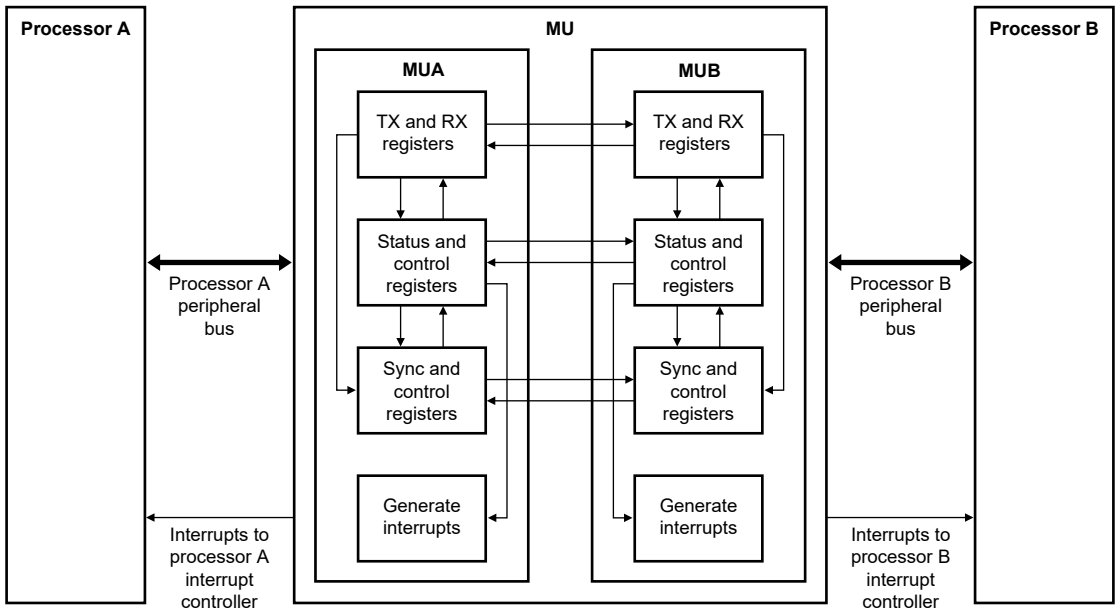


Figure 206. Block diagram

51.2.2 Features

- Memory-mapped registers (MU is connected as a peripheral under the peripheral bus on the processor A-side and processor B-side)
- Synchronized message transfers between cores
  - To send data or messages from one side to the other, messaging unit A (MUA) provides 4 transmit registers and 4 receive registers. Messaging unit B (MUB) provides 4 transmit registers and 4 receive registers.
  - Transmit empty flags (TSR[TEn]) and receive full flags (RSR[RFn]) facilitate the transfer of data or messages between cores on both sides of MU.
  - A synchronization mechanism updates the transmit and the receive flags. There is an inherent latency between updating the flag on one side and reflecting its status on the other side. See Event update timing.
  - MU has a 3-bit flag data register, which you can use to send flag data between the two MU sides.
- Interprocessor interrupts
  - MU has 12 asynchronous interrupt sources on each side (processor A-side, processor B-side) for signaling the other processor. You can use the interrupts for notification of receive and transmit events and for general-purpose signaling between processors. There are 4 general-purpose interrupt requests available and 8 receive and transmit interrupt sources.
  - Processor A can initiate a non-maskable interrupt (NMI) to processor B.
  - Processor B can initiate a non-maskable interrupt (NMI) to processor A.
- Reset (Each processor can issue a reset to MU via CR[MUR], which is a self-clearing field).

51.3 Functional description

MU enables two cores (processor A and processor B) to communicate with each other:

- By sharing messages and data.

- By enabling one core to wake the other core by using interrupts.

The messaging, control, and status registers of the two cores are mapped to processor A memory and processor B memory as a regular peripheral. The peripheral data bus is 32 bits wide inside MU.

Messaging logic is used with shared memory. Various messaging methods can implement a messaging protocol. For example, a message could mean one of the following:

- A message of *n* words has been written starting at offset *x* in the memory.
- The previous data block that was sent has been read.

The ability to keep messaging logic independent of the shared memory is not restricted to a predefined hardware protocol. The software required to manage the messaging is short and straightforward.

Most of the messaging mechanisms are symmetric. They are duplicated and are available on both the processor A side and processor B side. The messaging mechanisms are:

- 4 32-bit transmit registers, which are each reflected in 4 read-only receive registers on the side of the other processor. These registers can transfer 32-bit word messages or the frame information of the messages written to the shared memory. For example, they can transfer the number of words, initial address, and message type code.
- Writing to a transmitter-side transmit register (TR*n*) clears the Transmitter Empty flag in the transmitter-side Status register (TS*n*[TE*n*]), and sets the Receiver Full flag in the receiver-side Status register (RS*n*[RF*n*]). Setting the flag on the receiver side can trigger an interrupt on the receiver side (a maskable receive interrupt).
- Reading a receiver-side receive register (RR*n*) clears the Receiver Full flag in the receiver-side Status register (RS*n*[RF*n*]), and sets the Transmitter Empty flag in the transmitter-side Status register (TS*n*[TE*n*]). Setting the Transmitter Empty flag can trigger an interrupt on the transmitter side (a maskable transmit interrupt).
- 4 general-purpose interrupt request flags are reflected in General-purpose Status (GSR) on the receiver side.
- 3-bit flag data is transmitted from Flag Control (FCR) to Flag Status (FSR) on the side receiving the flag data. SR[FUP] sets when the flag data is transmitted and clears when the receiving side acknowledges the flag data (the flag is updated).

Writing to a transmit register signals to the receiver side that data is ready for retrieval.

Do not write to the transmit register again without verifying that the data is retrieved. The transmitter side cannot determine the exact time that the receiver attempts to retrieve the data. Before attempting to write to the transmit register again, the transmitter side must wait for the Transmitter Empty interrupt or it must poll TSR[TE*n*].

Reading a receive register signals to the transmitter side that data can be written to that register.

Do not read the receive register again without verifying that the data is written. The receiver side cannot determine the exact time that the transmitter attempts to write the data. Before attempting to read the receive register again, the receiver side must wait for the Receiver Full interrupt or it must poll RSR[RF*n*].

51.3.1 Submodules

51.3.1.1 MUA side

MUA receives its register configuration via the processor A peripheral bus. It sends or receives messages to or from MUB. Processor A can receive messages by reading MUA registers, and MUA can send interrupts to processor A when interrupts are enabled.

NOTE

Processor B should not access MUA registers. Processor C, if exist, should also not access MUA registers. TRDC might be needed to prevent such illegal access of Processor B or C to MUA registers.

51.3.1.2 MUB side

MUB receives its register configuration via the processor B peripheral bus. It sends or receives messages to or from MUA. Processor B can receive messages by reading MUB registers, and MUB can send interrupts to processor B when interrupts are enabled.

NOTE

Processor A should not access MUB registers. Processor C, if exist, should also not access MUB registers. TRDC might be needed to prevent such illegal access of Processor A or C to MUB registers.

51.3.2 Event update timing

The messaging side of each processor has a hardware mechanism to send event update requests to the other processor. An event occurs when the status register of the receiving processor must reflect any information change. The event update latency is the delay between the event being ready at one processor and the resulting update at the status register of the other processor:

- The minimum event latency is (1 clock cycle of the sending side) + (2.5 clock cycles of the receiving side). This minimum case happens when no event is pending when the new event occurs.
- The maximum event latency is (6 clock cycles of the sending side) + (6.5 clock cycles of the receiving side). The maximum case happens when the event occurs just after a previous event is sent to the other side.

The event update latency varies depending on the time at which the subsequent event is triggered.

51.3.3 Clocking

Table 432. MU clocks

Clock name	Description
Bus clock MUA	Used only for bus accesses to MUA control and configuration registers
Bus clock MUB	Used only for bus accesses to MUB control and configuration registers

51.3.4 Resets

The following sections list the reset sources included in MU. Each reset performs a different function for the MU module compared to the function it performs for the system.

51.3.4.1 Asynchronous system reset

When the asynchronous system reset on either side of MU is asserted, SR[MURS] becomes 1 until the asynchronous system reset sequence on both the MUA and MUB sides ends. Verify that SR[MURS] becomes 0 before accessing MU.

The asynchronous system reset on one side of MU resets the other side of MU. The reset forces all control and status registers to return to their default values and clears all internal states. The following table shows the exceptions to this behavior.

Table 433. Exceptions to asynchronous system reset

MUA-side exceptions	MUB-side exceptions
MUB_SR[MURS] MUB_CSSR0/MUB_CSR0	MUA_CCR0[BOOT] MUA_SR[MURS] MUA_CSSR0/MUA_CSR0

51.3.4.2 MU software reset

Writing 1 to CR[MUR] causes most control and status registers to return to their default values and clears all internal states.

The instruction immediately following the assertion of CR[MUR] must not write to the MU registers. The reset sequence may overwrite such a write, with the register retaining the reset value. To know the end of the reset sequence for both processors, monitor the value of SR[MURS]. After the reset sequence on both processors has ended, a write to the MU registers can be attempted.

NOTE

The process of CR[MUR] becoming 1 is delicate because it asynchronously affects the registers on the other side. CR[MUR] becoming 1 may cause unpredictable behavior if, for example, the other processor is concurrently testing an MU register field (TSR[TE*n*] in the other processor). Before writing 1 to CR[MUR], verify that the other processor is not engaged in an MU signaling activity.

51.3.5 Interrupts

MU controls interrupt requests that one processor makes to the other processor. This section describes all the interrupts that the module generates.

MU can generate these interrupt sources individually to send to the processors:

- 4 receive interrupts (asserted when the Receive Full flags are set in Receive Status (RSR) and enabled in Receive Control (RCR)) for each receive register. These interrupts are Ored into a single interrupt for each MUA or MUB, please consult the interrupt map file attached to this document.
- 4 transmit interrupts (asserted when the Transmit Empty flags are set in Transmit Status (TSR) and enabled in Transmit Control (TCR)) for each transmit register. These interrupts are Ored into a single interrupt for each MUA or MUB, please consult the interrupt map file attached to this document.
- 4 general-purpose interrupts (asserted when the GIP flags are set in General-Purpose Interrupt Enable (GIER) and enabled in General-Purpose Interrupt Enable (GIER))
- One non-maskable interrupt (NMI) flag (asserted when the NMI flag is set in Core Control 0 (CCR0))

All interrupts except NMI are maskable in the processor control registers: TCR, RCR, GIER, and CR. MU does not assume any internal priority of these interrupts. Multiple interrupts (for example, receive 0 and receive 1, or any transmit or general-purpose interrupts) can be asserted simultaneously. The interrupt controller must resolve the priority of these interrupts at the chip level.

Triggering any enabled interrupt wakes the processor from below mode before servicing the interrupt

- Wait mode
- Stop mode
- Power-down mode

The software (as part of the interrupt handler) must clear the general-purpose interrupt pending flags (GSR[GIP*n*]) to deassert the request to the interrupt controller.

The software must also clear the NMI by writing CSSR0[NIMC] (as a part of the interrupt handler) to deassert the NMI request.

When a processor writes to the general-purpose interrupt (GCR[GIR*n*]), MU synchronizes the write event to the other processor to set the general-purpose interrupt request pending flag (GSR[GIP*n*]). When GSR[GIP*n*] is set and the general-purpose interrupt is enabled on the receiving side (GIER[GIE*n*] is 1), the transmitting-side general-purpose interrupt is issued to the receiving processor, which clears this interrupt by writing 1 to GSR[GIP*n*]. The interrupt is deasserted as soon as the write to GSR[GIP*n*] occurs. MU synchronizes the write event of GSR[GIP*n*] to the other processor. The synchronized signal writes 0 to the GIR*n* interrupt.

Before writing 1 to GCR[GIR*n*], verify that the field is 0, which means that a general interrupt is not pending. Generally, MU ignores writing 1 to this field while the field is already 1, but in some cases it may issue a second interrupt.

51.4 External signals

This module has no external signals.

51.5 Initialization

MU does not require initialization.

51.6 Application information

MU facilitates messages between processors. For example, MU passes:

- Short messages. Transmit registers can pass short messages from 1 to 4 words in length for processor A and from 1 to 4 words for processor B. For example, for a four-word message, only one register must have its corresponding interrupt enabled on the receiving side. The first three words of the message are written to the registers with masked interrupts. The fourth word is written to the last register, triggering an interrupt on the receiving side.
- Frame information. Transmit registers can pass frame information for long messages written to the shared system memory. Such frame information normally includes a start address and a number of words. It can include a message type code.
- Event notices and requests. MU can signal events and requests that do not include data words between processors using general-purpose interrupts. For example, one such event is acknowledging that a long message is read from the shared system memory.
- Fixed-length data. Formatted data with a fixed length can be written to predetermined locations in the shared memory. A processor can use general-purpose interrupts to signal to the other processor that the data is ready.
- Announcements. A processor can use the 3 flags to announce its current program state or other billboard messages to the other processor.

51.6.1 Messaging protocols using interrupts

The example below describes a four-word messaging sequence sent between the processor A and processor B.

The transmitting processor writes to the transmit registers sequentially. When *n* = 0, 1, and 2, the interrupts are disabled, so no interrupt goes to the processor (although interrupt conditions occur). For *n* = 3, the interrupt is enabled, and MU generates the last receive interrupt request.

1. Write sequence:
    a. The transmitting processor writes the message information sequentially to its Transmit registers 0, 1, 2.
    b. When the write to Transmit register 3 occurs, RSR[RF3] is set after synchronization. It immediately triggers the receive full 3 interrupt on the receiving processor.
2. Read sequence:
    a. The receiving processor receives the receive full 3 interrupt and starts reading the message transferred from the receive registers.
    b. After the receiving processor reads Receive register 3, MU clears RSR[RF3].

Table 434 and Figure 207 describe the messaging model, using transmit and receive registers and the interrupt messaging protocol.

Table 434. Interrupt messaging protocol (generalized)

Step	Action	Description
1	Processor A writes data.	RR*n* on processor B's side reflects a data write to TR*n* by processor A.
2	Clear the transmitter empty flag and set the receiver full flag.	The data write to TR*n*: • Clears TSR[TE*n*] on the processor A side. • Sets RSR[RF*n*] on the processor B side.

Table continues on the next page...

Table 434. Interrupt messaging protocol (generalized) (continued)

Step	Action	Description
3	Generate the receive interrupt request.	Setting RSR[RF*n*] generates a receive interrupt request to processor B.
4	Processor B reads the data.	After receiving the receive interrupt request, processor B performs a data read of RR*n*.
5	Clear the receiver full flag and set the transmitter empty flag.	Reading the data from the RR*n* register: • Clears RSR[RF*n*] on the processor B side. • Sets TSR[TE*n*] on the processor A side.
6	Generate the transmit interrupt request.	Setting TSR[TE*n*] generates a transmit interrupt request to processor A.

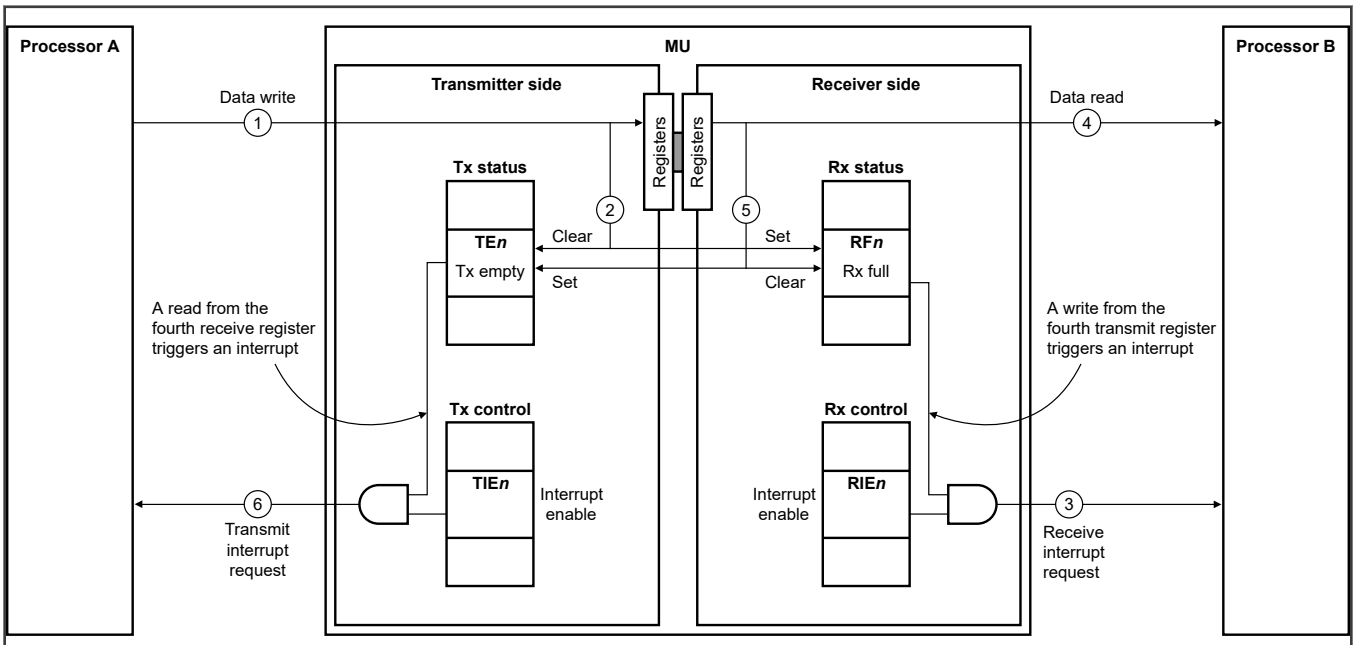


Figure 207. Messaging model using transmit and receive registers

You can use the messaging hardware to implement messaging protocols for an array of message types. MU provides full support for interrupt and polling management schemes.

51.6.2 Messaging protocols using event interrupts

MU can signal events and requests that do not include data words between processors using general-purpose interrupts.

Formatted data with a fixed length can be written to predetermined locations in the shared memory. A processor can use a general-purpose interrupt to signal to the other processor that the data is ready.

A processor can use the 3 flags to announce its current program state (or similar messages) to the other processor.

Table 435 and Figure 208 describe the event steps when the processor triggers a general-purpose interrupt.

Table 435. General-purpose interrupt messaging protocol (generalized)

Step	Action	Description
1	Processor A sets its associated general-purpose interrupt request flag.	Processor A sets GCR[GIR*n*].
2	The general-purpose interrupt request pending status flag is set.	GSR[GIP*n*] is set.
3	MU generates the general-purpose interrupt request to processor B.	Setting GSR[GIP*n*] generates the general-purpose interrupt request to processor B. GIER[GIE*n*] must be set for processor B.
4	Processor B reads the status register.	Processor B reads GSR[GIP*n*].
5	Processor B services the interrupt.	—
6	Processor B sets GSR[GIP*n*] to clear the interrupt.	Processor B writes 1 to the corresponding GSR[GIP*n*] flag to clear the interrupt.
7	GCR[GIR*n*] is cleared.	Setting GSR[GIP*n*] clears GCR[GIR*n*] on the processor A side.

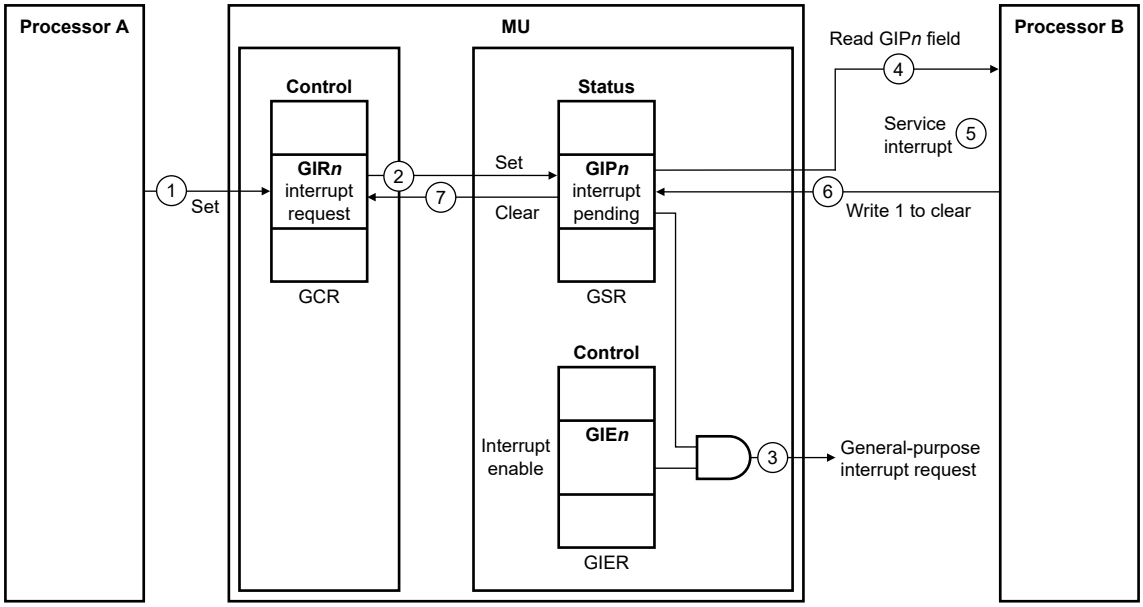


Figure 208. Messaging model using a general-purpose interrupt

51.6.3 Exclusive access to shared memory

MU can signal one processor about its current access to shared memory. This signaling prevents the other processor from overwriting data during the exclusive memory access period.

The following tables describe the signaling protocol that processor A uses to inform processor B about its current access (write) to shared memory:

- Table 436 shows processor A performing an exclusive access to shared memory.

- Table 437 shows processor B scanning for transaction information.
- Table 438 shows processor B accepting exclusive access from processor A.
- Table 439 shows processor B rejecting exclusive access from processor A.

According to the examples shown in the following tables, GCR[GIR*n*], RR*n*, and TR*n* are reserved to support exclusive access to the shared memory protocol.

Table 436. Processor A performs an exclusive access to shared memory

Step	Action	Description
1	Processor A sends the GIR*n* request to processor B using the processor A control register.	Before processor A performs an exclusive access to the shared memory, it sends a GIR*n* request to processor B.
2	Processor A sends an exclusive-access request using a transmit data register (TR*n*).	Processor A sends an exclusive-access request (command, location, and length of target access) to processor B using a selected transmit data register (TR0).
3	Processor A waits for a dedicated interrupt from processor B.	Processor A waits for a dedicated interrupt (as an acknowledgment) triggered by processor B before proceeding.
4	Processor A accesses the shared memory.	After receiving a dedicated interrupt from processor B, processor A proceeds.

Table 437. Processor B scans for transaction information

Step	Action	Description
1	Processor B receives an interrupt from a receive data register (RR*n*).	—
2	Processor B reads the receive data register (RR*n*).	—
3	Processor B scans the receive data register contents.	Processor B scans for transaction information (whether processor A has requested exclusive access).

Table 438. Processor B accepts exclusive access from processor A

Step	Action	Description
1	Processor B triggers a dedicated interrupt.	Processor B acknowledges the request from processor A by triggering a dedicated interrupt (ack) to processor A.
2	Processor B sends a code message to processor A.	With the acknowledge interrupt, processor B sends a code message to processor A through the selected transmit register (TR*n*). The message informs processor A that it can exclusively access the shared memory.

Table 439. Processor B rejects exclusive access from processor A

Step	Action	Description
1	Processor B ignores the request from processor A for exclusive access.	If processor B does not provide permission to processor A, processor B ignores the exclusive-access request.

51.6.4 Packet data transfers

The following table describes an example packet transfer sequence between processor B and processor A subsystems.

Table 440. Packet data transfer sequence

Step	Action	Description
1	Processor B requests DMA.	Processor B sends a DMA request to initiate the packet data transfer.
2	DMA data transfer	DMA acknowledges.
3		DMA starts transferring data from the specified processor B memory location to the specified shared memory.
4		DMA interrupts processor B to signal that the packet transfer has finished.
5	Processor B informs processor A that data is in shared memory.	Using a B-side transmit register, processor B sends a packet information message to processor A about the arrival of new packet data stored in shared memory. The message contains the command, location, and length of packet data.
6	Processor A receives an interrupt.	Processor A receives an interrupt (assuming its corresponding processor A MU-side receive interrupt is enabled). The pending processing task becomes active and processes packet data from memory.
7	Processor A reads data, then writes data.	Processor A reads or processes packet data from shared memory.
8		Processor A writes the result from packet processing to a separate buffer.
9	Processor A informs processor B that the transfer is finished.	After the processing of the packet data finishes, processor A informs processor B (using MU processor A-side transmit register, MUA_TR*n*).
10	Processor A sends an interrupt to processor B (a request for more data).	Processor B receives the next interrupt from processor A, in which processor A requests more packet data.

51.6.5 Freeing a processor from deadlock

During normal operation, one processor may determine that the other processor is not working or is deadlocked. Using Status (SR), the processor can use the methods in the following table to identify and correct the problem.

Table 441. Freeing a processor from deadlock

Processor mode	Technique	Description
—	Processor issues an interrupt.	The other processor can interrupt the processor by issuing one of the 12 (general purpose, receive, or transmit) interrupts.
Normal	Processor issues a non-maskable interrupt.	If a processor is in Normal mode, the other processor can issue a non-maskable interrupt (NMI). You can configure the NMI routine to execute a diagnostic routine that is predefined for such an event.

51.7 Register definition

MU provides transmit and receive data registers (*x*TR0–*n*, *x*RR0–*n*) for communication between processor A and processor B. It also provides control registers (*x*CR) for operations such as interrupts and resets, and status registers (*x*SR) for checking the status of the other MU-side. Figure 209 shows the schematic for MU registers.

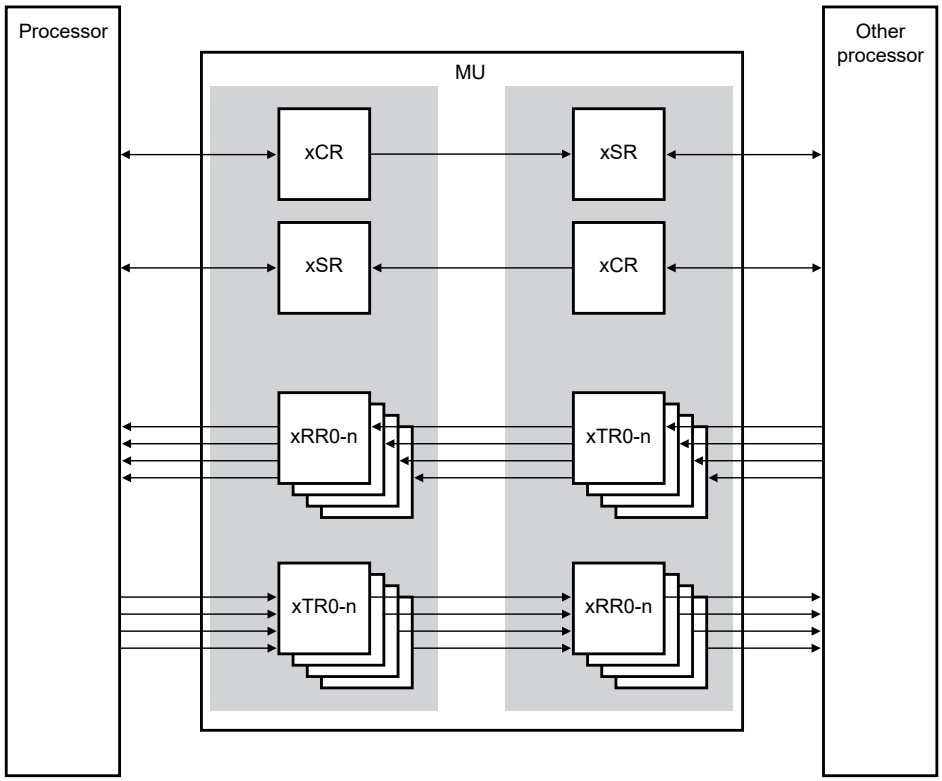


Figure 209. MU registers

51.7.1 MUA register descriptions

This section contains the detailed register descriptions for MUA registers.

NOTE

A module transfer error to processor A or processor B is generated when:

- A read or write access is made to an invalid location.
- A write operation is performed on a read-only register on the processor A side or processor B side of MU.

The only exception to this behavior is the MUA SR register. No transfer error occurs when accessing this location.

51.7.1.1 MUA memory map

MU.MUA base address: 4005_3000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VER)	32	R	0309_000Fh
4h	Parameter (PAR)	32	R	0304_0404h
8h	Control (CR)	32	RW	0000_0000h
Ch	Status (SR)	32	R	See section
10h	Core Control 0 (CCR0)	32	RW	0000_0014h
14h	Core Interrupt Enable 0 (CIER0)	32	RW	0000_0000h
18h	Core Sticky Status 0 (CSSR0)	32	RW	See section
1Ch	Core Status 0 (CSR0)	32	R	0000_0004h
100h	Flag Control (FCR)	32	RW	0000_0000h
104h	Flag Status (FSR)	32	R	0000_0000h
110h	General-Purpose Interrupt Enable (GIER)	32	RW	0000_0000h
114h	General-Purpose Control (GCR)	32	RW	0000_0000h
118h	General-purpose Status (GSR)	32	RW	0000_0000h
120h	Transmit Control (TCR)	32	RW	0000_0000h
124h	Transmit Status (TSR)	32	R	0000_000Fh
128h	Receive Control (RCR)	32	RW	0000_0000h
12Ch	Receive Status (RSR)	32	R	0000_0000h
200h - 20Ch	Transmit (TR0 - TR3)	32	RW	0000_0000h
280h - 28Ch	Receive (RR0 - RR3)	32	R	0000_0000h

51.7.1.2 Version ID (VER)

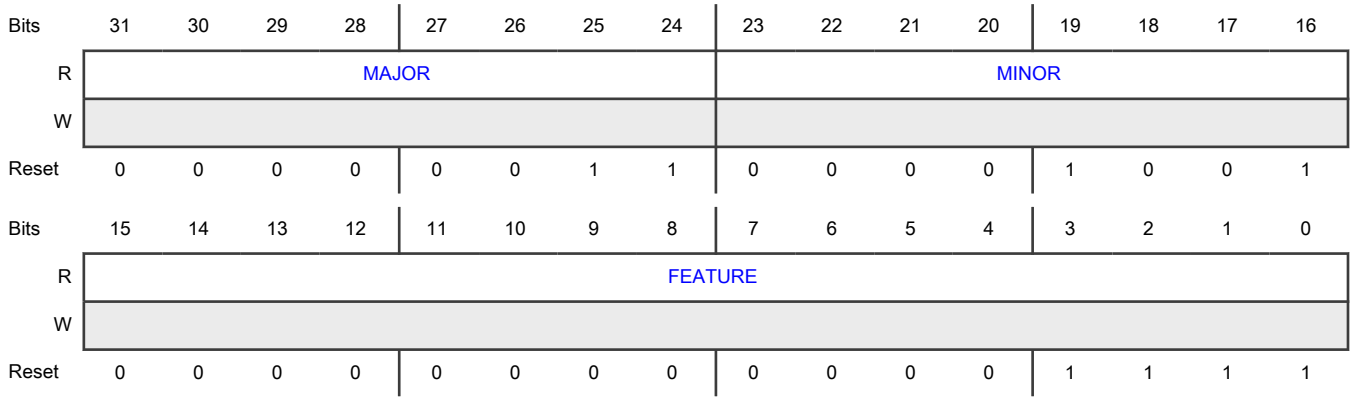
Offset

Register	Offset
VER	0h

Function

Determines the version ID and feature set number of MUA.

Diagram



Fields

Field	Function
31-24 MAJOR	Major Version Number
23-16 MINOR	Minor Version Number
15-0 FEATURE	Feature Set Number Indicates the feature set number. Each bit of this field specifies a different feature: • If FEATURE[0] = 1: Standard features are implemented. • If FEATURE[1] = 1: RAIP and RAIE fields are implemented. • If FEATURE[2] = 1: Core Control and Status registers are implemented in MUA and MUB. • If FEATURE[3] = 1: Expand the number of TR*n* and RR*n* registers. • FEATURE[4] - FEATURE[15]: Reserved for future use.

51.7.1.3 Parameter (PAR)

Offset

Register	Offset
PAR	4h

Function

Defines the number of flags, transmit registers, receive registers, and general-purpose interrupt requests available for MU.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	FLAG_WIDTH								GIR_NUM							
W																
Reset	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	RR_NUM								TR_NUM							
W																
Reset	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0

Fields

Field	Function
31-24 FLAG_WIDTH	Flag Width Specifies the number of flag bits (3) in the Flag Control (FCR) and Flag Status (FSR) registers.
23-16 GIR_NUM	General-Purpose Interrupt Request Number Specifies the number of general-purpose interrupt requests available (4).
15-8 RR_NUM	Receive Register Number Specifies the number of receive registers (4).
7-0 TR_NUM	Transmit Register Number Specifies the number of transmit registers (4).

51.7.1.4 Control (CR)

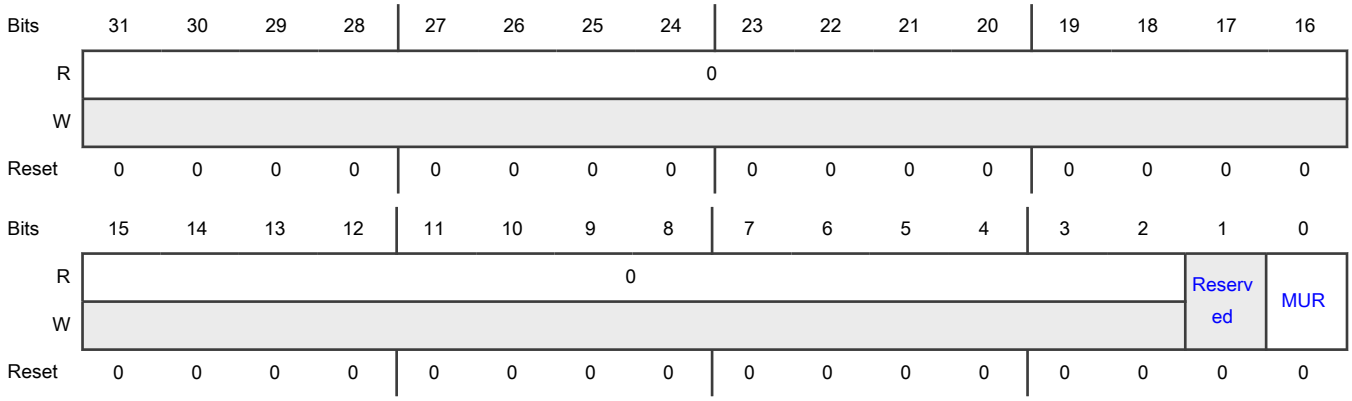
Offset

Register	Offset
CR	8h

Function

Controls MU reset and reset interrupt enable.

Diagram



Fields

Field	Function
31-2 —	Reserved
1 —	Reserved
0 MUR	MU Reset Resets MU. Writing 1 to this field resets the MUA and MUB sides. All internal states are cleared. It forces all control and status registers to return to their default values (except HR, HRM in MUA/B_CCR0 registers; MURS in MUA/B_SR registers and the MUA/B_CSSR0/CSR0 registers). Before writing 1 to this field, interrupt processor B because writing 1 to this field may affect the ongoing processor B program. After writing 1 to this field, monitor the value of MUA_SR[MURS] to know when the reset sequence on the processor B-side has ended. You can only write 1 to MUR when processor B is not in Stop mode or Power-Down mode. This field always reads 0, and it becomes 0 during the MU reset sequence. 0b - Idle 1b - Reset

51.7.1.5 Status (SR)

Offset

Register	Offset
SR	Ch

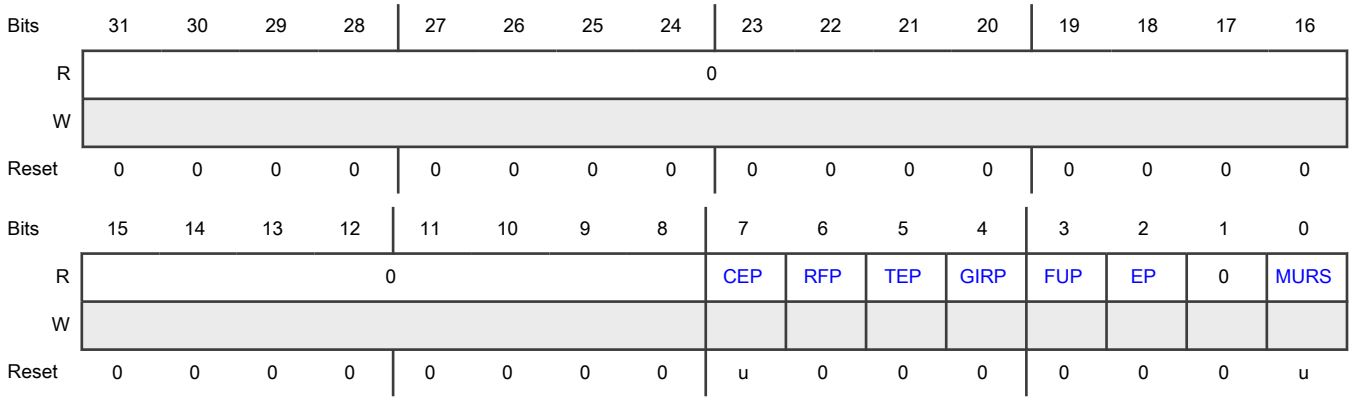
Function

Shows the status of MU resets and the status of pending events and requests.

NOTE

Writing to this register does not generate a transfer error.

Diagram



Fields

Field	Function
31-8 —	Reserved
7 CEP	Processor B Event Pending Indicates whether a processor event is pending. This field becomes 1 when MU detects any core operation mode entry event. After this field becomes 1, MU checks the CSSR0 register to determine which core operation mode entry event in Processor B occurs. This field becomes 0 when all core operation mode entry events are serviced by writing 1 to CSSR0[WAIT] and CSSR0[HRIP]. The reset value of this field is chip-specific. 0b - No event pending 1b - Event pending
6 RFP	MUA Receive Full Pending Indicates whether a receive full message is pending. This field becomes 1 when MUB writes to a TR*n* register to send data to MUA. After this field becomes 1, MU checks RSR[RF*n*] to determine whether the data in the Receive register is ready for MUA to read it. This field becomes 0 when all MUA RR*n* registers are read, or when MU is reset. 0b - Not pending; MUB is not writing to a Transmit register 1b - Pending; MUB is writing to a Transmit register
5 TEP	MUA Transmit Empty Pending Indicates whether a transmit empty message is pending.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	This field becomes 1 when any TCR[TIE*n*] field is 1 and TSR[TE*n*] flag is set. After this field becomes 1, MU checks TSR[TE*n*] to determine whether the data in the Transmit (TR*n*) register is ready for MUA to write to it. This field becomes 0 when write operations to all MUA Transmit (TR*n*) registers where TCR[TIE*n*] = 1 (transfer interrupt enabled) are completed, or when MU is reset. 0b - No MUA transmit empty event pending 1b - Pending; any TCR[TIEn] field is 1 and TSR[TEn] flag is set
4 GIRP	MUA General-Purpose Interrupt Pending Indicates that MUB has sent a general-purpose interrupt request. This field becomes 1 when the MUB side sends a general-purpose interrupt request to the MUA side. GSR[GIP*n*] identifies which general-purpose interrupt request is received. This field becomes 0 when all MUA_GSR[GIP*n*] fields are cleared, or when MU is reset. 0b - No request sent 1b - Request sent
3 FUP	MUA Flag Update Pending Indicates whether a flag update request is pending. MU generates this request when there is a change to the F*n*[2:0] bits of MUA_FCR. This field becomes 1 when the MUA side sends a flag update request to the MUB side. This field becomes 0 when MU acknowledges this flag update request internally (the flag is updated) from the MUB side, or during MU reset. No flag update changes are allowed when this field is 1. When FUP = 1, a write to the F*n*[2:0] bits of MUA_FCR does not generate a flag update event. The F*n*[2:0] bits do not change. If SR[EP] = 1 (event pending), writing to MUA_FCR does not immediately cause this field to become 1. 0b - No pending update flags (initiated by MUA) 1b - Pending update flags (initiated by MUA)
2 EP	MUA Side Event Pending Indicates a pending side event when the MUA side sends an event update request to the MUB side. An event is any hardware message that the Status register on the MUB side reflects. For example, an event occurs when Transmit register 0 is the target of a write operation. During normal operations, the update mechanism for this field operates automatically. MU clears this field automatically when the event update acknowledgment is received, or when MU resets. To ensure that events are posted to MUB before entering Stop mode, verify that this field is 0. If it is 1, wait and continue to poll this field before entering Stop mode until it becomes 0. Reading MUA_SR[EP] must be the last access to MUA. Perform this read operation before entering Stop or Wait mode. Otherwise, subsequent actions may cause this field to become 1. If MUB is in Stop mode and the MUA event is triggered, this field remains 1 until MUB wakes up.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Not pending 1b - Pending
1 —	Reserved
0 MURS	MUA and MUB Reset State Indicates the reset state of MUA and MUB. This field becomes 1 during any system reset or MU reset from the MUA or MUB side. This field becomes 0 when the reset sequence on both MUA and MUB sides ends. After issuing any of the aforementioned reset events, verify that this field is 0 before starting any access. 0b - Out of reset 1b - In reset

51.7.1.6 Core Control 0 (CCR0)

Offset

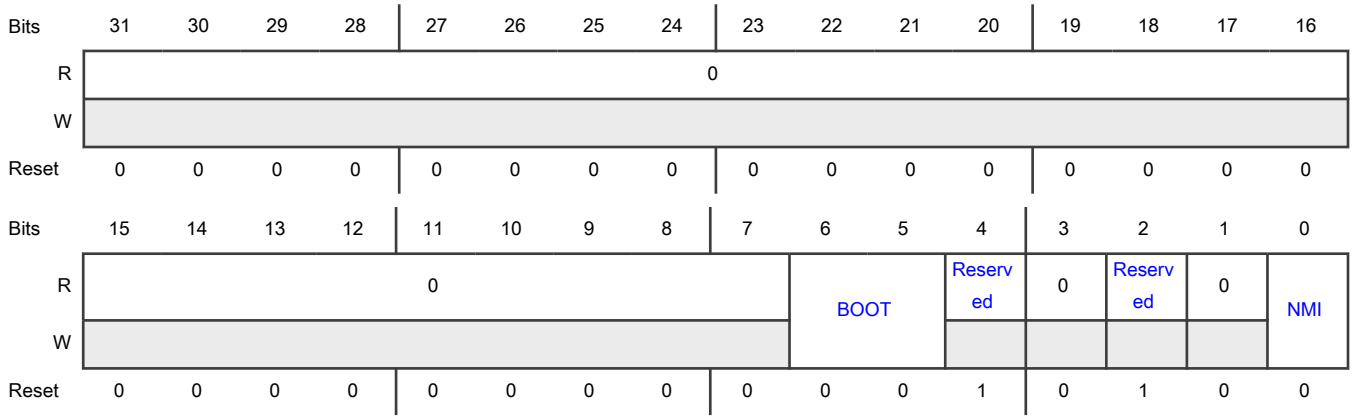
Register	Offset
CCR0	10h

Function

Allows MUA to control the processor on the MUB side.

Also allows control of the processor A hardware reset mask.

Diagram



Fields

Field	Function
31-7 —	Reserved
6-5 BOOT	Target Processor B Boot Configuration Configures the boot source for processor B when it is the target core. See the chip-specific details for more information on boot options. 00b - Processor Boot option 0 = 0x2002_0000 01b - Processor Boot option 1 = 0x2002_8000 10b - Processor Boot option 2 = 0x2003_0000 11b - Processor Boot option 3 = Reserved
4 —	Reserved
3 —	Reserved
2 —	Reserved
1 —	Reserved
0 NMI	MUB Nonmaskable Interrupt Request Indicates whether Processor A has issued a nonmaskable interrupt to Processor B. When this field becomes 1, it initiates a nonmaskable interrupt to processor B. This field becomes 0 after 1 is written to MUB_CSSR0[NMIC] to clear that field. After this field becomes 0, MUA can initiate another nonmaskable interrupt to MUB. This field is cleared when MU resets. 0b - Nonmaskable interrupt not issued 1b - Nonmaskable interrupt issued

51.7.1.7 Core Interrupt Enable 0 (CIER0)

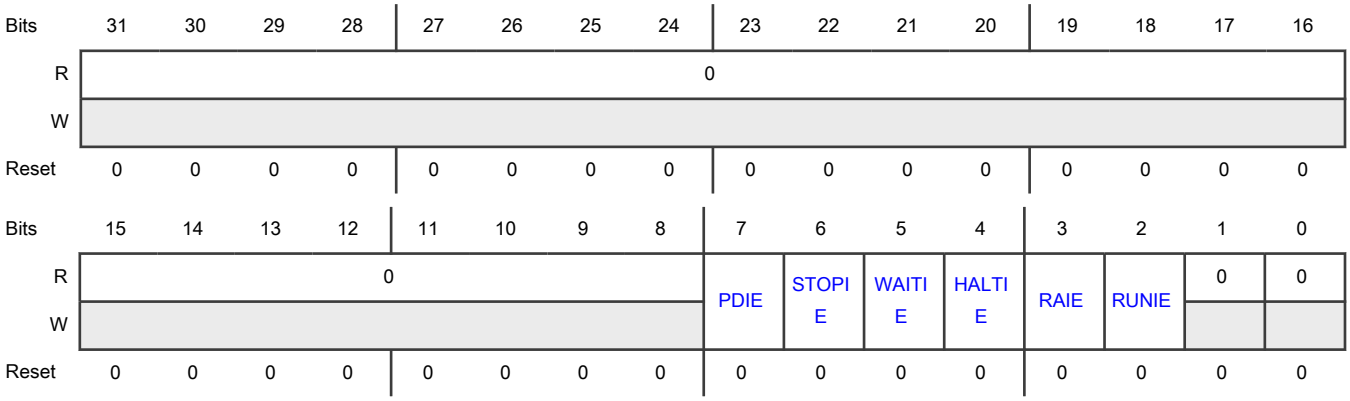
Offset

Register	Offset
CIER0	14h

Function

Controls interrupt enables.

Diagram



Fields

Field	Function
31-8 —	Reserved
7 PDIE	Processor B Power-Down Mode Entry Interrupt Enable Enables processor A Power-Down Mode Entry Interrupt request due to Processor B Power-Down mode entry. If the value of this field is 1, an MU Power-Down mode Entry Interrupt is issued to Processor A when MUA_CSSR0[PD] = 1. If the value of this field is 0, MU ignores the value of MUA_CSSR0[PD] and no MU Power-Down mode Entry Interrupt is issued. 0b - Disable 1b - Enable
6 STOPIE	Processor B Stop Mode Entry Interrupt Enable Enables Processor A Stop Mode Entry Interrupt request due to Processor B Stop mode entry. If the value of this field is 1, an MU Stop Mode Entry Interrupt is issued to Processor A when MUA_CSSR0[STOP] = 1. If the value of this field is 0, MU ignores the value of MUA_CSSR0[STOP] and no MU Stop Mode Entry Interrupt is issued. 0b - Disable 1b - Enable
5 WAITIE	Processor B Wait Mode Entry Interrupt Enable Enables Processor A Wait Mode Entry Interrupt request due to Processor B Wait Mode Entry.

Table continues on the next page...

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Field	Function
	If the value of this field is 1, an MU Wait Mode Entry Interrupt is issued to the processor A when MUA_CSSR0[WAIT] = 1. If the value of this field is 0, MU ignores the value of MUA_CSSR0[WAIT] and no MU Wait Mode Entry Interrupt is issued. 0b - Disable 1b - Enable
4 HALTIE	Processor B Halt Mode Entry Interrupt Enable Enables Processor A Halt Mode Entry Interrupt request due to Processor B Halt Mode Entry. If the value of this field is 1, an MU Halt Mode Entry Interrupt is issued to the Processor A when MUA_CSSR0[HALT] = 1. If the value of this field is 0, MU ignores the value of MUA_CSSR0[HALT] and no MU Halt Mode Entry Interrupt is issued. 0b - Disable 1b - Enable
3 RAIE	Processor B Reset Assertion Interrupt Enable Enables Processor A Reset Assertion Interrupt request due to Processor B reset assertion. If the value of this field is 1, an MU reset interrupt is issued to Processor A when MUA_CSSR0[RAIP] = 1. If the value of this field is 0, MU ignores the value of MUA_CSSR0[RAIP] and no MU reset interrupt is issued. 0b - Disable 1b - Enable
2 RUNIE	Processor B Run Mode Entry Interrupt Enable Enables Processor A Run Mode Entry Interrupt request due to Processor B Run Mode Entry. If the value of this field is 1, an MU Run Mode Entry Interrupt is issued to Processor A when MUA_CSSR0[RUN] = 1. If the value of this field is 0, MU ignores the value of MUA_CSSR0[RUN] and no MU Run Mode Entry Interrupt is issued. 0b - Disable 1b - Enable
1 —	Reserved
0 —	Reserved

51.7.1.8 Core Sticky Status 0 (CSSR0)

Offset

Register	Offset
CSSR0	18h

Function

Shows the status of interrupts pending (W1C).

The reset value is chip-specific.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								PD	STOP	WAIT	HALT	RAIP	RUN	0	NMIC
W									W1C	W1C	W1C	W1C	W1C	W1C		W1C
Reset	0	0	0	0	0	0	0	0	u	u	u	u	u	u	0	u

Fields

Field	Function
31-8 —	Reserved
7 PD	Processor B Power-Down mode Entry Interrupt Pending Flag Indicates to Processor A whether Processor B has entered Power-Down mode. This flag is set after Processor B enters Power-Down mode. If CIER0[PDIE] enables the interrupt, the Processor A Power-Down mode Entry Interrupt request is issued when Processor B enters Power-Down mode. Clearing this flag also clears the MU Power-Down mode Entry Interrupt request. 0b - Processor B did not enter Power-Down mode. 1b - Processor B entered Power-Down mode.
6 STOP	Processor B Stop Mode Entry Interrupt Pending Flag Indicates to Processor A whether Processor B has entered Stop mode. This flag is set after Processor B enters Stop mode. If CIER0[STOPIE] enables the interrupt, the Processor A Stop Mode Entry Interrupt request is issued when Processor B enters Stop mode.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	Clearing this flag also clears the MU Stop Mode Entry Interrupt request. 0b - Processor B did not enter Stop mode. 1b - Processor B entered Stop mode.
5 WAIT	Processor B Wait Mode Entry Interrupt Pending Indicates to Processor A whether Processor B has entered Wait mode. This flag is set after Processor B enters Wait mode. If CIER0[WAITIE] enables the interrupt, the Processor A Wait Mode Entry Interrupt request is issued when Processor B enters Wait mode. Clearing this flag also clears the MU Wait Mode Entry Interrupt request. 0b - Processor B did not enter Wait Mode. 1b - Processor B entered Wait Mode.
4 HALT	Processor B Halt Mode Entry Interrupt Pending Flag Indicates to Processor A whether Processor B has entered Halt mode. This flag is set after Processor B enters Halt mode. If CIER0[HALTIE] enables the interrupt, the Processor A Halt Mode Entry Interrupt request is issued when Processor B enters Halt mode. Clearing this flag also clears the MU Halt Mode Entry Interrupt request. 0b - Processor B did not enter Halt Mode. 1b - Processor B entered Halt Mode.
3 RAIP	Processor B Reset Asserted Interrupt Pending Flag Indicates to Processor A whether Processor B has entered reset. This flag is set after Processor B enters reset. If CIER0[RAIE] enables the interrupt, the Processor A reset interrupt request is issued when Processor B enters reset. Clearing this flag also clears the MU reset interrupt request. When Processor A leaves reset, this flag is cleared. Processor A then monitors the reset of processor B and sets this flag when its reset asserts. 0b - Processor B did not enter reset. 1b - Processor B entered reset.
2 RUN	Processor B Run Mode Entry Interrupt Pending Flag Indicates to Processor A whether Processor B has entered Run mode. This flag is set after Processor B enters Run mode. If CIER0[RUNIE] enables the interrupt, the Processor A Run Mode Entry Interrupt request is issued when Processor B enters Run mode. Clearing this flag also clears the MU Run Mode Entry Interrupt request. 0b - Processor B did not enter Run mode. 1b - Processor B entered Run mode.
1	Reserved

Table continues on the next page...

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Field	Function
—	
0 NMIC	Processor A Nonmaskable Interrupt Clear Clears the nonmaskable interrupt (NMI) request from the MUB side. The MUA-side NMI service routine uses this field. Writing 1 to this field clears MUB_CCR0[NMI], deasserting the NMI request and enabling MUB_CCR0[NMI] to trigger another NMI request. This field always reads as 0, so you cannot poll it. You can only use this field as part of the NMI service routine, in which you must write 1 to this field only once. This field is cleared when MU resets. 0b - Default 1b - Clear MUB_CCR0[NMI]

51.7.1.9 Core Status 0 (CSR0)

Offset

Register	Offset
CSR0	1Ch

Function

Shows the status of core events.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								PD	STOP	WAIT	HALT	RAIP	RUN	0	0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Fields

Field	Function
31-8 —	Reserved
7 PD	Processor B Power-Down Mode Entry Indicates whether Processor B is in Power-Down mode. This field becomes 1 after Processor B enters Power-Down mode. This field becomes 0 after Processor B exits Power-Down mode. 0b - Not in Power-Down mode 1b - In Power-Down mode
6 STOP	Processor B Stop Mode Entry Indicates whether Processor B is in Stop mode. This field becomes 1 after Processor B enters Stop mode. This field becomes 0 after Processor B exits Stop mode. 0b - Not in Stop mode 1b - In Stop mode
5 WAIT	Processor B Wait Mode Entry Indicates whether Processor B is in Wait mode. This field becomes 1 after Processor B enters Wait mode. This field becomes 0 after Processor B exits Wait mode. 0b - Not in Wait mode 1b - In Wait mode
4 HALT	Processor B Halt Mode Entry Indicates whether Processor B is in Halt mode. This field becomes 1 after Processor B enters Halt mode. This field becomes 0 after Processor B exits Halt mode. 0b - Not in Halt mode 1b - In Halt mode
3 RAIP	Processor B Reset Asserted Interrupt Pending Indicates whether Processor B is in reset. This field becomes 1 after Processor B enters reset. This field becomes 0 when Processor B leaves reset. 0b - Not in reset 1b - In reset

Table continues on the next page...

Table continued from the previous page...

Field	Function
2 RUN	Processor B Run Mode Entry Indicates whether processor B is in Run mode. This field becomes 1 after Processor B enters Run mode. This field becomes 0 after Processor B exits Run mode. 0b - Not in Run Mode 1b - In Run Mode
1 —	Reserved
0 —	Reserved

51.7.1.10 Flag Control (FCR)

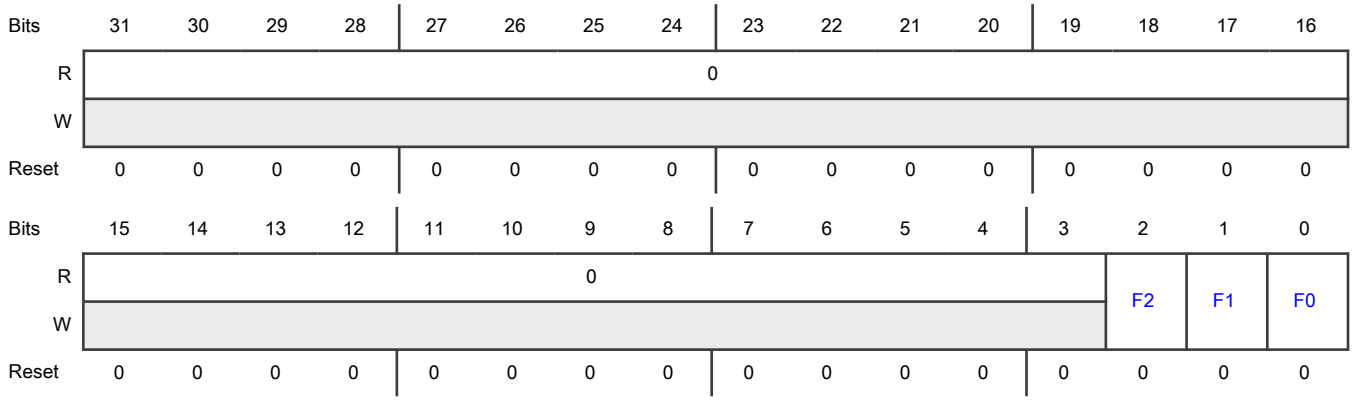
Offset

Register	Offset
FCR	100h

Function

Configures MUB_FSR[F*n*] flags.

Diagram



Fields

Field	Function
31-3 —	Reserved
2-0 Fn	MUA to MUB Flag Configures MUB_FSR[F*n*] flags, where *n* = 0 to 2. F*n* configures the corresponding MUB_FSR[F*n*] flag. F*n* becomes 0 when MU resets. 0b - Clear MUB_FSR[Fn] 1b - Set MUB_FSR[Fn]

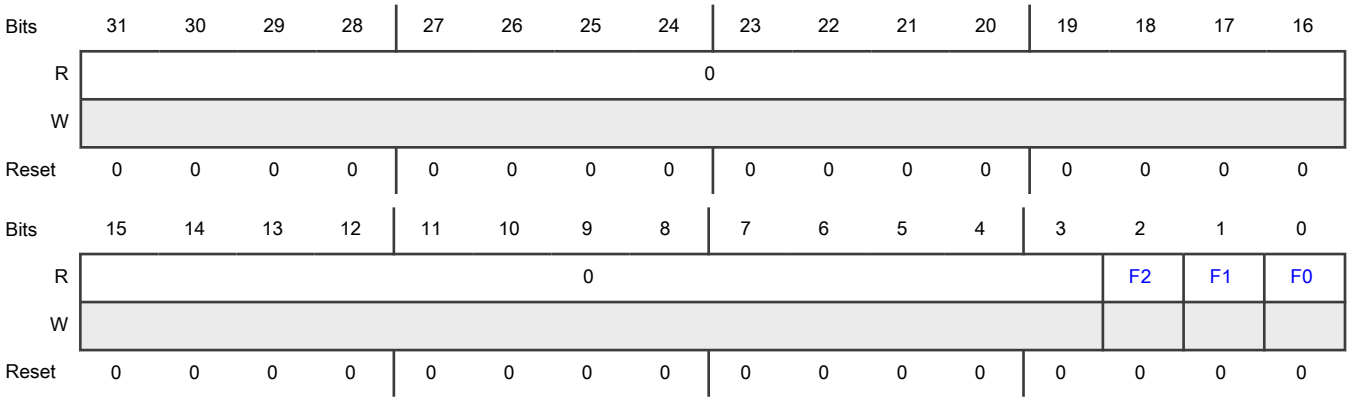
51.7.1.11 Flag Status (FSR)

Offset

Register	Offset
FSR	104h

Function
Contains flags configured by the values written to MUB_FCR[F*n*].

Diagram



Fields

Field	Function
31-3 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
2-0 Fn	MUB to MUA-Side Flag Contains flags configured by the values written to MUB_FCR[F*n*], where *n* = 0 to 2. F*n* is the MUA-side flag configured by the values written to MUB_FCR[F*n*]. When MUB_FCR[F*n*] is written to, the write event updates MUA_FSR[F*n*], after the event update latency. 0b - MUB_FCR[Fn] = 0 1b - MUB_FCR[Fn] = 1

51.7.1.12 General-Purpose Interrupt Enable (GIER)

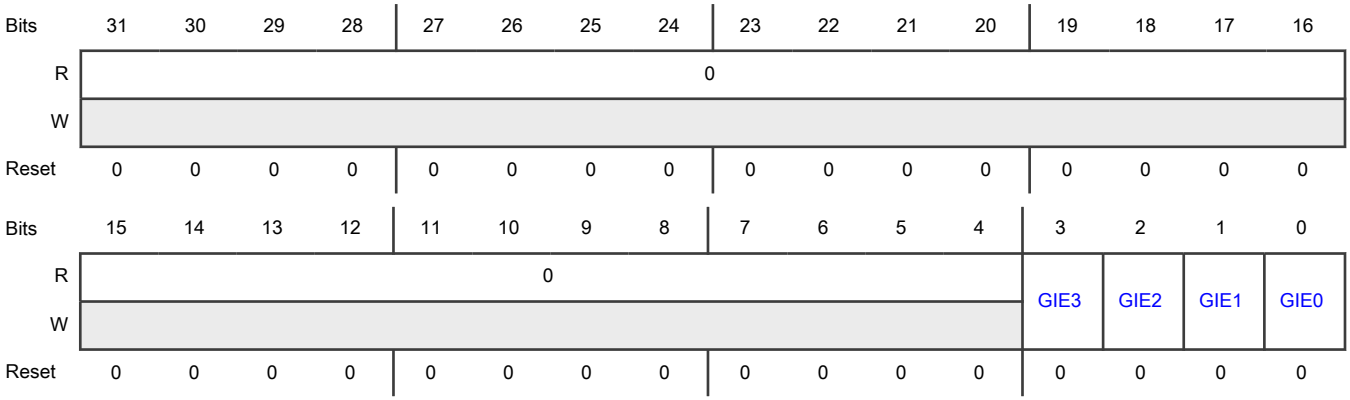
Offset

Register	Offset
GIER	110h

Function

Contains the MUA general-purpose interrupt enable fields.

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 GIEn	MUA General-purpose Interrupt Enable Enables general-purpose interrupt. There are 4 general-purpose interrupts (*n* = 0 to 3).

Table continues on the next page...

Table continued from the previous page...

Field	Function
	When GIE*n* = 1, a general-purpose interrupt *n* request is issued to processor A when MUA GSR[GIP*n*] = 1. If GIE*n* = 0, the general-purpose interrupt request pending does not trigger the general-purpose interrupt. GIE*n* becomes 0 when MU resets. 0b - Disable 1b - Enable

51.7.1.13 General-Purpose Control (GCR)

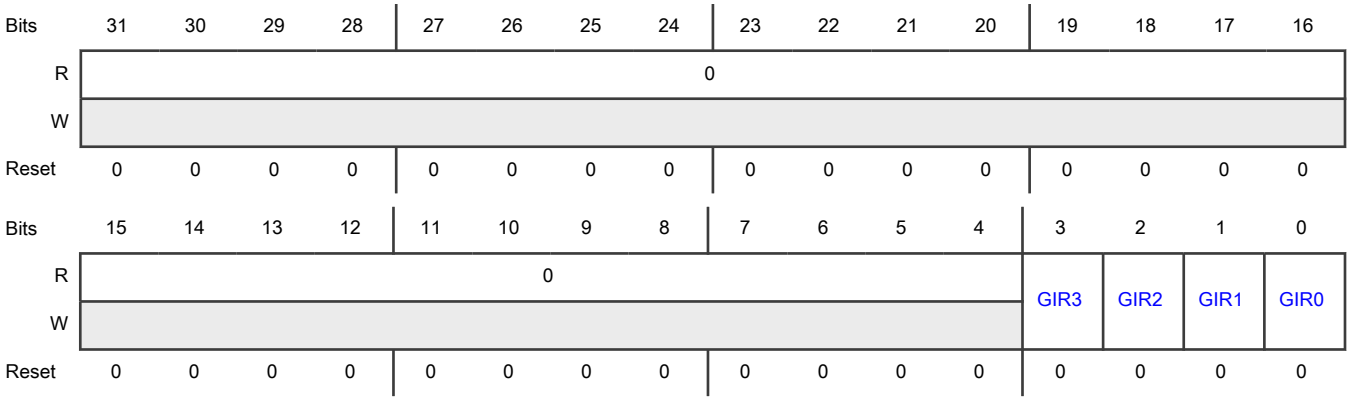
Offset

Register	Offset
GCR	114h

Function

Contains the MUA general-purpose interrupt request fields.

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 GIRn	MUA General-Purpose Interrupt Request Specifies whether general-purpose interrupts are requested to MUB. There are 4 general-purpose interrupts (*n* = 0 to 3).

Table continues on the next page...

Table continued from the previous page...

Field	Function
	Writing 1 to GIR*n* sets MUB_GSR[GIP*n*]. If MUB_GIER[GIE*n*] = 1, a general-purpose interrupt request is triggered on processor B. This field becomes 0 when MUB_GSR[GIP*n*] is cleared. This clearing informs MUA that the interrupt is accepted (cleared by software). To ensure proper operations, verify that GIR*n* is 0 (no pending interrupt) before writing 1 to it. This field becomes 0 when MU resets. 0b - Not requested 1b - Requested

51.7.1.14 General-purpose Status (GSR)

Offset

Register	Offset
GSR	118h

Function

Contains the status of the MUA general-purpose interrupt pending requests.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												GIP3	GIP2	GIP1	GIP0
W													W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-4 —	Reserved
3-0	MUA General-Purpose Interrupt Request Pending

Table continues on the next page...

Table continued from the previous page...

Field	Function
GIPn	Indicates whether a general-purpose interrupt request is pending. There are 4 general-purpose interrupts (*n* = 0 to 3). GIP*n* informs MUA that MUB_GCR[GIR*n*] changed from 0 to 1. If MUA_GIER[GIE*n*] = 1, a general-purpose interrupt request is issued to processor A. GIP*n* is cleared when MU resets. After GIP*n* is cleared, if MUA_GIER[GIE*n*] = 1, the general-purpose interrupt request is cleared on the MUA side. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not pending 1b - Pending When writing 0b - No effect 1b - Clear the flag

51.7.1.15 Transmit Control (TCR)

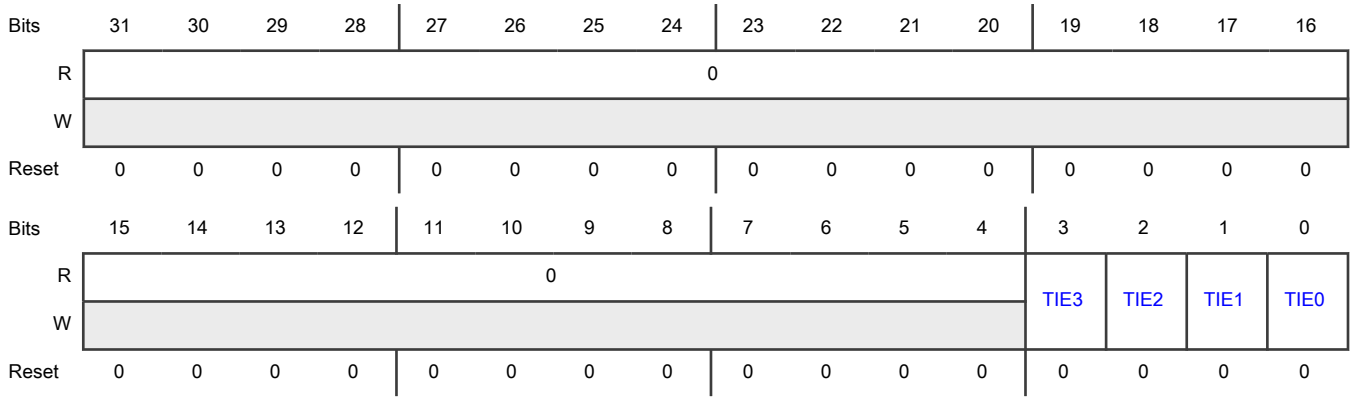
Offset

Register	Offset
TCR	120h

Function

Contains the MUA transmit interrupt enable fields.

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 TIEn	MUA Transmit Interrupt Enable Enables MUA transmit interrupt *n*, where *n* = 0 to 3. If this field is 1, an MUA transmit interrupt *n* request is issued when MUA_TSR[TE*n*] is set. If this field is 0, MU ignores the value of MUA_TSR[TE*n*], and no MUA transmit interrupt *n* request is issued. 0b - Disable 1b - Enable

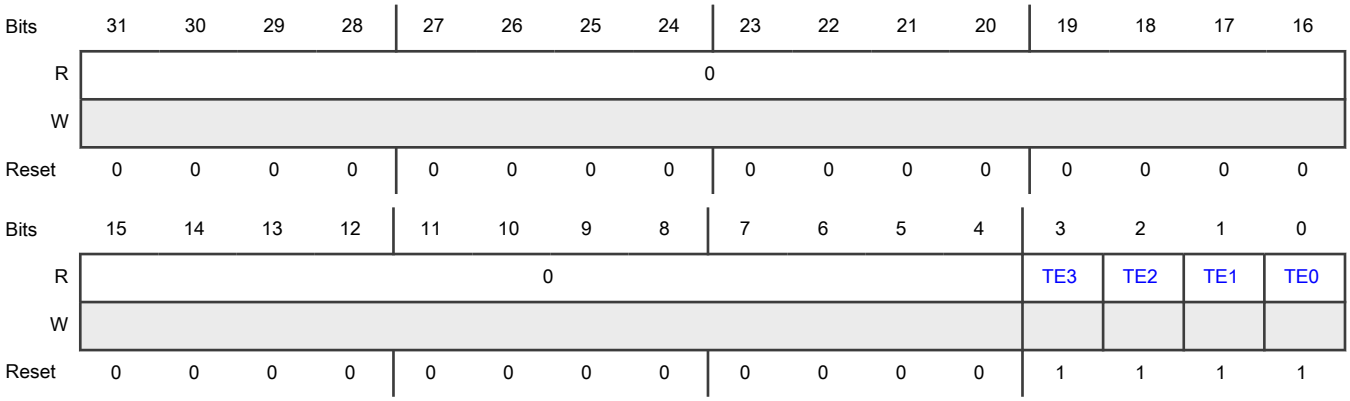
51.7.1.16 Transmit Status (TSR)

Offset

Register	Offset
TSR	124h

Function
Indicates whether the MUA transmit registers are empty.

Diagram



Fields

Field	Function
31-4 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
3-0 TEn	MUA Transmit Empty Indicates whether MUA Transmit (TR*n*) register is empty, where *n* = 0 to 3. This field becomes 1 after the MUB_RR*n* register is read on the MUB side. When TE*n* = 1, it indicates to the MUA side that the MUA_TR*n* register is ready to be written on the MUA side. If MUA_TCR[TIE*n*] = 1, a transmit *n* interrupt is issued on the MUA side. This field becomes 0 after the MUA_TR*n* register is written to on the MUA side. After this field becomes 0, if MUA_TCR[TIE*n*] = 1, the transmit *n* interrupt request is cleared on the MUA side. This field becomes 1 when MU resets. 0b - Not empty 1b - Empty

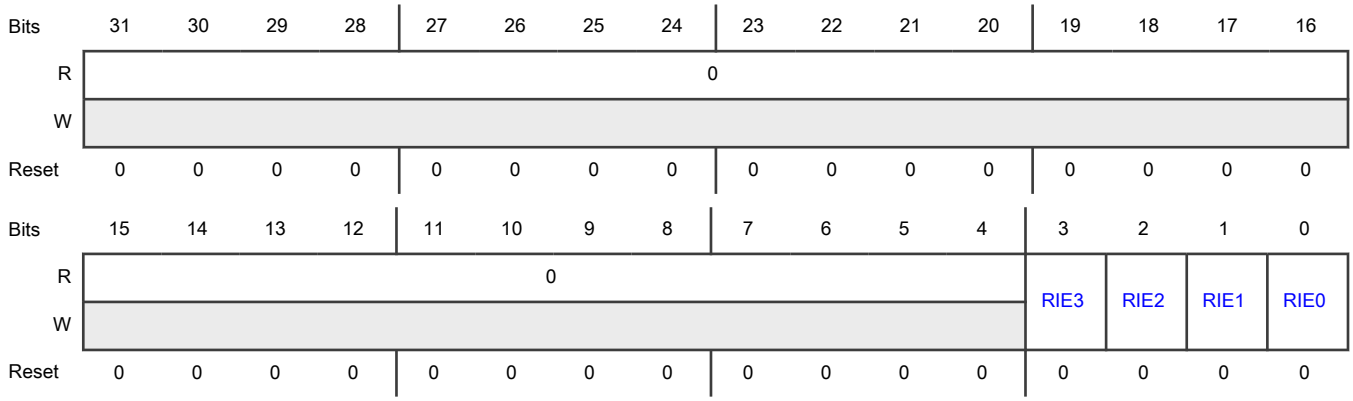
51.7.1.17 Receive Control (RCR)

Offset

Register	Offset
RCR	128h

Function
Contains the MUA receive interrupt enables.

Diagram



Fields

Field	Function
31-4 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
3-0 RIEn	MUA Receive Interrupt Enable Enables MUA receive interrupt *n*, where *n* = 0 to 3. If this field is 1, an MUA receive interrupt *n* request is issued when MUA_RSR[RF*n*] is set. If this field is 0, MU ignores the value of MUA_RSR[RF*n*], and no MUA receive interrupt request is issued. 0b - Disable 1b - Enable

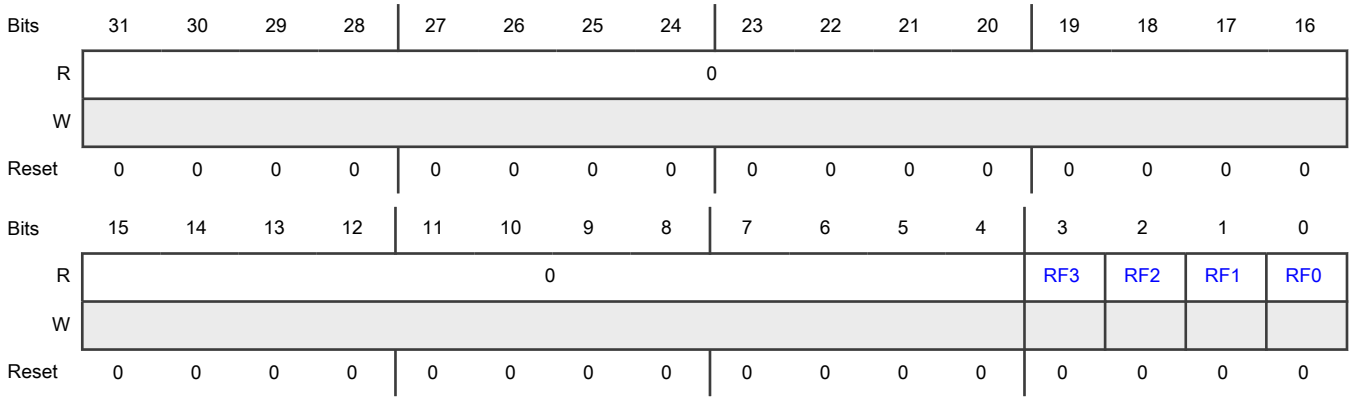
51.7.1.18 Receive Status (RSR)

Offset

Register	Offset
RSR	12Ch

Function
Indicates whether the MUA receive registers are full.

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 RFn	MUA Receive Register Full Indicates whether MUA Receive register (RR*n*) is full, where *n* = 0 to 3.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	RF*n* becomes 1 when the MUB_TR*n* register is written to on the MUB side. When RF*n* is 1, it indicates to the MUA side that new data in the MUA_RR*n* register is ready for MUA to read it. If MUA_RCR[RIE*n*] = 1, a receive *n* interrupt is issued on the MUA side. RF*n* becomes 0 when the MUA_RR*n* register is read, or when MU is reset. After RF*n* becomes 0, if MUA_RCR[RIE*n*] = 1, the receive *n* interrupt request is cleared on the MUA side. 0b - Not full 1b - Full

51.7.1.19 Transmit (TR0 - TR3)

Offset

Register	Offset
TR0	200h
TR1	204h
TR2	208h
TR3	20Ch

Function
Contains MUA transmit data.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W	TR_DATA															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W	TR_DATA															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0	MUA Transmit Data

Table continues on the next page...

Field	Function
TR_DATA	Contains MUA transmit data. MUB_RR*n* reflects the data written to this register. The TR*n* and RR*n* registers are not double-buffered. Writing to MUA_TR*n* overrides the data readable in the MUA_RR*n* register. A write to the Transmit register clears MUA_TSR[TE*n*] on the transmitter side, and sets MUB_RSR[RF*n*] on the receiver side. You can write to this register only when MUA_TSR[TE*n*] = 1. Reading this register returns all zeroes.

51.7.1.20 Receive (RR0 - RR3)

Offset

Register	Offset
RR0	280h
RR1	284h
RR2	288h
RR3	28Ch

Function

Contains MUA receive data.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	RR_DATA															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	RR_DATA															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 RR_DATA	MUA Receive Data Reflects the data written to MUB TR*n*.

Table continues on the next page...

Field	Function
	Reading this register clears MUA_RSR[RF*n*] on the receiver side, and sets MUB_TSR[TE*n*] on the transmitter side. You can read this register only when MUA_RSR[RF*n*] = 1. Reading it before MUA_RSR[RF*n*] becomes 1 may result in reading incorrect data. Poll MUA_RSR[RF*n*] to confirm it is set before reading RR*n*. Writing to this register generates an error response to MUA.

51.7.2 MUB register descriptions

This section contains the detailed register descriptions for MUB registers.

NOTE

A module transfer error to processor A or processor B is generated when:

- A read or write access is made to an invalid location.
- A write operation is performed on a read-only register on the processor A side or processor B side of MU.

51.7.2.1 MUB memory map

MU.MUB base address: E000_0000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID (VER)	32	R	0309_000Fh
4h	Parameter (PAR)	32	R	0304_0404h
8h	Control (CR)	32	RW	0000_0000h
Ch	Status (SR)	32	R	See section
10h	Core Control 0 (CCR0)	32	RW	0000_0000h
14h	Core Interrupt Enable 0 (CIER0)	32	R	0000_0000h
18h	Core Sticky Status 0 (CSSR0)	32	RW	See section
100h	Flag Control (FCR)	32	RW	0000_0000h
104h	Flag Status (FSR)	32	R	0000_0000h
110h	General-Purpose Interrupt Enable (GIER)	32	RW	0000_0000h
114h	General-Purpose Control (GCR)	32	RW	0000_0000h
118h	General-purpose Status (GSR)	32	RW	0000_0000h
120h	Transmit Control (TCR)	32	RW	0000_0000h
124h	Transmit Status (TSR)	32	R	0000_000Fh
128h	Receive Control (RCR)	32	RW	0000_0000h
12Ch	Receive Status (RSR)	32	R	0000_0000h
200h - 20Ch	Transmit (TR0 - TR3)	32	RW	0000_0000h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
280h - 28Ch	Receive (RR0 - RR3)	32	R	0000_0000h

51.7.2.2 Version ID (VER)

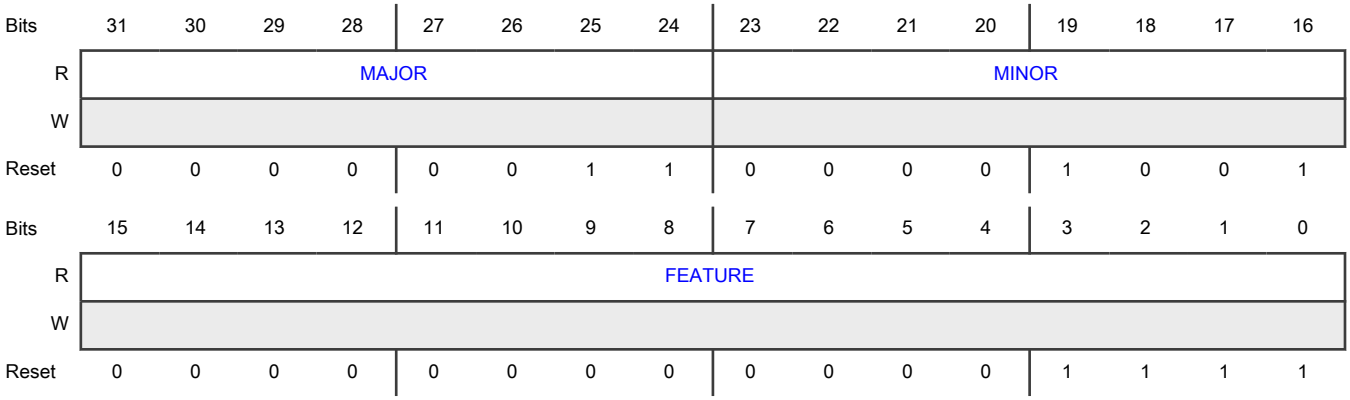
Offset

Register	Offset
VER	0h

Function

Determines the version ID and feature set number of MUB.

Diagram



Fields

Field	Function
31-24 MAJOR	Major Version Number
23-16 MINOR	Minor Version Number
15-0 FEATURE	Feature Set Number Indicates the feature set number. MU implements: • Standard features • Expanded number of TR*n*/RR*n* registers

51.7.2.3 Parameter (PAR)

Offset

Register	Offset
PAR	4h

Function

Defines the number of flags, transmit registers, receive registers, and general-purpose interrupt requests available for MU.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	FLAG_WIDTH								GIR_NUM							
W																
Reset	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	RR_NUM								TR_NUM							
W																
Reset	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0

Fields

Field	Function
31-24 FLAG_WIDTH	Flag Width Specifies the number of flag bits (3) in the Flag Control (FCR) and Flag Status (FSR) registers.
23-16 GIR_NUM	General-Purpose Interrupt Request Number Specifies the number of general-purpose interrupt requests available (4).
15-8 RR_NUM	Receive Register Number Specifies the number of receive registers (4).
7-0 TR_NUM	Transmit Register Number Specifies the number of transmit registers (4).

51.7.2.4 Control (CR)

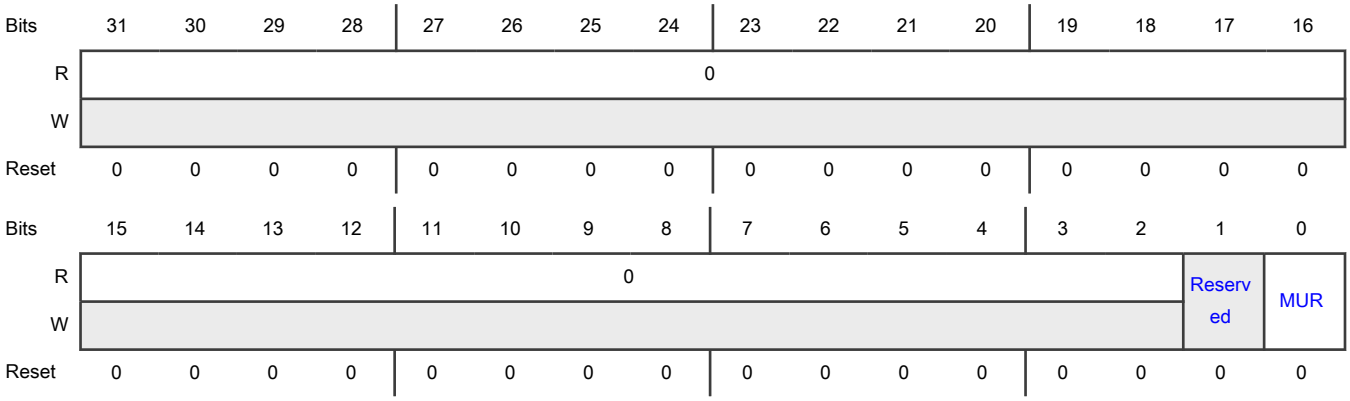
Offset

Register	Offset
CR	8h

Function

Controls MU reset and reset interrupt enable.

Diagram



Fields

Field	Function
31-2 —	Reserved
1 —	Reserved
0 MUR	MU Reset Resets MU. Writing 1 to this field resets the MUB and MUA sides. All internal states are cleared. It forces all control and status registers to return to their default values (except in MUB/A_CCR0 registers; MURS in MUB/A_SR registers). Before writing 1 to this field, interrupt processor A because writing 1 to this field may affect the ongoing processor A program. After writing 1 to this field, monitor the value of MUB_SR[MURS] to know when the reset sequence on the processor A-side has ended. This field always reads 0, and it becomes 0 during the MU reset sequence. 0b - Idle 1b - Reset

51.7.2.5 Status (SR)

Offset

Register	Offset
SR	Ch

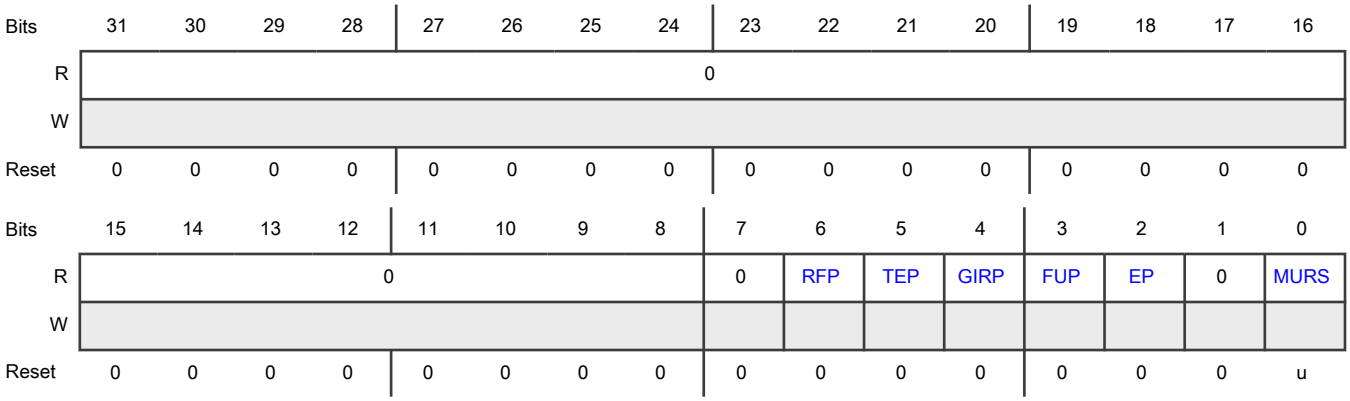
Function

Shows the status of MU resets and the status of pending events and requests.

NOTE

Writing to this register does not generate a transfer error.

Diagram



Fields

Field	Function
31-8 —	Reserved
7 —	Reserved
6 RFP	MUB Receive Full Pending Indicates whether a receive full message is pending. This field becomes 1 when MUA writes to a TR*n* register to send data to MUB. After this field becomes 1, MU checks RSR[RF*n*] to determine whether the data in the Receive register is ready for MUB to read it. This field becomes 0 when all MUB RR*n* registers are read, or when MU is reset. 0b - Not pending; MUA is not writing to a Transmit register 1b - Pending; MUA is writing to a Transmit register
5 TEP	MUB Transmit Empty Pending Indicates whether a transmit empty message is pending. This field becomes 1 when any TCR[TIE*n*] field is 1 and TSR[TE*n*] flag is set. After this field becomes 1, MU checks TSR[TE*n*] to determine whether the data in the Transmit (TR*n*) register is ready for MUB to write to it. This field becomes 0 when write operations to all MUB Transmit (TR*n*) registers where TCR[TIE*n*] = 1 (transfer interrupt enabled) are completed, or when MU is reset. 0b - No MUB transmit empty event pending

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Pending; any TCR[TIEn] field is 1 and TSR[TEn] flag is set
4 GIRP	MUB General-Purpose Interrupt Pending Indicates that MUA has sent a general-purpose interrupt request. This field becomes 1 when the MUA side sends a general-purpose interrupt request to the MUB side. GSR[GIP*n*] identifies which general-purpose interrupt request is received. This field becomes 0 when all MUB_GSR[GIP*n*] fields are cleared, or when MU is reset. 0b - No request sent 1b - Request sent
3 FUP	MUB Flag Update Pending Indicates whether a flag update request is pending. MU generates this request when there is a change to the F*n*[2:0] bits of MUB_FCR. This field becomes 1 when the MUB side sends a flag update request to the MUA side. This field becomes 0 when MU acknowledges this flag update request internally (the flag is updated) from the MUA side, or during MU reset. No flag update changes are allowed when this field is 1. When FUP = 1, a write to the F*n*[2:0] bits of MUB_FCR does not generate a flag update event. The F*n*[2:0] bits do not change. If SR[EP] = 1 (event pending), writing to MUB_FCR does not immediately cause this field to become 1. 0b - No pending update flags (initiated by MUB) 1b - Pending update flags (initiated by MUB)
2 EP	MUB Side Event Pending Indicates a pending side event when the MUB side sends an event update request to the MUA side. An event is any hardware message that the Status register on the MUA side reflects. For example, an event occurs when Transmit register 0 is the target of a write operation. During normal operations, the update mechanism for this field operates automatically. MU clears this field automatically when the event update acknowledgment is received, or when MU resets. To ensure that events are posted to MUA, verify that this field is 0. If it is 1, wait and continue to poll this field until it becomes 0. 0b - Not pending 1b - Pending
1 —	Reserved
0 MURS	MUA and MUB Reset State Indicates the reset state of MUA and MUB. This field becomes 1 during any system reset or MU reset from the MUA or MUB side.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	This field becomes 0 when the reset sequence on both MUA and MUB sides ends. After issuing any of the aforementioned reset events, verify that this field is 0 before starting any access. 0b - Out of reset 1b - In reset

51.7.2.6 Core Control 0 (CCR0)

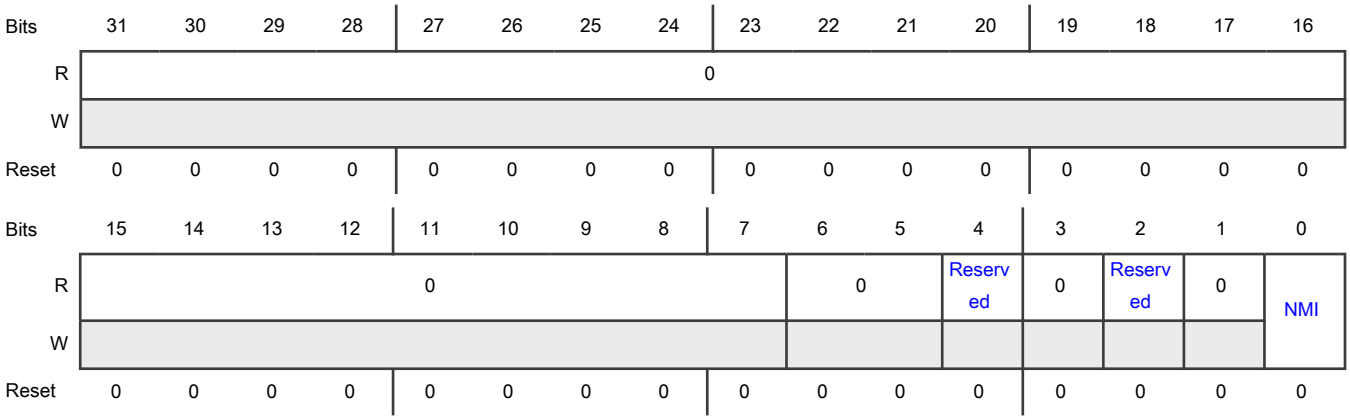
Offset

Register	Offset
CCR0	10h

Function

Allows MUB to control the processor on the MUA side.

Diagram



Fields

Field	Function
31-7 —	Reserved
6-5 —	Reserved
4 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
3 —	Reserved
2 —	Reserved
1 —	Reserved
0 NMI	MUA Nonmaskable Interrupt Request Indicates whether Processor B has issued a nonmaskable interrupt to Processor A. When this field becomes 1, it initiates a nonmaskable interrupt to processor A. This field becomes 0 after 1 is written to MUA_CSSR0[NMIC] to clear that field. After this field becomes 0, MUB can initiate another nonmaskable interrupt to MUA. This field is cleared when MU resets. 0b - Nonmaskable interrupt not issued 1b - Nonmaskable interrupt issued

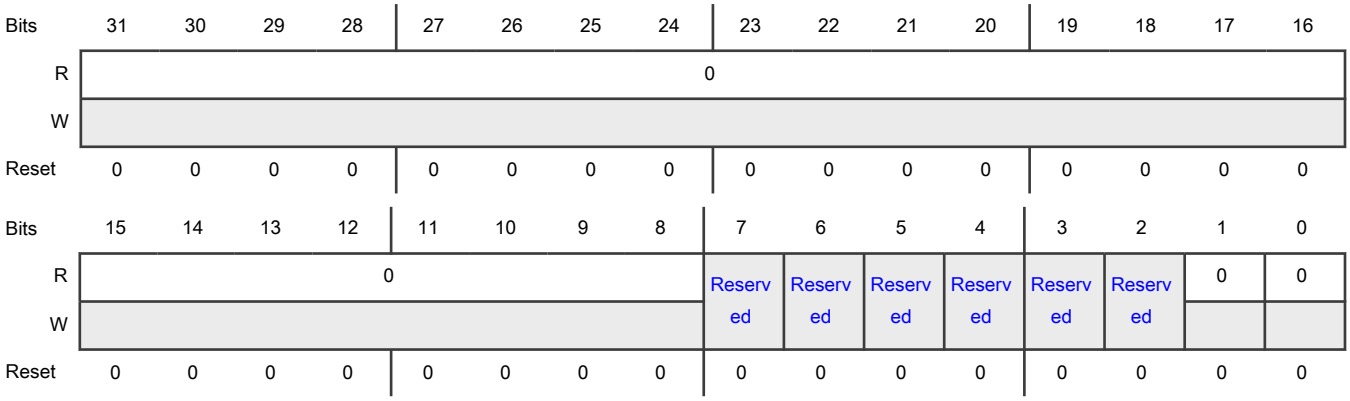
51.7.2.7 Core Interrupt Enable 0 (CIER0)

Offset

Register	Offset
CIER0	14h

Function
Controls interrupt enables.

Diagram



Fields

Field	Function
31-8 —	Reserved
7 —	Reserved
6 —	Reserved
5 —	Reserved
4 —	Reserved
3 —	Reserved
2 —	Reserved
1 —	Reserved
0 —	Reserved

51.7.2.8 Core Sticky Status 0 (CSSR0)

Offset

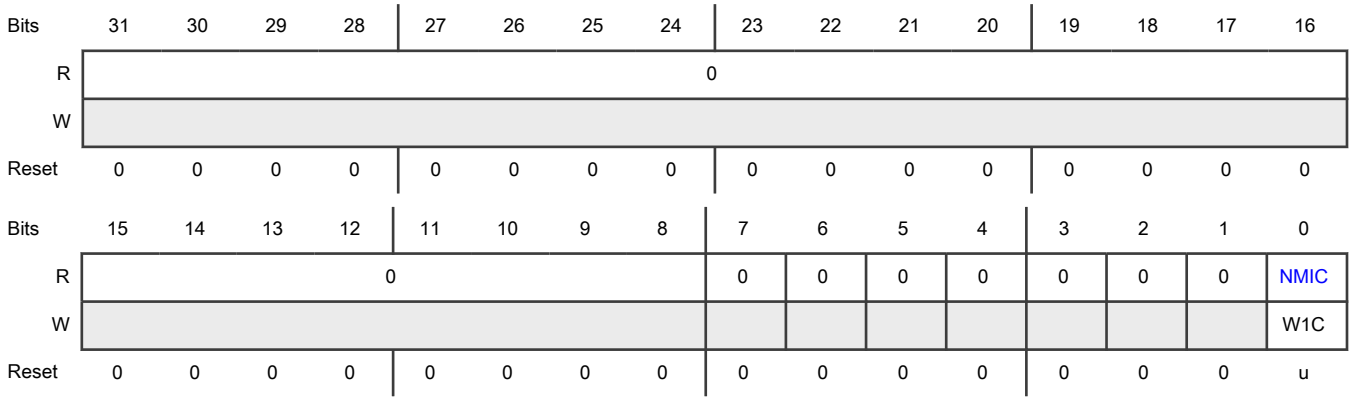
Register	Offset
CSSR0	18h

Function

Shows the status of interrupts pending (W1C).

The reset value is chip-specific.

Diagram



Fields

Field	Function
31-8 —	Reserved
7 —	Reserved
6 —	Reserved
5 —	Reserved
4 —	Reserved
3 —	Reserved
2 —	Reserved
1 —	Reserved
0 NMIC	Processor B Nonmaskable Interrupt Clear Clears the nonmaskable interrupt (NMI) request from the MUA side. The MUB-side NMI service routine uses this field. Writing 1 to this field clears MUA_CCR0[NMI], deasserting the NMI request and enabling MUA_CCR0[NMI] to trigger another NMI request.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	This field always reads as 0, so you cannot poll it. You can only use this field as part of the NMI service routine, in which you must write 1 to this field only once. This field is cleared when MU resets. 0b - Default 1b - Clear MUA_CCR0[NMI]

51.7.2.9 Flag Control (FCR)

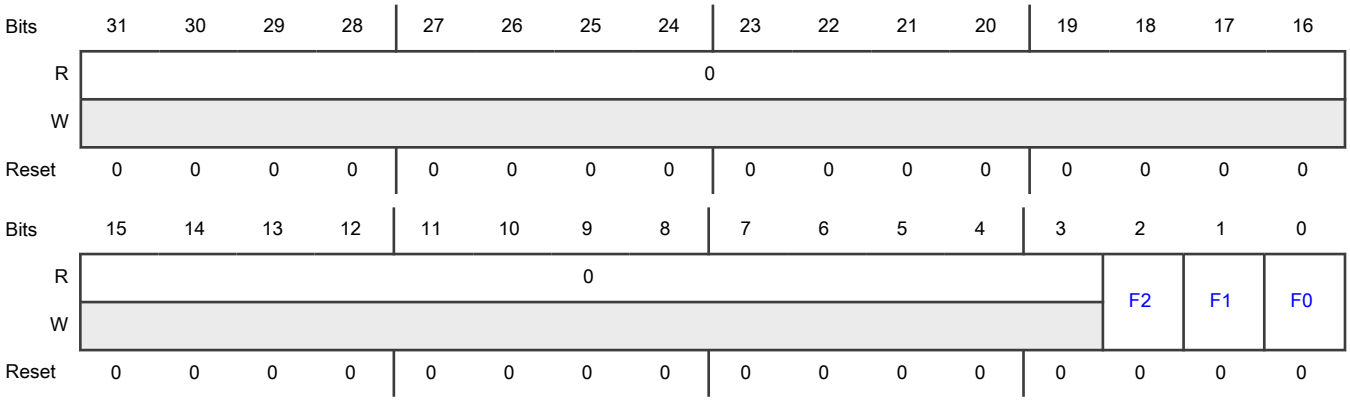
Offset

Register	Offset
FCR	100h

Function

Configures MUA_FSR[F*n*] flags.

Diagram



Fields

Field	Function
31-3 —	Reserved
2-0 Fn	MUB to MUA Flag Configures MUA_FSR[F*n*] flags, where *n* = 0 to 2. F*n* configures the corresponding MUA_FSR[F*n*] flag. F*n* becomes 0 when MU resets.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Clear MUA_FSR[Fn] 1b - Set MUA_FSR[Fn]

51.7.2.10 Flag Status (FSR)

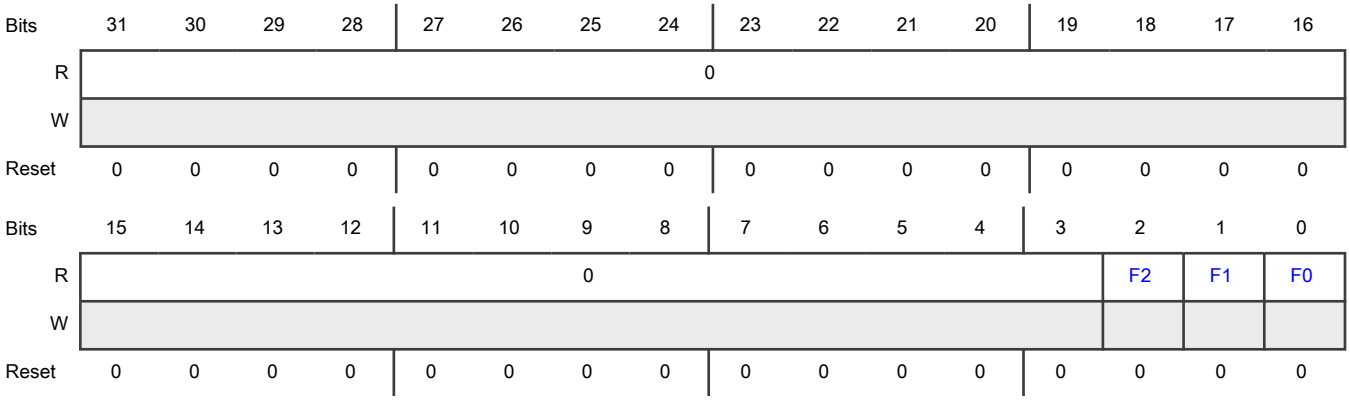
Offset

Register	Offset
FSR	104h

Function

Contains flags configured by the values written to MUA_FCR[F*n*].

Diagram



Fields

Field	Function
31-3 —	Reserved
2-0 Fn	MUA to MUB-Side Flag Contains flags configured by the values written to MUA_FCR[F*n*], where *n* = 0 to 2. F*n* is the MUB-side flag configured by the values written to MUA_FCR[F*n*]. When MUA_FCR[F*n*] is written to, the write event updates MUB_FSR[F*n*], after the event update latency. 0b - MUA_FCR[Fn] = 0 1b - MUA_FCR[Fn] = 1

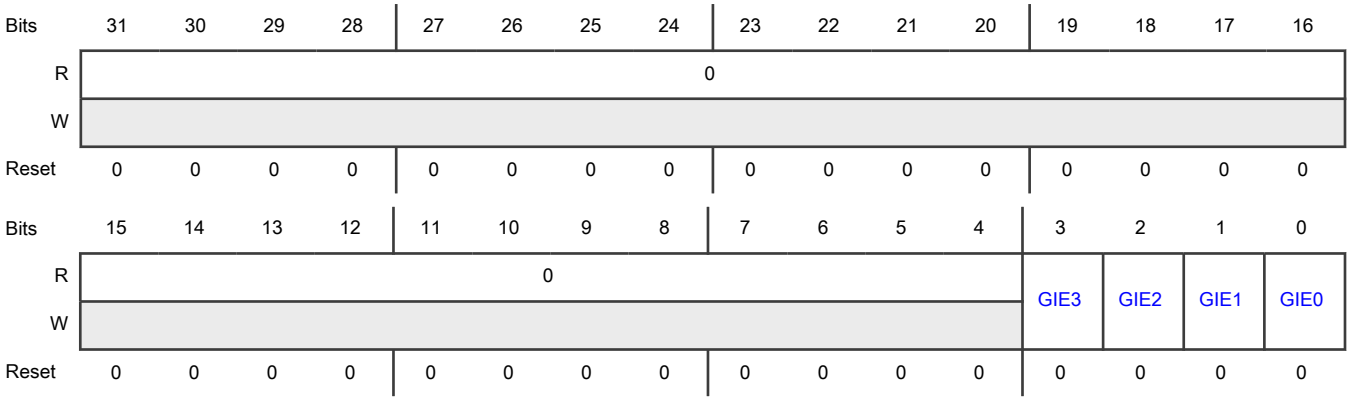
51.7.2.11 General-Purpose Interrupt Enable (GIER)

Offset

Register	Offset
GIER	110h

Function
Contains the MUB general-purpose interrupt enable fields.

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 GIEn	MUB General-purpose Interrupt Enable Enables general-purpose interrupt. There are 4 general-purpose interrupts (*n* = 0 to 3). When GIE*n* = 1, a general-purpose interrupt *n* request is issued to processor B when MUB GSR[GIP*n*] = 1. If GIE*n* = 0, the general-purpose interrupt request pending does not trigger the general-purpose interrupt. GIE*n* becomes 0 when MU resets. 0b - Disable 1b - Enable

51.7.2.12 General-Purpose Control (GCR)

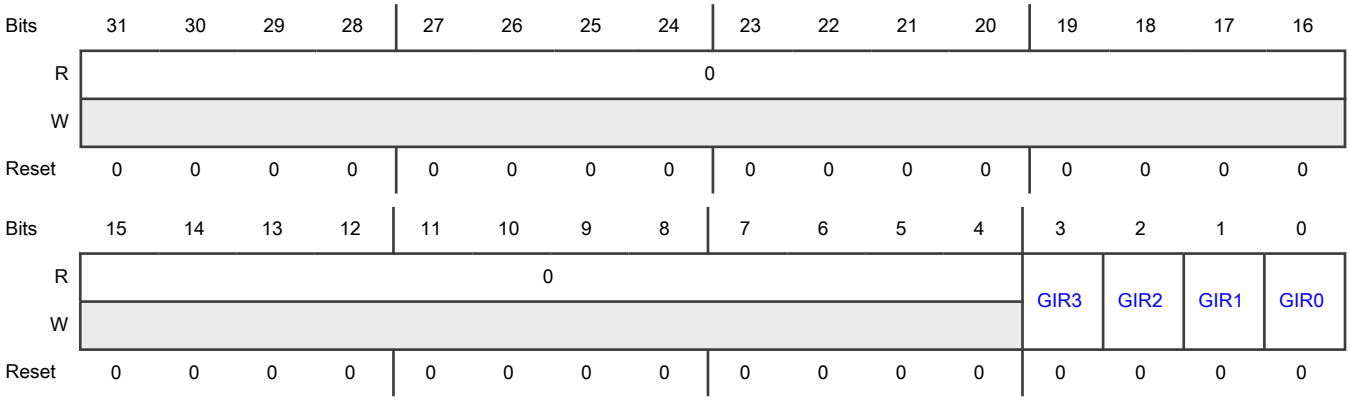
Offset

Register	Offset
GCR	114h

Function

Contains the MUB general-purpose interrupt request fields.

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 GIRn	MUB General-Purpose Interrupt Request Specifies whether general-purpose interrupts are requested to MUA. There are 4 general-purpose interrupts (*n* = 0 to 3). Writing 1 to GIR*n* sets MUA_GSR[GIP*n*]. If MUA_GIER[GIE*n*] = 1, a general-purpose interrupt request is triggered on processor A. This field becomes 0 when MUA_GSR[GIP*n*] is cleared. This clearing informs MUB that the interrupt is accepted (cleared by software). To ensure proper operations, verify that GIR*n* is 0 (no pending interrupt) before writing 1 to it. This field becomes 0 when MU resets. 0b - Not requested 1b - Requested

51.7.2.13 General-purpose Status (GSR)

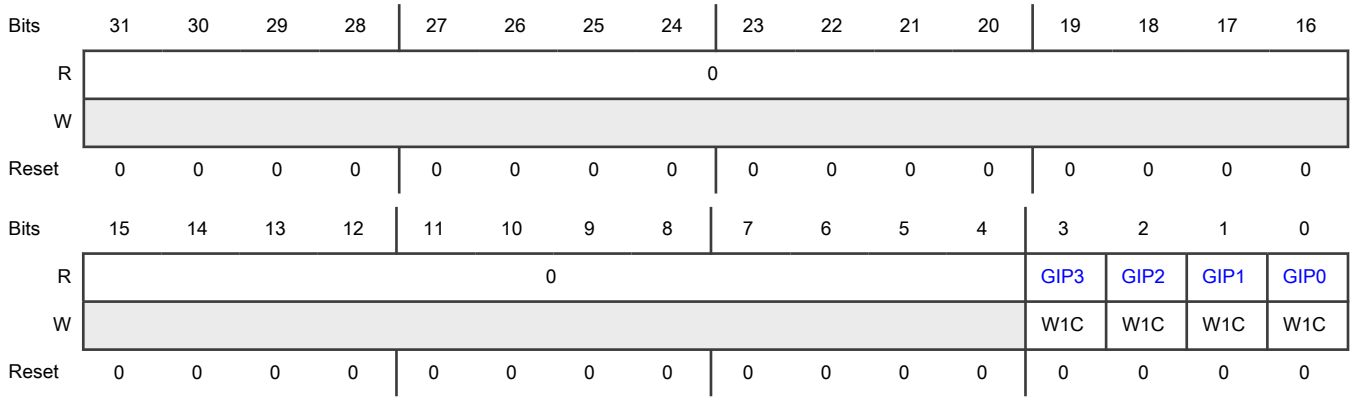
Offset

Register	Offset
GSR	118h

Function

Contains the status of the MUB general-purpose interrupt pending requests.

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 GIPn	MUB General-Purpose Interrupt Request Pending Indicates whether a general-purpose interrupt request is pending. There are 4 general-purpose interrupts (*n* = 0 to 3). GIP*n* informs MUB that MUA_GCR[GIR*n*] changed from 0 to 1. If MUB_GIER[GIE*n*] = 1, a general-purpose interrupt request is issued to processor B. GIP*n* is cleared when MU resets. After GIP*n* is cleared, if MUB_GIER[GIE*n*] = 1, the general-purpose interrupt request is cleared on the MUB side. **NOTE** This field behaves differently for register reads and writes. When reading 0b - Not pending 1b - Pending When writing 0b - No effect 1b - Clear the flag

51.7.2.14 Transmit Control (TCR)

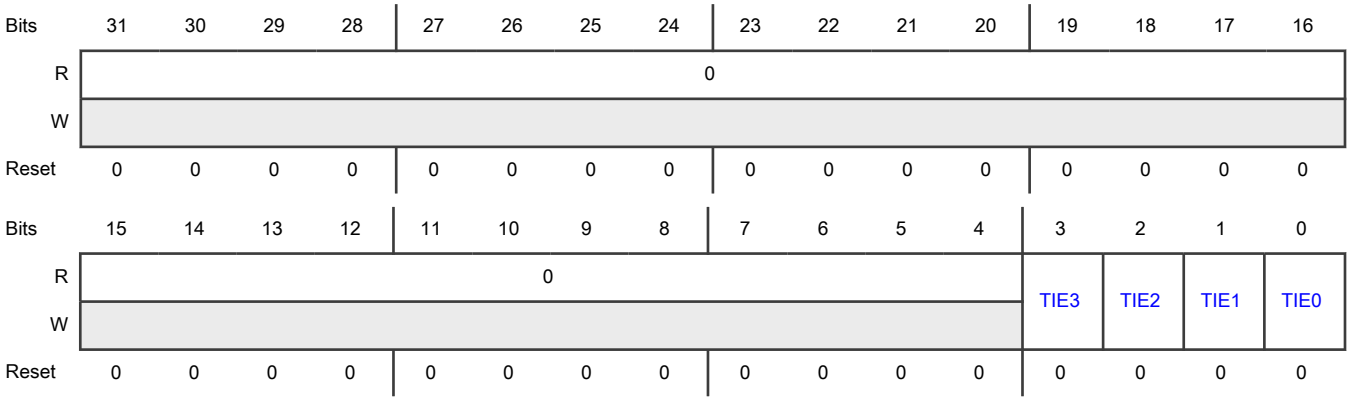
Offset

Register	Offset
TCR	120h

Function

Contains the MUB transmit interrupt enable fields.

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 TIEn	MUB Transmit Interrupt Enable Enables MUB transmit interrupt *n*, where *n* = 0 to 3. If this field is 1, an MUB transmit interrupt *n* request is issued when MUB_TSR[TE*n*] is set. If this field is 0, MU ignores the value of MUB_TSR[TE*n*], and no MUB transmit interrupt *n* request is issued. 0b - Disable 1b - Enable

51.7.2.15 Transmit Status (TSR)

Offset

Register	Offset
TSR	124h

Function

Indicates whether the MUB transmit registers are empty.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												TE3	TE2	TE1	TE0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1

Fields

Field	Function
31-4 —	Reserved
3-0 TEn	MUB Transmit Empty Indicates whether MUB Transmit (TR*n*) register is empty, where *n* = 0 to 3. This field becomes 1 after the MUA_RR*n* register is read on the MUA side. When TE*n* = 1, it indicates to the MUB side that the MUB_TR*n* register is ready to be written on the MUB side. If MUB_TCR[TIE*n*] = 1, a transmit *n* interrupt is issued on the MUB side. This field becomes 0 after the MUB_TR*n* register is written to on the MUB side. After this field becomes 0, if MUB_TCR[TIE*n*] = 1, the transmit *n* interrupt request is cleared on the MUB side. This field becomes 1 when MU resets. 0b - Not empty 1b - Empty

51.7.2.16 Receive Control (RCR)

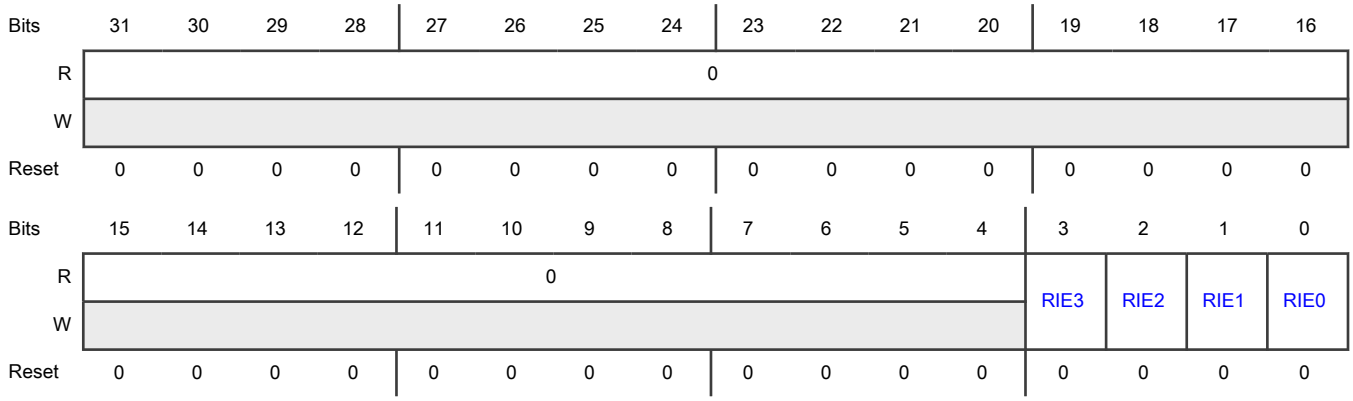
Offset

Register	Offset
RCR	128h

Function

Contains the MUB receive interrupt enables.

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 RIEn	MUB Receive Interrupt Enable Enables MUB receive interrupt *n*, where *n* = 0 to 3. If this field is 1, an MUB receive interrupt *n* request is issued when MUB_RSR[RF*n*] is set. If this field is 0, MU ignores the value of MUB_RSR[RF*n*], and no MUB receive interrupt request is issued. 0b - Disable 1b - Enable

51.7.2.17 Receive Status (RSR)

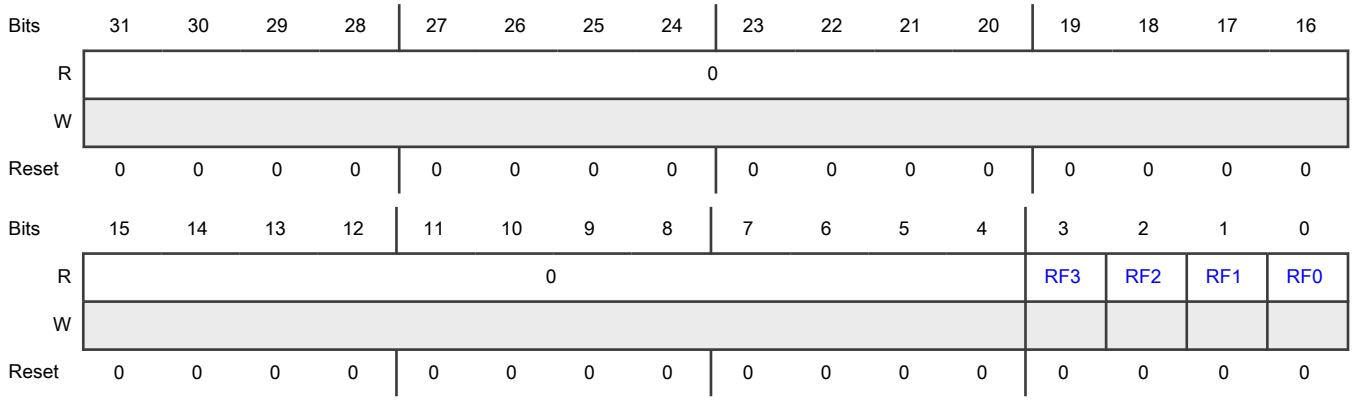
Offset

Register	Offset
RSR	12Ch

Function

Indicates whether the MUB receive registers are full.

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 RFn	MUB Receive Register Full Indicates whether MUB Receive register (RR*n*) is full, where *n* = 0 to 3. RF*n* becomes 1 when the MUA_TR*n* register is written to on the MUA side. When RF*n* is 1, it indicates to the MUB side that new data in the MUB_RR*n* register is ready for MUB to read it. If MUB_RCR[RIE*n*] = 1, a receive *n* interrupt is issued on the MUB side. RF*n* becomes 0 when the MUB_RR*n* register is read, or when MU is reset. After RF*n* becomes 0, if MUB_RCR[RIE*n*] = 1, the receive *n* interrupt request is cleared on the MUB side. 0b - Not full 1b - Full

51.7.2.18 Transmit (TR0 - TR3)

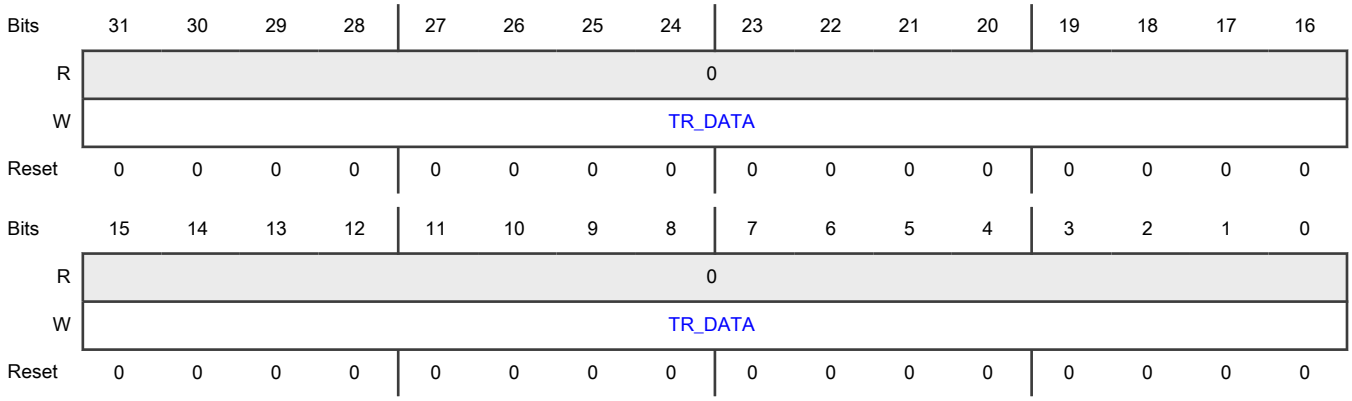
Offset

Register	Offset
TR0	200h
TR1	204h
TR2	208h
TR3	20Ch

Function

Contains MUB transmit data.

Diagram



Fields

Field	Function
31-0 TR_DATA	MUB Transmit Data Contains MUB transmit data. MUA_RR*n* reflects the data written to this register. The TR*n* and RR*n* registers are not double-buffered. Writing to MUB_TR*n* overrides the data readable in the MUA_RR*n* register. A write to the Transmit register clears MUB_TSR[TE*n*] on the transmitter side, and sets MUA_RSR[RF*n*] on the receiver side. You can write to this register only when MUB_TSR[TE*n*] = 1. Reading this register returns all zeroes.

51.7.2.19 Receive (RR0 - RR3)

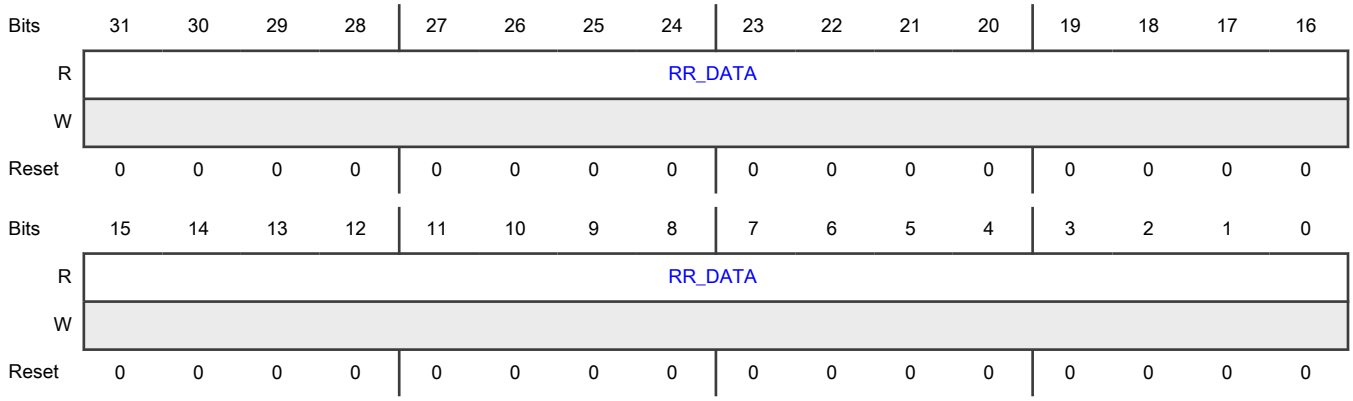
Offset

Register	Offset
RR0	280h
RR1	284h
RR2	288h
RR3	28Ch

Function

Contains MUB receive data.

Diagram



Fields

Field	Function
31-0 RR_DATA	MUB Receive Data Reflects the data written to MUA TR*n*. Reading this register clears MUB_RSR[RF*n*] on the receiver side, and sets MUA_TSR[TE*n*] on the transmitter side. You can read this register only when MUB_RSR[RF*n*] = 1. Reading it before MUB_RSR[RF*n*] becomes 1 may result in reading incorrect data. Poll MUB_RSR[RF*n*] to confirm it is set before reading RR*n*. Writing to this register generates an error response to MUB.

Chapter 52
Radio Platform

52.1 Chip-specific Radio Platform information

52.1.1 XTAL_OUT_EN

The XTAL_OUT_EN in this chapter is the RF_XTAL_OUT_ENABLE in the Package pinout.

52.2 Introduction

52.2.1 Introduction

The 2.4GHz Multi-Protocol Radio supports concurrent operation in the 2.4GHz bands.

The 2.4GHz band radio covers 2.36-2.4835GHz and is built to support multiple protocols.

- Bluetooth Low Energy v6.0 with support for optional features
  - Channel Sounding: Mandatory and Optional Features
  - 1Mbps
  - 2Mbps
  - Long Range 125kbps & 500kbps
- IEEE 802.15.4-2006 compliant PHY & MAC
  - Thread
  - Zigbee
- IEEE 802.15.4j-2012 Medical Body Area Network (MBAN) frequency bands spanning from 2360-2400MHz.
- Generic 2-level FSK/GFSK/MSK/GMSK
  - 250kbps
  - 500kbps
  - 1000kbps
  - 2000kbps
- Concurrent 802.15.4 and Bluetooth LE operation

The Radio block diagram is provided for illustration of the internal organization of the radio.

The Narrowband Unit (NBU) is a dedicated compute subsystem for the Narrowband Radio. The NBU is comprised of an Arm Cortex-M33 and associated peripherals that, in conjunction with the Bluetooth Unit, support the Bluetooth LE protocol. Among the supporting peripherals are timers, a messaging unit, and dedicated flash (distinct from the SoC flash). While the NBU allows for flexibility for evolving requirements, firmware to implement radio protocols is intended to be developed and delivered by NXP.

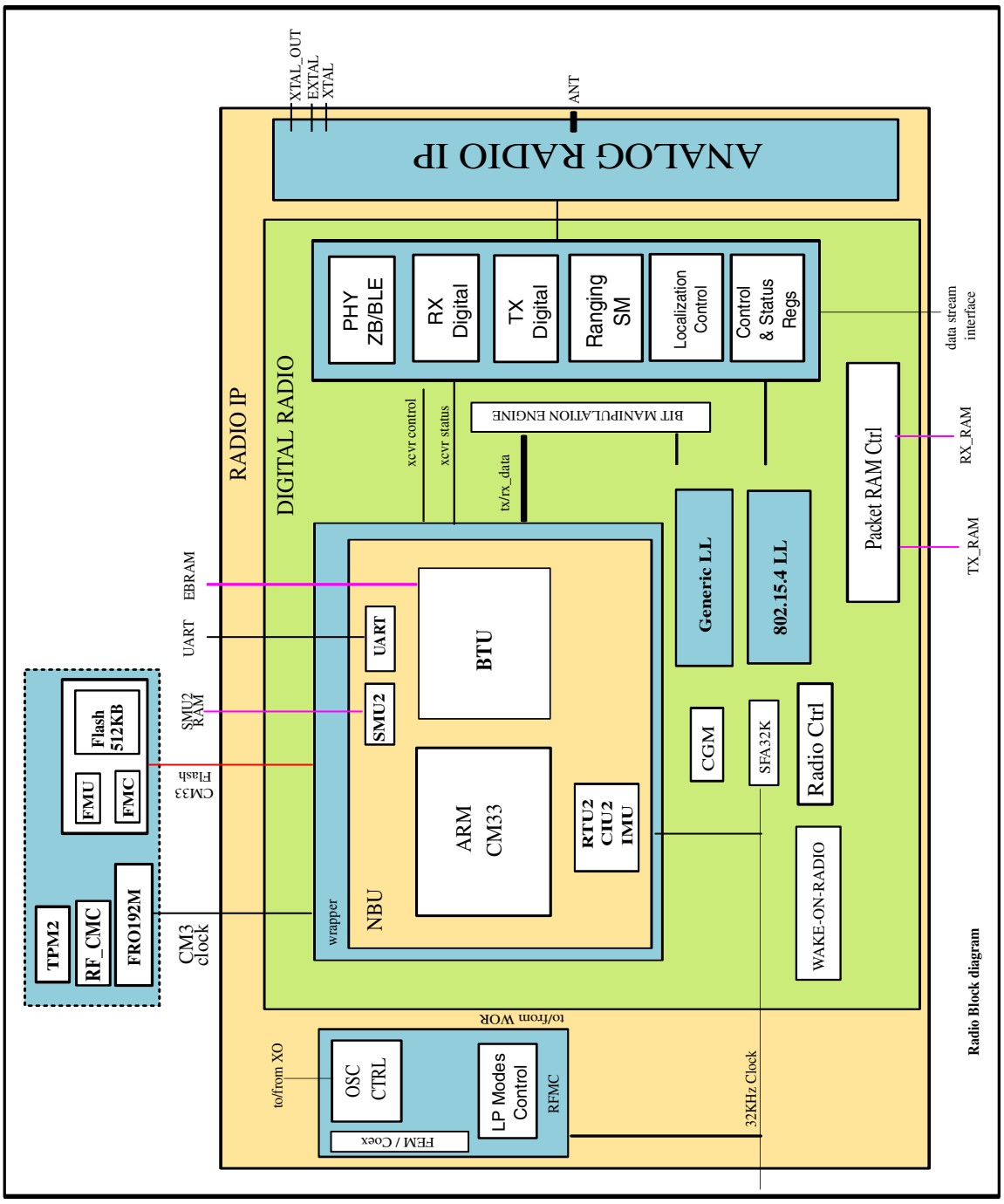


Figure 210. Radio Block diagram

52.2.2 Interface Specification

52.2.2.1 I/O Ports

This section describes all ports of the Radio IP at the top level.

52.2.2.1.1 Ports for XO and RFMC

The table below shows signals which are related to the XO or the RFMC .

Table 442. I/O Ports

Name	Size	Direction	Pad/ GPIO	Domain	ISO safe state value	Typ Switch Freq	Clock Domain	Test	Description
Analog/Power Interface									
EXTAL		IO	Pad	LDO_XO		40MHz	EXTAL		Input crystal waveform or square wave clock in bypass
XTAL		IO	Pad	LDO_XO		40MHz	EXTAL		Square wave oscillator output
XTAL_OUT		IO	Pad	LDO_XO			EXTAL		Buffered clock out for use by external device
DGO Interface - clock control									
ipp_do_xo_req_1p8v		O	GPIO	1p8v					To device external to the SoC to request clk to be input to RF XO.
ipp_ibe_xosc_ext_en_1p8v		O	GPIO	1p8v					Input Buffer Enable for above signal
ipp_ind_xosc_ext_en_1p8v		I	GPIO	1p8v					From device external to the SoC to request the RF Osc be enabled, for instance from WiFi chip.
DGO Interface - Coexistence / LANT / FAD									
ipp_ind_rf_nallowed_1p8v		I	GPIO	1p8v					Signal from external device indicating RF operation is not allowed
ipp_ibe_rf_nallowed_1p8v		O	GPIO	1p8v					Input Buffer Enable for above signals

52.2.2.1.2 Ports for 2.4GHz Radio

The table below shows signals which are specific to the 2.4GHz radio.

Table 443. I/O Ports

Name	Size	Direction	Pad/ GPIO	Domain	ISO safe state value	Typ Switch Freq	Clock Domain	Test	Description
Analog/Power Interface									
ANT		IO	Pad	VPA		2.4GHz			Antenna
GANT		IO	Pad	GND					Ground node for antenna to integrated balun
VDD_RF		IO	Pad	VDD_RF					Supply for Radio except for PA
GND_RF		IO	Pad	GND					Ground for Radio
VPA		IO	Pad	VPA					Supply for PA
DTEST/FPGA Interface									
ipp_do_dtest	13:0	O	GPIO	2.4 LV	0				DTEST data for 2.4GHz radio. Bus should present as coherent on the pads either by closing timing to ref clock or skew balancing.
ipp_obe_dtest	13:0	O	GPIO	2.4 LV	0				DTEST data for 2.4GHz radio. Bus should present as coherent on the pads either by closing timing to ref clock or skew balancing.
ipp_ind_dtest	13:0	I	GPIO	2.4 LV	0				
ipp_ibe_dtest	13:0	O	GPIO	2.4 LV	0				
ipp_ind_rf_fpga	5:0	I	GPIO	2.4 LV	0				
ipp_ibe_rf_fpga	5:0	O	GPIO	2.4 LV	0				

52.3 RFMC

52.3.1 Overview

The Radio Mode Controller (RFMC) is responsible for sequencing the power mode of the 2.4GHz radio domain and controlling the radio crystal oscillator (XO).

52.3.1.1 Block Diagram

The following diagram gives a high-level overview of the RFMC.

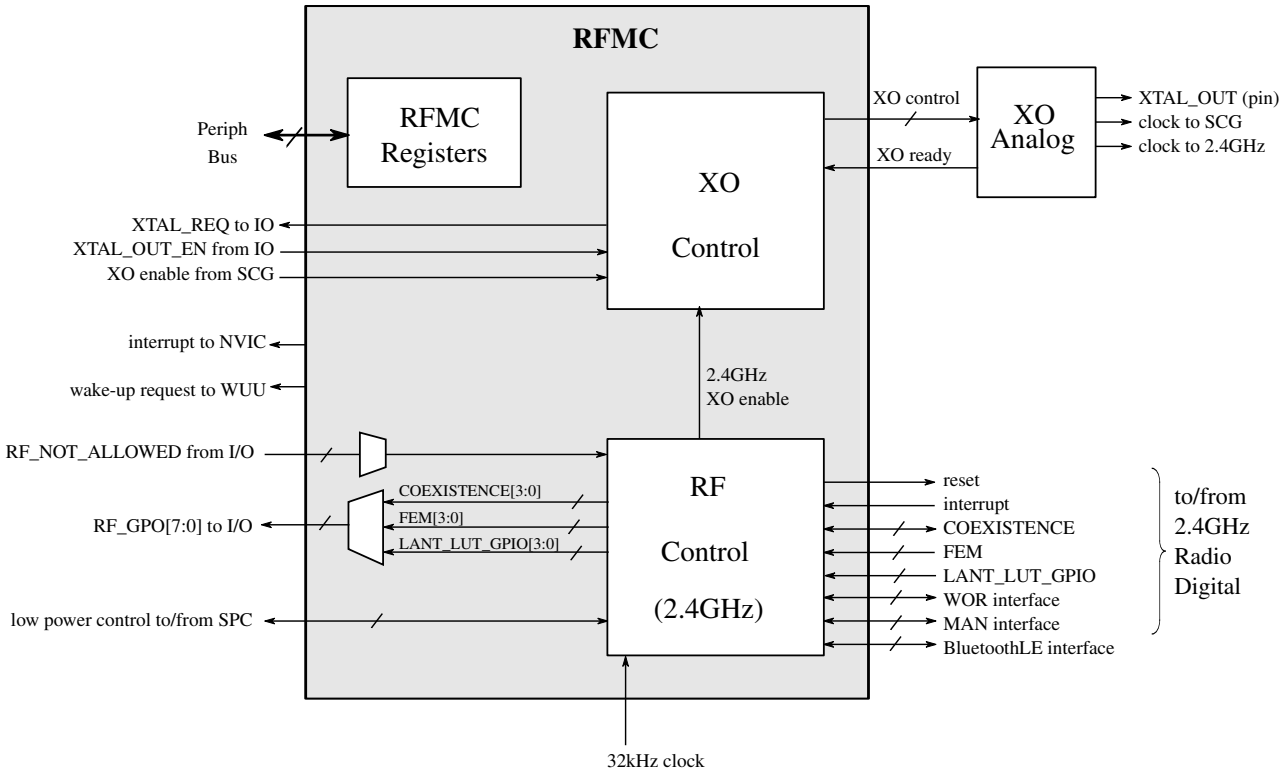


Figure 211. RFMC Block Diagram

52.3.1.2 Features

The Radio Mode Controller (RFMC) is responsible for sequencing the power mode of the 2.4GHz radio domain and controlling the radio crystal oscillator (XO). Specifically, it supports the following features:

- Support for Deep Sleep and Power Down modes.
- Low power mode entry/exit for the 2.4GHz radio power domain.
- Enable of XO supported from both internal and external sources.
- Support for external coexistence interface for 2.4GHz frequency band
- 32kHz timer to control low power entry/exit times via Wake on Radio (WOR) or Manual (MAN) counters.
- Timer offsets to ensure XO and radio power restored prior to WOR/MAN exit event.
- Interrupts supported for XO and low power radio wakeup events.

52.3.2 Functional description

52.3.2.1 XO Control

The XO Control sub-module is responsible for enabling the XO analog oscillator in response to a request from either the 2.4GHz radio, System Clock Generator (SCG) or an external request (XTAL_OUT_EN pin asserted). The clock output from the XO analog oscillator can be independently driven to 3 different clocking domains under RFMC control: 2.4GHz radio digital, SCG and XTAL_OUT pin. (Additional XO clock output(s) to the 2.4GHz radio analog blocks are not shown in the figures; this is enabled by TSM.) The figure below illustrates the logic implemented by the XO control sub-module to drive each of these domains.

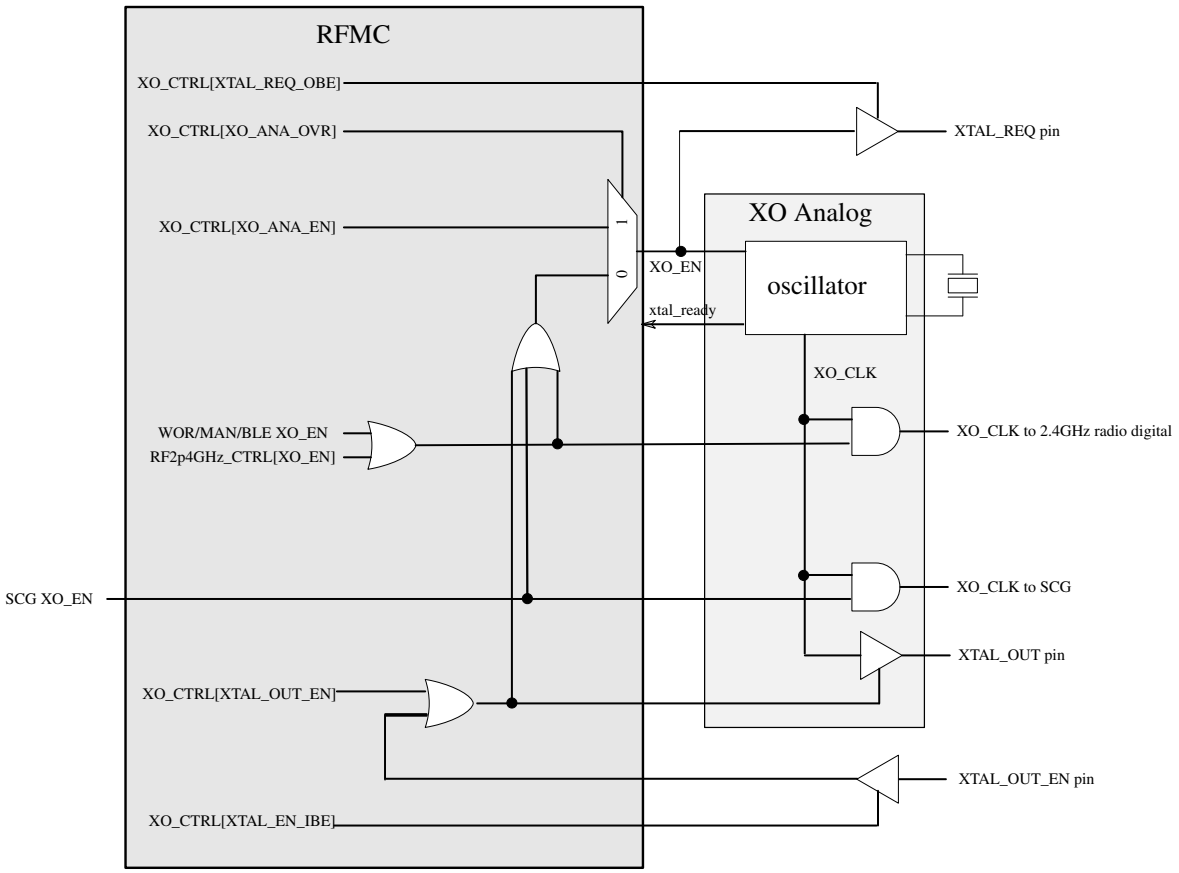


Figure 212. XO Control logic

The XO_CTRL[WKUP_OFFSET] can be used to pre-emptively enable the XO during a MAN/WOR wakeup sequence. This ensures the XO is ready and stable before the link layer begins operation at the designated MAN/WOR wakeup time.

Three flags with optional interrupts can be generated by the XO Control sub-module:

- RDY_FLAG: sets after the XO output is ready.
- INT_FLAG: sets when an internal source (SCG, 2.4GHz radio) has requested the XO.
- EXT_FLAG: sets when an external source (XTAL_OUT_EN pin) has requested the XO.

52.3.2.2 Low Power Mode Controllers

A major function of the RFMC is to control the power mode of the 2.4GHz radio . The RFMC itself resides in the system power domain and remains fully functional in all power modes except for Deep Power Down.

The 2.4GHz sub-module within the RFMC contains the following power controllers, any of which can be used to control low power entry/exit for the 2.4GHz radio:

- The MAN power controller can be used in conjunction with the Generic Link Layer or the 802.15.4 Link Layer. This controller is used to control the low power mode entry/exit time by programming the entry and wakeup time in the RFMC.
- The WOR power controller can be used in conjunction with the Generic Link Layer or the 802.15.4 Link Layer. This controller enters low power mode when directed -- and for the duration specified -- by the radio's WOR scheduler. The WOR scheduler is capable of scheduling multiple low power entry/exit and radio events.
- The Bluetooth LE power controller can only be used in conjunction with the Bluetooth LE Link Layer in the 2.4GHz radio. This power controller enters and exits low power as directed by the Bluetooth LE link layer in the radio. (Note that the Bluetooth

LE link layer controls a small amount of logic residing in the system power domain and which uses the 32kHz clock to keep track of time during low power mode.)

In addition to the power controllers, software can also set/clear the RF*_CTRL[LP_ENTER] bit to enter/exit low power mode.

When software or the power controller directs the radio to enter low power, the low power mode will be as selected as programmed by the RF*_CTRL[LP_MODE] bit field, which selects between the following:

- Deep Sleep: low power static mode with clocks gated, but all radio digital logic and SRAM state is retained.
- Power Down: full power down of all radio digital logic and SRAM.

Following a POR/LVD event, RF*_CTRL[LP_ENTER] is set and RF*_CTRL[LP_MODE] is configured such that both radios will initially be in Power Down mode until the RF*_CTRL[LP_ENTER] field is cleared.

The MAN, WOR and Bluetooth LE power controllers in the RFMC each implement its own state machine to sequence the radio in and out of low power modes. Each state machine implements the following states, which are also observable by reading the RF*_STAT[MAN/WOR/BLE_STATE] register fields:

- RESET: controller reset, waiting for controller to be enabled. Outputs set to XO_EN=0, RF_ACTIVE=0, LP_REQ=0.
- ACTIVE: radio in active mode. Outputs set to XO_EN=1, RF_ACTIVE=1, LP_REQ=0.
- SLEEP: radio in low power mode. Outputs set to XO_EN=0, RF_ACTIVE=0, LP_REQ=1.
- WKUP: radio begins transition to active mode. Outputs set to XO_EN=1, RF_ACTIVE=1 (after RF*_COEXT[RFACT_WKUP_DLY]), LP_REQ=0 (after RF*_CTRL[LP_WKUP_DLY]).

The following diagram shows the transitions between states for the power controllers.

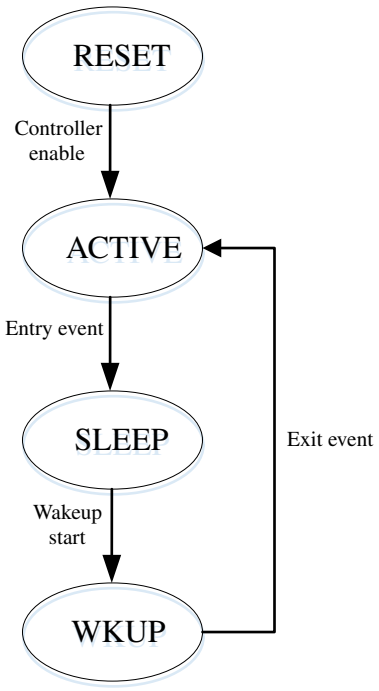


Figure 213. MAN/WOR/Bluetooth LE power control state diagram

Note that the transition from ACTIVE to SLEEP also depends on a "sleep ready" signal from the RF_CMC module, which ensures that other logic in the radio (especially the flash) is ready for the RFMC to put the radio is low power mode. This RF_CMC signal is reflected in the RF*_STAT[SLP_RDY_STAT] bit.

On transition from WKUP state to ACTIVE state, each power controller selected via RF*_CTRL[SFA_TRIG_EN] asserts a trigger to the SFA in the radio for one 32kHz clock cycle which will (if the SFA is properly configured) start a calibration cycle for the FRO32K clock.

To ensure correct sequencing of the radio power modes, it is recommended that only one of the power controllers be enabled at any given time. However, the RFMC does allow the MAN and WOR power controllers to be concurrently enabled in which case the radio will only enter low power when MAN and WOR power controllers both request low power.

The MAN/WOR/Bluetooth LE power controllers operate using the 32kHz OSC clock, and this clock must be available before enabling any of the power controllers for low power entry/exit.

52.3.2.2.1 MAN Power Controller

To enable the MAN power controller, the RF*_MAN2[MAN_EN] bit must be set. The RF*_TIMER[TIM_EN] must also be set to enable the 32kHz timer used by the MAN power control. For the 2.4GHz radio, the MAN must be assigned to a specific link layer in the 2.4GHz radio. In the WOR, the ENTER_TIME and WKUP_TIME for MAN should be programmed with the desired low power entry and exit time, respectively.

The low power entry/exit sequence is illustrated in the figure below. After the link layer has requested deep sleep entry (man_sleep_req in figure below, and reflected in the RF*_MAN1[ENTER_REQ] status bit) a MAN low power entry event is triggered when the RF*_TIMER[TIME] counter matches ENTER_TIME. Low power exit is scheduled to complete when the RF*_TIMER[TIME] counter matches WKUP_TIME. Prior to the WKUP_TIME, the MAN controller will enable the XO (xo_en) at XO_CTRL[WKUP_OFFSET] 32kHz cycles before WKUP_TIME, and request the SPC to wake the radio domain from low power mode (lp_stop_req de-assertion) at RF*_CTRL[LP_WKUP_DLY] 32kHz cycles after XO is enabled. It is expected that the WKUP_OFFSET is programmed to allow sufficient time for the XO to warmup and assert the xtal_ready signal. Likewise, the LP_WKUP_DLY is programmed to allow enough time for the SPC to bring the radio out of low power mode before WKUP_TIME. RF_ACTIVE can also be programmed to assert at RF*_COEXT[RFACT_WKUP_DLY] after XO is enabled. Flags RF*_STAT[LP_WKUP_FLAG] and RF*_STAT[MAN_WKUP_FLAG] (with optional interrupts) are set after the lp_stop_ack (from SPC) de-asserts and at WKUP_TIME, respectively. Before the MAN power controller will enter ACTIVE state, TIME must reach WKUP_TIME and man_sleep_req must be de-asserted. If properly configured in RF*_CTRL[SFA_TRIG_EN], a trigger (sfa_meas) will be issued to the radio SFA after the MAN power controller reaches the ACTIVE state. The MAN power controller's state is reflected in RF*_STAT[MAN_STATE] for use as needed by software.

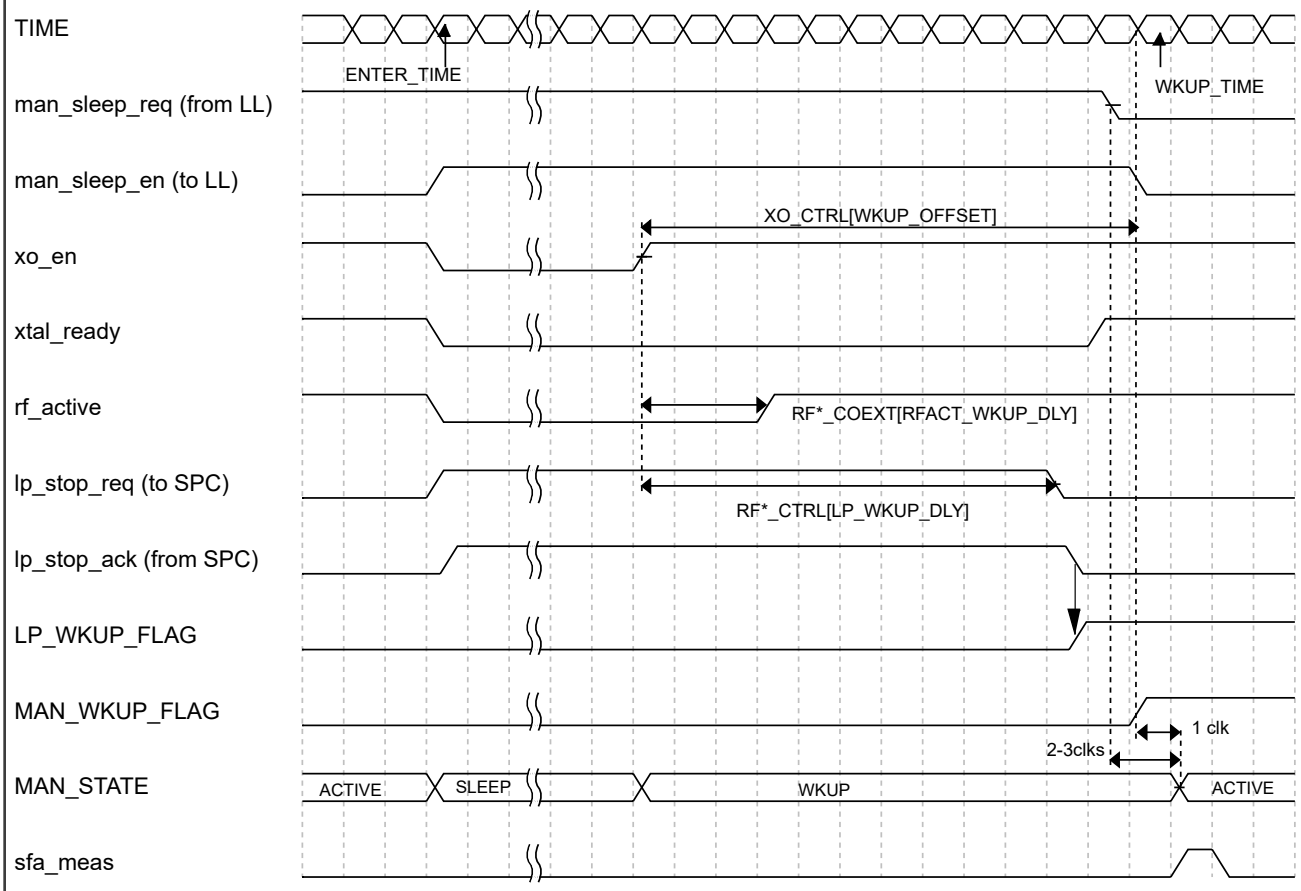


Figure 214. Low Power entry/exit for MAN Power Controller

If for some reason the radio needs to be woken before WKUP_TIME has been reached, the RF*_MAN2[MAN_WKUP] bit can be set by software to wake the radio prematurely. The radio can also be woken before WKUP_TIME has been reached if a debug request is raised from outside the radio by setting pin rfmc_radio_debug_req_1p8v.

52.3.2.2.2 WOR Power Controller

To enable the WOR power controller, the RF*_WOR2[WOR_EN] bit must be set. For the 2.4GHz radio, the WOR must be assigned to a specific link layer by programming the WOR_CTRL[WOR_PROTOCOL] in the 2.4GHz radio. The WOR low power entry is controlled by wor_sleep_req (reflected in RF*_WOR1[ENTER_REQ] bit) from the "WOR scheduler" (the WOR logic in the radio domain), and the desired low power duration (wor_sleep_duration -- reflected in RF*_WOR1[DURATION_TGT]) is also an input to the RFMC from the WOR scheduler.

The low power entry/exit sequence is illustrated in the figure below. Prior to low power entry, the WOR scheduler pulses the wor_sleep_duration_clr to clear the DURATION counter (RF*_WOR2[DURATION]) in the WOR power controller, then asserts wor_sleep_req. The WOR power controller needs to synchronize this request to the 32kHz clock domain, so after 2-3 cycles, low power mode is entered. Low power exit is scheduled to complete when the DURATION counter matches wor_sleep_duration. Prior to this time, the WOR controller will enable the XO (xo_en) at XO_CTRL[WKUP_OFFSET] 32kHz cycles before wor_sleep_duration, and request the SPC to wake the radio domain from low power mode (lp_stop_req de-assertion) at RF*_CTRL[LP_WKUP_DLY] 32kHz cycles after XO is enabled. It is expected that the WKUP_OFFSET is programmed to allow sufficient time for the XO to warmup and assert the xtal_ready signal. Likewise, the LP_WKUP_DLY is programmed to allow enough time for the SPC to bring the radio out of low power mode before WKUP_TIME. RF_ACTIVE can also be programmed to assert at RF*_COEXT[RFACT_WKUP_DLY] after XO is enabled. Flags RF*_STAT[LP_WKUP_FLAG]

and RF*_STAT[WOR_WKUP_FLAG] (with optional interrupts) are set after the lp_stop_ack (from SPC) de-asserts and at wor_sleep_duration, respectively. The WOR power controller does not move to ACTIVE state until after the WOR scheduler de-asserts the wor_sleep_req signal. If properly configured in RF*_CTRL[SFA_TRIG_EN], a trigger (sfa_meas) will be issued to the radio SFA after the WOR power controller reaches the ACTIVE state. The WOR power controller's state is reflected in RF*_STAT[WOR_STATE] for use as needed by software.

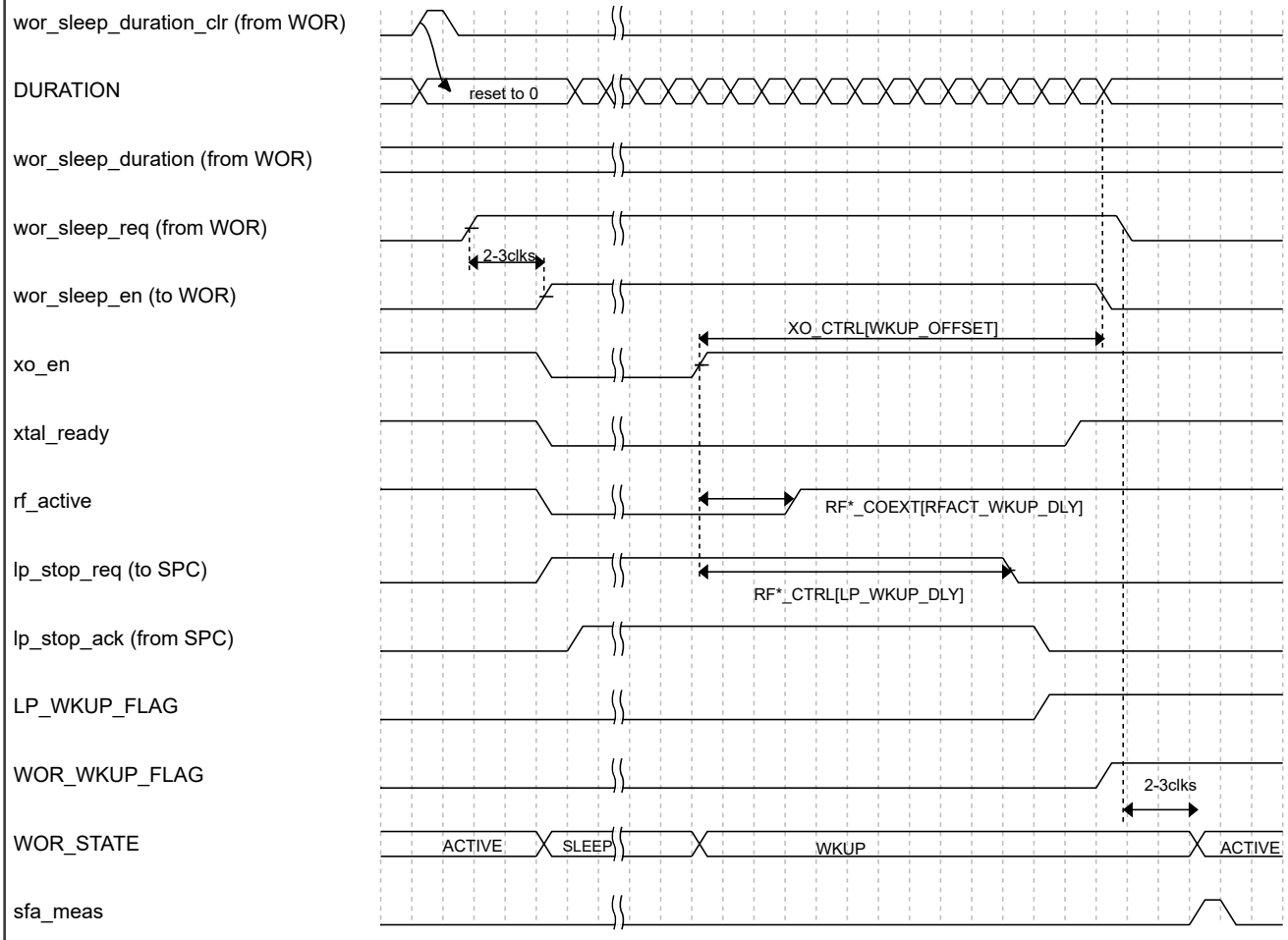


Figure 215. Low Power entry/exit for WOR Power Controller

If for some reason the radio needs to be woken before wor_sleep_duration has been reached, the RF*_WOR2[WOR_WKUP] bit can be set by software to wake the radio prematurely. The radio can also be woken before wor_sleep_duration if a debug request is raised from outside the radio by setting pin rfmc_radio_debug_req_1p8v.

52.3.2.2.3 Bluetooth LE Power Controller

To enable the Bluetooth LE power controller, the RF2p4GHz_CTRL[BLE_LP_EN] bit must be set. A Bluetooth LE low power entry and exit event is then controlled by the Bluetooth LE link layer (see Bluetooth LE link layer programming model).

NOTE

The 32kHz clock used by both the Bluetooth LE power controller and the Bluetooth LE link layer is enabled by setting RF2p4GHz_CTRL[BLE_LP_EN]. If for some reason the Bluetooth LE link layer needs this clock to be active while the Bluetooth LE power controller is not enabled (BLE_LP_EN bit not set), software can program RF2p4GHz_CTRL[CLK_OVR] to force the clock to be enabled.

The low power entry/exit sequence is illustrated in the figure below. When the Bluetooth LE link layer wants to enter low power, it de-asserts the bt_clk_req input to RFMC (this signal is reflected in RF*_STAT[BLE_WKUP_STAT]). When the Bluetooth LE link layer wants to exit low power, it asserts bt_clk_req. At that time, the Bluetooth LE power controller will enable the XO (xo_en), and after RF*_CTRL[LP_WKUP_DLY] 32kHz cycles it will request the SPC to wake the radio domain from low power mode (lp_stop_req de-assertion). It is expected that the LP_WKUP_DLY is programmed such that the SPC will complete bringing the radio out of low power mode near the time when the XO becomes ready (xtal_ready). However, in several cases, CM33 will want to have access to radio memory without using the radio. In that case, there is no need to start, and hence wait, for the XO. For this purpose, RF*_CFG[BLE_FAST_WKUP] bit can be set to 1. In this case, the Bluetooth LE power controller will request the SPC to wake the radio domain from low power mode without wakeup delay. RF_ACTIVE can also be programmed to assert at RF*_COEXT[RFACT_WKUP_DLY] after XO is enabled. Flags RF*_STAT[LP_WKUP_FLAG] and RF*_STAT[BLE_WKUP_FLAG] (with optional interrupts) are set after the lp_stop_ack (from SPC) de-asserts and at xo_en, respectively. The Bluetooth LE power controller moves to ACTIVE state in the cycle after lp_stop_req is de-asserted. If properly configured in RF*_CTRL[SFA_TRIG_EN], a trigger (sfa_meas) will be issued to the radio SFA after the Bluetooth LE power controller reaches the ACTIVE state. The Bluetooth LE power controller's state is reflected in RF*_STAT[BLE_STATE] for use as needed by software.

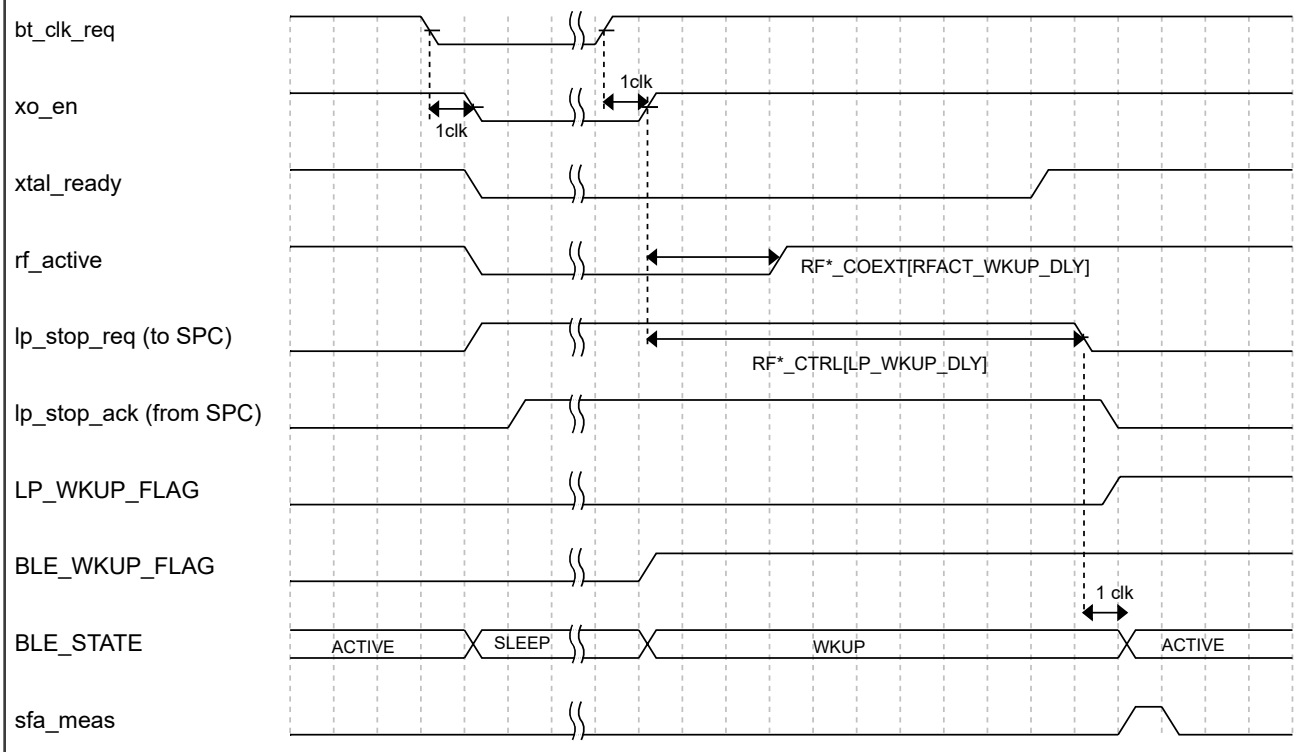


Figure 216. Low Power entry/exit for Bluetooth LE Power Controller

If for some reason the radio needs to be woken before the Bluetooth LE link layer is scheduled to assert bt_clk_req, the RF2p4GHz_CTRL[BLE_WKUP] bit can be set by software to wakeup the radio prematurely.

The Bluetooth LE power controller behavior is a bit different than the MAN and WOR power controllers. In particular

- The XO_CTRL[WKUP_OFFSET] bitfield is not used by the Bluetooth LE power controller. Instead the Bluetooth LE link layer has its own programmable bitfield "Osc_startup_delay" which is used to delay when the Bluetooth LE link layer switches timing control from the low power clock to the XO
- The Bluetooth LE power controller does not have a counter to keep track of the low power duration; that is handled in the Bluetooth LE link layer

- The BLE_WKUP_FLAG asserts at WKUP state, whereas the MAN_WKUP_FLAG and WOR_WKUP_FLAG assert at the end of the requested low power duration

The radio can also be woken earlier in one of these cases :

- One of the two external wakeup signals on pins rfmc_ext_wakeup_2p4GHz_1p8v[1:0] is set
- Debug request is raised from outside the radio by setting pin rfmc_radio_debug_req_1p8v

Because nbu core and soc host core can go to low power independently, Software needs to give indication to the other core for some information. For this purpose, specific mirror registers in always on domain are available so both cores can communicate without the need for one to wakeup the second. In the RFMC, these registers are RF 2.4GHz Buffer from Host to Radio (RF2p4GHz_HOST2RADIO) and RF 2.4GHz Buffer from Radio to Host (RF2p4GHz_RADIO2HOST). The equivalent mirror registers are in the Transceiver module.

52.3.2.3 Radio Coexistence

The 2.4GHz radio implements external IO signals to support coexistence with an external RF device operating within the same frequency band. The RFMC provides mux control (via RFMC's RF_GPO[7:0] output) for the coexistence outputs {RF_ACTIVE, RF_STATUS, and RF_PRIORITY[1:0]} from the 2.4GHz radio, provides additional control for the RF_ACTIVE signal, and provides control for the RF_NOT_ALLOWED coexistence input. The next few paragraphs discuss RFMC control of the RF_NOT_ALLOWED and RF_ACTIVE signals. For more information on coexistence refer to the Coexistence Interface and Coexistence/FEM/LANT connections sections of the Radio Control chapter.

For RF_NOT_ALLOWED, the RFMC provides programmable control (RF*_COEXT[RFNA_IE] bitfield) so that this coexistence signal can be sourced from any of 5 device pins, or disabled. Some status bits related to RF_NOT_ALLOWED are also available in XCVR_MISC->RSM_INT_STATUS register of the Transceiver.

For RF_ACTIVE, the RFMC provides programmable control (RF*_COEXT[RFACT_SRC] bitfield) to select whether this coexistence output is sourced by the RFMC, the Bluetooth LE bt_clk_req signal, or a mux of the TSM's RF_ACTIVE signal and the active link layer's REQUEST signal. If RF_ACTIVE is sourced by the RFMC (RF*_COEXT[RFACT_SRC]=00), this signal relies on the RFMC’s low power controllers (one of the RFMC’s low power controllers should be enabled); in this configuration the RF_ACTIVE behavior is as follows:

- If RF*_COEXT[RFACT_IDIS]=0
  - Asserts during the RFMC low power controller's wakeup sequence, RF*_COEXT[RFACT_WKUP_DLY] 32kHz clock cycles after the XO is enabled
  - De-asserts when the RFMC low power controller requests that the radio enters a low power mode
  - Software can cause RF_ACTIVE to be asserted during a low power mode by setting the RF*_COEXT[RFACT_EN] bitfield
- If RF*_COEXT[RFACT_IDIS]=1
  - Asserts when the TSM is busy
  - De-asserts when the TSM is idle

Also related to RF_ACTIVE are the QUIET_REQ outputs. These also indicate when the radios are active, but are used inside the SOC to suppress SOC Core flash and/or RF Core flash activity if needed. These outputs have configurable behavior using the RF*_COEXT register's QREQ_SRC, QREQ_SOC_EN and QREQ_RF_EN bits.

52.3.2.4 Radio FEM Control

The RFMC provides mux control (via RFMC's RF_GPO[7:0] output) for the FEM (front-end module) signals {ANT_A, ANT_B, RX_SWITCH, and TX_SWITCH} from the 2.4GHz radio, but does not otherwise make use of, or affect these signals. For more information on these signals, refer to the Transceiver Localization and Antenna Control section of the Transceiver chapter and Coexistence/FEM/LANT connections sections of the Radio Control chapter.

52.3.2.5 Radio Localization Antenna Select

The RFMC provides mux control (via RFMC's RF_GPO[7:0] output) for the LANT_LUT_GPIO[3:0] (localization antenna select) signals from the 2.4GHz radio, but does not otherwise make use of, or affect these signals. For more information on these signals, refer to the Transceiver Localization and Antenna Control section of the Transceiver chapter and Coexistence/FEM/LANT connections sections of the Radio Control chapter.

52.3.2.6 Clocking

The RFMC uses the following clock sources :

- ipg_clk : provided at SOC level at radio top's ipg_clk_s_1p8v pin to control Read/Write operations to registers.
- 32 kHz clock : provided from SOC level at radio IP's clk_32k_1p8v pin, it is the functional clock of the RFMC
- 32 kHz clock : provided from SOC level at radio IP's clk_32k_nbu_1p8v pin, it is gated then provided to the radio digital part

Those clocks are managed only at SOC level.

52.3.2.7 Reset

The RFMC and 2.4GHz radio are reset on any system reset event or by setting the RFMC_CTRL[RFMC_RST] bit, with the exception of the following registers bits which are only reset on a POR/LVD event: RFMC_CTRL[RFMC_RST] (resets to 0) and RFMC_CTRL[RST_MSK] (resets to 0).

The RFMC can also generate software resets for the 2.4GHz radio via the RF*_CTRL[RF_POR], RF*_CTRL[RST] and RF*_CTRL[CPU_RST] bits. Setting RF*_CTRL[RF_POR], RF*_CTRL[RST], or RF*_CTRL[CPU_RST] will have no effect on the RFMC itself however. The reset associated with RF*_CTRL[CPU_RST], ipg_async_cpu_reset_lv, is used primarily to hold the CM3 core in reset for flash loading. The reset associated with RF*_CTRL[RF_POR], ipg_async_por_2p4GHz_b_lv, provides POR for the LV domain logic. On exit from Power Down or Deep Power Down low power modes, a signal from the SPC (spc_pd_pwrdwn_exit) asserts all of the LV resets.

There is also a RF*_CTRL[CPU_RST_LOCK] bit associated with the RF*_CTRL[CPU_RST]. If the CPU_RST_LOCK bit is set, the CPU_RST bit cannot be cleared until the next system reset (ipg_async_reset_1p8v). The lock bit is used by boot ROM code to force the radio CPU to remain in reset if the radio flash verification fails.

The radio also needs to be held off until the flash has finished its initialization (its IFR outputs are valid, and it is ready to accept read requests) after a reset. The radio flash output signal msf_core_hold is used by the RF_CMC module for this purpose: the RF_CMC delays de-assertion of the non-POR resets used by the radio.

For testing purposes, the RFMC and radio power domains can be isolated from system reset events by setting the RFMC_CTRL[RST_MSK] register bit. Note that the RFMC_CTRL[RFMC_RST] and RF*_CTRL[RST] register bits are still functional when the RFMC_CTRL[RST_MSK] bit is set.

The figure below illustrates reset bits and signals for the RFMC, RF_CMC and radio. The ipg_async_reset_rfmc_1p8v is an output from the RFMC to use to reset any other 1.8v logic in the radio power domain.

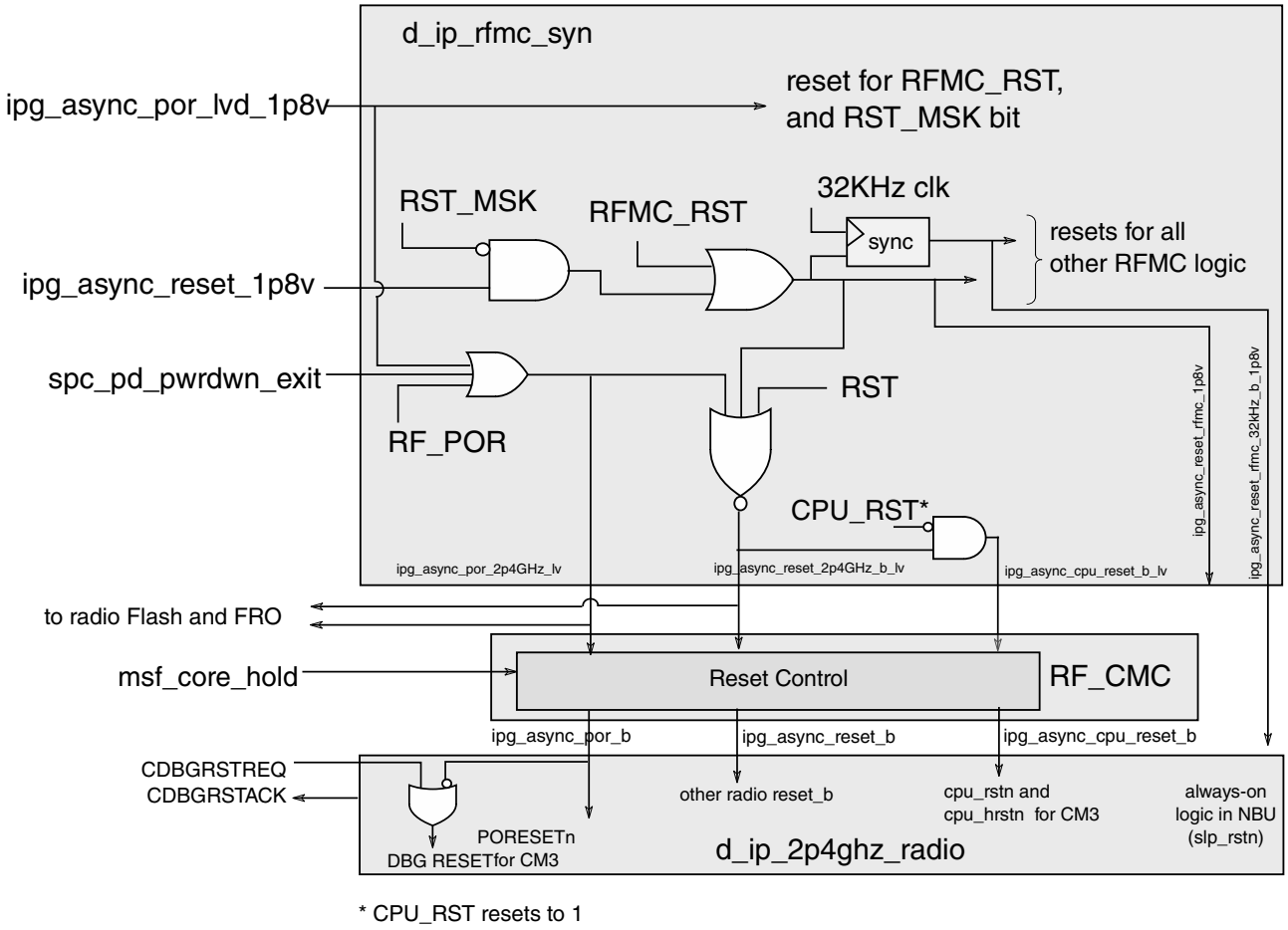


Figure 217. Reset

52.3.2.8 Interrupt and wake-up request

The RFMC generates an output for the SOC's interrupt controller (NVIC) and a wake-up request for the SOC's wake-up unit (WUU). As shown in the figure below, all enabled interrupt sources within the RFMC -- from the XO control and the 2.4GHz low power controllers -- are combined to generate the rfmc interrupt. The wake-up request for the WUU combines enabled interrupt requests from the Bluetooth LE, WOR and MAN low power controllers within the RFMC with interrupt requests from the 2.4GHz radio .

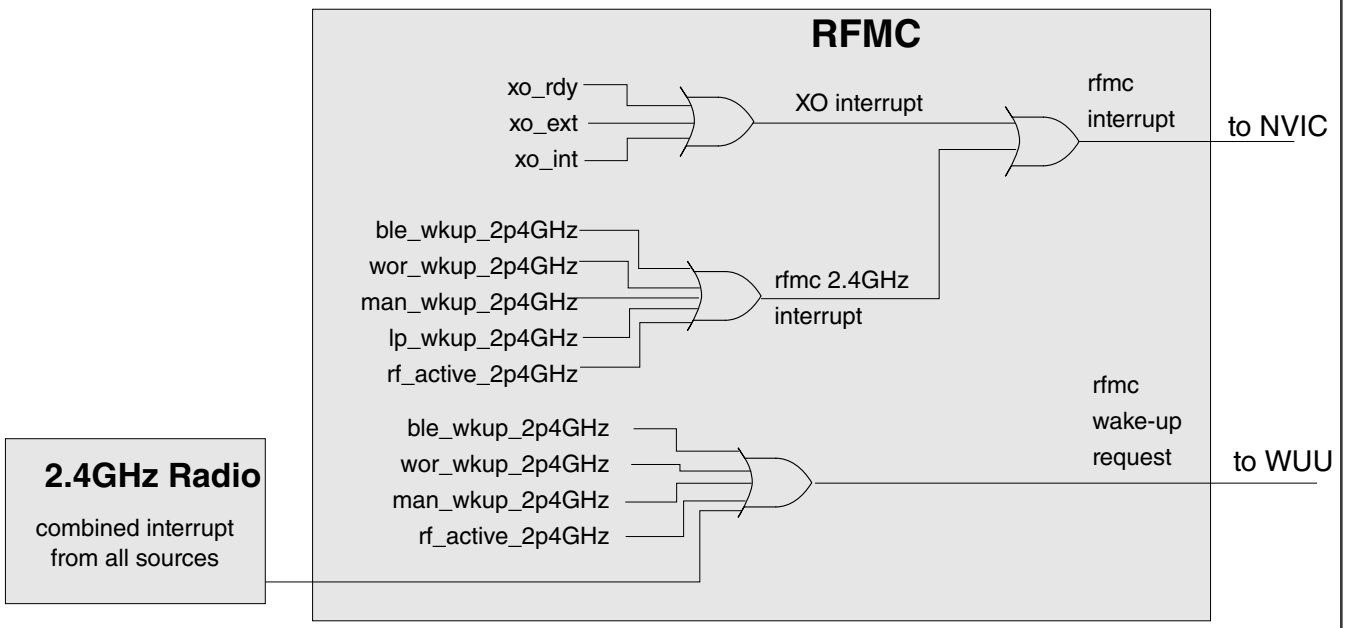


Figure 218. Interrupt and wake-up request

52.3.2.9 Power-on Sequence

After a POR/LVD event, the RFMC is released from reset, the 2.4GHz radio is powered up and released from reset, but the XO is disabled and the NBU CPU is held in reset . The following steps are needed by software. (Note that steps 1-3 may optionally be supported by the SOC boot ROM.)

1. Configure the XO. Program the EXT_MODE, XTAL_REQ_OBE and other bits in the XO_CTRL register as needed
2. Set RF*_CTRL[XO_EN] to enable the XO, or enable of the RFMC's low power controllers to allow it to enable the XO.
3. Clear the RF*_CTRL[CPU_RST] bit to release the NBU CPU from reset.
4. Wait for XO_STAT[RDY_FLAG] to be set. An RFMC interrupt is also associated with this event. Software can access the radio modules which use the XO clock after the XO is ready. (Software can access the radio modules which use the radio FRO clock before the XO is ready.)

52.3.3 External signals

Table 444. RFMC external I/O

Signal	Description	I/O
XO Interface		
XTAL_REQ	Request to enable an external crystal when internal XO is bypassed.	O
XTAL_OUT_EN	Enable from an external source to activate internal XO.	I
Radio Coexistence, FEM Control, and Localization Antenna Select Interfaces		
RF_GPO[7:0]	Software can select any two of {4 Coexistence signals, 4 FEM Control signals, 4 Localization Antenna Select signals} on this 8bit output.	O

Table continues on the next page...

Table 444. RFMC external I/O (continued)

Signal	Description	I/O
RF_NOT_ALLOWED[4:0]	Software can select 1 of 5 input pins to use for the "RF not allowed" Coexistence signal, which blocks radio activity when asserted.	I

52.3.4 Initialization

RFMC does not require any special initialization.

In order to start the NBU CM33 core, the RF2p4GHz_CTRL[CPU_RST] needs to be de-asserted, so that its reset gets released.

52.3.5 Application Information

As RFMC is managing the power modes transition for the Radio power domain, here it given the typical LowPower entry and exit sequences. Low power mode entry is always initiated by the Radio itself, while Wakeup sequence can be triggered either internally by the Radio using internal timers, or by the main power domain (i.e. to access SMU for sending messages to the Radio).

For Low Power entry/exit, the following parameters need initially to be configured:

- RF2p4GHz_CTRL[BLE_LP_EN] should be set, it will enable the BLE LP state machine.
- RF2p4GHz_CTRL[LP_WKUP_DLY] is defining the startup time of the Radio XO. Typical value is 0x10, translating into a XO startup time of 488us. This parameter ensures that XTAL is up and running prior to Low Power mode exit.
- RF2p4GHz_CTRL[LP_MODE] configures the LP mode entered when requested. Unless Radio is used, target LP_MODE is set to 0x3, corresponding to Deep Sleep: low power static mode with retention of digital logic and SRAMs.
- Inside RF_CMC, RADIO_LP[SLEEP_EN] should also be set to ungate LP entry after Radio CM33 WFI deepsleep request

52.3.6 Register descriptions

52.3.6.1 RFMC register descriptions

52.3.6.1.1 RFMC memory map

RADIO.RFMC base address: 4004_0000h

Offset	Register	Width (In bits)	Access	Reset value
0h	RFMC Version ID Register (VERID)	32	R	0200_4700h
4h	RFMC Parameter Register (PARAM)	32	R	0000_0001h
8h	RFMC Control Register (CTRL)	32	RW	0000_0000h
Ch	XO Control Register (XO_CTRL)	32	RW	0022_0000h
10h	XO Status Register (XO_STAT)	32	RW	0000_0000h
14h	XO Test Register (XO_TEST)	32	RW	0020_61E5h
18h	2.4GHz Radio Control Register (RF2p4GHz_CTRL)	32	RW	2000_0000h
1Ch	2.4GHz Radio Status Register (RF2p4GHz_STAT)	32	RW	0000_0400h
20h	2.4GHz Radio Coexistence Register (RF2p4GHz_COEXT)	32	RW	0000_0000h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
24h	2.4GHz TIMER Register (RF2p4GHz_TIMER)	32	RW	0000_0000h
28h	2.4GHz WOR Register 1 (RF2p4GHz_WOR1)	32	R	0000_0000h
2Ch	2.4GHz WOR Register 2 (RF2p4GHz_WOR2)	32	RW	0000_0000h
30h	2.4GHz MAN Register 1 (RF2p4GHz_MAN1)	32	R	0000_0000h
34h	2.4GHz MAN Register 2 (RF2p4GHz_MAN2)	32	RW	0000_0000h
38h	2.4GHz MAN Register 3 (RF2p4GHz_MAN3)	32	R	0000_0000h
3Ch	2.4GHz MAN Register 4 (RF2p4GHz_MAN4)	32	R	0000_0000h
48h	RF 2.4GHz Buffer from Host to Radio (RF2p4GHz_HOST2RADIO)	32	RW	0000_0000h
4Ch	RF 2.4GHz Buffer from Radio to Host (RF2p4GHz_RADIO2HOST)	32	R	0000_0000h
50h	2.4GHz Radio Configuration Register (RF2p4GHz_CFG)	32	RW	0000_0000h
54h	2.4GHz Radio WakeUp Source Register (RF2p4GHz_WKUP_SRC)	32	R	0000_0000h

52.3.6.1.2 RFMC Version ID Register (VERID)

Offset

Register	Offset
VERID	0h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	MAJOR								MINOR							
W																
Reset	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	RADIO_ID															
W																
Reset	0	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 MAJOR	Major RFMC Version Number This read only field returns the major version number of the RFMC.
23-16 MINOR	Minor RFMC Version Number This read only field returns the minor version number of the RFMC.
15-0 RADIO_ID	Radio Identification Number This 16bit read only field returns the Radio ID. [15:12] : Radio major family (e.g. 4'd4 = Gen4) [11: 8] : Radio minor family (e.g. 4'd0 = GenX.0) [7: 4] : Reserved [3: 0] : Radio ECO/TO number, starting from 4'd0

52.3.6.1.3 RFMC Parameter Register (PARAM)

Offset

Register	Offset
PARAM	4h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															RF2p4 GH...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Fields

Field	Function
31-1 —	Reserved

Table continues on the next page...

Table continued from the previous page...

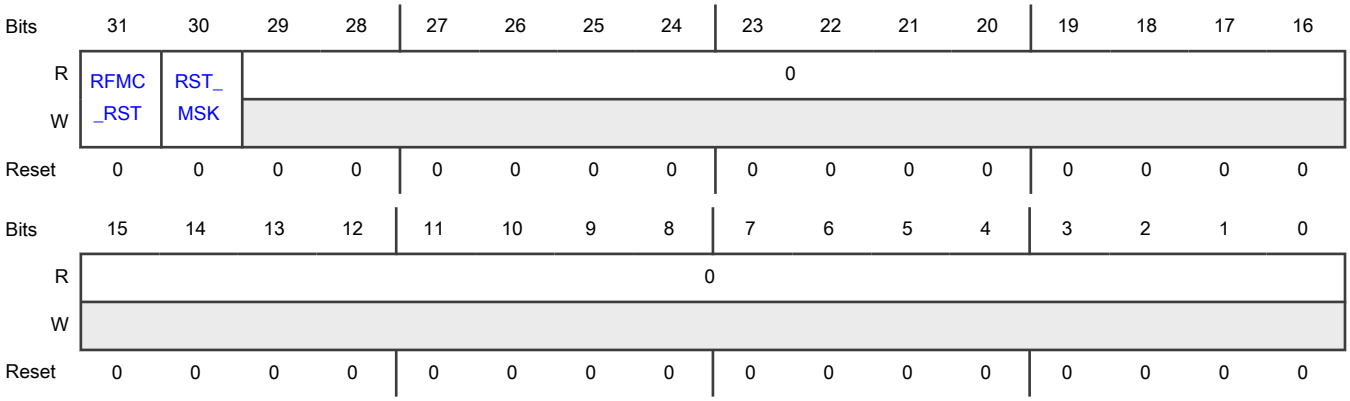
Field	Function
0 RF2p4GHz_EN	Indicates whether 2.4GHz radio is enabled (as determined by fuse bit). When disabled, the 2.4GHz radio will remain in Power Down. 0b - 2.4GHz radio disabled 1b - 2.4GHz radio enabled

52.3.6.1.4 RFMC Control Register (CTRL)

Offset

Register	Offset
CTRL	8h

Diagram



Fields

Field	Function
31 RFMC_RST	S/W System Reset for RFMC This causes a system reset for the RFMC. It resets all registers in the RFMC except for the RST_MSK and RFMC_RST register bits. This also resets the 2.4GHz radio. Note, the RFMC_RST bit is only reset on a POR/LVD event. 0b - Release the RFMC from reset 1b - Hold the RFMC in reset
30 RST_MSK	Reset Mask When set, masks system reset events (does not include POR/LVD) from resetting the RFMC, and 2.4GHz radio. Note the RFMC_RST bit is still functional, but will not reset the RST_MSK bit. The RST_MSK bit is only reset on a POR/LVD event.

Table continues on the next page...

Table continued from the previous page...

Field	Function
29-0 —	Reserved

52.3.6.1.5 XO Control Register (XO_CTRL)

Offset

Register	Offset
XO_CTRL	Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	XO_ANA_...	XO_ANA_...	XO_LDO_...	XO_LDO_...	SPARE				XTAL_RD...	XTAL_RD...	EXT_MODE	LDO_BYP...	XTAL_OU...	RDY_CNT...	RDY_CNT	
Reset	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		WKUP_OFFSET						0	XTAL_EN...	XTAL_RE...	XTAL_OU...	0	EXT_IE	INT_IE	RDY_IE
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 XO_ANA_EN	XO Analog Enable When the XO_ANA_OVR bit is set, this bit will control the XO analog enable. Note this bit only enables the XO analog, but will not enable its output to the SCG, XTAL_OUT pin, or 2.4GHz radio domain. 0b - XO analog disabled 1b - XO analog enabled
30 XO_ANA_OVR	XO Analog Enable Override When set, allows the XO_ANA_EN bit to override any internal or external requests for the XO. 0b - XO analog enable not overridden 1b - XO analog enable overridden by XO_ANA_EN bit
29 XO_LDO_EN	XO LDO Enable When the XO_LDO_OVR bit is set, this bit will control the XO LDO enable.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - XO LDO disabled 1b - XO LDO enabled
28 XO_LDO_OVR	XO LDO Enable Override When set, allows the XO_LDO_EN bit to override any internal or external requests for the XO LDO. 0b - XO LDO enable not overridden 1b - XO LDO enable overridden by XO_LDO_EN bit
27-24 SPARE	XO Spare Registers Bit 3:1 - Reserved Bit 0 - Bypass CLK_AUX_DRV_LDO
23 XTAL_RDY_OVR	XTAL Ready Override When the XTAL_RDY_OVR_EN bit is set, this bit will override the XTAL ready signal from the XO analog.
22 XTAL_RDY_OVR_EN	XTAL Ready Override Enable When set, allows the XTAL_RDY_OVR to override the XTAL ready signal from the XO analog.
21 EXT_MODE	External Clock Mode 0b - DC coupled external clock mode (amplifier powered down). 1b - AC coupled external clock mode or crystal mode (amplifier powered up).
20 LDO_BYPASS	XO LDO Bypass
19 XTAL_OUT_INV	XO Clock Output Invert Inverts the polarity of the XTAL_OUT clock relative to the internal XO clock. Also referred to as AUX_DRV_FLIP. 0b - XTAL_OUT not inverted 1b - XTAL_OUT inverted
18 RDY_CNT_OFF	XTAL Ready Count Disable 0b - XTAL Ready Count Enabled 1b - XTAL Ready Count Disabled
17-16 RDY_CNT	XTAL Ready Count Configures the ready counter value (in number of XO clock cycles) for XO startup time. 00b - 1024

Table continues on the next page...

Table continued from the previous page...

Field	Function
	01b - 2048 10b - 4096 11b - 8192
15-14 —	Reserved
13-8 WKUP_OFFSET	XO Wakeup Offset Configures number of 32kHz reference clocks before a MAN/WOR wakeup event to enable the XO.
7 —	Reserved
6 XTAL_EN_IBE	XTAL_OUT_EN Input Pin Enable Enables an external source to request the XO to be enabled (see chip configuration chapter for pin mapping). 0b - XTAL_OUT_EN input pin disabled 1b - XTAL_OUT_EN input pin enabled
5 XTAL_REQ_OBE	XTAL_REQ Output Pin Enable Enables output pin for XO request (see chip configuration chapter for pin mapping). 0b - XTAL_REQ output pin disabled 1b - XTAL_REQ output pin enabled
4 XTAL_OUT_EN	XTAL_OUT Output Pin Enable Enables the XO clock and drives it to the XTAL_OUT output pin (see chip configuration chapter for pin mapping). 0b - XTAL_OUT output disabled 1b - XTAL_OUT output enabled
3 —	Reserved
2 EXT_IE	XO External Request Interrupt Enable Configures the XO to generate an interrupt when the EXT_FLAG is set. 0b - XO external request interrupt disabled 1b - XO external request interrupt enabled
1	XO Internal Request Interrupt Enable Configures the XO to generate an interrupt when the INT_FLAG is set.

Table continues on the next page...

Table continued from the previous page...

Field	Function
INT_IE	0b - XO internal request interrupt disabled 1b - XO internal request interrupt enabled
0 RDY_IE	XTAL Ready Interrupt Enable Configures the XO to generate an interrupt when the RDY_FLAG is set. 0b - XTAL ready interrupt disabled 1b - XTAL ready interrupt enabled

52.3.6.1.6 XO Status Register (XO_STAT)

Offset

Register	Offset
XO_STAT	10h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0										XO_EN	XTAL_RDY	0	EXT_FLAG	INT_FLAG	RDY_FLAG
W														W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-6 —	Reserved
5 XO_EN	XO_EN Reflects the instantaneous value of the XO enable signal from RFMC to the XO. This signal combines all of the sources which can enable the XO.
4	XTAL Ready

Table continues on the next page...

Table continued from the previous page...

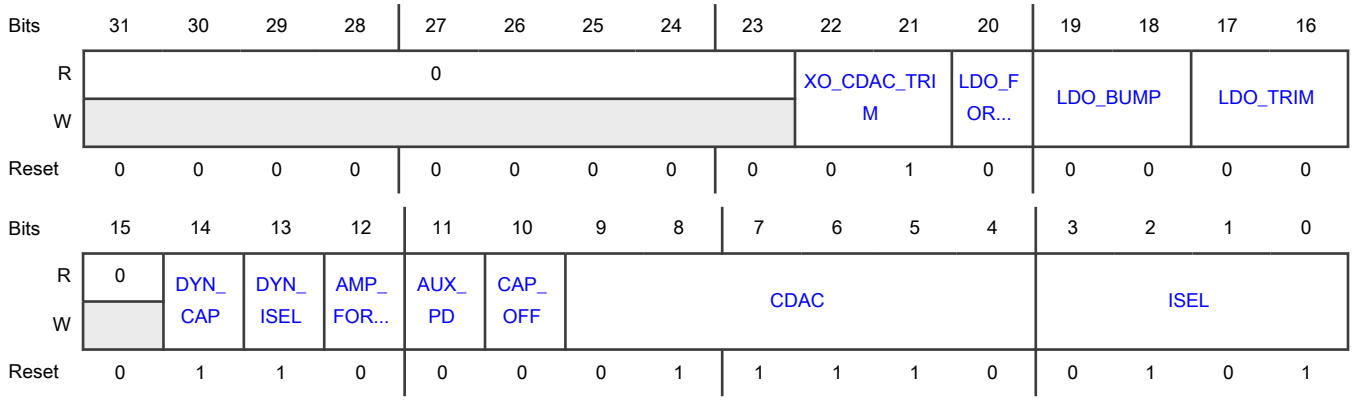
Field	Function
XTAL_RDY	Reflects the instantaneous value of the XTAL ready signal from the XO analog.
3 —	Reserved
2 EXT_FLAG	XO External Request Flag Flag which sets after an external source (XTAL_OUT_EN bit) has requested the XO to be enabled (write 1 to clear).
1 INT_FLAG	XO Internal Request Flag Flag which sets after an internal source (e.g. SCG or 2.4GHz radios) has requested the XO to be enabled (write 1 to clear).
0 RDY_FLAG	XTAL Ready Flag Flag which sets after the XTAL ready output from XO analog asserts (write 1 to clear).

52.3.6.1.7 XO Test Register (XO_TEST)

Offset

Register	Offset
XO_TEST	14h

Diagram



Fields

Field	Function
31-23 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
22-21 XO_CDAC_TRIM	XO fixed cap bank C_FIX trimming These values are per simulation, and they are not guaranteed. The parasitic components included on these values can varies with temperature and process. These values considers only internal capacitances, including pin, packaging/wire bond, pads, and parasitic component in the chip. It does not consider parasitic capacitance added in the PCB. 00b - 5.19pF 01b - 3.81pF 10b - 2.44pF 11b - 1.98pF
20 LDO_FORCE	XO LDO Force PTAT Startup
19-18 LDO_BUMP	XO LDO PTAT Current Bump 00b - PTAT current bump default 01b - PTAT current boost: +30%
17-16 LDO_TRIM	XO LDO Output Voltage Trim 00b - 0.92V 01b - 0.885V 10b - 0.955V 11b - 1.011V
15 —	Reserved
14 DYN_CAP	XO On-chip Load Capacitor: enable switching during startup
13 DYN_ISEL	XO Amplifier: enable current switching during startup
12 AMP_FORCE	XO Amplifier Force PTAT Startup
11 AUX_PD	XO CLK_AUX_DRV Powerdown Also referred to as CLK_AUX_DRV_PDN_FORCE.
10 CAP_OFF	XO Load Capacitor Disable

Table continues on the next page...

Table continued from the previous page...

Field	Function
9-4 CDAC	XO On-chip Load Capacitor Trim See XO_CDAC_TRIM bitfield for more details 00_0000b - C_FIX 11_1111b - C_FIX + 14.36pF
3-0 ISEL	XO Amplifier Current Select Selectable from 40uA to 640uA, with 40uA step size. Example programming shown below 0000b - 40uA (min) 0001b - 80uA 0101b - 240uA (default) 1111b - 640uA (max)

52.3.6.1.8 2.4GHz Radio Control Register (RF2p4GHz_CTRL)

Offset

Register	Offset
RF2p4GHz_CTRL	18h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	RST	RF_POR	CPU_RST	CPU_RST...	CLK_OVR				XO_EN	XO_EN_G...	LP_STOP...	SFA_TRIG_EN			LP_WKUP_DLY	
Reset	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	LP_WKUP_DLY				LP_MODE				LP_ENTER	BLE_LP_...	BLE_WKUP	LP_WKUP...	RFACT_IE	BLE_WKU...	MAN_WKU...	WOR_WKU...
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 RST	S/W Reset for 2.4GHz Radio When set, the RST bit will cause a reset of the 2.4GHz radio domain. Note, setting this bit has no effect on the RFMC's registers and this bit remains functional even when the RFMC_CTRL[RST_MSK] bits is set.

Table continues on the next page...

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Field	Function
	0b - Release the 2.4GHz radio from reset 1b - Hold the 2.4GHz radio in reset
30 RF_POR	S/W Power-on-Reset for 2.4GHz Radio When set, the RF_POR bit will cause a power-on-reset of the 2.4GHz radio domain. Note, setting this bit has no effect on the RFMC's registers and this bit remains functional even when the RFMC_CTRL[RST_MSK] bits is set. 0b - Release the 2.4GHz radio from power-on-reset 1b - Hold the 2.4GHz radio in power-on-reset
29 CPU_RST	S/W Reset for 2.4GHz Radio CPU When set, the CPU_RST bit will cause a reset of the 2.4GHz radio CPU. Note that this bit is set after a system reset, so SOC Core software will have to clear it to bring the 2.4GHz radio CPU out of reset. Setting this bit has no effect on the RFMC's registers and this bit remains functional even when the RFMC_CTRL[RST_MSK] bits is set. 0b - Release the 2.4GHz radio CPU from reset 1b - Hold the 2.4GHz radio CPU in reset
28 CPU_RST_LOCK	LOCK for CPU_RST When set, the CPU_RST bit will be locked and unable to be reprogrammed until the next system reset. Note that this bit is not affected by the RST bit in this register, or by the RFMC CTRL[RFMC_RST] bit. This bit remains functional even when the RFMC_CTRL[RST_MSK] bits is set. 0b - CPU_RST bit is not locked 1b - CPU_RST bit is locked
27-24 CLK_OVR	Clock Gating Override Controls whether low power mode controller clocks are gated off when the logic is not enabled (default), or whether the clocks are on regardless of whether the logic is enabled. 0xxxb - Bluetooth LE power controller clock (and 32kHz clock used by Bluetooth LE link layer) only enabled when BLE_LP_EN=1 (default) 1xxxb - Bluetooth LE power controller clock (and 32kHz clock used by Bluetooth LE link layer) always enabled x0xxb - WOR power controller clock only enabled when WOR_EN=1 (default) x1xxb - WOR power controller clock always enabled xx0xb - MAN power controller clock only enabled when MAN_EN=1 (default) xx1xb - MAN power controller clock always enabled xxx0b - TIMER clock only enabled when TIM_EN=1 xxx1b - TIMER clock always enabled
23	XO Enable for 2.4GHz Radio

Table continues on the next page...

Table continued from the previous page...

Field	Function
XO_EN	Software enable of the XO analog and output to the 2.4GHz radio domain. Note that this software enable is logically or'd with enables from the 2.4GHz MAN/WOR/Bluetooth LE power controllers. 0b - XO software enable deasserted 1b - XO software enable asserted
22 XO_EN_GLITCH_DIS	XO_EN Glitch Disable for 2.4GHz Radio If set, this disables logic added to suppress potential glitches on the xo_en signal to the analog when both MAN and WOR power controllers are enabled.
21 LP_STOP_REQ_GLITCH_DIS	LP_STOP_REQ Glitch Disable for 2.4GHz Radio If set, this disables logic added to suppress potential glitches on the lp_stop_req signal to the SPC when both MAN and WOR power controllers are enabled.
20-18 SFA_TRIG_EN	SFA Trigger Enable Selects which low power controllers can cause an SFA trigger on transition from WKUP to ACTIVE state 0xxb - Bluetooth LE Low Power Controller is not allowed to cause an SFA trigger. 1xxb - Bluetooth LE Low Power Controller is allowed to cause an SFA trigger. x0xb - WOR Low Power Controller is not allowed to cause an SFA trigger. x1xb - WOR Low Power Controller is allowed to cause an SFA trigger. xx0b - MAN Low Power Controller is not allowed to cause an SFA trigger. xx1b - MAN Low Power Controller is allowed to cause an SFA trigger.
17-12 LP_WKUP_DLY	LP Wakeup Delay Configures number of 32kHz reference clocks following enable of the XO to initiate SPC recovery for a MAN/WOR/Bluetooth LE wakeup event. Note, LP_WKUP_DLY should always be set to a value greater than or equal to XO_CTRL[WKUP_OFFSET].
11-8 LP_MODE	Radio Low Power Mode Configures the radio low power mode entered after any request is asserted e.g. from S/W, MAN or WOR. The mode bits should not be changed while the radio is in or transitioning through power modes (LP_REQ_STAT and LP_ACK_STAT status bits should be clear). 0000b - Active: clock gating only (only intended for debug) 0001b - Sleep: clock gating, PMC in low power mode(only intended for debug) 0011b - Deep Sleep: low power static mode with retention of digital logic and SRAMs. 0111b - Power Down: power down of radio digital logic, optional SRAM retention. 1111b - Deep Power Down: power down of radio digital logic and SRAMs.
7 LP_ENTER	S/W Low Power Entry Request Software initiated request to enter low power mode. Note that the LP_ENTER bit is clear after a POR/LVD event, resulting in the radio defaulting to a powered up state.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Deassert S/W request for low power mode entry 1b - Assert S/W request for low power mode entry
6 BLE_LP_EN	Bluetooth LE Low Power Enable Enable the Bluetooth LE power controller's wakeup output to initiate Radio low power mode entry/ wakeup. 0b - Bluetooth LE wakeup request disabled 1b - Bluetooth LE wakeup request enabled
5 BLE_WKUP	Bluetooth LE Wakeup Force early Bluetooth LE wakeup from low power mode. 0b - Bluetooth LE low power mode wakeup deasserted 1b - Bluetooth LE low power mode wakeup asserted
4 LP_WKUP_IE	Low Power Wakeup Interrupt Enable Configures the radio to generate an interrupt when the LP_WKUP_FLAG is set. 0b - Low Power wakeup interrupt disabled 1b - Low Power wakeup interrupt enabled
3 RFACT_IE	RF_ACTIVE Interrupt Enable Configures the radio to generate an interrupt when the RFACT_FLAG is set. (It is not recommended to use RFACT_IE or RFACT_FLAG except when RFACT_SRC=2'b00.) 0b - RF_ACTIVE interrupt disabled 1b - RF_ACTIVE interrupt enabled
2 BLE_WKUP_IE	Bluetooth LE Wakeup Interrupt Enable Configures the radio to generate an interrupt when the BLE_WKUP_FLAG is set. 0b - Bluetooth LE wakeup interrupt disabled 1b - Bluetooth LE wakeup interrupt enabled
1 MAN_WKUP_IE	MAN Wakeup Interrupt Enable Configures the radio to generate an interrupt when the MAN_WKUP_FLAG is set. 0b - MAN wakeup interrupt disabled 1b - MAN wakeup interrupt enabled
0 WOR_WKUP_IE	WOR Wakeup Interrupt Enable Configures the radio to generate an interrupt when the WOR_WKUP_FLAG is set. 0b - WOR wakeup interrupt disabled 1b - WOR wakeup interrupt enabled

52.3.6.1.9 2.4GHz Radio Status Register (RF2p4GHz_STAT)

Offset

Register	Offset
RF2p4GHz_STAT	1Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0									0		BLE_STATE			MAN_STATE	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	MAN_STA...	WOR_STATE			0	BLE_WKU...	LP_ACK_...	LP_REQ_...	FRO_CLK...	RST_STAT	SLP_RDY...	LP_WKUP...	RFACT_F...	BLE_WKU...	MAN_WKU...	WOR_WKU...
W												W1C	W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-23 —	Reserved
22-21 —	Reserved
20-18 BLE_STATE	Bluetooth LE Low Power State Returns the current state of the RFMC's Bluetooth LE low power controller. 000b - RESET state (BLE_LP_EN=0). 001b - ACTIVE state (XO enabled, RF_ACTIVE asserted, LP request deasserted). 010b - SLEEP state (XO disabled, RF_ACTIVE deasserted, LP request asserted). 011b - WAKEUP state (XO enabled, RF_ACTIVE asserted after RFACT_WKUP_DLY, LP request deasserted after LP_WKUP_DLY).
17-15 MAN_STATE	MAN Low Power State Returns the current state of the MAN low power controller. 000b - RESET state (MAN_EN=0). 001b - ACTIVE state (XO enabled, RF_ACTIVE asserted, LP request deasserted).

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Field	Function
	010b - SLEEP state (XO disabled, RF_ACTIVE deasserted, LP request asserted). 011b - WAKEUP state (XO enabled, RF_ACTIVE asserted after RFACT_WKUP_DLY, LP request deasserted after LP_WKUP_DLY).
14-12 WOR_STATE	WOR Low Power State Returns the current state of the WOR low power controller. 000b - RESET state (WOR_EN=0). 001b - ACTIVE state (XO enabled, RF_ACTIVE asserted, LP request deasserted). 010b - SLEEP state (XO disabled, RF_ACTIVE deasserted, LP request asserted). 011b - WAKEUP state (XO enabled, RF_ACTIVE asserted after RFACT_WKUP_DLY, LP request deasserted after LP_WKUP_DLY).
11 —	Reserved
10 BLE_WKUP_STAT	Bluetooth LE Wakeup Status Returns the current status of the Bluetooth LE wakeup request (bt_clk_req) to the RFMC.
9 LP_ACK_STAT	Low Power Acknowledge Status Returns the current status of the Radio low power acknowledge from the SPC. Note that the LP_ACK_STAT bit will be set after a POR/LVD event
8 LP_REQ_STAT	Low Power Request Status Returns the current status of the Radio low power request to the SPC. Note that the LP_REQ_STAT bit will be set after a POR/LVD event
7 FRO_CLK_VLD_STAT	FRO Clock Valid Status Returns the current status of the FRO Clock Valid signal.
6 RST_STAT	Reset Status Returns the current status of the RF_CMC's reset output. 0b - Reset is not asserted. 1b - Reset is asserted.
5 SLP_RDY_STAT	RF_CMC Sleep Ready Status Returns the current status of the Sleep Ready signal from RF_CMC.
4	Low Power Wakeup Flag

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Field	Function
LP_WKUP_FLAG	Flag which sets after deassertion of the Radio low power acknowledge from the SPC, indicating radio power domain wakeup is complete (write 1 to clear). Note, this flag will assert for all sources of radio wakeup e.g. MAN/WOR/Bluetooth LE controller or software clear of LP_ENTER bit.
3 RFACT_FLAG	RF_ACTIVE Flag This flag is associated with the RF_ACTVE pin, but only when RFACT_SRC=2'b00. (It is not recommended to use this flag for other settings of RFACT_SRC.) Write 1 to clear.
2 BLE_WKUP_FLAG	Bluetooth LE Wakeup Flag Flag which sets when Bluetooth LE low power controller transitions to WAKEUP state during a Bluetooth LE wakeup event (write 1 to clear).
1 MAN_WKUP_FLAG	MAN Wakeup Flag Flag which sets when MAN low power controller transitions to ACTIVE state after a MAN wakeup event (write 1 to clear).
0 WOR_WKUP_FLAG	WOR Wakeup Flag Flag which sets when WOR low power controller transitions to ACTIVE state after a WOR wakeup event (write 1 to clear).

52.3.6.1.10 2.4GHz Radio Coexistence Register (RF2p4GHz_COEXT)

Offset

Register	Offset
RF2p4GHz_COEXT	20h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	RFNA_IBE			0	QREQ_RF...	QREQ_SO...	QREQ_SRC	0	RFACT_WKUP_DLY						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	RFACT_EN	RFACT_I...	RFACT_SRC		PORTA_P...	RFGPO_SRC			RFGPO_OBE							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 —	Reserved
30-28 RFNA_IBE	RF_NOT_ALLOWED Input Buffer Enables Enables input pin for RF_NOT_ALLOWED. 000b - RF_NOT_ALLOWED input pin disabled 001b - RF_NOT_ALLOWED input pin uses PTA16 010b - RF_NOT_ALLOWED input pin uses PTA17 011b - RF_NOT_ALLOWED input pin uses PTA22 100b - RF_NOT_ALLOWED input pin uses PTC7 101b - RF_NOT_ALLOWED input pin uses PTD6
27 —	Reserved
26 QREQ_RF_EN	QUIET_REQ Enable for Radio CPU Flash Enables QUIET_REQ to suppress Radio CPU Flash activity. 0b - QUIET_REQ is not enabled for Radio CPU Flash 1b - QUIET_REQ is enabled for Radio CPU Flash
25 QREQ_SOC_EN	QUIET_REQ Enable for SOC Core Flash Enables QUIET_REQ to suppress SOC Core Flash activity. 0b - QUIET_REQ is not enabled for SOC Core Flash 1b - QUIET_REQ is enabled for SOC Core Flash
24 QREQ_SRC	QUIET_REQ Source Selects the QUIET_REQ source from the RFMC or TSM/LL outputs. 0b - QUIET_REQ is driven by the RFMC 1b - QUIET_REQ is driven by the TSM/LL
23-22 —	Reserved
21-16 RFACT_WKUP_DLY	RF_ACTIVE Wakeup Delay If RFACT_SRC=2'b00, this configures number of 32kHz reference clocks following enable of the XO to assert the RF_ACTIVE pin for a MAN/WOR/Bluetooth LE wakeup event. Note, RFACT_WKUP_DLY should always be set to a value less than or equal to XO_CTRL[WKUP_OFFSET].
15 RFACT_EN	S/W Enable of RF_ACTIVE pin If RFACT_SRC=2'b00 and RFACT_IDIS=0, this can be used by software to assert the RF_ACTIVE pin.

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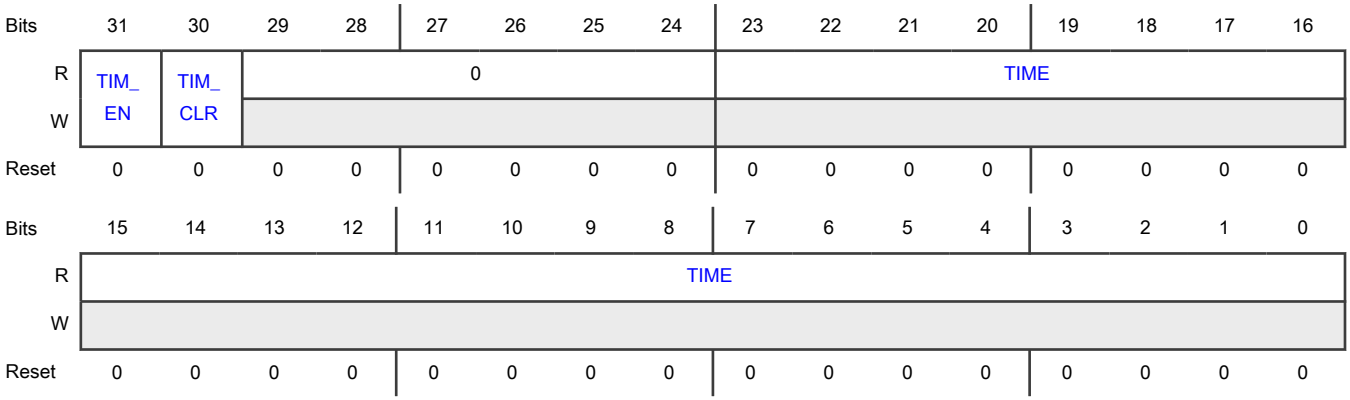
Field	Function
	0b - Take no action 1b - Assert RF_ACTIVE pin
14 RFACT_IDIS	RF_ACTIVE Idle Disable if RFACT_SRC=2'b00, this configures the RF_ACTIVE pin to deassert when TSM is idle. 0b - RF_ACTIVE does not deassert when TSM is idle (will deassert on next low power mode entry) 1b - RF_ACTIVE will deassert when TSM is idle
13-12 RFACT_SRC	RF_ACTIVE Source Selects the RF_ACTIVE source from the RFMC, TSM/LL or Bluetooth LE wakeup request. 00b - RF_ACTIVE is driven by the RFMC 01b - RF_ACTIVE is driven by the TSM/LL 10b - RF_ACTIVE is driven by the Bluetooth LE wakeup request (bt_clk_req) 11b - Reserved
11 PORTA_PWR	PORTA Power Some of the coexistence or FEM control pins are mapped to PORTA pin in the SOC. This bit controls whether PORTA pins (in the CORE_WAKE domain) remain powered when the MCU is in Deep Power Down 0b - PORTA pins do not remain powered (default behavior) 1b - PORTA pins remain powered
10-8 RFGPO_SRC	RF_GPO Source Selects the Source for RF_GPO[7:0]. In description below, coext[3:0] = {rf_priority[1:0], rf_status, rf_active}, and fem_ctrl[3:0] = {ant_b, ant_a, rx_switch, tx_switch} 000b - RF_GPO[7:0] = {coext[3:0], fem_ctrl[3:0]} 001b - RF_GPO[7:0] = {fem_ctrl[3:0], coext[3:0]} 010b - RF_GPO[7:0] = {lant_lut_gpio[3:0], fem_ctrl[3:0]} 011b - RF_GPO[7:0] = {fem_ctrl[3:0], lant_lut_gpio[3:0]} 100b - RF_GPO[7:0] = {lant_lut_gpio[3:0], coext[3:0]} 101b - RF_GPO[7:0] = {coext[3:0], lant_lut_gpio[3:0]}
7-0 RFGPO_OBE	RF_GPO Output Buffer Enable Enables output pins for RF_GPO[7:0] (see chip configuration chapter for pin mapping). 0 - output pin disabled 1 - output pin enabled

52.3.6.1.11 2.4GHz TIMER Register (RF2p4GHz_TIMER)

Offset

Register	Offset
RF2p4GHz_TIMER	24h

Diagram



Fields

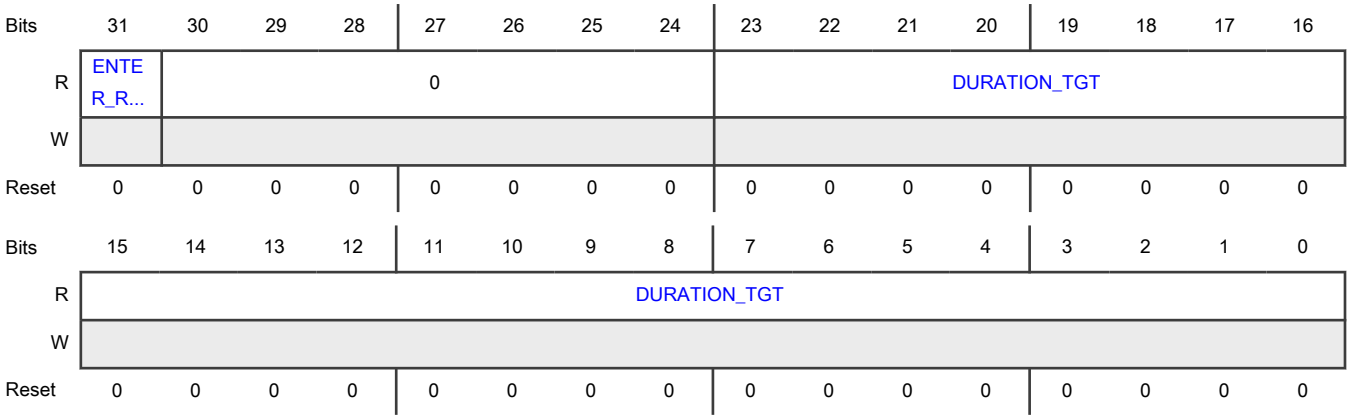
Field	Function
31 TIM_EN	Timer Enable Enables 32kHz reference clock timer (used by the MAN low power controller) to begin incrementing. 0b - Timer disabled 1b - Timer enabled
30 TIM_CLR	Timer Clear Causes 32kHz reference clock timer (used by the MAN low power controller) to clear to 0. Note after writing a 1 to TIM_CLR, user should poll TIME count to ensure it has cleared before writing 0 to TIM_CLR 0b - Timer not cleared 1b - Timer cleared
29-24 —	Reserved
23-0 TIME	Timer Count Current 32kHz reference clock time (used by the MAN low power controller).

52.3.6.1.12 2.4GHz WOR Register 1 (RF2p4GHz_WOR1)

Offset

Register	Offset
RF2p4GHz_WOR1	28h

Diagram



Fields

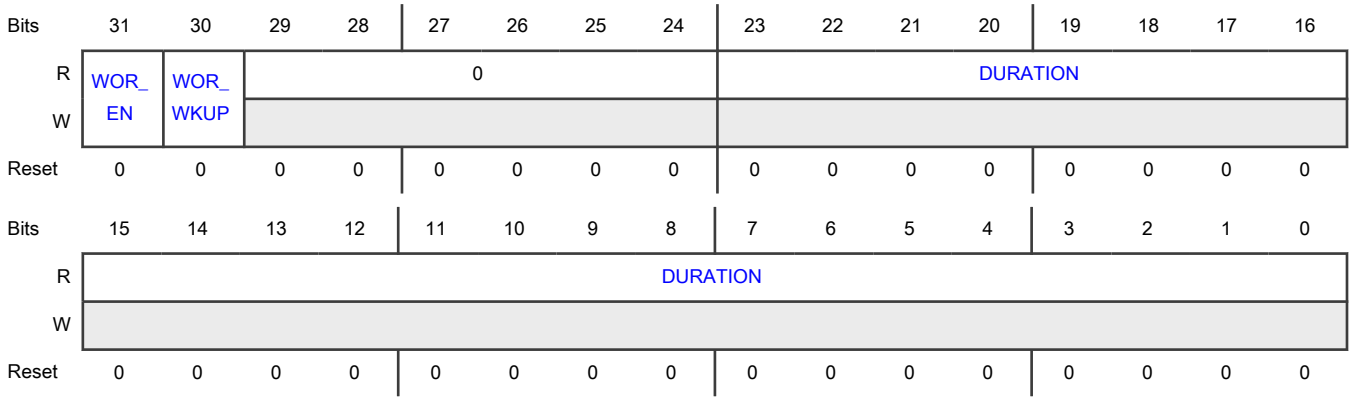
Field	Function
31 ENTER_REQ	WOR Low Power Entry Request WOR request asserted for low power mode entry. 0b - WOR low power mode request deasserted 1b - WOR low power mode request asserted
30-24 —	Reserved
23-0 DURATION_TGT	WOR Low Power Duration Target Target duration for radio to remain in low power mode. Note, value is only valid when ENTER_REQ is asserted.

52.3.6.1.13 2.4GHz WOR Register 2 (RF2p4GHz_WOR2)

Offset

Register	Offset
RF2p4GHz_WOR2	2Ch

Diagram



Fields

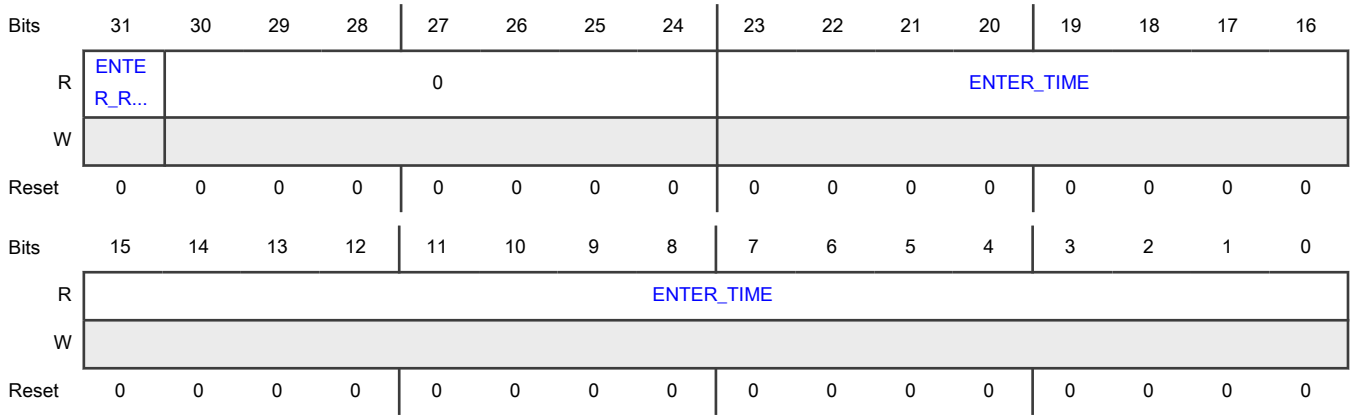
Field	Function
31 WOR_EN	WOR Enable Enable WOR to initiate low power mode entry/wakeup. 0b - WOR low power mode entry/wakeup disabled 1b - WOR low power mode entry/wakeup enabled
30 WOR_WKUP	WOR Wakeup Force early WOR wakeup from low power mode. 0b - WOR low power mode wakeup deasserted 1b - WOR low power mode wakeup asserted
29-24 —	Reserved
23-0 DURATION	WOR Low Power Duration Duration radio remained in low power mode due to WOR low power mode request. Note, value is only valid when ENTER_REQ is deasserted.

52.3.6.1.14 2.4GHz MAN Register 1 (RF2p4GHz_MAN1)

Offset

Register	Offset
RF2p4GHz_MAN1	30h

Diagram



Fields

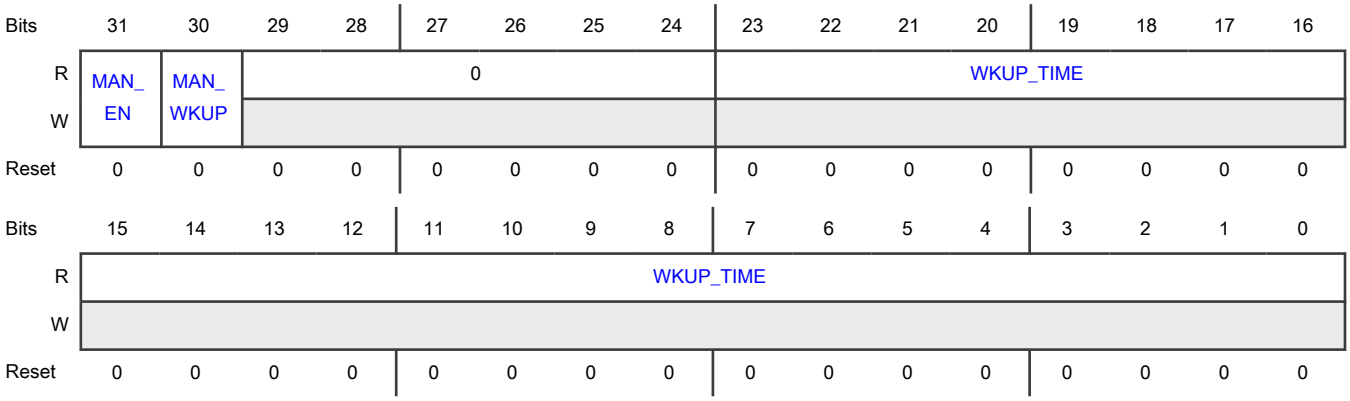
Field	Function
31 ENTER_REQ	MAN Low Power Entry Request MAN request asserted for low power mode entry. 0b - MAN low power mode request deasserted 1b - MAN low power mode request asserted
30-24 —	Reserved
23-0 ENTER_TIME	MAN Low Power Entry Time Stamp Reflects the instantaneous value of the Time stamp at which the MAN should initiate low power entry.

52.3.6.1.15 2.4GHz MAN Register 2 (RF2p4GHz_MAN2)

Offset

Register	Offset
RF2p4GHz_MAN2	34h

Diagram



Fields

Field	Function
31 MAN_EN	MAN Enable Enable MAN to initiate low power mode entry/wakeup. 0b - MAN low power mode entry/wakeup disabled 1b - MAN low power mode entry/wakeup enabled
30 MAN_WKUP	MAN Wakeup Force early MAN wakeup from low power mode. 0b - MAN low power mode wakeup deasserted 1b - MAN low power mode wakeup asserted
29-24 —	Reserved
23-0 WKUP_TIME	MAN Low Power Wakeup Time Stamp Reflects the instantaneous value of the Time stamp at which the MAN should complete low power wakeup.

52.3.6.1.16 2.4GHz MAN Register 3 (RF2p4GHz_MAN3)

Offset

Register	Offset
RF2p4GHz_MAN3	38h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0								ENTER_TIME_CAPT							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	ENTER_TIME_CAPT															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 —	Reserved
23-0 ENTER_TIME_CAPT	MAN Low Power Entry Time Captured Captured Time stamp for MAN entry to low power. The value of ENTER_TIME is captured when the man_sleep_req asserts.

52.3.6.1.17 2.4GHz MAN Register 4 (RF2p4GHz_MAN4)

Offset

Register	Offset
RF2p4GHz_MAN4	3Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0								WKUP_TIME_CAPT							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	WKUP_TIME_CAPT															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 —	Reserved
23-0 WKUP_TIME_CAPT	MAN Low Power Wakeup Time Captured Captured Time stamp for MAN exit from low power. The value of WKUP_TIME is captured when the man_sleep_req asserts. However, if MAN_WKUP bit is set, the value is updated when that occurs to reflect the early exit time.

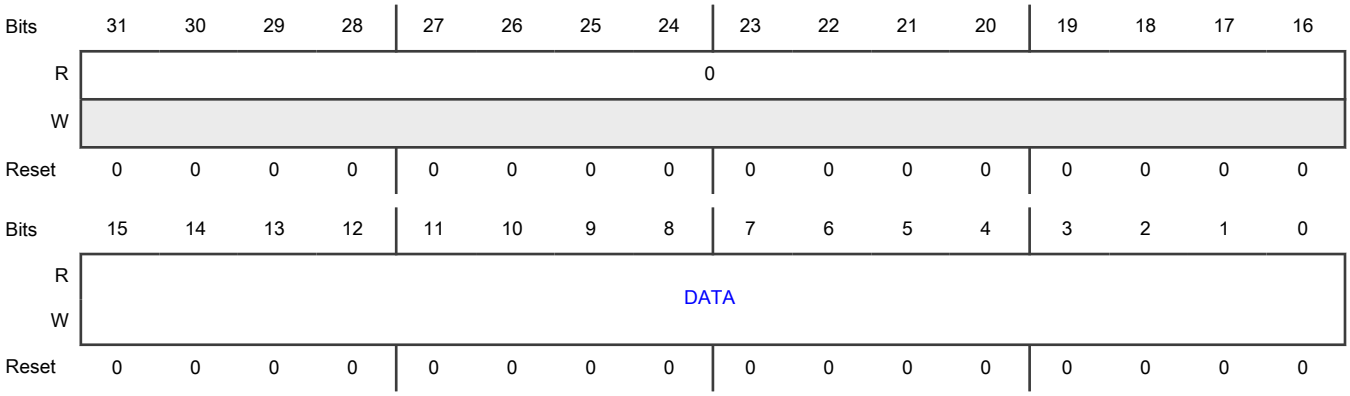
52.3.6.1.18 RF 2.4GHz Buffer from Host to Radio (RF2p4GHz_HOST2RADIO)

Offset

Register	Offset
RF2p4GHz_HOST2RADIO	48h

Function
This buffer allows communication between CPU cores without the need for one core to wakeup the other core

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 DATA	Data of Buffer0 This register field is mirrored in XCVR_MISC.HOST2RADIO.HOST2RADIO_DATA register.

52.3.6.1.19 RF 2.4GHz Buffer from Radio to Host (RF2p4GHz_RADIO2HOST)

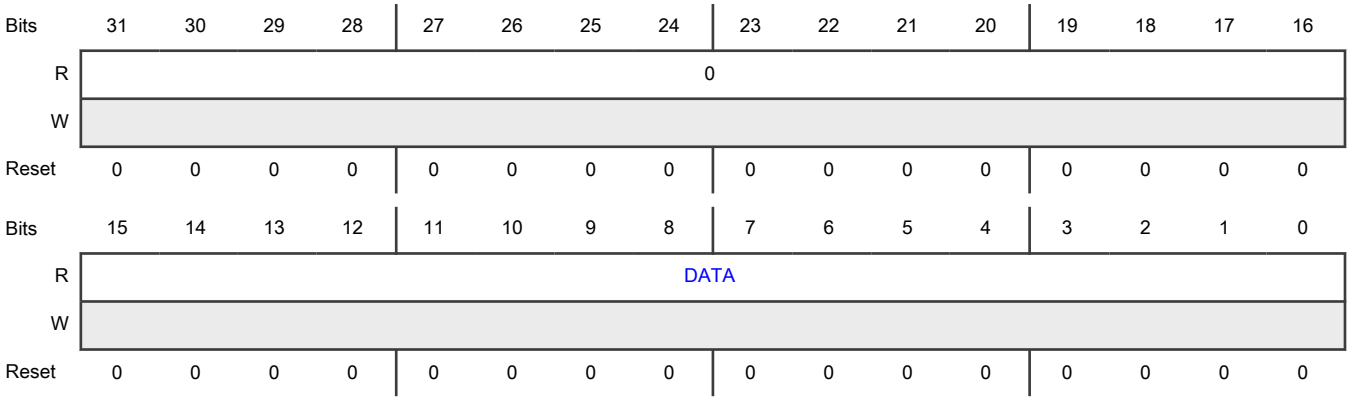
Offset

Register	Offset
RF2p4GHz_RADIO2HOST	4Ch

Function

This buffer allows communication between CPU cores without the need for one core to wakeup the other core.

Diagram



Fields

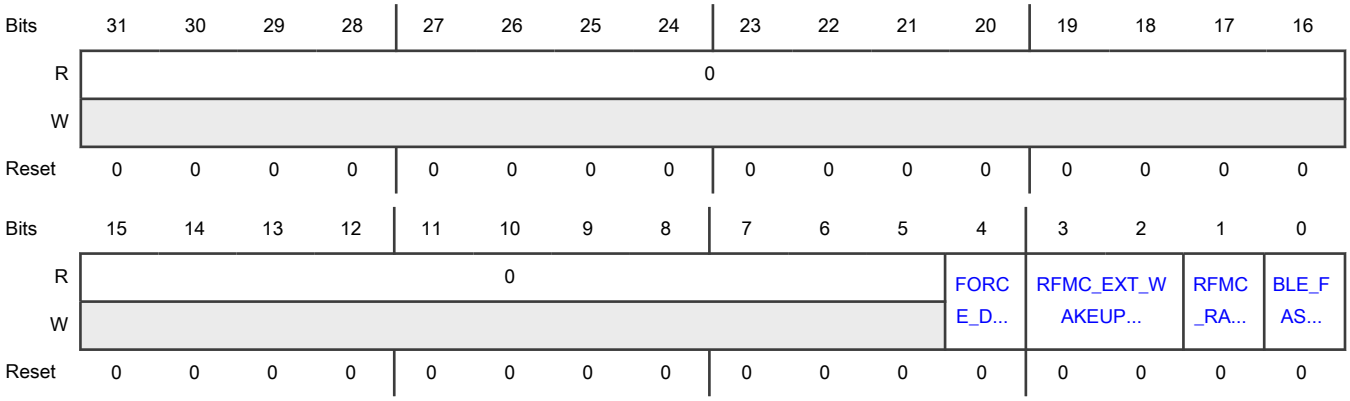
Field	Function
31-16 —	Reserved
15-0 DATA	Data of Buffer0 This register field is mirrored from the XCVR XCVR_MISC.RADIO2HOST.RADIO2HOST_DATA register.

52.3.6.1.20 2.4GHz Radio Configuration Register (RF2p4GHz_CFG)

Offset

Register	Offset
RF2p4GHz_CFG	50h

Diagram



Fields

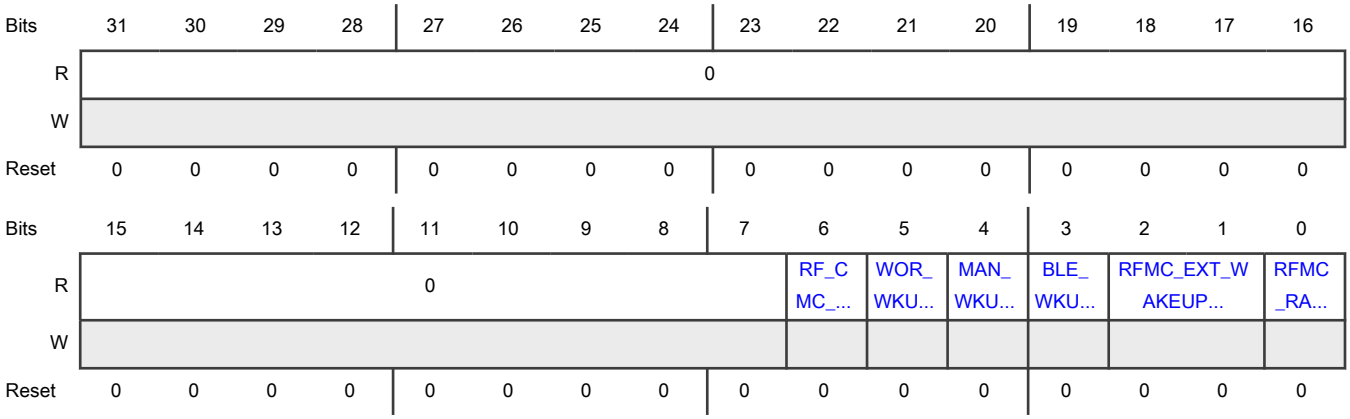
Field	Function
31-5 —	Reserved
4 FORCE_DBG_PWRUP_ACK	Controls the Radio ack so that Radio can go into power down in debug mode also
3-2 RFMC_EXT_WAKEUP_EN	Enable Radio wakeup by external source RFMC_EXT_WAKEUP_EN[0]==1 to enable Radio wakeup via rfmc_ext_wakeup[0] line (i.e. LPTMR interrupt) RFMC_EXT_WAKEUP_EN[1]==1 to enable Radio wakeup via rfmc_ext_wakeup[1] line
1 RFMC_RADIO_DEBUG_REQ_EN	rfmc_radio_debug_req_en enable rfmc_radio_debug_req : This bit allows host debugger to force ON the radio power.
0 BLE_FAST_WKUP	No LP Wakeup Delay on WakeUp from Host

52.3.6.1.21 2.4GHz Radio WakeUp Source Register (RF2p4GHz_WKUP_SRC)

Offset

Register	Offset
RF2p4GHz_WKUP_SRC	54h

Diagram



Fields

Field	Function
31-7 —	Reserved
6 RF_CMC_BLE_WKUP_STATUS	RF_CMC BLE Wakeup status
5 WOR_WKUP_STATUS	RFMC WOR Wakeup status (Host Controlled)
4 MAN_WKUP_STATUS	RFMC MAN Wakeup status (Host Controlled)
3 BLE_WKUP_STATUS	RFMC BLE Wakeup status (Host Controlled)
2-1 RFMC_EXT_WAKEUP_STATUS	Radio wakeup by external source status
0 RFMC_RADIO_DEBUG_REQ_STATUS	Radio debug request status

52.4 2.4GHz Radio

52.4.3 Overview

The radio supports the following bus interfaces to allow software access to radio peripherals and memories:

1. RADIO(NBU) CM33 interface to the RADIO(NBU) CM33 memories, the memory-mapped peripherals inside the NBU, access to the radio resources (Generic LL, XCVR, etc.) outside of the NBU via the radio's PBRIDGE, access to resources (radio flash, TPM2, RF_CMC, radio FRO192M) related to -- but outside of -- the radio via NBU PBRIDGE, and access to HOST CM33 peripherals (e.g., DSB, EdgeLock Secure Enclave, SEMA42, and RFMC) via AXBS PBRIDGE0. (For a detailed list of peripherals accessible via PBRIDGE0, refer to the Peripheral Bridge section of the Core overview chapter of this Reference Manual.)
2. HOST CM33 access some NBU resources, and NBU PBRIDGE resources. Note that this path only allows access to certain regions of the NBU/RADIO CM33 memory space, and (unlike #1 above) it is not allowed access to the radio PBRIDGE or the AXBS's PBRIDGE0.
3. CM33 access to the radio PBRIDGE to access radio resources (Generic LL, XCVR, etc.) outside of the NBU
4. HOST CM33 and NBU CM33 access to RFMC registers. The NBU CM33 access is via AXBS PBRIDGE0 (#1 above).

52.4.3.1 Block Diagram

The 2.4 GHz Radio Block Diagram is shown in the picture below:.

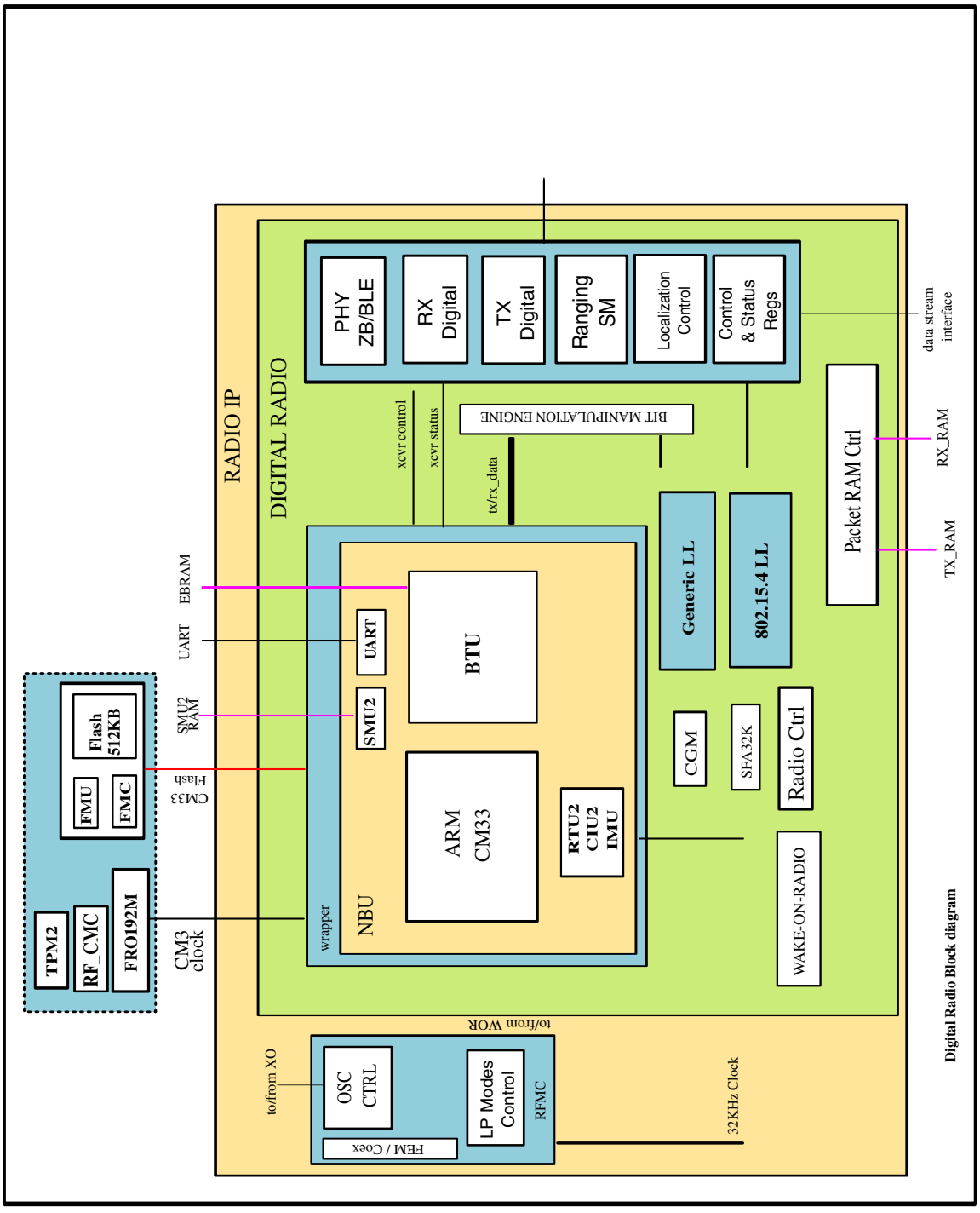


Figure 219. Radio Block Diagram

The block diagram highlights the different bus interfaces

52.4.3.2 Features

The Digital Radio IP provides the logic to drive the 2.4GHz multi-protocol radio, and it supports the following protocols:

1. Bluetooth Low Energy v6.0, supporting all mandatory features
   - Channel Sounding
   - 1Mbps
   - 2Mbps
   - Long Range (125kbps and 500kbps)
2. IEEE 802.15.4-2006 compliant PHY and MAC
   - Thread
   - Zigbee
3. Generic 2-level FSK/GFSK/MSK/GMSK
   - 250kbps
   - 500kbps
   - 1000kbps
   - 2000kbps
4. Concurrent IEEE 802.15.4 and Bluetooth Low Energy operation

52.4.4 Functional Description

52.4.4.1 Radio Control

52.4.4.1.1 Wake On Radio

52.4.4.1.1.1 Overview

The 2.4GHz Wake-On-Radio (WOR) Scheduler, is a hardware automation block, intended to reduce radio and SoC dynamic power consumption, and facilitate radio frequency hopping.

Wake-On-Radio (WOR) substantially increases the autonomy of the radio within the SoC, taking advantage of the separated power domains for the MCU and the Radio in the SoC, by providing sufficient hardware automation to ensure very long MCU low-power intervals, encompassing multiple RF operations, whenever possible.

52.4.4.1.1.1.1 Block Diagram

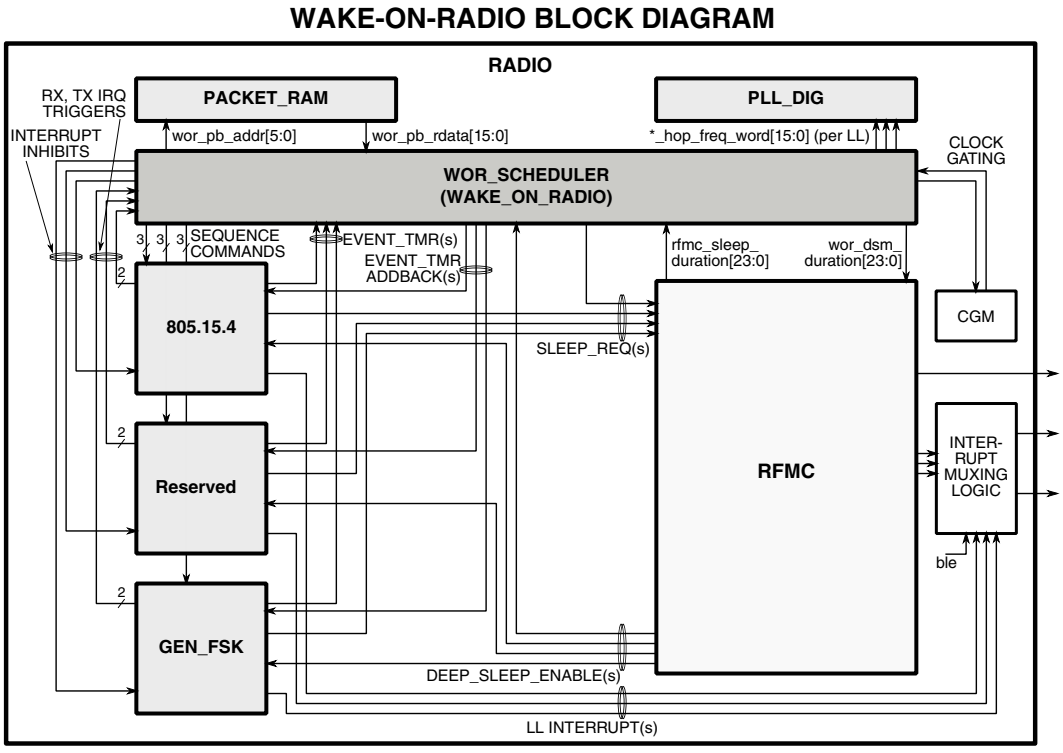


Figure 220. WAKE-ON-RADIO BLOCK DIAGRAM

52.4.4.1.1.1.2 Features

The 2.4GHz Radio Wake-On-Radio Scheduler provides hardware automation for the following operations:

- Insertion of the radio digital logic into Deep Sleep Mode (DSM), and subsequent DSM exit
- Sequencing of RF operations, both TX and RX, between DSM cycles, without MCU intervention.
- RF Frequency Hopping

Two different scheduling methods are supported:

- Timeslot-based scheduling
- Constant-Interval scheduling

WOR supports the radio's 802.15.4, and GENERIC_FSK protocol engine(s), and interfaces to the radio's RFMC (Radio Mode Controller) for the scheduling of DSM entry/exit.

WOR also provides the following features:

- Divide future RF operations into "timeslots", which can occur at regularly-, or non-regularly-scheduled intervals.
- Descriptor-based format for software to program timeslot information.
- Interaction with the protocol engines to dynamically manage radio interrupts, allowing link layer interrupts to propagate only when it is necessary to notify the MCU of required action.

52.4.4.1.1.2 Functional Description

52.4.4.1.1.2.1 Assign To Protocol

The 2.4GHz radio supports multiple protocols, each with its own protocol engine. All protocols can benefit from scheduling in advance several RF operations and DSM cycles, with the radio conducting the successive operations autonomously, allowing the MCU to remain in low power state for the duration. This is the concept behind Wake-On-Radio (WOR).

The WOR function can be assigned to any one of the following protocol(s): 802.15.4, GENERIC_FSK. (Bluetooth LE has its own, internal DSM and wake-on-radio control scheme, as well as hardware-controlled frequency hopping, built into the IP, so it does not interact with the WOR Scheduler).

Assigning WOR to a protocol is done by way of the WOR_PROTOCOL register, as shown in the following table:

WOR_PROTOCOL[2:0]	ASSIGNED PROTOCOL ENGINE
0	Not Assigned
1	802.15.4
2	GENERIC_FSK
3	Reserved

Assigning to protocol means that the assigned Link Layer's WOR interface signals are routed, exclusively, to and from the WOR state machine. WOR interface signals include the event timers, sequence start- and stop-command signals, interrupt inhibits, and event timer addback commands. These interface signals are covered in more details in later sections.

The following diagram illustrates how 1 of the 3 WOR-capable Link Layers is assigned to the WOR function:

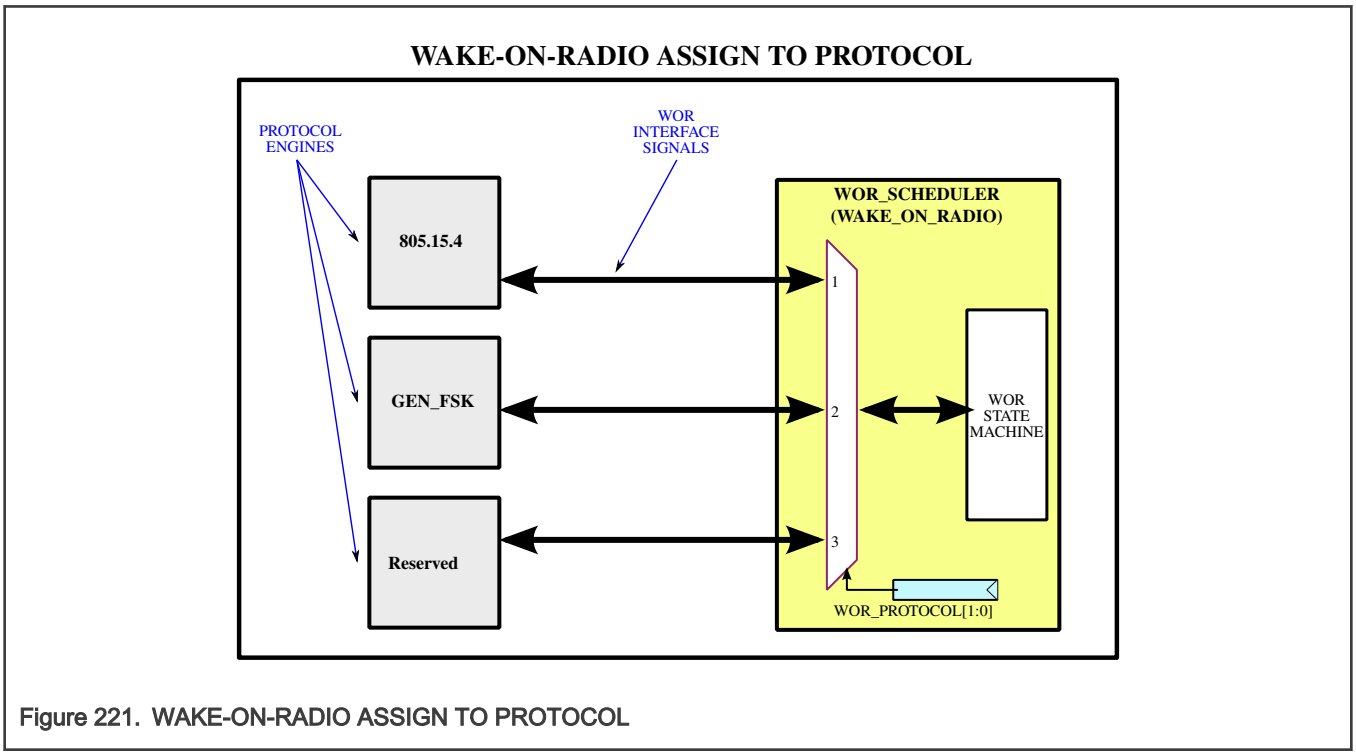


Figure 221. WAKE-ON-RADIO ASSIGN TO PROTOCOL

In a multi-protocol setting, assigning a protocol to Wake-On-Radio does not mean that unassigned protocols are incapable of DSM. There is a back-up method, Manual DSM, which uses software-driven DSM entry and exit. In a multi-protocol setting, any 2 of the radio's protocols can be assigned to different DSM control scheme, with the control schemes being Wake-On-Radio, Manual DSM, and Bluetooth LE DSM.

52.4.4.1.1.2.2 Scheduling Modes

For maximum flexibility in scheduling future RF operations and Deep Sleep cycles, Wake-On-Radio (WOR) defines 2 scheduling modes: Timeslot Mode, and Constant Interval Mode. These modes are described in the sections below.

Timeslot Mode

Timeslot mode is desirable when the schedule for RF transactions is sporadic, varies over time, or is otherwise non-periodic. Timeslot mode is based loosely on the TSCH (Timeslotted Channel Hopping) concept, first defined in IEEE Std 802.15.4-2015. Key principles of TSCH are adopted by WOR, but far short of full adherence.

In TSCH, time is divided into slots of fixed duration. Slots are grouped into slotframes, containing fixed number of slots. Once a TSCH PAN (network) is established, slotframes will repeat forever, back-to-back. Devices can be assigned to 1 or more slots within a slotframe. For any given device on any given slot, the assigned slot can be TX or RX. One device can be assigned to transmit in a given slot; another device can be assigned to receive in the same slot. Assigning Device A to Transmit, and Device B to Receive, in the same slot, creates a link. Links can be dedicated (one TX and one RX device assigned). Or, links can be shared (multiple TX devices, using CSMA, and multiple RX devices). Typically, each slot uses a different hop frequency.

Slotframes are TDMA structures, with time on one axis and hop frequency on the other. The diagram below shows one "row" of a typical slotframe, with links established for Devices A, B, and C, all on the same hop frequency. This slotframe consists of 3 timeslots: TS0, TS1, and TS2.

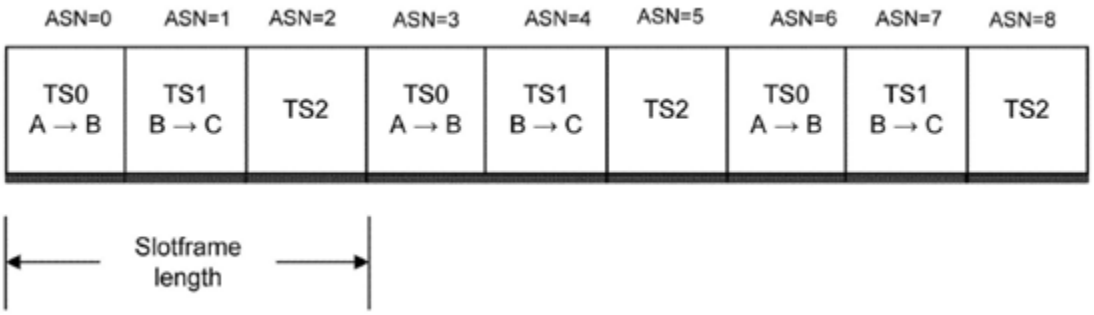


Figure 222. IEEE Std 802.15.4 TSCH 1-D SLOTFRAME

Another diagram below, shows a slotframe of 2 dimensions. The time axis has 100 slots, and the frequency axis has 4 indices into a table of available hop frequencies. Devices A, B, C, and D are assigned to various slots, and links are created amongst them.

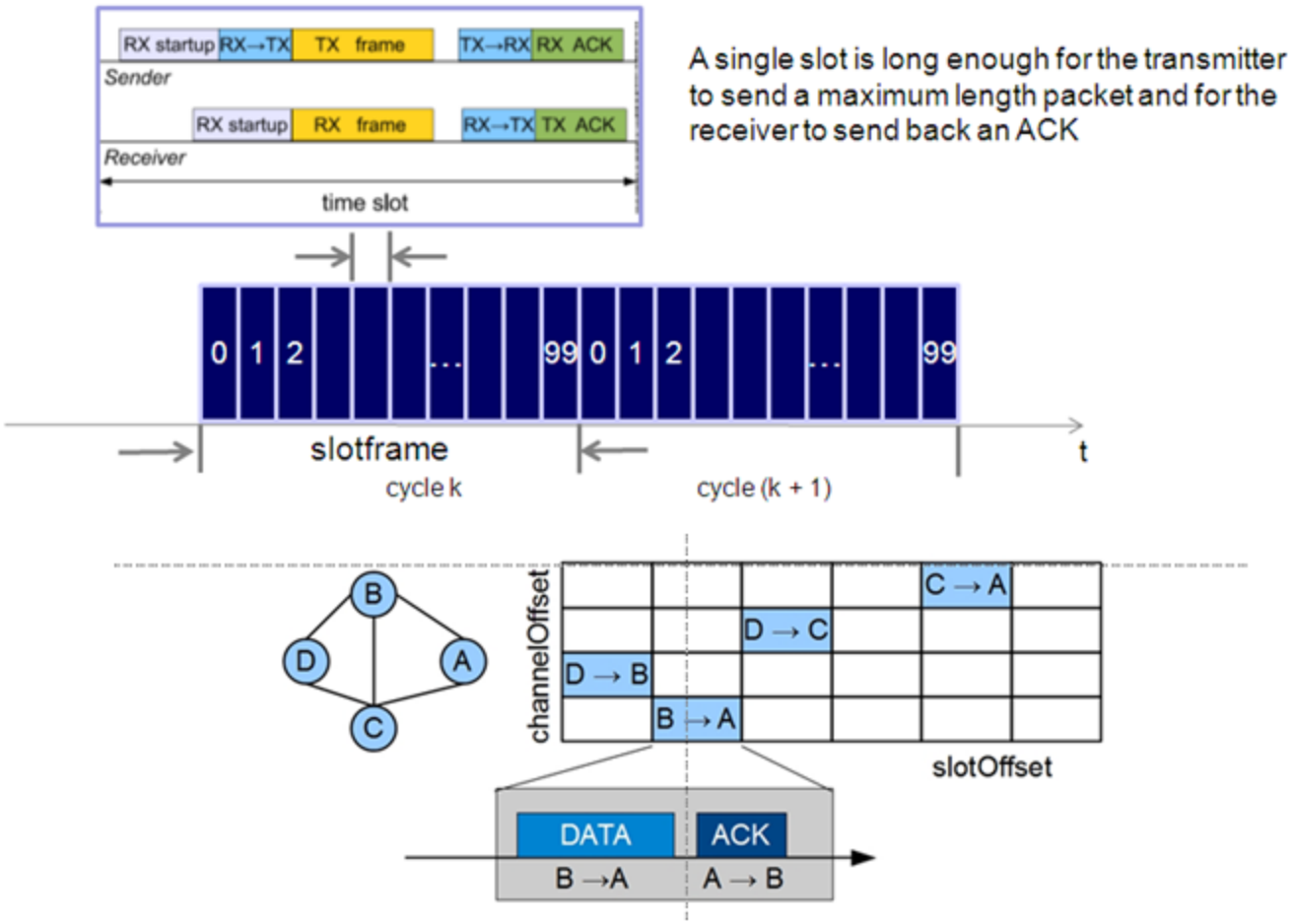


Figure 223. IEEE Std 802.15.4 TSCH 2-D SLOTFRAME

When RF operations are to be scheduled using Wake-On-Radio in a TIMESLOT context, the start times for the next *N* operations are programmed into the descriptor table to assign them to slots. One field of each slot descriptor, START_TIME, holds this information for WOR. See Section Descriptor Format for more information on the descriptor fields, and how they are packed into the descriptor. *N* is the number of slots used, and can be any integer from 2 to 4. The register SLOTS_USED is programmed with this value. The start times programmed into the descriptors, are relative to the Event Timer of the assigned Link Layer. WOR software will read the Event Timer, add to this value the desired time-to-next-event, and write the sum into the descriptor START_TIME. WOR hardware will monitor the assigned Link Layer's Event Timer; when it matches the START_TIME field of the current slot's descriptor, WOR hardware will initiate an RF sequence. The type of sequence is determined by the descriptor's FUNCTION field, and can be TX or RX or RT or TR. The RF operation will be allowed to continue, until it either self-terminates, or a timeout is reached. The timeout period for TIMESLOT scheduling mode is determined by the RECEIVE_TIMEOUT[15:0] register. The units of this register are microseconds. If a timeout is reached, i.e.,

EVENT_TMR = START_TIME + RECEIVE_TIMEOUT,

WOR hardware will terminate the sequence. Timeout applies to RX sequences only. RX sequences may result in no packet being received, a packet being received which is not addressed to the device, or a packet which is received corruptly. Any of these scenarios will result in a timeout and a WOR shutdown of the sequence. A correctly received packet addressed to the device will self-terminate the RX sequence before the timeout is reached. Timeout is not relevant to TX sequences, since these always self-terminate. The following diagram depicts how the WOR hardware processes the descriptor table, the assigned Event Timer, and the RECEIVE_TIMEOUT register, to start and terminate an RF operation.

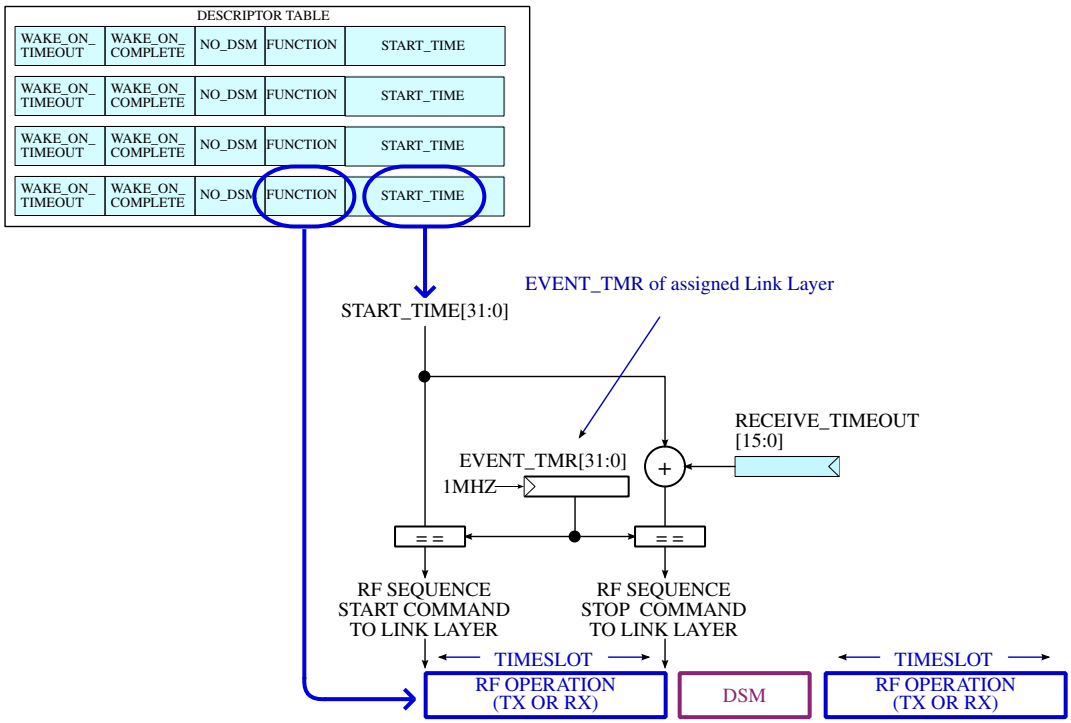


Figure 224. EVENT SCHEDULING IN TIMESTLOT SCHEDULING MODE

If the assigned protocol engine is 802.15.4 or GENERIC_FSK, an autosequence is available which is a TX sequence preceded by a CCA (Clear Channel Assessment). If the CCA results in a busy channel, the autosequence terminates without transmission; otherwise the transmission proceeds. This autosequence can be used in WOR Timeslot mode by appropriately configuring the 802.15.4 or GENERIC_FSK Link Layer.

In any timeslot, if the assigned FUNCTION is RX or RT, a TIMESTAMP can be captured to record the instant the packet's Access Address or SFD arrives at the Link Layer packet processor. There are 4 TIMESTAMP registers, once for each slot; hence, timestamps for the last 4 slots during which packets are received, can be recorded. See Section Timestamps for more details.

To execute the function RT, Link Layer should be configured with **AUTOACK** set. When Event Timer match, WOR will assert **wor_rx_start_ext signal** to Link Layer to start the RX sequence. After Link Layer completes the Auto-ACK sequence, it will send the signal **tx_irq_trig** to WOR to advance to the next state. If the RX operation timeout occurs, either nominal or delayed, WOR will assert **wor_seq_stop_ext** to the assigned Link Layer, causing an immediate abort of the RX sequence. RT function is effected by the window widening feature. A TIMESTAMP is captured in the RT sequence.

To execute the function TR, when Event Timer match, WOR will assert **wor_tx_start_ext** signal as well as **wor_function_is_tr** signal to Link Layer to start the TR sequence. After Link Layer completes the TR sequence, it will send signal **rx_irq_trig** to WOR to advance to the next state. If the RX operation timeout occurs, either nominal or delayed, WOR will **assert wor_seq_stop_ext** to the assigned Link Layer, causing an immediate abort of the RX sequence. TR function is not effected by the window widening feature. A TIMESTAMP is captured in the TR sequence.

Typically, for RX timeslots, it is desirable to wake the MCU on good packets only. Thus, the slot descriptor's WAKE_ON_COMPLETE field should be set to 1. If it is desired to wake the MCU on no-packet, or on incorrecty-received packets, the WAKE_ON_TIMEOUT descriptor field can be set to 1. If WAKE_ON_TIMEOUT is set to 1 on any slot's descriptor, the WAKE_ON_COMPLETE field is *implied* to be set to 1 as well, regardless of its actual programmed value.

Typically, for TX timeslots, it is desirable to wake the MCU after each transmission, to service the Packet Buffer. In such scenarios, WAKE_ON_COMPLETE should be set to 1. If it is required to transmit the same packet repeatedly, across multiple slots, such that the Packet Buffer does not require regular service, WAKE_ON_COMPLETE can be set to 0, to skip the MCU wakeup, on any slot.

In Timeslot Scheduling mode, the MCU *must* be awakened at least once every *N* slots, to refresh the descriptor table (or at least, to refresh the START_TIME's), with *N* being the value of SLOTS_USED. This periodic wakeup requirement must be enforced by

appropriate setting of the WAKE_ON_COMPLETE and WAKE_ON_TIMEOUT fields of the 4 slot descriptors. This is a requirement imposed on WOR software. (The same period wakeup requirement does not necessarily apply to Constant Interval scheduling mode. See next section.)

Constant-Interval Mode

Constant-Interval mode is appropriate when the schedule for RF transactions is perfectly periodic. A good example of such a scheduling regime, is the Bluetooth Low Energy Scanning State. In this state, a SCAN_INTERVAL is defined, which sets the interval between receive operations, and a SCAN_WINDOW is defined, which sets the duration of receiver "ON" time within the SCAN_INTERVAL. Wake-On-Radio adopts the principles of Bluetooth LE SCAN_INTERVAL and SCAN_WINDOW, broadening their scope to apply to any type of RF operation (TX or RX), and modifying the nomenclature to better represent the nature of the operations, to WOR_EVENT_INTERVAL and WOR_EVENT_WINDOW.

Instead of programming timeslot START_TIME's into the slot descriptors, Contant-Interval requires that WOR_EVENT_INTERVAL and WOR_EVENT_WINDOW be programmed instead. An additional parameter, WOR_EVENT_START, determines the instant of the first RF operation of the Constant-Interval WOR session, in case the desired start time is not immediate. WOR_EVENT_START is also programmed into the descriptor table. In Constant-Interval scheduling mode, WOR hardware processes the descriptors, and uses WOR_EVENT_INTERVAL, WOR_EVENT_WINDOW, and WOR_EVENT_START, to calculate the start time (Event Timer match), for the first RF operation, as well as all subsequent RF operations, on a rolling basis. WOR software is not required to refresh the descriptor table on a periodic basis, and would only intervene in the descriptors if a change was required to any parameter (e.g., a Bluetooth LE "Anchor Point Move" during a connection would require descriptor updates). In Constant-Interval mode, the start of WOR_EVENT_WINDOW always aligns to the start of WOR_EVENT_INTERVAL.

Aside from replacing the Timeslot descriptor START_TIME parameters with WOR_EVENT_INTERVAL, WOR_EVENT_WINDOW, and WOR_EVENT_START, the descriptor format is identical across the 2 scheduling modes, and the descriptor storage space (registers) is completely shared, since only 1 scheduling mode can be in effect at any given time. See Section Descriptor Format for more information on the descriptor fields, and how they are packed into the descriptor, and how the descriptor table is shared between the 2 scheduling modes.

A diagram depicting an example of Constant-Interval scheduling mode is shown below. In this diagram, the scanning device is in Constant-Interval mode, with the WOR_EVENT_INTERVAL and WOR_EVENT_WINDOW indicated.

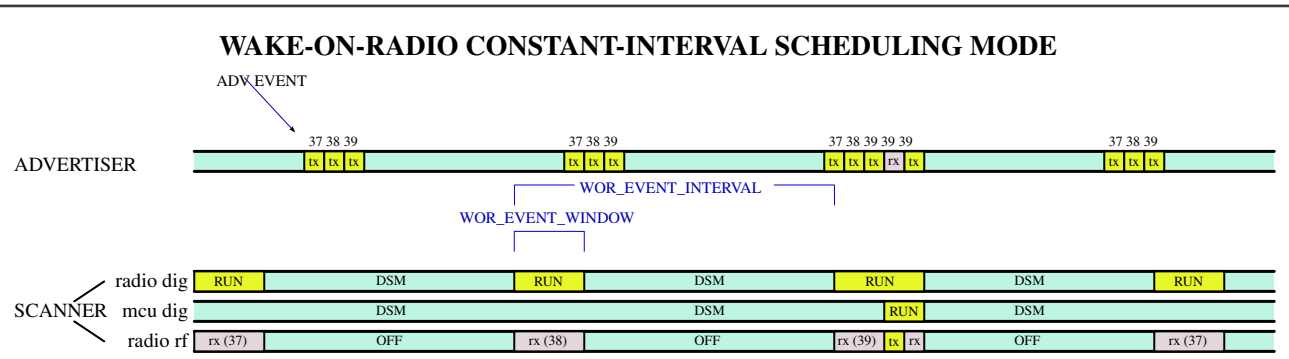


Figure 225. CONSTANT-INTERVAL SCHEDULING MODE EXAMPLE

When RF operations are to be scheduled using Wake-On-Radio in a Constant-Interval context, the WOR_EVENT_START, WOR_EVENT_INTERVAL, and WOR_EVENT_WINDOW parameters for the Constant-Interval operation are programmed into the descriptor table. These need be programmed only once, unless a change in network timing require an on-the-fly change to one of these parameters. The units for all 3 WOR_EVENT parameters are microseconds. See Section Descriptor Format for more information on the descriptor fields, and how they are packed into the descriptor. WOR hardware will process these 3 parameters to calculate the initial start time, and all subsequent start times, on a rolling basis. The start times computed by WOR hardware, are relative to the Event Timer of the assigned Link Layer. WOR hardware will monitor the assigned Link Layer's Event Timer; when it matches the next computed start time, WOR hardware will initiate an RF sequence. The type of sequence is determined by the current slot descriptor's FUNCTION field, and can be TX or RX. The RF operation will be allowed to continue, until it either self-terminates, or a timeout is reached. The timeout period for Constant-Interval scheduling mode is determined by the WOR_EVENT_WINDOW descriptor field. If a timeout is reached, i.e.,

EVENT_TMR = START_TIME (computed) + WOR_EVENT_WINDOW (descriptor),

WOR hardware will terminate the sequence. Timeout applies to RX sequences only. RX sequences may result in no packet being received, a packet being received which is not addressed to the device, or a packet which is received corruptly. Any of these scenarios will result in a timeout and a WOR shutdown of the sequence. A correctly received packet addressed to the device will self-terminate the RX sequence before the timeout is reached. Timeout is not relevant to TX sequences, since these always self-terminate. The concept of slots still applies to Constant-Interval Mode. The number of slots used can be any integer from 3 to 4 for Constant-Interval mode. The register SLOTS_USED is programmed with this value. Consecutive RF operations are assigned to consecutive slots, with the slot descriptor's parameters (e.g. FUNCTION, or WAKE_ON_COMPLETE) applying to the current slot. As in Timeslot mode, in Constant-Interval mode, WOR hardware will increment the slot number for each new RF operation, modulo SLOTS_USED.

In any timeslot, the assigned FUNCTION is a simple TX or RX operation. There is no automatic acknowledgement of packets. If acknowledgement is required during a timeslot, the MCU must be awakened (by setting the WAKE_ON_COMPLETE bit of the slot's descriptor), and the software must handle the acknowledgement, using standard Link Layer (not WOR) resources, within the turnaround time requirement (if any). WOR hardware will hold its state and wait for software to complete the acknowledgement, and other required tasks, before advancing to the next slot on software command.

If the assigned protocol engine is 802.15.4 or GENERIC_FSK, an autosequence is available which is a TX sequence preceded by a CCA (Clear Channel Assessment). If the CCA results in a busy channel, the autosequence terminates without transmission; otherwise the transmission proceeds. This autosequence can be used in WOR Timeslot mode by appropriately configuring the 802.15.4 or GENERIC_FSK Link Layer.

In any timeslot, if the assigned FUNCTION is RX, a TIMESTAMP can be captured to record the instant the packet's Access Address or SFD arrives at the Link Layer packet processor. There are 4 TIMESTAMP registers, once for each slot; hence, timestamps for the last 4 slots during which packets are received, can be recorded. See Section Timestamps for more details.

Typically, for RX timeslots, it is desirable to wake the MCU on good packets only. Thus, the slot descriptor's WAKE_ON_COMPLETE field should be set to 1. If it is desired to wake the MCU on no-packet, or on incorrecty-received packets, the WAKE_ON_TIMEOUT descriptor field can be set to 1. If WAKE_ON_TIMEOUT is set to 1 on any slot's descriptor, the WAKE_ON_COMPLETE field is *implied* to be set to 1 as well, regardless of its actual programmed value.

Typically, for TX timeslots, it is desirable to wake the MCU after each transmission, to service the Packet Buffer. In such scenarios, WAKE_ON_COMPLETE should be set to 1. If it is required to transmit the same packet repeatedly, across multiple slots, such that the Packet Buffer does not require regular service, WAKE_ON_COMPLETE can be set to 0, to skip the MCU wakeup, on any slot.

Unlike Timeslot mode, in Constant-Interval mode, it is not required to wake up the MCU at least every *Nth* slot to refresh the descriptor start times, because WOR hardware is able to compute all future start times on a rolling basis. If all slots are of the same type (same FUNCTION, TX or RX, and same descriptor information), there is no hard limit on the number of consecutive slots that can be executed between MCU wakeups. To set such a upper limit, the WAKE_ON_NTH_SLOT[7:0] register can be programmed with a value. When the number of slots elapsed after setting SLOTS_USED to a non-zero value to begin a WOR session, reaches the value of WAKE_ON_NTH_SLOT, the MCU will automatically be awakened at the end of the current slot, regardless of the setting of the WAKE_ON_COMPLETE and WAKE_ON_TIMEOUT bits in the descriptor. The WAKE_ON_NTH_SLOT register is only relevant to Constant-Interval scheduling mode, and has no effect in Timeslot mode. In Constant-Interval mode, if automatic wake on *Nth* slot is not desired, set WAKE_ON_NTH_SLOT=0 to disable this wakeup upper-limit. However, if a zero setting is used, software *must* program at least one of the slot descriptors to schedule an MCU wakeup by setting the either WAKE_ON_COMPLETE or WAKE_ON_TIMEOUT fields of the descriptor to 1; otherwise a situation could arise where the MCU is never awakened by WOR.

52.4.4.1.1.2.3 Descriptor Format

As mentioned in previous sections, Wake-On-Radio allows the next several RF operations to be scheduled in advance. For scheduling purposes, each of the next, several RF operations is assigned to a slot. Each slot is associated with a descriptor, which is a hardware-based data structure containing information about the characteristics of the slot, and instructions for how WOR hardware should execute it. Characteristics include start time of the RF operation, and type (function) or operation to be conducted by WOR. Software schedules the next *N* RF operations (slots) by programming the next *N* descriptors with the slots' characteristics. Software then sets the SLOTS_USED register to *N* to begin a WOR session. WOR hardware includes a 2-bit slot counter that cycles through the slots, in order, starting with SLOT 0; the slot counter is used to select the "current descriptor". The current descriptor's slot characteristics are forwarded to the WOR state machine, which executes the RF operation per the

instructions in the descriptor. After the RF operation is complete, the slot counter is incremented by 1 (modulo SLOTS_USED), and the next slot's descriptor becomes the "current" one. The process repeats indefinitely until the WOR session is ended by setting SLOTS_USED=0. WOR hardware automatically inserts (unless instructed otherwise in the descriptor) a DSM cycle, after the current slot's RF operation completes, with a DSM duration that lasts until the start time of the *next* slot, so that time between RF operations is always filled with DSM, for maximum power savings. After setting SLOTS_USED to a non-zero value to begin a WOR session, the MCU can be put into a low power state, and remain there, until the last (*Nth*) slot completes, assuming Timeslot scheduling mode. (For Constant Interval mode, MCU wake up on the *Nth* slot is not required. See Section Scheduling Modes for information on when and how the MCU is to be awakened for Constant-Interval mode.)

The descriptor format for Timeslot scheduling mode is shown in the diagram below, indicating the various fields in the descriptor, and the bits assigned to each field:

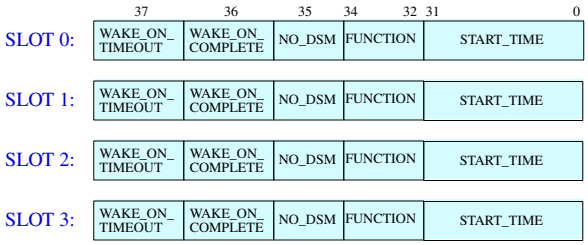


Figure 226. DESCRIPTOR FORMAT (TIMESLOT MODE)

The descriptor format for Constant-Interval scheduling mode is shown in the diagram below, indicating the various fields in the descriptor, and the bits assigned to each field:

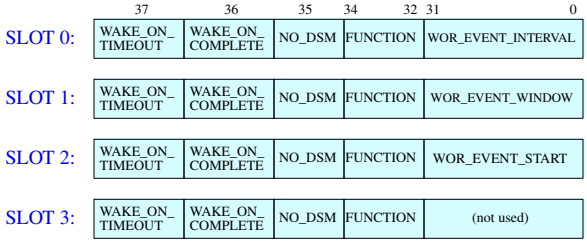


Figure 227. DESCRIPTOR FORMAT (CONSTANT-INTERVAL MODE)

The descriptor formats for Timeslot and Constant-Interval scheduling modes are almost identical, and so the descriptor hardware is almost completely shared by the 2 scheduling modes, as shown in the diagram below:

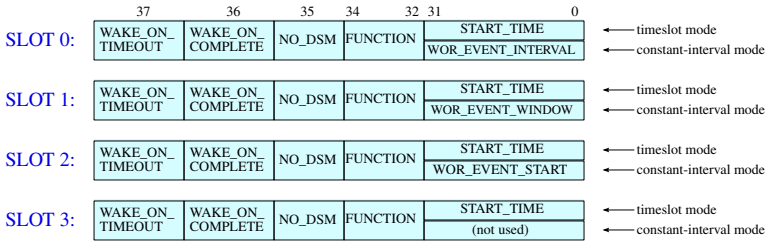


Figure 228. DESCRIPTOR FORMAT (SHARED)

Descriptor fields are described in the table below:

FIELD	DESCRIPTION
START_TIME	The instant at which to begin the current slot's RF operation. START_TIME is relative to the assigned Link Layer's Event Timer. Units are microseconds. Because the Event Timers' bit widths vary with protocol, see START_TIME programming information later in this section. Applies to Timeslot mode only. WOR hardware will automatically adjust this value with window-widening, if enabled.
WOR_EVENT_INTERVAL	Sets the interval between the start of RF operations for consecutive slots. Units are microseconds. Applies to Constant-Interval mode only. WOR hardware will automatically adjust this value with window-widening, if enabled.
WOR_EVENT_WINDOW	Maximum duration of the transceiver "ON" time for the current slot. "ON" time will be less than this if the RF operation self-terminates. Units are microseconds. Applies to Constant-Interval mode only. The start of the WOR_EVENT_WINDOW aligns to the start of the WOR_EVENT_INTERVAL. WOR hardware will automatically adjust this value with window-widening, if enabled.
WOR_EVENT_START	The instant at which to begin the RF operation for the first SLOT 0 of the WOR session. WOR_EVENT_START is relative to the assigned Link Layer's Event Timer. Units are microseconds. Because the Event Timers' bit widths vary with protocol, see WOR_EVENT_START programming information later in this section. Applies to Constant-Interval mode only. WOR hardware will automatically adjust this value with window-widening, if enabled.
FUNCTION	This 3 -bit field defines the RF function of the slot: 0: No RF 1: TX 2: RX 3: RT 4: TR 5~7: Reserved
NO_DSM	By default, a DSM cycle is automatically entered at the end of the current slot's RF operation, and the DSM cycle is timed to expire just before the start time of the next consecutive slot. If this field is set to 1, DSM is not entered, and the WOR state machine holds the radio in RUN state until the start time of the next slot is reached. NO_DSM can be used to execute back-to-back, or closely spaced RF operations, such as a Bluetooth LE 3-channel advertising event.
WAKE_ON_COMPLETE	Instructs the WOR state machine to permit an interrupt to wake up the MCU at the end of a successfully completed

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FIELD	DESCRIPTION
	RF operation. RX operations are successfully completed if a packet is received before the timeout, which passes CRC and packet filtering rules. TX operations are always successfully completed. A successfully completed operation with WAKE_ON_COMPLETE=1 will cause the WOR state machine to temporarily remove its Link Layer interrupt inhibits, allowing the assigned Link Layer's RF interrupts (RXIRQ, TXIRQ, and/or SEQ_END_IRQ) to propagate, resulting in an MCU wakeup. If WAKE_ON_TIMEOUT=1, WAKE_ON_COMPLETE is *implied* to be 1 as well, regardless of the setting of this field.
WAKE_ON_TIMEOUT	Instructs the WOR state machine to permit an interrupt to wake up the MCU at the point of timeout of an RX operation. For Timeslot mode, timeout is determined by the RECEIVE_TIMEOUT[15:0] register; for Constant-Interval mode, timeout is determined by WOR_EVENT_WINDOW descriptor field. In either case, window-widening will automatically adjust the timeout instant, if enabled. A timeout which occurs with WAKE_ON_TIMEOUT=1 will cause the WOR state machine to temporarily remove its Link Layer interrupt inhibits, allowing the assigned Link Layer's SEQ_END_IRQ to propagate, resulting in an MCU wakeup, with a notification of timeout.

Event Timer bit width various across protocols. For 802.15.4, Event Timer is 28 bits; for GENERIC_FSK, Event Timer is 32 bits. In all cases, the Event Timer clock rate is 1MHz.

When FUNCTION is set to "NO_RF", no RF operation is performed during the slot. In this scenario, the WOR state machine will wait until the slot's programmed (or computed) START_TIME, and then automatically re-enter DSM until the next consecutive slot's START_TIME is reached. This allows multiple (up to 4) DSM-only slots which effectively extends the maximum DSM duration fourfold, to 1073 seconds (about 18 minutes), for the 802.15.4 and GENERIC_FSK protocol. However the RF Oscillator is activated briefly at each slot's START_TIME so that the WOR can process the current slot descriptor, and update the assigned Link Layer's Event Timer. Extending the DSM duration using the "NO_RF" method is referred to as "DSM cascading".

During an RX operation on any slot, if an AA or SFD has been detected at the point of timeout, the timeout (and the automatic shut-down of the sequence by the WOR state machine) is *deferred* until either:

1: The packet is fully received and determined to be good. In this case the WAKE_ON_COMPLETE bit determines if the MCU is to be awakened.

2: The packet is fully received and determined not to be good. In this case the WAKE_ON_TIMEOUT bit determines if the MCU is to be awakened.

There are no time restrictions on programming the descriptor table. All descriptor fields can be modified at any time. Needless to say, caution should be exercised with modifying descriptor START_TIME, and other parameters, for the *current* slot; START_TIME (or WOR_EVENT_START) must be in the future, and FUNCTION should not be modified once the START_TIME has been reached.

52.4.4.1.1.2.4 State Machine

In Wake-On-Radio, future RF operations are scheduled by programming instructions into the WOR Descriptor table. Based on descriptor specifications, WOR hardware organizes the scheduled RF operations into slots, with one RF operation per slot. The slot includes more than just the RF operation. Idle time between the current time, and the start of the RF operation, is filled

with DSM. WOR hardware must compute the required DSM duration, and request DSM from RFMC (Radio Mode Controller). A diagram showing how WOR hardware processes the descriptor table, and organizes the required operations into consecutive slots, encompassing both DSM and RF, is shown below.

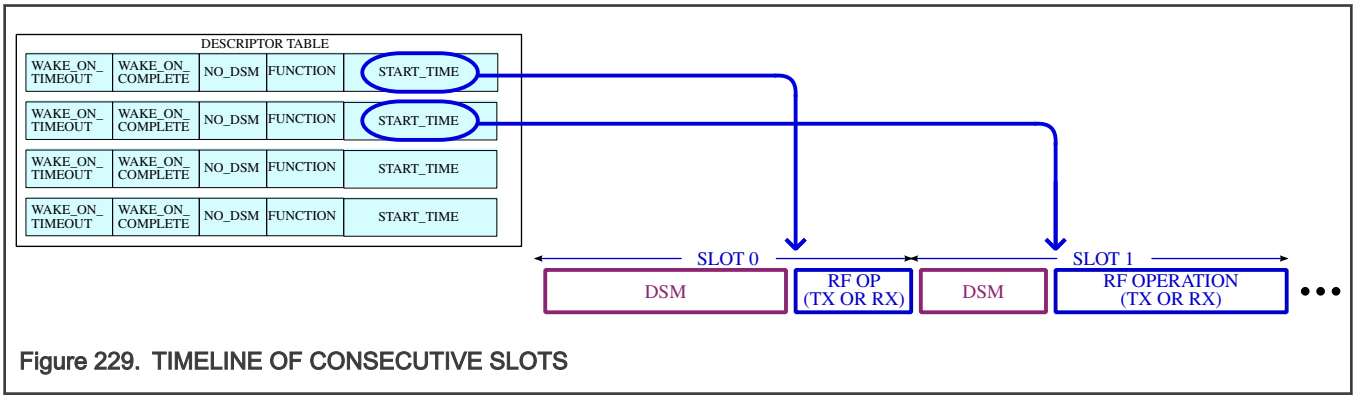

Figure 229. TIMELINE OF CONSECUTIVE SLOTS

Once a WOR session has been initiated by setting SLOTS_USED to a non-zero value, the timeline of consecutive slots shown, will repeat indefinitely, with the slot number increasing by 1 after each slot, modulo SLOTS_USED.

During each slot, WOR hardware must perform a series of tasks, e.g., computing the DSM duration, commanding the assigned Link Layer to start and stop the RF sequence, etc. Some of the required WOR hardware tasks are superimposed on the slot timeline, in the diagram below.

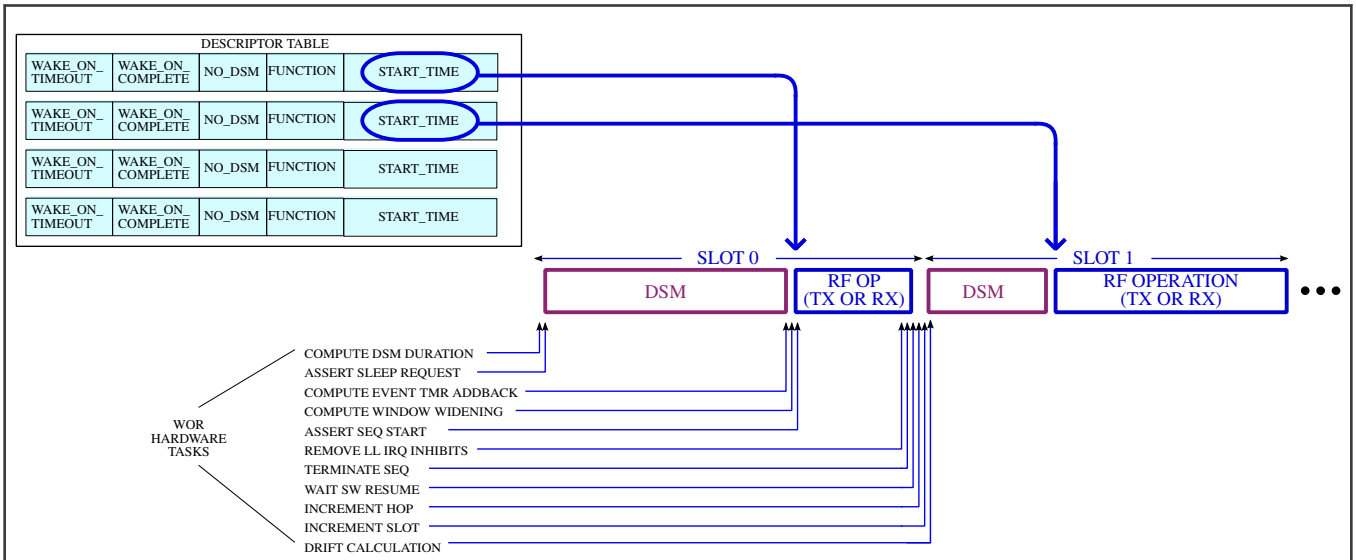

Figure 230. SLOT TIMELINE WITH HARDWARE TASKS

The WOR state machine is responsible for processing the descriptor table, and performing all the required tasks during each slot. The 11 -state machine interfaces with the assigned Link Layer for sequence operations, and with RFMC for DSM operations. The state machine also controls the incrementing of the slot counter, and the frequency hop table index. A state diagram of the WOR state machine is shown below.

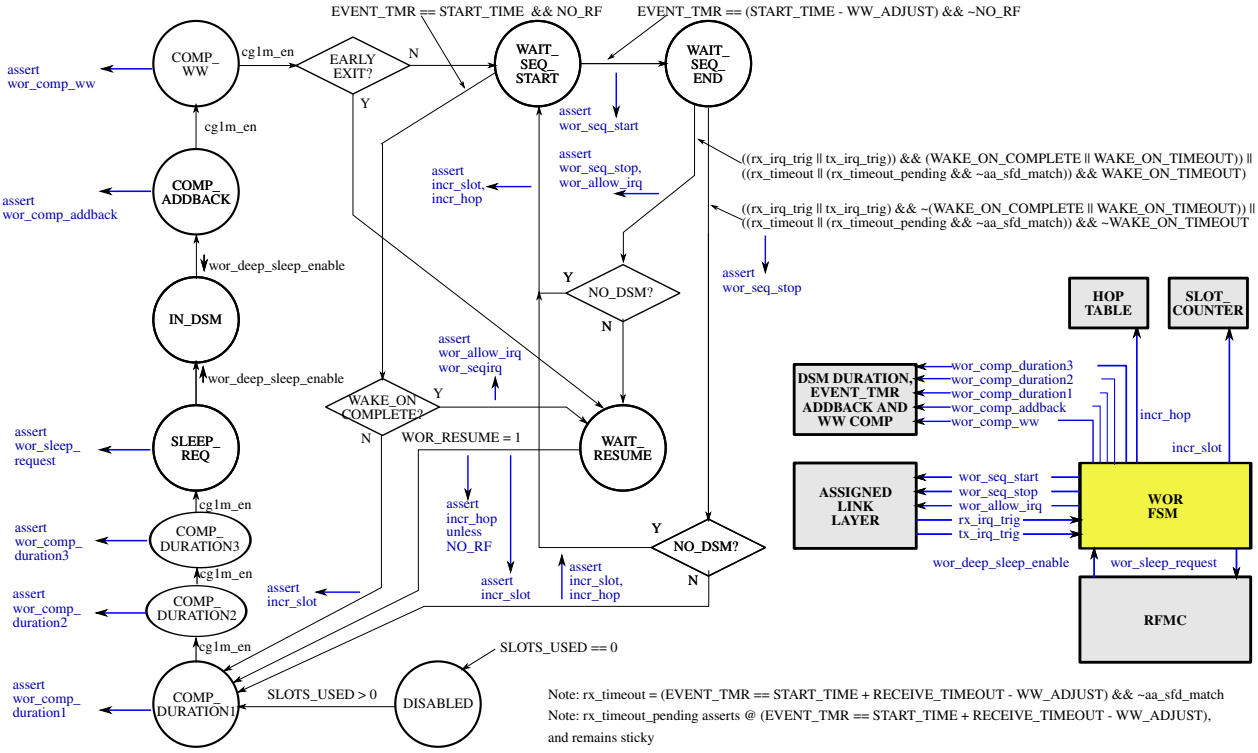

Figure 231. WAKE-ON-RADIO STATE DIAGRAM

A description of the WOR states follows.

DISABLED

WOR is in its disabled state whenever SLOTS_USED=0. WOR can be taken to "DISABLED" from any state by setting SLOTS_USED=0. WOR can be enabled by setting SLOTS_USED to a non-zero value, which initiates a new WOR "session".

COMP_DURATION1

WOR must compute the duration of the upcoming DSM cycle. This is done in 3 stages (states). COMP_DURATION1 is the first stage. Whenever the slot counter is incremented to begin a new slot, the slot's (descriptor's) START_TIME is in the future. In most cases, the START_TIME is distant enough that DSM is justified. During COMP_DURATION1, WOR computes the time to the next START_TIME, by subtracting both the current time (the assigned Link Layer's Event Timer) and the time-accumulated window-widening (if enabled) from the slot descriptor's START_TIME. (See Section Window Widening for more details on this feature.) The result of this subtraction is MICROSECONDS_TO_START_TIME[27:0]. This value must be converted to 32.768KHz cycles to be of use to RFMC. The multiplier is (549755 / 2^24), which is an approximation to the ideal conversion factor. The product is truncated to integer, the result represents the number of 32.768KHz cycles to remain in DSM prior to the next START_TIME. The hardware computations which take place during COMP_DURATION1 are shown in the following diagram.

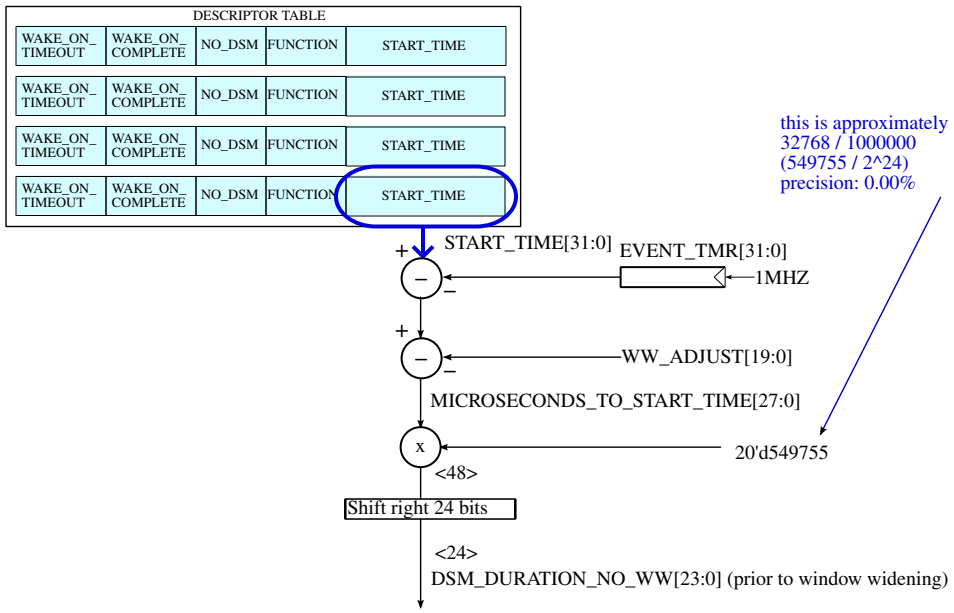

Figure 232. COMP_DURATION1

However this intermediate result does not account for the fact that window-widening for the upcoming DSM cycle itself, must be subtracted from this product. This is separate from the "accumulated" window-widening which has built up during the WOR session so far, which has already been accounted for. The estimate for the next DSM cycle's window widening is handled in the next state, COMP_DURATION2

The WOR output wor_clr_dsm_duration is asserted in this state, which is sent to the RFMC to proactively clear the DSM Duration Counter, which becomes active in the IN_DSM state (see below). The wor_clr_dsm_duration is an active-high, registered (glitch-proof) output signal.

COMP_DURATION2 and COMP_DURATION3

If window-widening is enabled, the DSM duration computed during COMP_DURATION1 may be long enough that it will need to be shortened slightly to account for window-widening which will accumulate during the DSM cycle itself. The computation for this window-widening is performed during this state. (See Section Window Widening for more details on this computation, and the usage of WW_DSM_FACTOR.) The (intermediate) duration from COMP_DURATION1 is multiplied by the DSM window-widening factor, and the product is subtracted from the duration estimate. The difference is a more accurate duration that accounts for window-widening during the DSM cycle. In a final step, a guardband is subtracted from the DSM duration. The guardband, with units of 32.768KHz clock cycles, guarantees that the DSM will complete on time before the next START_TIME is reached, accounting for RFMC synchronization and other delays in processing the WOR's sleep request. The guardband, which applies to all DSM cycles initiated by WOR, is determined by the register DSM_GUARDBAND[3:0]. The result of this step, is the final DSM duration (wor_dsm_duration[23:0]) which is then sent to the RFMC, which is responsible for radio DSM entry and exit. The hardware computations which take place during COMP_DURATION2 and COMP_DURATION3(alongside those covered by COMP_DURATION1) are shown in the following diagram.

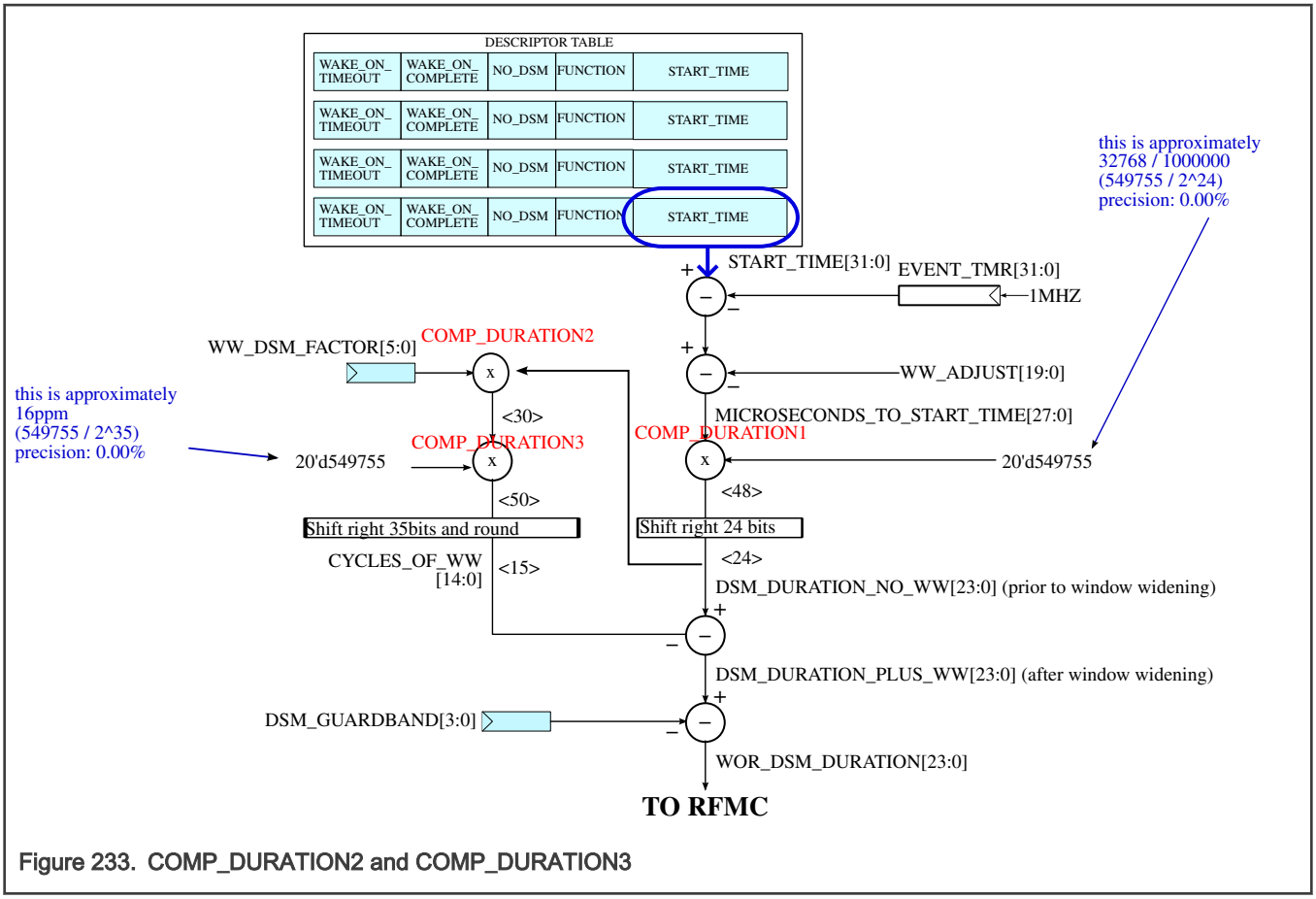

Figure 233. COMP_DURATION2 and COMP_DURATION3

SLEEP_REQ

In this state, WOR asserts its sleep request (wor_sleep_request) to the RFMC. This is a level, active-high, and registered (glitch-proof) signal to RFMC to indicate a DSM cycle is being requested of precise duration wor_dsm_duration[23:0], which was computed during the prior 2 WOR states. The units of wor_dsm_duration[23:0] are 32.768KHz clock cycles. RFMC shall synchronize wor_sleep_request into the 32.768KHz clock domain, and use it to activate the RFMC's DSM state machine. The RFMC DSM state machine shall place the radio in DSM, and simultaneously assert the output: wor_deep_sleep_enable. This signal is the precise indicator of DSM being "in effect", and is used to gate the assigned Link Layer's clocks and freeze its Event Timer.

IN_DSM

DSM is in effect during this state. Because the RF Oscillator has been disabled, there are no clocks to WOR, including its state machine, or the Link Layer, in this state. This is merely a holding state that prevails until DSM exits and the clocks to WOR and Link Layer are restarted. During this state, RFMC will use wor_deep_sleep_enable to enable a 24-bit counter which counts out the precise number of cycles in wor_dsm_duration[23:0]. When this counter reaches wor_dsm_duration, RFMC shall exit DSM and de-assert wor_deep_sleep_enable. RFMC shall provide the final count of the 24-bit counter which was used to time the DSM, using output signal rfmc_sleep_duration[23:0]. In most cases, rfmc_sleep_duration will be an exact match to wor_dsm_duration; the exceptional case is an unscheduled, early exit of DSM (see Section DSM Early Exit.) The interface signals between WOR and RFMC, and a high-level description of the hardware tasks performed by RFMC during IN_DSM state, is shown in the following diagram.

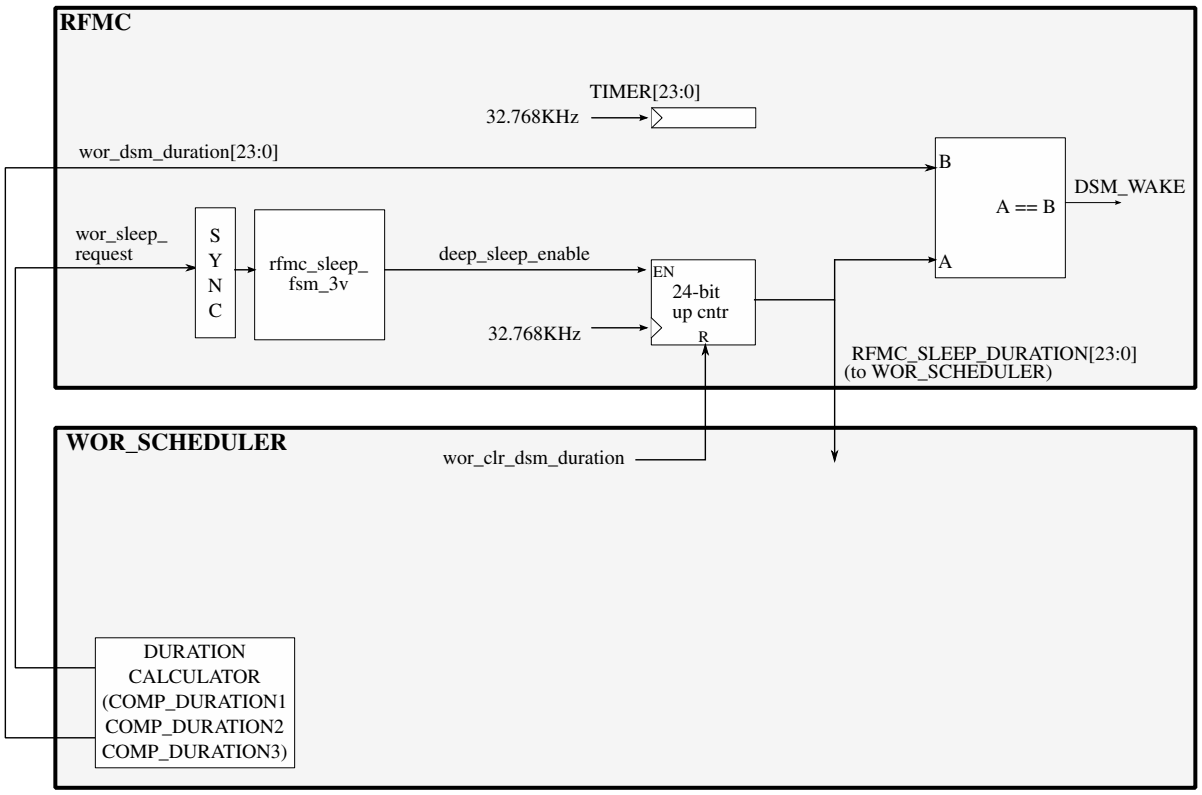

Figure 234. IN_DSM

COMP_ADDBACK

During the previous state, IN_DSM, the Reference Oscillator was disabled, and so the Event Timer of the assigned Link Layer was frozen. After DSM completes, clocks are restored and Event Timer resumes counting, but it is "behind" by the amount of time that the radio was in DSM. WOR hardware must compute the amount of DSM time, convert it to microseconds, and "add it back" to the Event Timer, so that after the addback, the Event Timer timebase is restored to where it would have been, had there been no DSM. (Note: there is a maximum of 1us of "loss of precision" upon every DSM exit; this timebase error is random and will not accumulate, it will average out over many DSM cycles). In this state, WOR computes the addback value by multiplying the rfmc_sleep_duration[23:0] (the precise number of 32.768KHz clock cycles during which RFMC held the radio in DSM) by 30.517578125 (the number of microseconds per 32.768KHz clock cycle). The 30.517578125 is an unsigned 14-bit value with 5 integer bits. The other multipicand, rfmc_sleep_duration is an unsigned integer. The product is the DSM elapsed time in microseconds, a 38 unsigned bit value with 29 integer bits. The product is rounded to the nearest integer and the 1 MSB's are discarded, resulting in the final wor_addback[27:0] value. At the end of this state, this result is sent to the assigned Link Layer's Event Timer, along with the wor_addback command (pulse), indicating to the Link Layer that it must add this amount to the current state of its Event Timer. After this point the protocol's timebase has been restored and operations can now be performed referencing the Event Timer. The following diagram depicts the hardware tasks performed in the COMP_ADDBACK state.

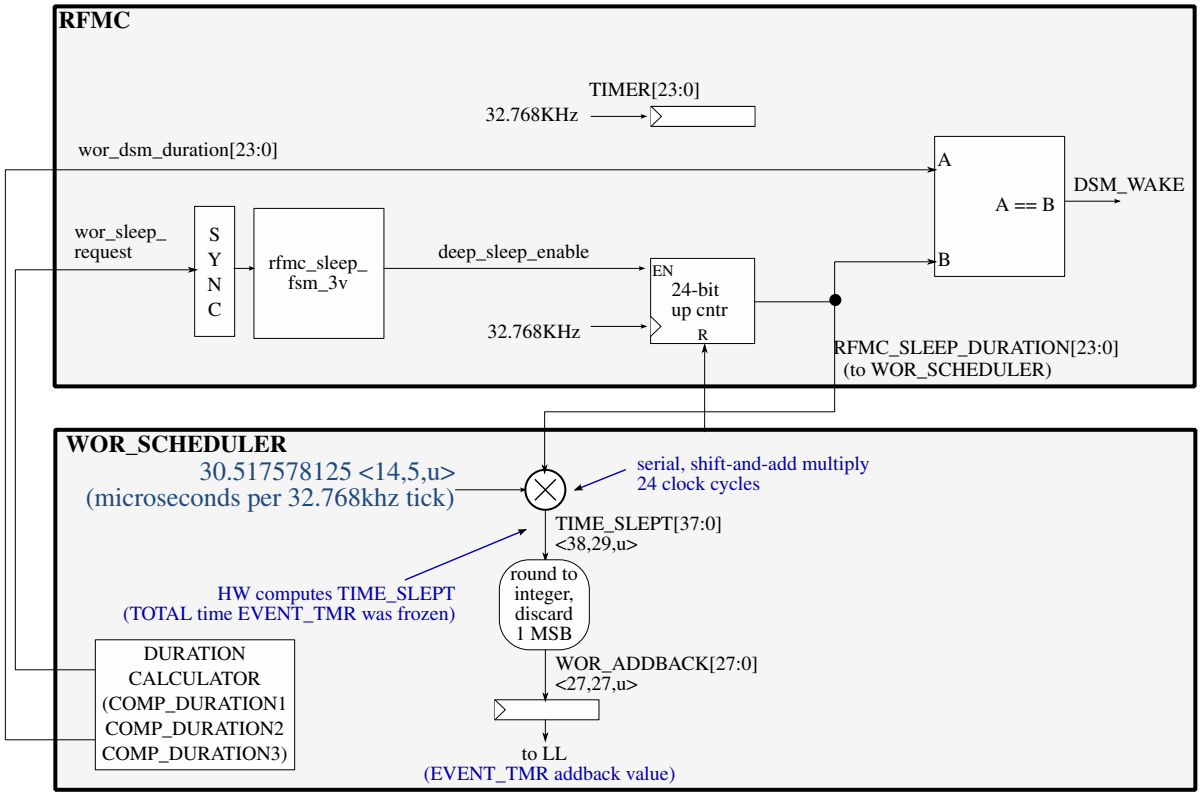

Figure 235. COMP_ADDBACK

COMP_WW

If window-widening is enabled, WOR must compute how much to increase the receive window by, based on the duration of the just-completed DSM cycle, so that this early-start offset to the receive window is ready in advance of the slot descriptor's START_TIME. The window-widening increment is computed during this state. Details of this hardware task are described in Section Window Widening.

WAIT_SEQ_START

After COMP_WW state, the WOR is ready to command an RF operation, and is only waiting for the slot descriptor's START_TIME to arrive. This start time will be in the near future since the DSM duration was timed to wake up "just in time" to start the RF operation, with sufficient guardband to guarantee that a DSM wake up can never occur too late. The WAIT_SEQ_START state merely waits for the assigned Event Timer to match the current slot descriptor's START_TIME. If the slot's FUNCTION is RX or RT, and window widening is enabled, START_TIME is modified by the hardware to be:

START_TIME - ww_adjust[19:0],

where ww_adjust[19:0] is the time-accumulated window-widening "early start" amount for the RX operation (see Section Window Widening.) If the FUNCTION is not RX or if window-widening is disabled, START_TIME is unmodified. Once a START_TIME match to the Event Timer occurs, WOR asserts the Link Layer interface signal wor_tx_start_ext (if FUNCTION is TX or TR), or wor_rx_start_ext (if FUNCTION is RX or RT). Neither interface signal is asserted if FUNCTION is NO_RF. The assigned Link Layer will commence an RF operation, TX or RX, based on this WOR command. At this point, the WOR state machine arrives at a fork:

- If FUNCTION = NO_RF and the descriptor WAKE_ON_COMPLETE=1, the next state is WAIT_RESUME
- Else if FUNCTION = NO_RF and WAKE_ON_COMPLETE=0, the next state returns to COMP_DURATION1 to begin the next slot. The slot counter and hop table index are incremented.
- Else, this is an RF operation that must be waited for. The state machine advances to the WAIT_SEQ_END state.

WAIT_SEQ_END

This state has been reached because an RF operation was launched during the previous state, and WOR is waiting for that operation to end. There are 3 ways for an RF operation to end:

- A TX operation self-terminates, indicated when the Link Layer asserts tx_irq_trig to WOR.
- A RX operation self-terminates due to a good packet reception, indicated when the Link Layer asserts rx_irq_trig to WOR.
- A RXor RT or TR operation times out. The rx_irq_trig is not asserted before the timeout. See Section Scheduling Modes for a description on the 2 methods WOR uses to compute the point-of-timeout, based on Scheduling Mode.

If either tx_irq_trig or rx_irq_trig is asserted, WOR advances to the next state (see below). If a point-of-timeout is reached without an rx_irq_trig, WOR hardware checks to see if Access Address Match has occurred or if SFD has been detected. If either is the case, timeout is deferred until either:

- The rx_irq_trig is ultimately asserted to indicate a good packet was received. This is a delayed good packet reception.
- The packet reception underway at point-of-timeout ultimately results in a CRC- or filtering-violation. This will automatically trigger a Link Layer RX recycle which will negate the AA-match or SFD-match indicator. WOR will detect this negation and declare a delayed timeout at this point.

If a timeout occurs, either nominal or delayed, WOR will assert wor_seq_stop_ext to the assigned Link Layer, causing an immediate abort of the RX sequence. This abort shall be handled by the protocol engine like a software abort. The wor_seq_stop_ext will not assert for a deferred timeout which results in a delayed good packet reception.

Nominally, WOR blocks the assigned Link Layer's RF-related interrupts from propagating to the MCU, to prevent unintended MCU wakeups during a WOR session. The RF-related interrupts for the supported protocol engines, are nearly identical in function across a 3 protocols, and are called RXIRQ, TXIRQ, and SEQ_END_IRQ. At the conclusion of an RF operation on a slot, WOR must decide whether to temporarily remove the Link Layer interrupt inhibits, to allow the Link Layer interrupt to be asserted to wake the MCU, based on which of the 5 outcomes to the RF operation occurred, and the state of the WAKE_ON_COMPLETE and WAKE_ON_TIMEOUT descriptor fields. The following table specifies whether WOR blocks, or allows, the RF interrupts to propagate, at the conclusion of the RF operation.

RF OPERATION OUTCOME	WAKE_ON_TIMEOUT=0, WAKE_ON_COMPLETE=0	WAKE_ON_TIMEOUT=0, WAKE_ON_COMPLETE=1	WAKE_ON_TIMEOUT=1, WAKE_ON_COMPLETE=x
tx_irq_trig	BLOCK	ALLOW	ALLOW
rx_irq_trig (nominal)	BLOCK	ALLOW	ALLOW
rx_irq_trig (delayed)	BLOCK	ALLOW	ALLOW
no rx_irq_trig @ nominal timeout	BLOCK	BLOCK	ALLOW
no rx_irq_trig @ delayed timeout	BLOCK	BLOCK	ALLOW

At the conclusion of the RF operation, the WOR next state is a function of whether the Link Layer RF interrupts were BLOCKED or ALLOWED (see previous table), as well as the NO_DSM descriptor field as illustrated in the following table.

RF OPERATION OUTCOME	INTERRUPTS BLOCKED, NO_DSM=0	INTERRUPTS ALLOWED, NO_DSM=0	NO_DSM=1
tx_irq_trig	COMP_DURATION1 (increment slot, hop idx)	WAIT_RESUME	WAIT_SEQ_START (increment slot, hop idx)
rx_irq_trig (nominal)	COMP_DURATION1 (increment slot, hop idx)	WAIT_RESUME	WAIT_SEQ_START (increment slot, hop idx)

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RF OPERATION OUTCOME	INTERRUPTS BLOCKED, NO_DSM=0	INTERRUPTS ALLOWED, NO_DSM=0	NO_DSM=1
rx_irq_trig (delayed)	COMP_DURATION1 (increment slot, hop idx)	WAIT_RESUME	WAIT_SEQ_START (increment slot, hop idx)
no rx_irq_trig @ nominal timeout	COMP_DURATION1 (increment slot, hop idx)	WAIT_RESUME	WAIT_SEQ_START (increment slot, hop idx)
no rx_irq_trig @ delayed timeout	COMP_DURATION1 (increment slot, hop idx)	WAIT_RESUME	WAIT_SEQ_START (increment slot, hop idx)

WAIT_RESUME

If WOR has allowed the MCU to be awakened (interrupted) by temporarily negating the RF interrupt inhibits, WOR must enter a state which permits the MCU executing WOR or Link Layer software, to complete all its assigned tasks on the slot. These tasks may include processing and decrypting a received packet, servicing the packet buffer, and formulating and transmitting an acknowledge packet. The WAIT_RESUME state serves that purpose. The WAIT_RESUME state is reached whenever all of the following conditions are met:

- Current state is WAIT_SEQ_END
- FUNCTION is TX or RXor RT or TR
- RF operation completes with any outcome (rx_irq_trig, tx_irq_trig, nominal, or delayed timeout)
- NO_DSM=0
- RF Interrupts are ALLOWED (see table, WAIT_SEQ_END state)

WAIT_RESUME is also reached whenever all of these following conditions are met:

- Current state is WAIT_SEQ_START
- FUNCTION is NO_RF
- START_TIME match to the assigned Link Layer's Event Timer
- WAKE_ON_COMPLETE=1

Once WAIT_RESUME is reached, WOR software must authorize WOR hardware to resume the WOR session and advance to the next slot, by setting the WOR_RESUME register bit to 1. When WOR_RESUME is set to 1 in WAIT_RESUME state, WOR hardware takes the following steps:

1. Advances to the next slot (slot counter++ % SLOTS_USED)
2. Increments the frequency hop table index *unless* FUNCTION = NO_RF
3. Enters COMP_DURATION1 state on the new slot
4. Reimposes Link Layer interrupt inhibits

52.4.4.1.1.2.5 Window Widening

OVERVIEW

Because a device in a connected state is not receiving all the time, its timebase will invariably drift with respect to the timebase of other device(s) in the network, due to finite crystal oscillator tolerances amongst the networked devices. Reducing the duty cycle of the receiver, albeit necessary to achieve power savings, exacerbates the drift problem.

To compensate for drift, Receive Window Widening can be employed. As time elapses in a network connection between successful packet receptions, the window-widening algorithm gradually moves future receiver turn-on times to the left (advance) and the turn-off time to the right (retard) to allow the transmitted packet to fall within the receiver's window in the presence of a

drifting timebase. The effect of window-widening on successive receive cycles, none of which result in a good packet reception, is illustrated in the following diagram.

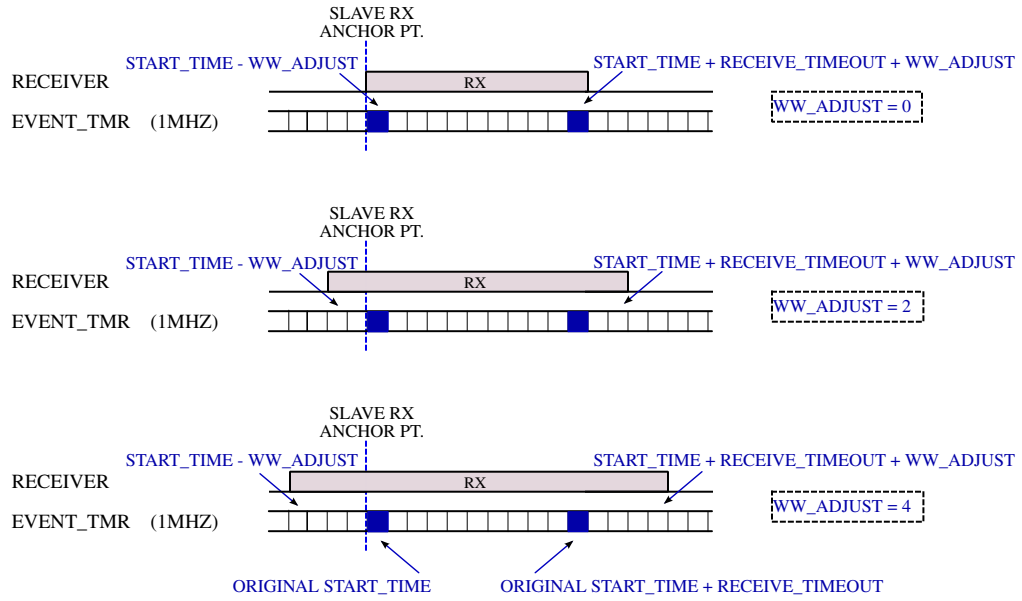

Figure 236. EFFECT OF WINDOW WIDENING ON RECEIVE WINDOW

Window widening is typically applicable only to the slave device(s) in a network, as the master (coordinator) of the network is normally the master of network timing. Thus, in Wake-On-Radio, window widening is optional, enabled by the by setting the WW_EN register bit to 1.

The Window widening algorithm needs to take into account the "Sleep Clock Accuracy" of the devices in the network. Sleep Clock Accuracy (SCA) is a *Bluetooth Low Energy* concept, and the Bluetooth LE nomenclature is adopted by Wake-On-Radio, and extrapolated to all supported protocols.

In Bluetooth LE, drift encountered by a slave device must be compensated by accounting for the SCA of both the master and the slave (self). The master transmits its SCA to the slave in the connection request (CONNECT_REQ), an advertising channel packet which informs an advertising slave of the master's desire to form a connection with it; the parameters on the CONNECT_REQ include the master's SCA. The slave device knows its own SCA, so the composite SCA is known at the point of connection establishment. Wake-On-Radio adopts this concept, although the precise method of informing the slave of Master SCA is protocol-dependent and takes place at a higher level, beyond the scope of this document.

Bluetooth LE subdivides the allowed Master SCA into coarse ranges, to reduce the number of over-the-air bits required to inform the slave. The ranges are shown in the following diagram.

SCA	masterSCA
0	251 ppm to 500 ppm
1	151 ppm to 250 ppm
2	101 ppm to 150 ppm
3	76 ppm to 100 ppm
4	51 ppm to 75 ppm
5	31 ppm to 50 ppm
6	21 ppm to 30 ppm
7	0 ppm to 20 ppm

Figure 237. SCA RANGES

The slave SCA must be accounted for as well, so the maximum composite SCA is 1000ppm. For Wake-On-Radio, this is the maximum allowed drift as well, and window-widening programmability will allow for drift amounts within these ranges to be compensated.

FACTS

In the WOR hardware, the window-widening adjustment, is a value, ww_adjust[19:0], that is subtracted from the receiver START_TIME, and added to the receiver TIMEOUT, when the slot's FUNCTION = RX, as shown in the diagram below.

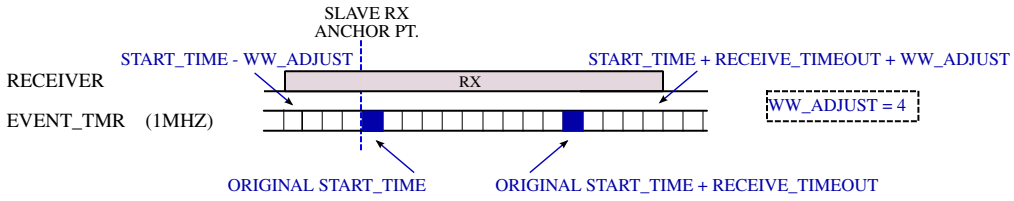

Figure 238. WINDOW WIDENING EFFECT ON RX SEQUENCE

The ww_adjust[19:0] adjustment, has no effect on START_TIME for slots using FUNCTION TX or NO_RF.

After system reset, if window-widening is enabled using WW_EN, ww_adjust[19:0] will increase linearly over time.

The adjustment, ww_adjust[19:0], will be reset to 0 under any of the following conditions:

1. system reset
2. good packet received (CRC verified and packet filtering passes)
3. Software writes a 1 to WW_NULL register bit

The reset-on-good-packet (item #2 above), can be inhibited by setting register bit WW_RESET_ON_RX=0. By default this bit is set.

The adjustment, ww_adjust[19:0], consists of 2 components, which are summed together:

1. **DSM adjustment:** computed at the conclusion of every DSM cycle based on rfmc_sleep_duration[23:0]
2. **RUNTIME adjustment:** computed by periodically incrementing a binary counter by 1 every *N* EVENT_TMR ticks whenever NOT in DSM

The rates at which window-widening accumulates during DSM and RUNTIME, are controlled by 2 programmable registers. The programmed values of these registers should be informed by the combined (master + slave) SCA.

The 2 components of the window-widening adjustment, and the reset conditionality, are illustrated in the following diagram:

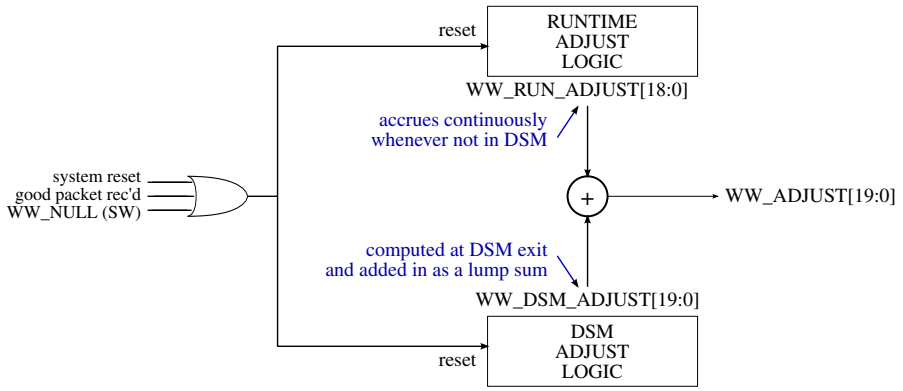

Figure 239. WINDOW WIDENING COMPONENTS AND RESET CONDITIONALITY

WINDOW WIDENING DSM ADJUSTMENT

In Wake-On-Radio, every slot includes a DSM cycle (unless NO_DSM=1 in the descriptor). WOR hardware computes the window-widening DSM adjustment after the DSM cycle completes, during the WOR COMP_WW state. This state immediately follows the COMP_ADDBACK state which updates the Event Timer for time-slept. The WW DSM adjustment, ww_dsm_adjust[19:0], is computed, and then added to the composite, accumulated adjustment, ww_adjust[19:0], as a lump sum. During COMP_WW state, WOR hardware multiplies rfmc_sleep_duration[23:0], which is the precise number of 32.768KHz cycles for which the RFMC held the radio in DSM, by a programmable factor which represents the number of microseconds per 32.768KHz clock cycle, scaled by the combined SCA of the master and slave (drift), i.e.,

DSM_DURATION (from RFMC) * (masterSCA + slaveSCA), converted to µs

Programmable register WW_DSM_FACTOR maps the composite SCA (masterSCA + slaveSCA), in parts per million, to a multiplicand which represents

N *** 16ppm * 30.5178125µs,**

where *N* = WW_DSM_FACTOR, and

30.5178125 is the *precise* number of microseconds per 32.768KHz tick, not an approximation.

Register WW_DSM_ADJUST allows SCA to be applied in coarse ranges, as described earlier in this section. Each LSB of WW_DSM_ADJUST is worth 16ppm of 30.5178125µs. Valid values are 0 ≤ WW_DSM_FACTOR ≤ 63. Consider the table below as a guide for selecting WW_DSM_FACTOR based on composite SCA:

masterSCA + slaveSCA	Use this WW_DSM_FACTOR
251 ppm to 500 ppm	16 (256ppm) - 32(512ppm)
151 ppm to 250 ppm	10 (160ppm) - 16(256ppm)
101 ppm to 150 ppm	7 (112ppm) - 10(160ppm)
76 ppm to 100 ppm	5 (80ppm) - 6 (96ppm)
51 ppm to 75 ppm	4 (64ppm)
31 ppm to 50 ppm	3 (48ppm)
21 ppm to 30 ppm	2 (32ppm)
0 ppm to 20 ppm	1 (16ppm)

Figure 240. WW_DSM_FACTOR BASED ON COMPOSITE SCA

A summary of all the hardware tasks performed to compute ww_dsm_adjust[19:0] during the COMP_WW state, is shown in the diagram below.

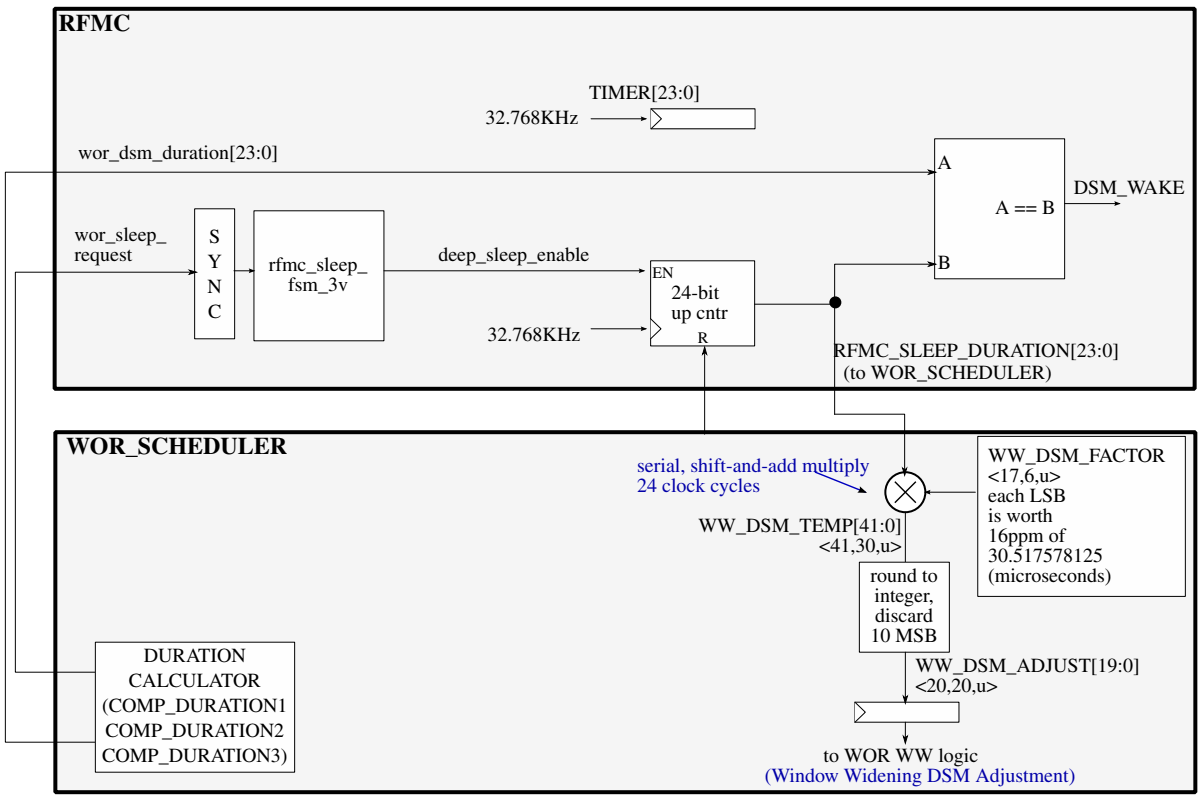

Figure 241. HARDWARE TASKS DURING COMP_WW STATE

WINDOW WIDENING RUNTIME ADJUSTMENT

The window-widening RUNTIME adjustment is computed by incrementing a binary counter every *N* EVENT_TMR ticks whenever NOT in DSM (i.e., EVENT_TMR is running). *N* is a variable based on programmable register WW_RUN_ADJUST[4:0]. The programmable resolution, or granularity, of the DSM adjustment (16ppm), will be matched by the RUNTIME adjustment. Unlike the DSM adjustment, the RUNTIME adjustment is an approximation to the ideal value of *N*, since *N* is the result of a division operation whose quotient is not always an integer number of microseconds. However, the objective in Wake-On-Radio is to spend as little time in RUN between events as possible, so the DSM adjustment will dominate the sum. Therefore, additional resolution in the RUNTIME adjustment, although achievable, would have little benefit in overall power savings.

N is a modulo for the binary counter which tracks the runtime adjustment, and represents the ideal number of microseconds between each increment to the adjustment, which is simply the reciprocal of the composite SCA, i.e.,

***N* = 1 / (master SCA + slave SCA)**

Using an example of composite SCA = 192ppm,

***N* = 1 / 192e-6 = 5208.333**

For implementation, each SCA range (the same table of ranges defined for the DSM adjustment) becomes an input to a look-up table (LUT) which approximates this division, rounding the quotient to the nearest integer. SCA range is represented by the WW_RUN_FACTOR. If WW_RUN_FACTOR=0, the RUNTIME adjustment never increments (special case). Valid values are 0 ≤ WW_RUN_FACTOR ≤ 16.

Every time the modulo *N* is reached, the binary counter resets to 0, and the RUNTIME adjustment is incremented by 1, meaning that the start of the next receive operation, has been advanced by 1µs. The hardware which implements the window widening RUNTIME adjustment is shown in the following diagram.

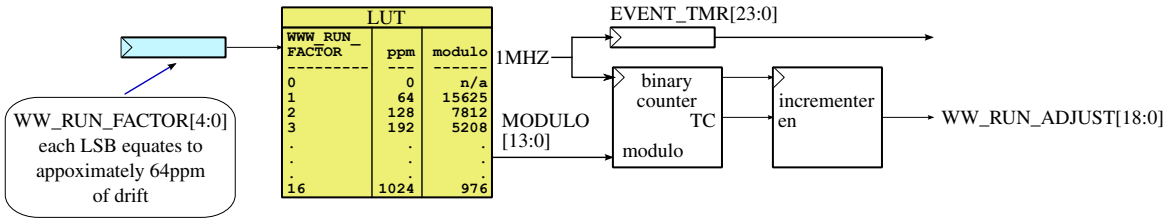

Figure 242. WINDOW WIDENING RUNTIME ADJUSTMENT

COMPENSATING DSM DURATION FOR WINDOW WIDENING

In executing each slot as specified by the WOR descriptor, there is one other instance where window widening must be accounted for. During the COMP_DURATION1 state, WOR computes the DSM duration based on descriptor START_TIME and current (Event Timer) time. This duration is timed to complete the DSM cycle as close as possible to the desired START_TIME, but with sufficient guardband to ensure wakeup can never occur too late. But the duration computed during this state may be sufficiently long that the desired START_TIME needs to be advanced, due to drift within the DSM cycle itself. Thus, window widening needs to be estimated and subtracted from this computation. This window widening estimation is used only for the purpose of the duration estimation, and does not accumulate from one DSM cycle to the next (i.e., from one slot to the next). This window widening compensation to DSM duration occurs during the COMP_DURATION2 and COMP_DURATION3 state. See Section State Machine for a description of WOR states.

The difference between this window widening computation, and the computation during COMP_WW, is that the result must be in units 32.768KHz clock cycles, because it is targeted for RFMC, instead of microseconds for an Event Timer offset. The COMP_DURATION2 and COMP_DURATION3 computation multiplies the DSM duration (in 32K cycles) computed in COMP_DURATION1 by an estimate of the SCA (drift), to arrive at a product which represents the number of 32.768KHz cycles by which to foreshorten the upcoming DSM cycle due to the widening requirement. So there is no conversion of units.

CYCLES_OF_WW[14:0] = DSM_DURATION_NO_WW[23:0] (result of COMP_DURATION1, neglecting widening) * *WW_DSM_FACTOR* * 549755 / 2^35

This product is subtracted from the DSM duration estimate, along with the DSM_GUARDBAND[3:0], to arrive at the final wor_dsm_duration[23:0] sent to RFMC for execution:

WOR_DSM_DURATION[23:0] = DSM_DURATION_NO_WW[23:0] - CYCLES_OF_WW[14:0] - DSM_GUARDBAND[3:0].

The following diagram illustrates all of the hardware tasks performed during COMP_DURATION2 and COMP_DURATION3 state:

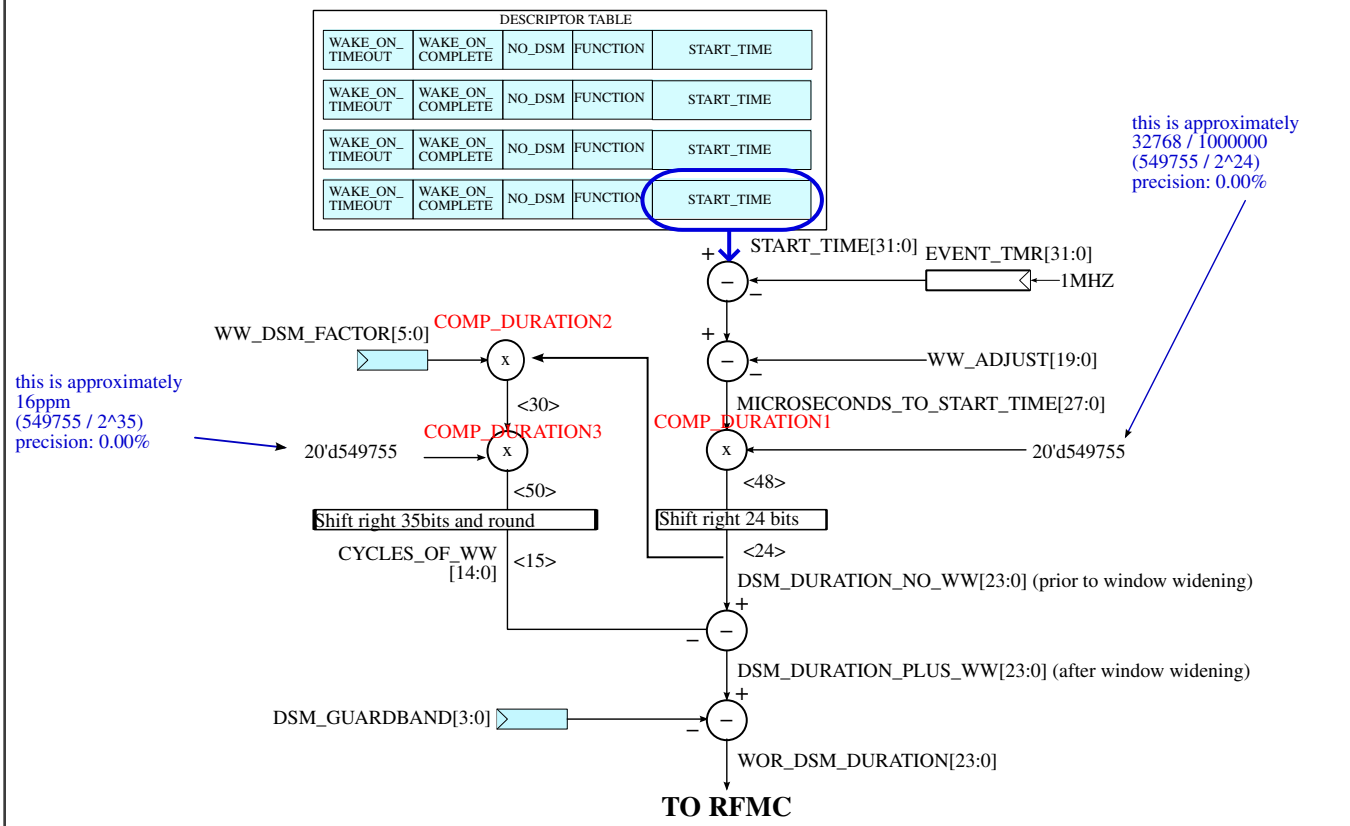

Figure 243. COMP_DURATION2

APPLYING THE WINDOW WIDENING

Now that the window-widening adjustment has been computed, it must be put into effect, by modifying the START_TIME of the RF operation to advance it by the number of microseconds in ww_adjust[19:0], which is the combined DSM and RUNTIME window widening adjustment. This occurs during the WAIT_SEQ_START state. The same adjustment is applied again, by modifying the TIMEOUT of the RF operation (assuming timeout is reached), by delaying it by the same number of microseconds that START_TIME was advanced by. This occurs during the WAIT_SEQ_END state. The following diagram illustrates how window-widening is applied in Timeslot Scheduling mode.

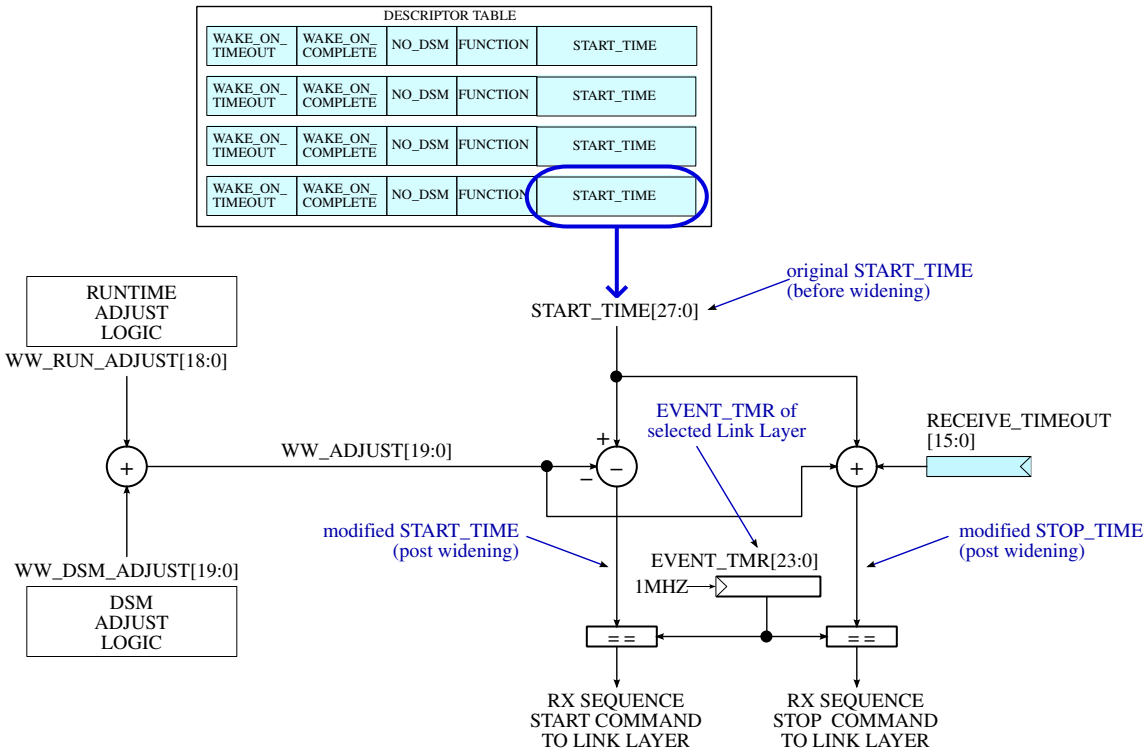

Figure 244. APPLYING WINDOW WIDENING (TIMESLOT MODE)

The application of window-widening in Constant-Interval scheduling mode, is largely the same as Timeslot mode; however the way the WOR hardware determines START_TIME and TIMEOUT is different, these need to be computed by WOR on a slot-by-slot basis. The following diagram illustrates how window-widening is applied in Constant-Interval Scheduling mode.

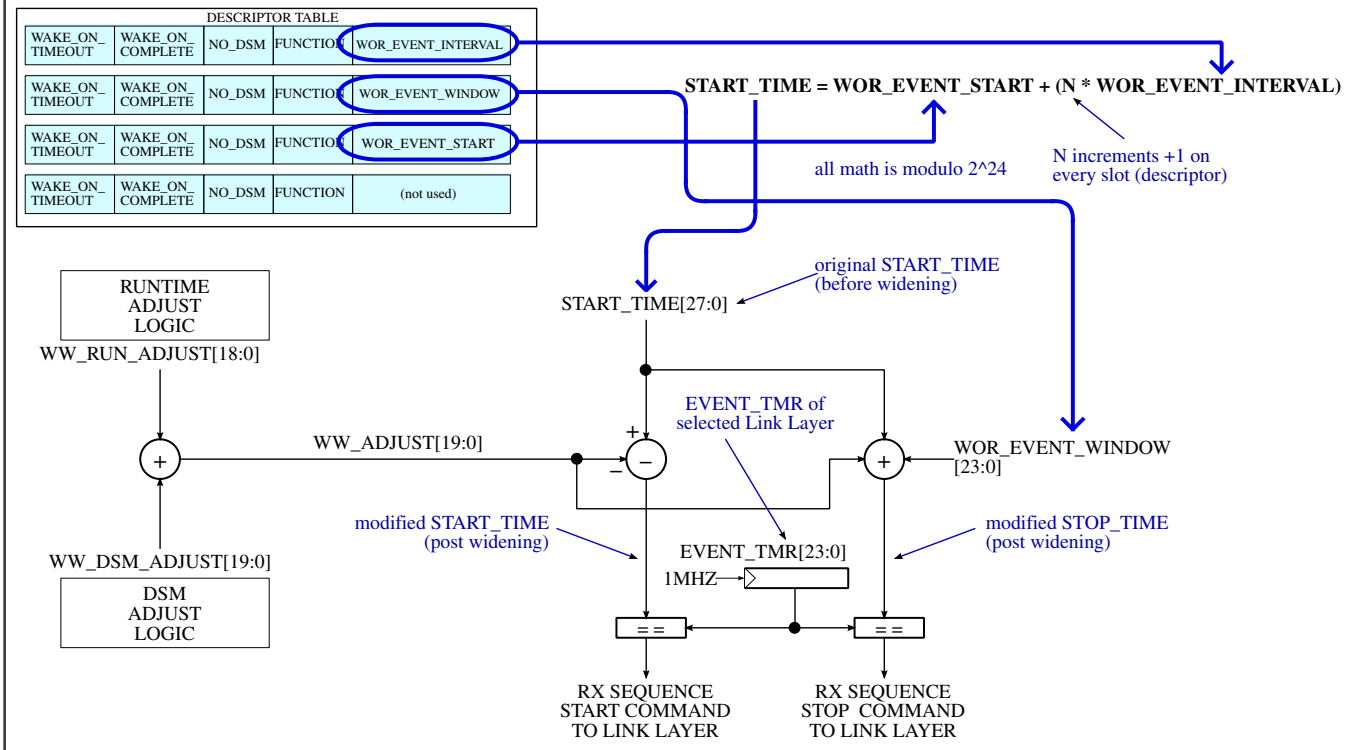

Figure 245. APPLYING WINDOW WIDENING (CONSTANT-INTERVAL MODE)

NOTE

When dealing with the combination of high SCA (Sleep Clock Accuracy) as well as long requested DSM intervals, it is the responsibility of software to guarantee that the accumulation of window widening does not become excessively large. Window widening should not be allowed to accumulate to such an extent that the adjusted START_TIME is advanced so much that it moves to the left of the *previous* slot's START_TIME, or that the TIMEOUT is retarded so much that is moves to the right of the *next* slot's START_TIME, especially in scenarios where no good packets are received for an extended period of time. Software should periodically monitor window widening accumulation using mandatory MCU wakeups after every third or fourth slot (timeslot mode), or WAKE_ON_NTH_SLOT (constant interval mode), and use caution when scheduling long DSM intervals (distance between START_TIME on consecutive slots) with high WW_DSM_FACTOR values.

52.4.4.1.1.2.6 Auto DSM Drift Calculation

Usually, the combination of SCA (Sleep Clock Accuracy) is hard to get, so for Window Widening, user has to set a big enough WW_DSM_FACTOR to cover the worst case. This makes the window larger enough to receive the packets but also wastes power. And also, the accumulation of window widening may become excessively large after many slots.

The "Auto Drift Calculation" feature is used to solve these shortcomings. This feature can only be used in Constant-Interval mode and it is enabled by register AUTO_CAL set when WW_EN is also enabled.

Its basic concept is that (the timestamp of the packet arrives - expected) is proportional to (the set drift - the actual drift). Based on this theory, hardware can calculate the actual drift after received a packet and then apply the calculated drift to the next slot to get the optimized window to save power. The detailed process is as follows.

1. Theory of Drift Calculation

Below figure shows a 4 slots receive case in Constant-Interval mode. After the reception of the first packet which is called the synchronization packet, software configures the WOR to the Constant-Interval mode and enables the Window Widening feature.

The term Rx(x=sync, 0~3) denotes the timestamp recorded in the link layer's Event Timer when the packet actually arrives, and Sx(x=0~3) denotes the expected timestamp which is calculated by the WOR hardware. RX_ENx(x=0~3) denotes the RX_EN signal assertion time.

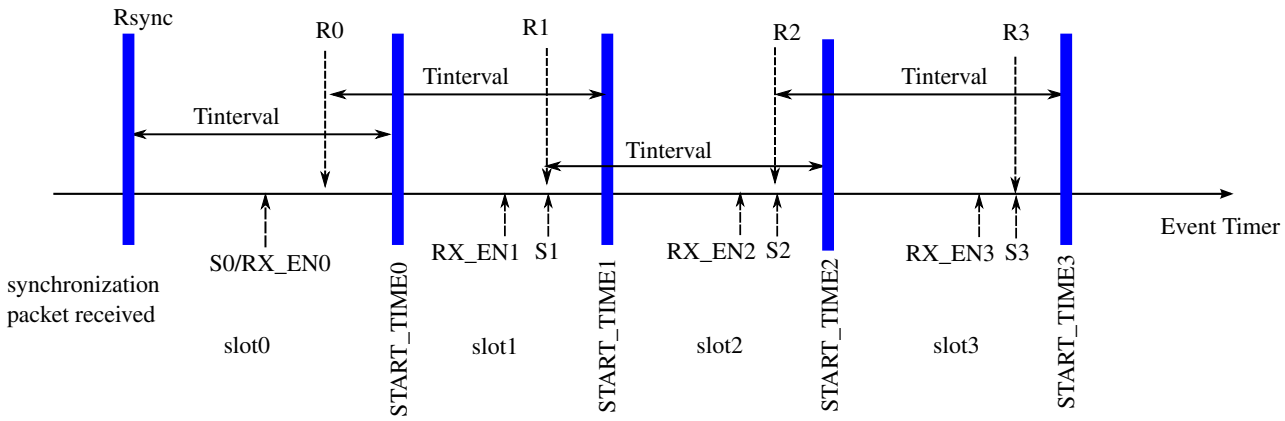

Figure 246. Auto Drift Calculation Algorithm

Software programs the START_TIME(WOR_EVENT_START) of the slot0 as

START_TIME0 = Rsync + Tinterval, Tinterval is WOR_EVENT_INTERVAL,

because if there is no clock drift, this is the next packet arrive time.

Since the START_TIME is the time which WOR hardware informs the Link Layer to assert the RX_EN signal, so it should consider the RX warm up time and the Preamble-SFD delay. The precise START_TIME should be

START_TIME0 = Rsync + Tinterval - AA_SFD_DLY,

where AA_SFD_DLY is a programmable register which counts for the RX warm up time and the Preamble-SFD delay.

AA_SFD_DLY does not effect the drift calculation, so for simplicity, it is ignored in the discussion below.

In this example, at slot0, user will set an initial WW_DSM_FACTOR to cover the worst case drift. If ignore the RUNTIME adjustment, the window will open WW_DSM_ADJUST0(Tsleep0 * drift_set0) earlier before the START_TIME. Due to the combination of SCA, the real packet arrive time is R0, it is (Tsleep0 * drift_real0) earlier than the START_TIME. That is to say,

the expected packet arrive time is:

S0 = START_TIME0 - WW_DSM_ADJUST0

= START_TIME0 - Tsleep0 * drift_set0 / 1000000, where drift_set0 = WW_DSM_FACTOR * 16 (ppm), Tsleep0 is the sleep time in slot0,

the real packet arrive time is:

R0 = START_TIME0 - Tsleep0 * drift_real0 / 1000000, where drift_real0 is the real drift during slot0, the unit is ppm

Hardware uses the delta time between S0 and R0, delta_time0, to get the drift_real0 as:

delta_time0 = R0 -S0

= Tsleep0 * (drift_set0 - drift_real0) / 1000000 (us)

drift_real0 = drift_set0 - (delta_time0 / Tsleep0 * 1000000) (ppm)

In the above formula, It is difficult for the hardware to calculate the division, so an approximate method is using Tinterval instead of Tsleep0:

drift_real0 = drift_set0 - (delta_time0 / Tinterval * 1000000) (ppm)

Convert drift_real0 to 16ppm unit as:

drift_real0_factor = drift_real0 / 16

= drift_set0_factor - (delta_time0 / Tinterval * 1000000 / 16) (LSB), where drift_set0_factor = WW_DSM_FACTOR

If user calculates the 1000000/Tinterval/16 and programs the result into register TINT_DIV_MILLION, hardware can simplify division into multiplication as,

drift_real0_factor = drift_set0_factor - (delta_time0 * TINT_DIV_MILLION) (LSB)

To cover the whole range of Tinterval, which is about 500 us to 2^28 us, the actual value programmed to the TINT_DIV_MILLION is

TINT_DIV_MILLION = (1000000 / Tinterval / 16) * 2^17

The hardware will take this extension into account and handle it accordingly.

The calculated drift_real_factor is readable by register **CAL_DSM_FACTOR** which is a signed register of two's complement value. A negative value means the packet comes later than expected.

2. START_TIME Calculation for Each Slot

To calculate and track the drift in each slot, the START_TIME calculation is different with the normal Constant Interval Mode.

In normal Constant Interval Mode, the slot1's START_TIME is calculated as,

START_TIME1 = START_TIME0 +Tinterval

When AUTO_CAL is set, and if Link Layer received a packet in slot0, WOR calculates the next START_TIME as

START_TIME1 = R0 + Tinterval,

and the expected packet arrive time is:

S1 = START_TIME1 - WW_DSM_ADJUST1

= START_TIME1 - Tsleep1 * drift_set1 / 1000000, where drift_set1 = drift_real0, Tsleep1 is the sleep time in slot1,

and the real packet arrive time is:

R1 = START_TIME1 - Tsleep1 * drift_real1 / 1000000, where drift_real1 is the real drift during slot1, the unit is ppm

So, drift_real1 can be calculated as:

drift_real1 = drift_set1 - (delta_time1 / Tsleep1 * 1000000)

By this way, at each slot, hardware repeats to calculate and track the drift.

Ideally, the drift_real in slot0 and slot1 is same, so S1 is equal to R1. This means the packet may come at the exact time when the window opens. This achieves the longest sleep time.

But due to the drift calculation error in slot0 or/and drift change between the slots, the packet may come a little bit earlier(like in slot2) or later than the expected time. To make sure that the packet is received, the real window open time is TIME_MGN earlier than the calculated point, Sx, where TIME_MGN is a user programmable register with us unit.

TIME_MGN can be calculated as:

TIME_MGN = (drift_calculation_err + inter_slot_drift_change) * Tinterval

The real Window Open time for slot 1 is

RX_EN1 = S1 - TIME_MGN

and the real STOP_TIME, i.e., Window Close time is

STOP1 = S1 + WOR_EVENT_WINDOW + TIME_MGN

For summary, for slot n, if there is a packet received in the previous slot n-1,

START_TIME(n) = R(n-1) + Tinterval

S(n) = START_TIME(n) - WW_DSM_ADJUST(n)

RX_EN(n) = S(n) - TIME_MGN

STOP(n) = S(n) + WOR_EVENT_WINDOW + TIME_MGN

3. Packet Missed Case

When a slot missed a packet due to some reasons, like drift sudden changes or RF signal is blocked, it will impact the drift calculation process.

Below figure shows the case that a packet is missed at slot 0. The basic idea is to apply the initial WW_DSM_FACTOR to slot 1, after received in slot 1, then apply the initial WW_DSM_FACTOR to slot2, after received in slot 2, the drift_real2 is calculated.

Since packet is missed in slot0, the initial WW_DSM_FACTOR is still used in slot1 and there is no margin time applied to START/STOP_TIME.

For slot1,

START_TIME1 = S0+Tinterval

RX_EN1 = START_TIME1 - WW_DSM_ADJUST1

STOP1 = RX_EN1 + WOR_EVENT_WINDOW + 2 * WW_DSM_ADJUST

WW_DSM_ADJUST is the accumulated DSM adjust,

WW_DSM_ADJUST = WW_DSM_ADJUST0 + WW_DSM_ADJUST1

WW_DSM_ADJUST0 is the DSM adjust of slot0,

WW_DSM_ADJUST0 = Tsleep0 * drift_set0 / 1000000, drift_set0 = WW_DSM_FACTOR * 16 (ppm)

WW_DSM_ADJUST1 is the DSM adjust of slot1,

WW_DSM_ADJUST1 = Tsleep1 * drift_set1 / 1000000, drift_set1 = WW_DSM_FACTOR * 16 (ppm)

For slot2,

START_TIME2 = R1+Tinterval

RX_EN2(S2) = START_TIME2 - WW_DSM_ADJUST2,

STOP2 = RX_EN2 + WOR_EVENT_WINDOW + 2 * WW_DSM_ADJUST2,

WW_DSM_ADJUST2 is the DSM adjust of slot2,

WW_DSM_ADJUST2 = Tsleep2 * drift_set2 / 1000000, drift_set2 = WW_DSM_FACTOR * 16 (ppm)

R2 = START_TIME2 - Tsleep2 * drift_real2 / 1000000

Using R2 and S2, we can get the drift_real2 and apply it to slot3.

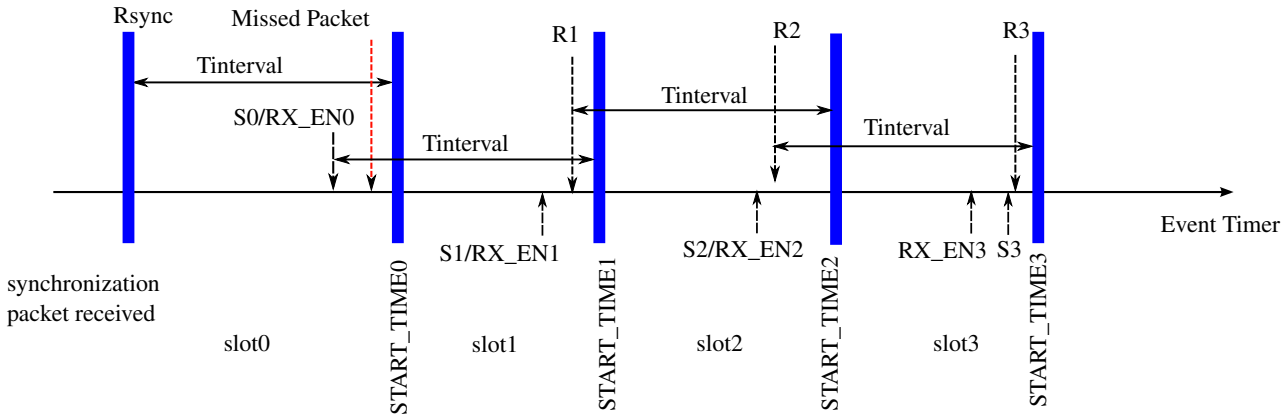

Figure 247. Handle of Missed Packet(Example 1)

As another example below, in slot0 packet is received, but in slot1, the packet is missed. The basic idea is to apply the drift_real0 to slot 2, after received in slot 2, then apply the initial WW_DSM_FACTOR to slot3, after received in slot 3, the drift_real3 is calculated..

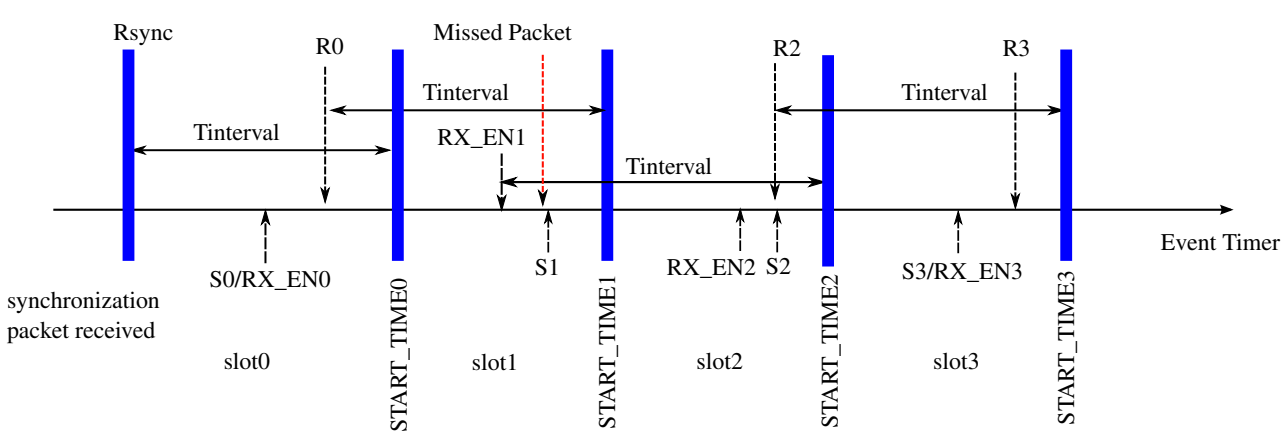

Figure 248. Handle of Missed Packet(Example 2)

Since packet is received in slot0, drift_real0 can be calculated.

For slot1,

START_TIME1 = R0+Tinterval

RX_EN1 = START_TIME1 - Tsleep1 * drift_real0 / 1000000 - TIME_MGN

STOP1 = RX_EN1 + WOR_EVENT_WINDOW + 2 * TIME_MGN

For slot2,

Then the START_TIME is calculated as:

START_TIME2 = RX_EN1+Tinterval

And hardware still applies the calculated drift_real0 to slot 2. Consider the drift change between slot0 and slot1, slot1 and slot2, the real window open point is TIME_MGN us before S2.

RX_EN2 = START_TIME2 - Tsleep2 * drift_real0 / 1000000 - TIME_MGN

and the real STOP_TIME, i.e., Window Close time is

STOP2 = RX_EN2 + WOR_EVENT_WINDOW + 4 * TIME_MGN

For summary, for slot n, if there is no packet received in the previous slot n-1,

START_TIME(n) = RX_EN(n-1) + Tinterval

RX_EN(n) = START_TIME(n) - Tsleep(n) * drift_set(n) / 1000000 - TIME_MGN

STOP(n) = RX_EN(n) + WOR_EVENT_WINDOW + 2 * (k+1) * TIME_MGN, where k is the number of missed slots since last received

In this example, in slot2, the packet is received. At this point, hardware does not calculate the drift_real for the next slot, because the calculation may be not correct since two slots passed. So hardware uses the initial WW_DSM_FACTOR for the next slot, slot3. and

START_TIME3 = R2 + Tinterval

So, if slot3 received a packet, the situation is like slot0, hardware get the drift_real for the next slot again.

S3 = START_TIME3 - Tsleep3 * drift_set3 / 1000000, where drift_set3 = WW_DSM_FACTOR * 16 (ppm)

R3 = START_TIME3 - Tsleep3 * drift_real3 / 1000000

drift_real3 = drift_set3 - (delta_time3 / Tsleep3 * 1000000) (ppm)

4. Slot with Function TX/TR/NO_RF

For slots with function TX/TR/NO_RF, they are not effected by the window widening. That is to say, for TX/TR, the TX_EN is asserted at the START_TIME_T:

START_TIME_T(n) = START_TIME_T(n-1) + Tinterval

START_TIME_T(0) = WOR_EVENT_START

For NO_RF, at the START_TIME_T, the WoR state machine jumps to next slot.

There is the case that TX/TR/NO_RF may be mixed with RX/RT function. In this case, the slot with TX/TR/NO_RF function is treated as "missed slot" since there is no packet received.

5. Handle of Missing Many Slots

In WoR operation, there may be some cases that many slots missed packets. The window will become larger and larger if missed so many packets and it is responsible for the WoR to wake up the MCU to check the fail condition and re-configure the radio block again.

WoR block provides a register **RX_SLOT_FAIL_THRESH**. When the number of missed slot is equal to this value plus 1, the WOR_RX_FAIL_IRQ is set. And when WOR_RX_FAIL_IRQ_ EN is set, the related interrupt will be sent to the MCU.

6. Software Do the Drift Calculation

Because the hardware uses Tinterval to approximate Tsleep, there is error. The WoR hardware provides a software interface that uses the MCU to calculate drift_real. When register **TIME_REC** is set with AUTO_CAL, some timing information is recorded to the Packet RAM. There can be at most 8 slots timing information can be recorded. WOR uses 160 bytes of Packet RAM for the timing information.

The timing information for one slot is as shown in below table.

Basically the drift_real can be calculated with:

drift_real_factor = drift_set_factor - (aa_match_time_delta_signed / Tsleep * 1000000 / 16) (LSB)

Where

Tsleep = rfmc_sleep_duration * 1000 / 32.768 (us)

Note, the calculation is only make sense when received a packet in a slot with the previous slot also received, or received a packet in the first slot.

This calculated drift factor can be programmed into register **SW_DRIFT_SET**, which is a two's complement value and each LSB is worth 16ppm.

Table 445. Timing Information for One Slot

Timing information word #	Timing information
Timing information word 0	{16'h0, packet_received, NO_DSM, 3'h0, wor_function[2:0], wor_slot_count[7:0]}
Timing information word 1	{{8{1'b0}}, rfmc_sleep_duration[23:0]}
Timing information word 2	TX_EN or RX_EN assert time
Timing information word 3	Packet arrived time, TimeStamp
Timing information word 4	{{11{1'b0}}, aa_match_time_delta_signed[20:0]} (aa_match_time_delta_signed is the delta time between Sx and Rx, two's complement value)

7. Calculation Error

There are many cases which will cause the calculation error. All these error can be covered by properly setting the register **TIME_MGN.**

7.1 Using Tinterval as Tsleep

Since the hardware are using Tinterval as Tsleep during the drift calculation, this will cause error.

7.2 Using 16ppm granularity

Since the hardware finally calculates the drift in 16ppm granularity, due to the round function, there may be 0.5 LSB(8 ppm) error

7.3 Drift change during slots

Due to the voltage or temperature change, the drift may change during slots.

7.4 The Event Timer Jitter after sleep

The event timer has a random ±1 us error after sleep. This error is caused and cannot be avoided by the fact that the 1MHz clock and the 32KHz clock are async. As shown in below waveform.

This will cause the delta_time ±1 us error, so will cause the calculation has error as:

When the Tinterval is 1ms, this 1us error will cause the calculated drift ±1000ppm error;

When the Tinterval is 10ms, ±100ppm error

When the Tinterval is 100ms, ±10ppm error

When the Tinterval is 1s, ±1ppm error

So the register TIME_MGN should be set to also consider this ±1 us error.

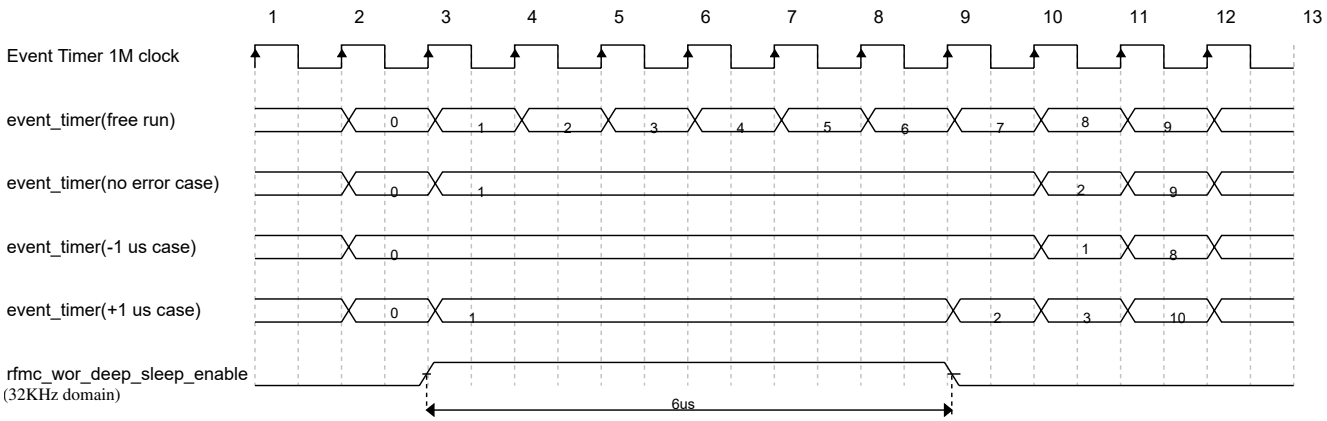

Figure 249. Event Timer Jitter

52.4.4.1.1.2.7 Timestamps

In Wake-On-Radio, every slot with FUNCTION=RX can capture a timeslot associated with any packet that is received in the slot. Any receive slot which results in an Access Address or an SFD detection will capture a timestamp into a register. Timestamps assist Link Layer software in maintaining and fine-tuning the network timebase across 2 or more networked devices.

Timestamp Capture

In Wake-On-Radio, each descriptor is associated with a slot. Any slot can be assigned an RX operation. RX operations require a timestamp to be captured. So, the timestamp can be thought of as being associated with the descriptor. The bit width of the timestamp is the same as the bit-width of the assigned Link Layer; i.e., 32 bits for GENERIC_FSK, and 28 bits for 802.15.4. Association of timestamps to descriptors is illustrated in the following diagram.

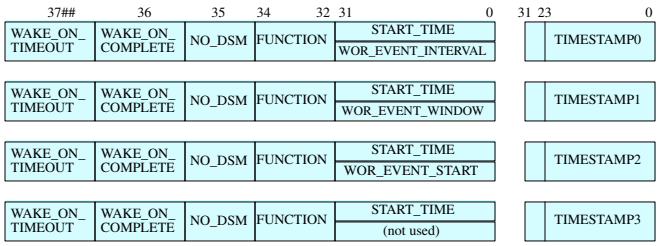

Figure 250. TIMESTAMP CAPTURE

Capture occurs at the instant AA or SFD is detected, and results in the current state of the assigned Link Layer's Event Timer being transferred to a TIMESTAMP register. WOR hardware does not apply any offset to the captured timestamp. A timestamp is captured for the last *N* RX operations, which result in (at least) one AA or SFD detection, where *N* = SLOTS_USED (typically 4).

Timestamp capture is area-intensive, due to:

- wide bit-width
- multiplicity (per descriptor)

Each of the supported protocol engines already has a TIMESTAMP register of the required bit-width. It is used for non-WOR (legacy) operations. To save area, when WOR is engaged, the TIMESTAMP register indigenous to the Link Layer, is used to capture the timestamp for WOR SLOT 0. Thus, in WOR mode (WOR_EN=1), the assigned Link Layer's TIMESTAMP register will only capture a timestamp when WOR SLOT=0, and will not change otherwise. If WOR is not engaged, the Link Layer TIMESTAMP register will capture all timestamps, the legacy behaviour. When WOR_EN, timestamps associated with SLOTS 1, 2, and 3 are captured in the TIMESTAMP1, TIMESTAMP2, and TIMESTAMP3 registers, respectively, which are new, and resident in the WOR scheduler. This distribution of timestamp register resources is illustrated in the following diagram.

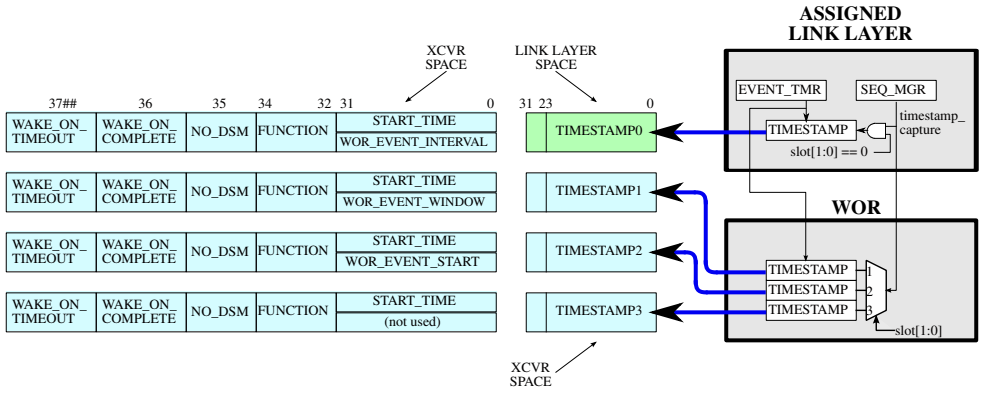

Figure 251. TIMESTAMP REGISTER DISTRIBUTION

Software should be aware of the fact that the designating the SLOT 0 timestamp to reside in the assigned Link Layer's TIMESTAMP register means that the TIMESTAMP registers in Wake-On-Radio, are not all in one address space: TIMESTAMP0 resides in the assigned Link Layer's address space, while TIMESTAMP1-3 register reside in XVCR address space, alongside all the other WOR registers.

TIMESTAMP STATUS

A timestamp will be captured into a TIMESTAMPx register on any slot assigned to FUNCTION RX, whenever an Access Address or SFD is detected during the receive window. Whenever a timestamp is captured as described above, a 3-bit read-only status register is updated with information regarding status of the reception which occurred during the slot. The timestamp status, TIMESTAMPx_STS[2:0], becomes valid, and final (for the current slot), at the end of the receive window, and is made available to MCU when it is next awakened, along with the TIMESTAMP itself. The status information can be used by software to ascertain the validity of the timestamp. The following diagram describes timestamp status.

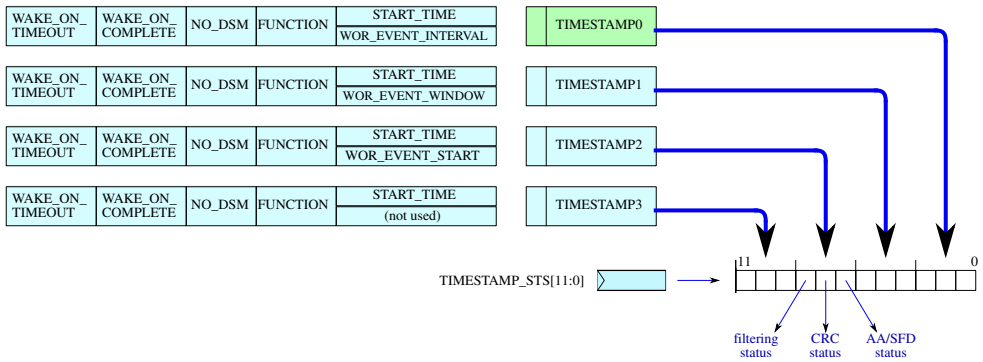

Figure 252. TIMESTAMP STATUS

A breakdown of the 3-bit status field, per timestamp, follows in the table below.

- 0: AA/SFD status
- 1: CRC status
- 2: Packet Filtering status

For any WOR slot assigned to RX, the 3-bit timestamp status field for that slot is cleared to 000 at the instant that WOR state WAIT_SEQ_START is reached. This is prior to the launch of the receive operation. (The bits are not cleared if the slot's function is not RX.) Once reception begins, the individual timestamp status bits are updated in realtime as the circumstances of the reception warrant. The 3-bit timestamp status is considered valid at the end of the receive window, and the bits reflect reception status per the following table.

TIMESTAMPx_STS bit	Meaning if 0	Meaning if 1
[0] AA/SFD status	No AA or SFD was detected during the receive window.	At least one AA or SFD was detected. RX recycles can lead to multiple occurrences.
[1] CRC status	For the packet associated with last (most recently) detected AA or SFD, CRC verification failed.	For the packet associated with last (most recently) detected AA or SFD, CRC verification passed.
[2] Packet Filter status	For the packet associated with last (most recently) detected AA or SFD, at least 1 packet filtering rule was violated.	For the packet associated with last (most recently) detected AA or SFD, all packet filtering rules passed.

Packet filtering rules, and hence the meaning of the TIMESTAMPx_STS[2] bit, vary across protocols, as summarized in the following table.

PROTOCOL	MEANING OF TIMESTAMP_STSx[2] (PACKET FILTER)
802.15.4	Reflects the Packet Processor FILTERFAIL flag
GENERIC_FSK	There are 3 packet filter criteria: 1. H0 matching 2. H1 matching 3. LENGTH_MAX compliance (maximum packet length verification)

Timestamp status bits are sticky. Once they become valid at the end of the receive window (end of WAIT_SEQ_END state), they remain valid until the *next* time the same slot number comes up again, and WOR reaches WAIT_SEQ_START state on that slot number.

In general, the MCU does not need to be notified on "bad packets." However, timestamp status may still be of value to WOR software even without Data Indication on any given slot. Notification policy can be modified at the protocol level, to enable RXIRQ on bad packets, mainly for debug purposes. If notification policy is modified by configuring the assigned Link Layer accordingly, this will affect Wake-On-Radio was well, as an rx_irq_trig will be generated on otherwise "bad" packets. See Section State Machine, specifically the WAIT_SEQ_END state, for details on how WOR responds to rx_irq_trig during this state, to determine how modifying notification rules would affect WOR response.

WOR software can use timestamp status to gauge the validity of the timestamp in any given slot. The following tables provides some guidelines.

TIMESTAMPx_STS	TIMESTAMPx REGISTER VALIDITY	MEANING
0b000	stale	No AA or SFD was received during this timeslot. The TIMESTAMPx register was not updated by HW and continues to hold the timestamp captured after the last AA or SFD detection on this slot number.
0bX01	invalid	At least 1 AA or SFD was detected during this timeslot. For the last (most recent) AA or SFD detected, CRC verification failed. TIMESTAMP register holds the EVENT_TMR captured for

Table continues on the next page...

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TIMESTAMPx_STS	TIMESTAMPx REGISTER VALIDITY	MEANING
		this reception. Because CRC failed, the TIMESTAMP should be deemed invalid, but this decision is left to the application.
0b011	valid	At least 1 AA or SFD was detected during this timeslot. For the last (most recent) AA or SFD detected, CRC verification passed. TIMESTAMP register holds the EVENT_TMR captured for this reception, and can be deemed valid. However Packet Filtering failed, so typically there would be no Data Indication.
0b111	valid	At least 1 AA or SFD was detected during this timeslot. For the last (most recent) AA or SFD detected, CRC verification passed. TIMESTAMP register holds the EVENT_TMR captured for this reception, and is valid. Packet Filtering passed.

52.4.4.1.1.2.8 Interrupts

WOR hardware utilizes the assigned Link Layer's interrupts for all MCU wakeups and notifications. In Wake-On-Radio, the MCU is in a low-power state most of the time. So, interrupts are allowed to assert only when it is mandatory to wake the MCU out of its low power state, to tend to required Link Layer or WOR tasks. WOR hardware modifies the interrupt activity of the assigned Link Layer by dynamically blocking and/or allowing Link Layer interrupts to propagate to the MCU, under control of the current slot descriptor specifications. Each of the 3 supported protocol engines have been modified to allow WOR to manage its RF-related interrupts. The RF-related interrupts have nearly identical functions and meanings across the 3 protocols:

- TXIRQ (or TX_IRQ)
- RXIRQ (or RX_IRQ)
- SEQ_END_IRQ (or SEQIRQ)

The modifications to the protocol engines, involve an AND gate inserted between each interrupt trigger, and the interrupt status bit, allowing or blocking the trigger from asserting the status bit. A gating signal, wor_allow_irq, is provided by WOR to each protocol engine to enable/disable the AND gate. The gating signal is updated dynamically by the WOR state machine based on state, RF operation status, and the current descriptor's WAKE_ON_* fields. See Section State Machine, specifically the description of the WAKE_SEQ_END state, for more details on how and when WOR allows and blocks RF-related interrupts. For protocols not assigned to WOR, interrupts are always allowed.

The raw interrupt triggers themselves (the inputs to the AND gates), namely, tx_irq_trig and rx_irq_trig, are passed directly to WOR hardware, so that WOR state machine can react to RF operation status in realtime, and sequence through the states as specified by the current slot's descriptor.

WOR manages one other Link Layer interrupt, for non-RF-related notifications. Each protocol engine has an existing interrupt, WAKE_IRQ, to notify MCU on wakeup from Manual DSM mode (not Wake-On-Radio). See Section Manual DSM for more details on this DSM control scheme. For any protocol, Wake-On-Radio and Manual DSM are mutually-exclusive control schemes, so when a protocol is assigned to WOR, its WAKE_IRQ is re-purposed, and re-named, to WOR_IRQ.

Like the "allow/block" gating WOR uses to manage the RF-related interrupts, WOR uses 2 signals to either block or *force* a WAKE_IRQ / WOR_IRQ:

- **wor_block_wake_irq:** prevents the (legacy) WAKE_IRQ from asserting at DSM exit, this is *mandatory* for Manual DSM, but is *conditional* for WOR.
- **wor_force_wake_irq:** WOR needs to assert WOR_IRQ under 3 conditions (see below)

There are 3 conditions for which WOR needs to compel the Link Layer to assert WOR_IRQ. WOR maintains 3 read-only status flags to indicate each of these conditions. The status flags exist in XCVR (WOR) address space, even though the WOR_IRQ resides in the protocol-specific address space. The 3 conditions, and the associated status flag for each, are described in the following table.

- **WOR_NO_RF_FLAG:** START_TIME has been reached on a slot with FUNCTION = NO_RF and WAKE_ON_COMPLETE=1
- **WOR_MAX_SLOT_FLAG:** In Constant-Interval scheduling mode, the WOR_SLOT_COUNT[7:0] has reached WAKE_ON_NTH_SLOT[7:0]
- **WOR_DSM_EXIT_FLAG:** An unscheduled, asynchronous DSM "Early Exit" has occurred

To service an WOR_IRQ, the interrupt service routine should query the 3 read-only status flags to determine the cause of the MCU wake up. At least one of these flags will be set. It is possible that more than 1 of the flags is set. For the WOR_NO_RF_FLAG, WAKE_ON_COMPLETE would typically not be set on a NO_RF slot, since the purpose of NO_RF is to allow "DSM cascading"; only for debug purpose has this flag been provided. Servicing of the other 2 flags is beyond the scope of this document.

Clear the WOR_IRQ by writing a 1 to this bit in the protocol-specific address space. However the 3 WOR flags are "sticky". Any flag which is set will remain set until a new WOR session has begun, which means taking WOR to DISABLED by setting SLOTS_USED=0, followed by re-enabling by setting SLOTS_USED>0.

In initializing the assigned Link Layer for WOR operation, it is *essential* that software enable (unmask) the 3 RF-related interrupts, as well as WAKE_IRQ / WOR_IRQ. It is equally essential that all non-WOR related interrupt sources are *disabled* when a protocol is assigned to WOR, to prevent unnecessary MCU wakeups. The following tables describe all the Link Layer interrupts, their controllability (or lack of) by WOR, and the required enabling/unmasking by software.

INTERRUPT CONFIGURATION (802.15.4)

INTERRUPT	WOR CONTROL	SW INIT	COMMENTS
TXIRQ	gated by wor_irq_allow	ENABLE	Asserted after packet transmission when: WAKE_ON_COMPLETE || WAKE_ON_TIMEOUT
RXIRQ	gated by wor_irq_allow	ENABLE	Asserted after good packet reception when: WAKE_ON_COMPLETE || WAKE_ON_TIMEOUT
SEQIRQ	gated by wor_irq_allow	ENABLE	1. Asserted after any good packet transmission or reception when: WAKE_ON_COMPLETE || WAKE_ON_TIMEOUT 2. Asserted after bad (or no) packet reception when: WAKE_ON_TIMEOUT
CCAIRQ	unaffected	DISABLE	Not used in WOR

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INTERRUPT	WOR CONTROL	SW INIT	COMMENTS
RXWTRMRKIRQ	unaffected	DISABLE	Not used in WOR
FILTERFAIL_IRQ	unaffected	DISABLE	Not used in WOR
PLL_UNLOCK_IRQ	unaffected	OPTIONAL	If enabled, would cause an immediate MCU LLWU on occurrence of a PLL unlock event.
WAKE_IRQ / WOR_IRQ	blocked by wor_block_wake_irq, forced by wor_force_wake_irq	ENABLE	1. Asserted when START_TIME reached on a slot with FUNCTION=NO_RF and WAKE_ON_COMPLETE=1 2. Asserted in CI mode when WOR_SLOT_COUNT==WAKE_ON_NTH_SLOT 3. Asserted after an unscheduled "DSM Early Exit"
TMRxIRQ	unaffected	DISABLE	Not used in WOR
TSM_IRQ	unaffected	DISABLE	Not used in WOR

INTERRUPT CONFIGURATION (non-802.15.4)

INTERRUPT	WOR CONTROL	SW INIT	COMMENTS
TX_IRQ	gated by wor_irq_allow	ENABLE	Asserted after packet transmission when: WAKE_ON_COMPLETE || WAKE_ON_TIMEOUT
RX_IRQ	gated by wor_irq_allow	ENABLE	Asserted after good packet reception when: WAKE_ON_COMPLETE || WAKE_ON_TIMEOUT
SEQ_END_IRQ	gated by wor_irq_allow	ENABLE	1. Asserted after any good packet transmission or reception when: WAKE_ON_COMPLET

Table continues on the next page...

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INTERRUPT	WOR CONTROL	SW INIT	COMMENTS
			E || WAKE_ON_TIMEOUT 2. Asserted after bad (or no) packet reception when: WAKE_ON_TIMEOUT
NTW_ADR_IRQ	unaffected	DISABLE	Not used in WOR
T1_IRQ	unaffected	DISABLE	Not used in WOR
T2_IRQ	unaffected	DISABLE	Not used in WOR
PLL_UNLOCK_IRQ	unaffected	OPTIONAL	If enabled, would cause an immediate MCU LLWU on occurrence of a PLL unlock event.
WAKE_IRQ / WOR_IRQ	blocked by wor_block_wake_irq, forced by wor_force_wake_irq	ENABLE	1. Asserted when START_TIME reached on a slot with FUNCTION=NO_RF and WAKE_ON_COMPLETE=1 2. Asserted in CI mode when WOR_SLOT_COUNT==WAKE_ON_NTH_SLOT 3. Asserted after an unscheduled "DSM Early Exit"
TSM_IRQ	unaffected	DISABLE	Not used in WOR
RX_WATERMARK_IRQ	unaffected	DISABLE	Not used in WOR

52.4.4.1.1.2.9 Channel Hop Table

Typically, in either Timeslot or Constant-Interval scheduling mode, RF operations on consecutive slots use different RF channels. Using Wake-On-Radio to program slot specifications for the next few RF operations in advance, would be of little value if the MCU had to wake up on every slot to program the assigned Link Layer's CHANNEL_NUM register. Thus, Wake-On-Radio provides hardware automation for channel hopping on a slot-by-slot basis.

A table of channel hop frequencies is maintained by hardware. The number of entries in the table (hop sequence length) is programmable. Prior to starting a WOR session, software will program the desired sequence of channel numbers into the table. After WOR is activated by setting SLOTS_USED>0, The WOR state machine controls the index (read pointer) into the table. The index is typically incremented at the end of every slot, when the slot counter is incremented. The increment is +1 modulo "hop sequence length". The RF operation on the current slot, is then carried out on the RF channel pointed to by the hop table index. If necessary, WOR or Link Layer software can update the hop table index at any time.

Rather than adding a channel number field to the descriptor, to save area, the hop table is decoupled from the descriptor table. The hop tables utilizes a small section of Packet RAM which is not otherwise used by the supported WOR protocols. WOR uses 128 bytes of Packet RAM for the channel hop table.

The channel information entered into the hop table, can use the (legacy) 7-bit "mapped channel" format, which allows channels to be specified on a 1MHz boundary; or one of 2 new 16-bit formats that allows channel frequency of higher resolution. The option for the legacy format, provides backwards compatibility to existing software, which does not use WOR, to program RF channel information the way it does today, without any changes. The inclusion of the new formats allows additional flexibility for programming channels which deviate from a 1MHz boundary, coupled with the automation built in to WOR. The format selected, determines:

1. how the hop table is organized in RAM
2. how software programs the hop table
3. how the WOR parses the table during execution of the current slot
4. and how the PLL digital block interprets the frequency word extracted from the table.

Selecting the hop table configuration is by way of the HOP_TBL_CFG[2:0] register. Based on this setting, the source of channel information, can either be the CHANNEL_NUM[6:0] bit register that exists in each protocol engine today (legacy), or the new hop table, according to the following table:

Source of RF channel information, based on HOP_TBL_CFG[2:0]:

0: Assigned Link Layer's CHANNEL_NUM register (legacy)

1: WOR Hop Table

2: WOR Hop Table

3: WOR Hop Table

4-7: Reserved

To allow for the legacy option, the 3 protocol-specific CHANNEL_NUM registers are now routed to WOR, which multiplexes them with the hop table output based on HOP_TBL_CFG and WOR_PROTOCOL settings. WOR then outputs 3 16 bit frequencies words, one per protocol, to PLL Digital, conveying the required channel information.

Hop table organization is determined by HOP_TBL_CFG, as per the following table:

Hop Table Organization, based on HOP_TBL_CFG[2:0]:

0: N/A

1: Table size is 128 entries. Two 7-bit CHANNEL_NUM fields are packed into a 16-bit hop frequency word for RAM storage

2: Table size is 128 entries. Each 16-bit hop frequency word in RAM contains a specification for a single RF channel

3: Table size is 128 entries. Each 16-bit hop frequency word in RAM contains a specification for a single RF channel

4-7: Reserved

The content of the hop frequency word provided to PLL Digital, and how it is interpreted by that block, also varies with HOP_TBL_CFG, as per the following table:

PLL Digital Interpretation of Hop Frequency Word, based on HOP_TBL_CFG[2:0]:

0: Lower 7 bits of hop frequency word contain a mapped channel (legacy format). Upper 9 bits are 0

1: Lower 7 bits of hop frequency word contain a mapped channel (legacy format). Upper 9 bits are 0

2: All 16 bits are valid. See Chapter *PLL Digital* for interpretation

3: All 16 bits are valid. See Chapter *PLL Digital* for interpretation

4-7: Reserved

The following diagram summarizes the routing of channel hop signalling amongst the supported protocol engines, the WOR scheduler, the PLL Digital, and Packet RAM. It also shows the 2 hop table configurations, and hop frequency word generation, based on HOP_TBL_CFG. The existing (legacy) configuration is on the left, and the new, WOR-based configuration is on the right.

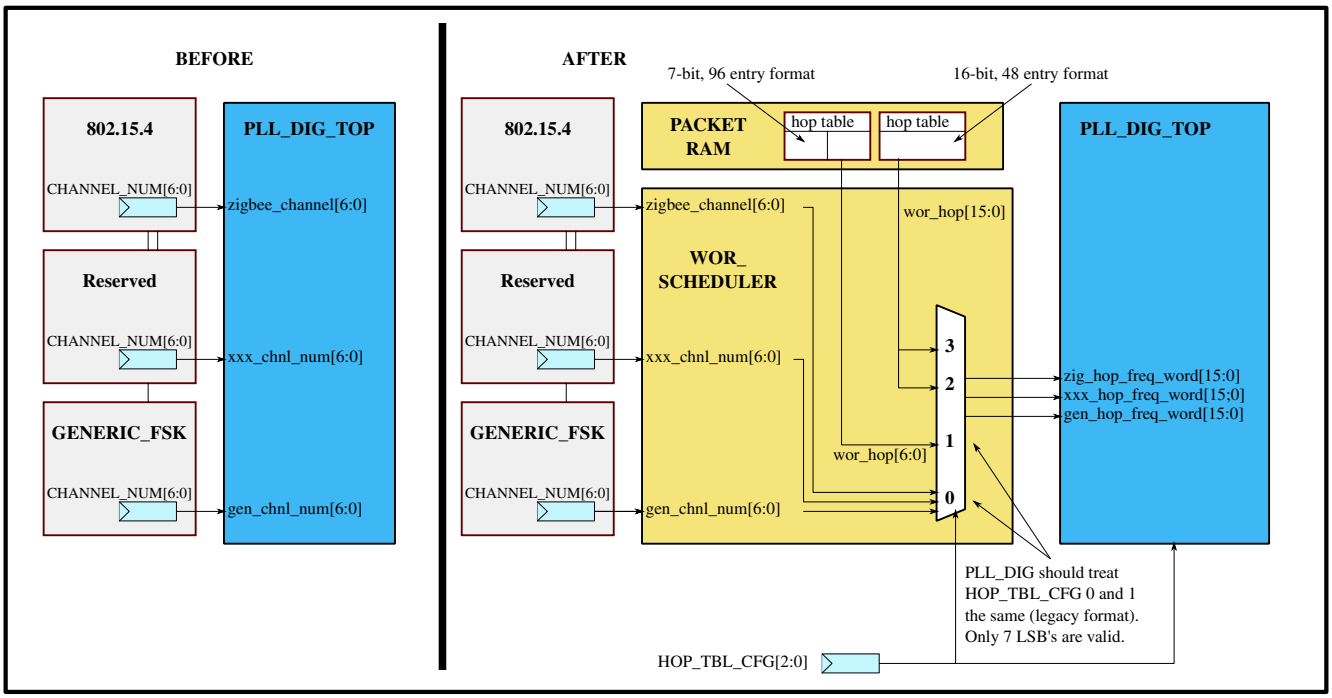


Figure 253. CHANNEL HOP SIGNAL ROUTING AND CONFIGURATION

The number of entries in the table is determined by programmable register HOP_SEQ_LENGTH[7:0]. If HOP_TBL_CFG=1, HOP_SEQ_LENGTH determines the number of 7-bit CHANNEL_NUM entries in the Packet RAM table, which are packed 2 per RAM word. HOP_SEQ_LENGTH must not exceed 128 in this case. If HOP_TBL_CFG=2 or HOP_TBL_CFG=3, HOP_SEQ_LENGTH determines the number of 16-bit format entries in the Packet RAM table, one per RAM word. HOP_SEQ_LENGTH must not exceed 128 in this case.

At the start of new WOR "session" (setting SLOTS_USED to a non-zero value), WOR hardware initializes the table index (read pointer) to 0. (Software can modify this index, see below.) After slot execution completes, as the WOR state machine increments the slot counter to service the next slot, the hop table index is incremented by +1 (modulo HOP_SEQ_LENGTH). An exception is made to this rule, if the FUNCTION field of the slot descriptor is set to NO_RF, the hop index is *not* incremented when the slot counter is incremented to advance to the next slot. The NO_RF function is used for "DSM cascading".

Software can take control of the hop table index at any time, by writing a new desired index to the NEW_HOP_IDX[6:0], and with the UPDATE_HOP_IDX register set to 1. These 2 steps can be performed as a single, atomic IPS bus write. WOR hardware will update the index accordingly. From this point forward, the hop-table hardware incrementing rules, discussed in the previous paragraph, apply. This way, software can execute a one-time "jump" in the hop table indexing.

The read-only register WOR_HOP_IDX[6:0] allows software to read the instantaneous, hardware-controlled hop table index at any time. Similarly, the read-only register WOR_HOP_FREQ_WORD[15:0] allows software to read the instantaneous, hardware-generated frequency word sent to PLL digital. This word is the output of the hop table configuration selection mux shown in the diagram above, the protocol-specific word currently selected by WOR_PROTOCOL.

A diagram showing the RAM-based, 128-entry hop table (HOP_TBG_CFG=1), where it is situated in Packet RAM space, how the channel information is organized in the table, and how WOR hardware indexes the table, is shown below.

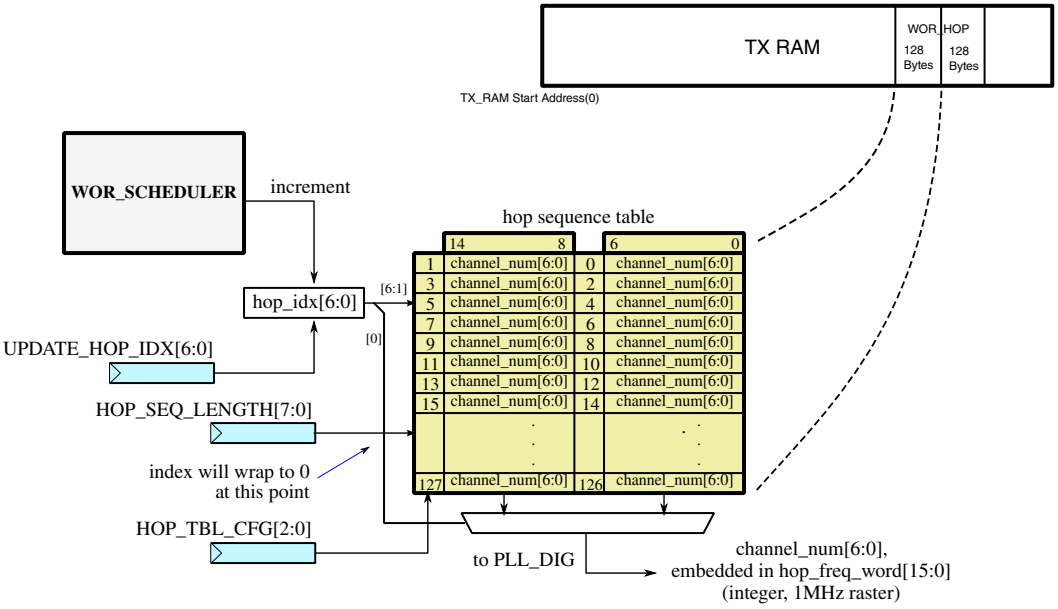


Figure 254. 128-ENTRY HOP TABLE

A diagram showing the RAM-based, 128-entry hop table (HOP_TBG_CFG=2 or 3), where it is situated in Packet RAM space, how the channel information is organized in the table, and how WOR hardware indexes the table, is shown below.

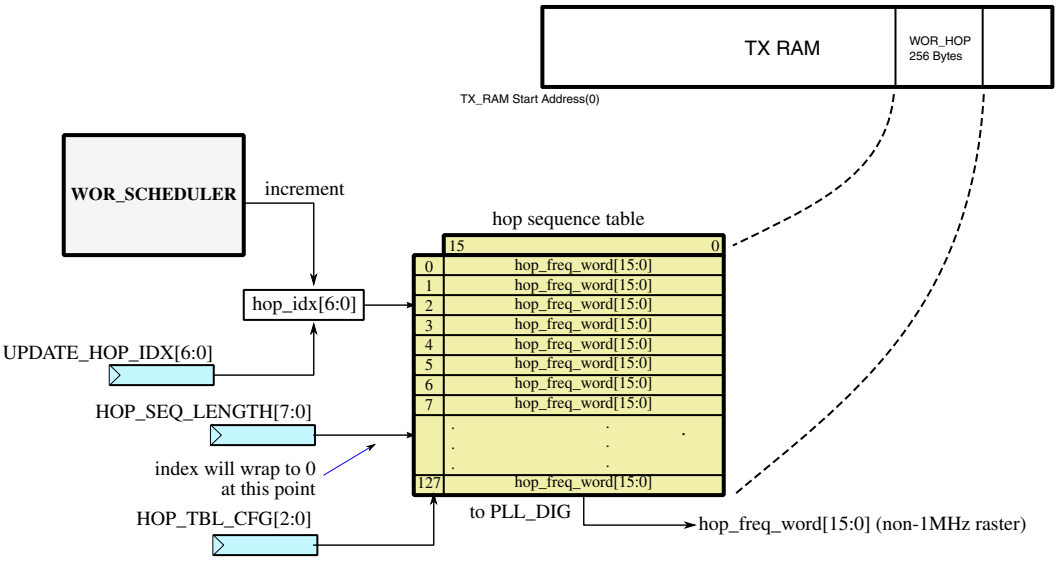


Figure 255. 128-ENTRY HOP TABLE

The 256 bytes of Packet RAM are reserved for the WOR hop table. The table is fixed in this position, and does not move based on HOP_TBL_CFG.

The WOR hop table should not be accessed (no writes or reads) while an RF operation is underway. There is no hardware to de-conflict RAM accesses with those originating in the protocol engines. Aside from this restriction, the hop table can be accessed at any time. A convenient time to modify the hop table, if required, would be during the WOR WAIT_RESUME state.

Follow the instructions below to program the WOR hop table.

1. Program the hop table

2. Program HOP_CTRL[HOP_SEQ_LENGTH] with the desired size of the hop sequence
3. Program HOP_CTRL[HOP_TBL_CFG] to select the desired table configuration and enable hopping during WOR

52.4.4.1.1.2.10 DSM Early Exit

As described in Section State Machine, for every slot, WOR hardware computes the duration of the upcoming DSM cycle based on descriptor START_TIME, current time, and window-widening, during the COMP_DURATION1 and COMP_DURATION2 states. WOR outputs the desired duration on wor_dsm_duration[23:0]. The Radio Mode Controller (RFMC) then executes this DSM for the prescribed number of 32.768KHz clock cycles, and when complete, sends the actual duration back to WOR using rfmc_sleep_duration[23:0]. Normally, these 2 durations will match precisely.

Conditions exist where the DSM cycle may occasionally need to be cut short, due to circumstances beyond the control of the radio. The SoC, starting with the MCU, must be awakened out of its low power state before the WOR DSM duration expires. When this happens, software handling the event which triggered the wakeup, will determine if the radio needs to be awakened as well. If this is the case, software will set the RFMC_WOR_WKUP bit. This will trigger an unscheduled wakeup process out of DSM by the RFMC deep sleep state machine. The wakeup will complete before the wor_dsm_duration[23:0] time has expired. RFMC will capture the *actual* DSM duration, cut short by the early exit, into rfmc_sleep_duration[23:0]

After DSM wakeup, WOR hardware always performs this check during the COMP_WW state:

rfmc_sleep_duration[23:0] == wor_dsm_duration[23:0]

If this check fails, WOR hardware declares an "DSM Early Exit", and takes the following steps:

1. Forces the assigned Link Layer to assert its WAKE_IRQ / WOR_IRQ (see Section Interrupts)
2. Sets the WOR_DSM_EXIT_FLAG in WOR space
3. Transitions to the WAIT_RESUME state and waits for software to service the WOR_IRQ.

Software should then take whatever steps are necessary to configure the radio to respond to the conditions which triggered the early exit. Servicing of a DSM early exit interrupt is beyond the scope of this document.

52.4.4.1.1.2.11 Manual DSM

Prior to Wake-On-Radio, implementation of the 2.4GHz used a software-driven, "manual" DSM. This DSM control scheme does not have any of the hardware automation associated with WOR, and software must perform such tasks as computing the Event Timer addback time, window-widening, etc.

Manual DSM still exists as an alternative to Wake-On-Radio. Manual mode can be of value in a multiprotocol setting. See Section Multiprotocol for more details.

Any of the 3 protocols supported by Wake-On-Radio, can utilize Manual DSM as an alternative to Wake-On-Radio. In short, Manual DSM works by programming a desired DSM start time into the ENTER_TIME register, and a desired DSM wake time into the WKUP_TIME register. The ENTER_TIME and WKUP_TIME registers are referenced to the 32.768KHZ TIMER, the radio's low-power (DGO) timer. ENTER_TIME, WKUP_TIME, and TIMER reside in RFMC address space.

When a match on TIMER to ENTER_TIME occurs, RFMC places the radio in deep sleep mode. The RF Oscillator is shut off, and the Link Layer's Event Timer is frozen in place. When a match on TIMER to WKUP_TIME occurs, the Event Timer resumes from where it left off. The RF Oscillator, is re-started as part of the DSM wake up process, and is running before WKUP_TIME is reached. At the instant the Event Timer resumes, the Link Layer asserts its WAKE_IRQ. The MCU should use the WAKE_IRQ ISR to compute the precise amount of time the radio was in DSM, convert this value to microseconds, and add this value to the current Link Layer Event Timer, to restore the timer to where it would have been, had DSM not occurred. There is a 1us loss-of-precision in the Event Timer timebase incurred on every DSM wakeup. This timebase error is random, and averages out over many DSM cycles.

Regarding the DSM wakeup process, there is additional programmability to configure the lead time for power-domain wakeup and oscillator re-start, relative to DSM exit (WKUP_TIME). This configurability is covered by the RFMC register. See the *Radio Mode Controller* chapter for more details.

52.4.4.1.1.2.12 Multiprotocol

The 2.4GHz radio supports 4 protocols, any 2 of which can be enabled for multiprotocol use on an alternating, time-shared basis. Both of the active protocols may require DSM. The following section describes the rules to be applied when assigning a protocol to a DSM control scheme.

The radio has 3 DSM control schemes:

1. Bluetooth LE-internal
2. Wake-On-Radio
3. Manual DSM

The Bluetooth LE-internal DSM controller applies to the Bluetooth LE protocol engine only, and is the only DSM option for Bluetooth LE.

Wake-On-Radio can be assigned to any one of the following protocols (see Section *Assign To Protocol*):

1. 802.15.4
2. GENERIC_FSK

Manual DSM can be assigned to any one of the following protocols (see Section *Manual DSM*):

1. 802.15.4
2. GENERIC_FSK

52.4.4.1.1.2.13 Hardware Multiplier

Wake-On-Radio requires 6 multiplies while executing each slot. The multiplications take place in the following WOR states (See Section State Machine):

1. COMP_DURATION1: to compute the upcoming DSM duration, excluding window widening
2. COMP_DURATION2 and COMP_DURATION3: to compute the subtractor to the upcoming DSM duration, for window widening
3. COMP_ADDBACK: to compute the Event Timer addback value based on RFMC-provided DSM duration
4. COMP_WW: to compute the DSM-component of window-widening incurred during the just-completed DSM cycle
5. DRIFT_CAL: to compute the clock drift

For maximum area and power saving, there is 1 hardware multiplier instance, which is timeshared for the 6 multiplies. Also, because the state machine has been architected to allow sufficient time to perform these computations before the results are needed, the multiplier uses a serial, add-and-accumulate construction. The multiplicands are 30 bits and 20 bits. The 30 bit operand is appropriately sized for the DSM_DURATION_NO_WW[23:0] * WW_DSM_FACTOR[5:0]. The 20 bit operand is appropriately sized to achieve the precision of the required calculations, as described in the earlier sections.

For each calculation, the multiplier requires 20 clocks (20 shifts). Each multiply takes place within the confines of a single state of duration 1µs. There are 32 periods of the reference oscillator during that period (26 for a 26MHz crystal), more than enough to complete the multiply. The clock to the multiplier runs at the reference oscillator rate, but runs only during the 6 1µs states listed above, to maximize power savings.

Depending on the calculation, the required precision, the positioning of the integer bits within the product, etc., the bits of the product tapped for each calculation varies. Also, depending on the calculation, combinational rounding or truncation of the product occurs, external to the multiplier.

52.4.4.1.1.2.14 Clocking

Because of the intensive interaction between Wake-On-Radio and 3 protocol engines it supports, the WOR hardware runs at 1MHz. This facilitates signalling between the WOR and the assigned Link Layers, with no additional pulse-stretching or signal-conditioning required. Like the protocol engines and the TSM, the CGM's cg1m_en gating signal is used to generate the common 1MHz, so the phasing of the clocks across all the communicating modules remains in sync.

All WOR clocks are conditioned on WOR_EN=1. This bit should be set, and remain set, whenever Wake-On-Radio is in use (it should not be toggled or modified dynamically by software, since module clock-gating is based on it). This bit should not be set if WOR is not in use; that way, the WOR hardware block will consume zero dynamic power.

In total, there are 4 clocks used by WOR hardware:

1. **ipg_clk_wor_1m**: Most of the WOR hardware runs off this 1MHz clock, including the state machine, descriptor processing, and hop table indexing. All link layer interface outputs are generated with this clock, and link layer inputs sampled by it.
2. **ipg_clk_wor_ww_1m**: Identical in timing to ipg_clk_wor_1m, but used only by functions that require window widening to be enabled. The additional clock gating granularity saves power when widening is disabled.
3. **ipg_clk_wor_comp**: This is the "compute clock" used by the serial multiplier. This clock runs at the reference oscillator frequency (derivative of xcvr_ref_clk_gated), but only during the 4 1µs-long states (per slot) during which the multiplier is in use; See Section Hardware Multiplier)
4. **ipg_clk_wor_timestamp**: This is the "timestamp clock". Because the protocol engines determine the timestamp-capture timing, based on AA/SFD detection, the clock-gate enable for the capture is sent to the CGM, which routes the resulting timestamp clock itself to WOR so that it can update its TIMESTAMP1,2, and 3 registers. This clock will typically pulse once per RX slot, and not at all for slots of other types.

All gating for the WOR clocks is performed in CGM. WOR provides the gating-enable signal, and CGM provides the clock.

All WOR clocks are in the Reference Oscillator domain. There are no clock domain crossings inside the module.

No WOR critical timing paths are anticipated, nor any timing exceptions (e.g., multicycle paths).

52.4.4.1.1.2.15 Reset

The WOR has a main asynchronous reset input (ipg_hard_async_reset_b) that clears all the logic.

In addition, some internal accumulators for window-widening can be reset by two other conditions:

- Software writes 1 to the WW_CTRL [WW_NULL] bit.
- Good Packet Reception. For more details on this condition, please check Window Widening section.

52.4.4.1.1.3 External signals

Some of the WOR I/O signals are shown in the table below.

Signal	I/O	Description
ipg_hard_async_reset_b	input	Async reset - active low
ipg_clk_wor	input	Reference CLK
scan_mode	input	Scan mode
ipg_clk_wor_1m	input	1Mhz CLK
ipg_clk_wor_comp	input	Module IP clock, for computation
ipg_clk_wor_timestamp	input	Module IP clock, for timestamp
ipg_clk_wor_1m	input	Module IP clock, for WW
cg1m_en	input	1MHz CLK gating enable, restes accumulator
ips_clk	input	IPS clock
ips_module_en	input	IPS module enable

Table continues on the next page...

Table continued from the previous page...

Signal	I/O	Description
ips_addr	input	IPS address
ips_rwb	input	IPS read/write select
ips_byte_en	input	IPS byte enable
ips_wdata	input	IPS write data
ips_rdata	output	IPS read data
ips_xfr_wait	output	IPS Transceiver wait request
ips_xfr_err	output	IPS Transceiver error status
rfmc_time_rdata	input	RFMC Current 32kHz reference clock time
rfmc_enter_time_capt_rdata	input	RFMC captured value of Sleep Enter Time
rfmc_wkup_time_capt_rdata	input	RFMC captured value of Sleep WakeupTime
rfmc_enter_time	output	see registers description
rfmc_wkup_time	output	see registers description
zigbee_tsm_recycle	input	Zigbee LL's tsm_recycle[0]
ipi_int_wor_async	output	interrupt source
zig_timestamp	input	timestamp from Zigbee LL
ant_timestamp	input	timestamp from Ant LL
gen_timestamp	input	timestamp from Gen LL
rsim_dsm_duration	input	Actual Time Elapsed in DSM, from RSIM
sleep_request	input	sleep request from link layers
rsim_wor_deep_sleep_enable	input	from RSIM
rsim_man_deep_sleep_enable	input	from RSIM
wor_txirq_trig	input	trigger from LL
wor_rxirq_trig	input	trigger from LL
wor_wake_irq_trig	input	trigger from LL
wor_aa_sfd_matched	input	from PHY/ DEMOD , access address match
event_tmr	input	Timer events from LLs
*status_for_wor	input	Status from LLs
*channel_num	input	Channel number from LLs
timestamp_clk_en	input	clock enable from LLs
pb_rdata	input	from Packet RAM
rna_abort	input	from TSM: rf not allowed

Table continues on the next page...

Table continued from the previous page...

Signal	I/O	Description
wor_time_pb*	output	access signals to packet RAM
wor_en	output	to RSIM
wor_sleep_request	output	to RSIM
man_sleep_request	output	to RSIM
wor_dsm_duration	output	to RSIM
dsm_*_deep_sleep_enable	output	to LLs and CGM
wor_protocol	output	to select man interrupt
man_dsm_sel	output	to select man interrupt
wor_compute	output	to CGM
wor_tx_start_ext	output	to LLs
wor_rx_start_ext	output	to LLs
wor_seq_stop_ext	output	to LLs
wor_allow_irq	output	to LLs
wor_addback	output	to LLs
wor_event_tmr_add	output	to LLs
wor_force_wake_irq	output	to LLs
wor_block_wake_irq	output	to LLs
timestamp_inhibit	output	to LLs
wor_pb_*	output	Access signals to Packet RAM
*_hop_freq_word	output	to PLL_DIG , word for RF frequency hopping
hop_tbl_cfg	output	to PLL_DIG
wor_timestamp_clk_en	output	clock enable to CGM
*_for_dtest	output	Debug signals

52.4.4.1.1.4 Initialization

There is no particular sequence to initialize the WOR.

52.4.4.1.1.5 Application information

There are no specific procedures to be used by the application.

52.4.4.1.1.6 Register descriptions

Programmable registers to provide configuration and status for the Wake-On-Radio Scheduler are mapped into Transceiver Address Space. WOR registers are described in the table below.

52.4.4.1.1.6.1 WOR register descriptions

52.4.4.1.1.6.1.1 WOR_ADDR memory map

RADIO.WOR_REGS base address: 48A0_6100h

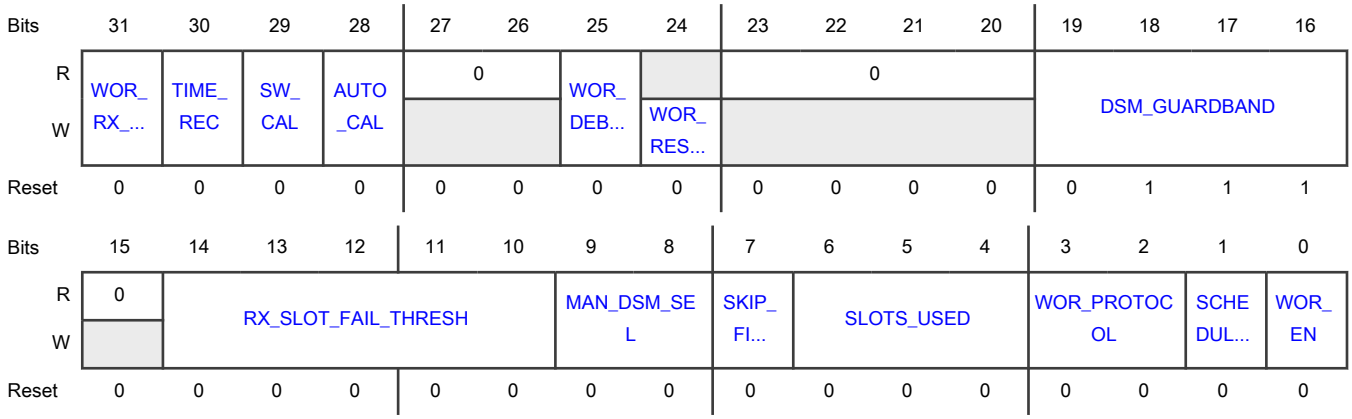
Offset	Register	Width (In bits)	Access	Reset value
0h	WAKE-ON-RADIO CONTROL (CTRL)	32	RW	0007_0000h
4h	WAKE-ON-RADIO TIMEOUT (TIMEOUT)	32	RW	00FF_0000h
8h	WAKE-ON-RADIO TIMESTAMP 1 (TIMESTAMP1)	32	R	See section
Ch	WAKE-ON-RADIO TIMESTAMP 2 (TIMESTAMP2)	32	R	See section
10h	WAKE-ON-RADIO TIMESTAMP 3 (TIMESTAMP3)	32	R	See section
14h	WAKE-ON-RADIO STATUS (STATUS)	32	RW	0000_0000h
18h	WINDOW-WIDENING CONTROL (WW_CTRL)	32	RW	0000_0002h
1Ch	FREQUENCY HOP CONTROL (HOP_CTRL)	32	RW	0030_0000h
20h	SLOT 0 DESCRIPTOR (LSB) (SLOT0_DESC0)	32	RW	0000_0000h
24h	SLOT 0 DESCRIPTOR (MSB) (SLOT0_DESC1)	32	RW	0000_0000h
28h	SLOT 1 DESCRIPTOR (LSB) (SLOT1_DESC0)	32	RW	0000_0000h
2Ch	SLOT 1 DESCRIPTOR (MSB) (SLOT1_DESC1)	32	RW	0000_0000h
30h	SLOT 2 DESCRIPTOR (LSB) (SLOT2_DESC0)	32	RW	0000_0000h
34h	SLOT 2 DESCRIPTOR (MSB) (SLOT2_DESC1)	32	RW	0000_0000h
38h	SLOT 3 DESCRIPTOR (LSB) (SLOT3_DESC0)	32	RW	0000_0000h
3Ch	SLOT 3 DESCRIPTOR (MSB) (SLOT3_DESC1)	32	RW	0000_0000h
40h	Auto Drift Calculation 1 (AUTO_DRIFT1)	32	RW	0000_0000h
44h	Auto Drift Calculation 2 (AUTO_DRIFT2)	32	RW	0000_0000h
48h	Auto Drift Calculation 3 (AUTO_DRIFT3)	32	RW	0000_0000h
4Ch	Auto Drift Calculation 4 (AUTO_DRIFT4)	32	RW	0000_0000h
98h	Timer Count (TIME)	32	R	0000_0000h
9Ch	MAN Low Power Entry Time Captured (ENTER_TIME_CAPT)	32	R	0000_0000h
A0h	MAN Low Power Wakeup Time Captured (WKUP_TIME_CAPT)	32	R	0000_0000h
A4h	MAN Low Power Entry Time Stamp (ENTER_TIME)	32	RW	0000_0000h
A8h	MAN Low Power Wakeup Time Stamp (WKUP_TIME)	32	RW	0000_0000h

52.4.4.1.1.6.1.2 WAKE-ON-RADIO CONTROL (CTRL)

Offset

Register	Offset
CTRL	0h

Diagram



Fields

Field	Function
31 WOR_RX_FAIL_IRQ_EN	WOR_RX_FAIL_IRQ Enable 1: WOR_RX_FAIL_IRQ interrupt is enabled 0: WOR_RX_FAIL_IRQ interrupt is not enabled
30 TIME_REC	Enable the WOR HW to record the timing information to the Packet RAM. 1: Record the timing information to the Packet RAM 0: Do not record the timing information to the Packet RAM.
29 SW_CAL	Enable the WOR SW to calculate the drift. Only when AUTO_CAL is set. Software can calculate the drift based on the timing information stored in the Packet RAM. When AUTO_CAL is enabled, this calculated drift can override the HW result. 1: Enable the software drift override. 0: Disable the software drift override.
28 AUTO_CAL	Auto calculate and track the drift enable Enable the WOR HW to auto calculate the drift. For Constant-Interval mode only. 1: Enable the drift auto calculation. 0: Disable the drift auto calculation.
27-26 —	Reserved
25 WOR_DEBUG_REG	WAKE-ON-RADIO Debug Register Enable WOR_DEBUG_REG alters the readback values of several read-only registers, for debug purposes. The registers which have a different readback value when WOR_DEBUG_REG=1 are:

Table continues on the next page...

Table continued from the previous page...

Field	Function
	• TIMESTAMP1 • TIMESTAMP2 • TIMESTAMP3 See the description of those registers, which indicates their nominal, and debug-mode readback values.
24 WOR_RESUME	WAKE-ON-RADIO Resume This bit causes the WOR state machine to advance from its WAIT_RESUME state. The state machine will enter WAIT_RESUME on any slot in which an MCU wakeup occurs (based on descriptor WAKE_ON_COMPLETE and/or WAKE_ON_TIMEOUT fields). After waking up (interrupting) the MCU, WOR will hold in WAIT_RESUME, giving software whatever time it needs to complete all required activity. Software then sets WOR_RESUME=1, causing the state machine to break out of WAIT_RESUME, advance to the next slot, and enter DSM. This bit is write-only. Writes of '0' have no effect. Readback value is always 0. Setting WOR_RESUME has no effect if WOR state machine is not in WAIT_RESUME. 1: Causes WOR state machine to advance out of WAIT_RESUME state, and begin the next slot 0: No effect.
23-20 —	Reserved
19-16 DSM_GUARDBAND	WAKE-ON-RADIO DSM Guardband Determines the number of 32.768KHz clock cycles of guardband used by the WOR state machine in computing duration of the DSM for any slot. Increasing this setting by 1 LSB causes WOR to shorten the DSM duration by 1 32.768KHz clock cycle. This guardband takes into account synchronization, and other, delays within the RFMC, and ensures that DSM will wakeup will never occur "too late" with respect to the slot descriptor's START_TIME field. The current default setting is 7. Values below 7 should not be used.
15 —	Reserved
14-10 RX_SLOT_FAIL_THRESH	RX Slot Fail Thresh When the number of missed slot is equal to (RX_SLOT_FAIL_THRESH + 1), the WOR_RX_FAIL_IRQ is set.
9-8 MAN_DSM_SEL	Manual DSM Selector Assigning Manual DSM to a protocol is done by way of the MAN_DSM_SEL[1:0] register, as shown in the following table: 0: Manual DSM Not Assigned 1: Manual DSM Assigned to 802.15.4 2: Manual DSM Assigned to GENERIC_FSK
7	WAKE-ON-RADIO Skip DSM On First Slot

Table continues on the next page...

Table continued from the previous page...

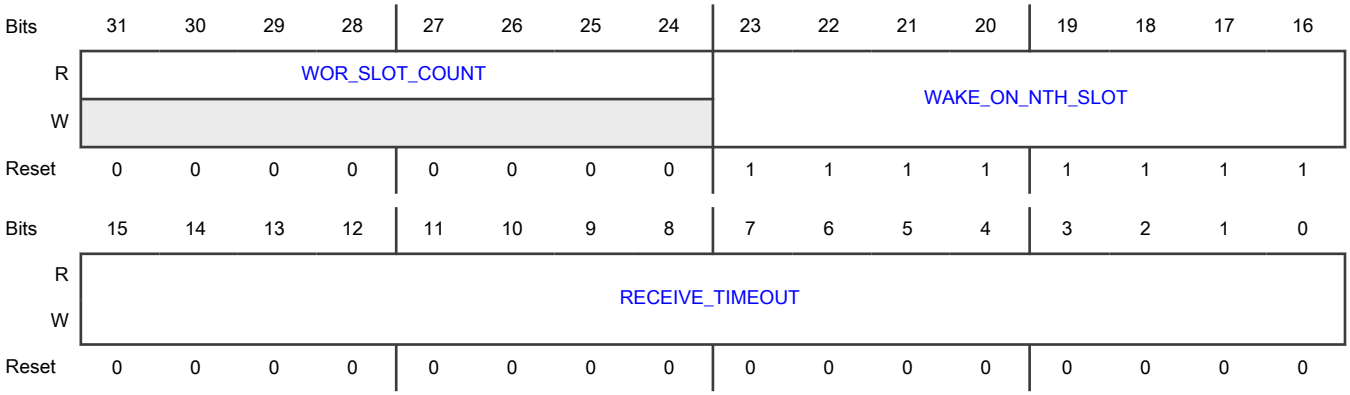
Field	Function
SKIP_FIRST_DSM	Setting this bit causes the WOR State Machine to skip the DSM entry/exit cycle for the first SLOT (SLOT 0) encountered after setting SLOTS_USED > 0, regardless of the setting of the NO_DSM field of the slot's descriptor. Subsequent slots, including SLOT 0 when it is re-encountered, will enter/exit DSM based on the descriptor NO_DSM. The SKIP_FIRST_DSM feature is useful, especially in Constant Interval Scheduling mode, when the desire is to begin RF operations immediately (at the start of the first EVENT_INTERVAL), as programmed in the descriptor START_TIME, without waiting out a DSM cycle 1: WOR skips DSM entry/exit on the first SLOT 0 after setting SLOTS_USED > 0, regardless of descriptor NO_DSM 0: WOR always obeys descriptor NO_DSM **Note:** SKIP_FIRST_DSM should not be used if the SLOT 0 descriptor FUNCTION is set to "NO_RF".
6-4 SLOTS_USED	WAKE-ON-RADIO Number Of Slots Used Determines the number of timeslots used to schedule future DSM and RF operations, for either scheduling mode. Up to 4 timeslots can be enabled. Increasing the number of timeslots used decreases average power consumption. Valid values are 0 ≤ SLOTS_USED ≤ 4. The SLOTS_USED register is the mechanism by which the WOR state machine is activated and de-activated. Setting SLOTS_USED to 0 disables the WOR state machine and puts the WOR functionality in an IDLE state. A subsequent write of a non-zero value to SL0TS_USED activates the state machine, initializing to SLOT 0, and starts a new WOR "session".
3-2 WOR_PROTOCOL	WAKE-ON-RADIO Protocol Selector Assigns the Wake-On-Radio function to one of the radio's protocol engines. 0: Not assigned 1: Assigned to 802.15.4 2: Assigned to GENERIC_FSK 3: Reserved
1 SCHEDULING_MODE	WAKE-ON-RADIO Scheduling Mode Determines the scheduling mode used by the WOR HW to organize future DSM and RF operations. 1: Constant-Interval Scheduling mode. 0: Timeslot Scheduling mode.
0 WOR_EN	WAKE-ON-RADIO Enable Wake-On-Radio Master Enable. In addition to enabling the block function, this bit gates the clock to the WOR module. This bit should be set, and remain set, whenever WOR is in use. 1: Wake-On-Radio is enabled. 0: Wake-On-Radio is disabled, and clocks to the module are gated off.

52.4.4.1.1.6.1.3 WAKE-ON-RADIO TIMEOUT (TIMEOUT)

Offset

Register	Offset
TIMEOUT	4h

Diagram



Fields

Field	Function
31-24 WOR_SLOT_COUNT	WAKE-ON-RADIO Absolute Slot Count This read-only register indicates the number of slots that have elapsed since SLOTS_USED was set to a non-zero value to activate the WOR state machine. WOR_SLOT_COUNT can be considered an Absolute Slot Number. WOR_SLOT_COUNT counts slots up to a maximum of 255. If the number of elapsed slots exceeds 255, WOR_SLOT_COUNT will remain at 255. WOR_SLOT_COUNT is "sticky" in the sense that it will hold its value after the WOR session has ended by setting SLOTS_USED=0; WOR_SLOT_COUNT will clear to 0 when a new WOR session is started by taking SLOTS_USED from 0 to any non-zero value.
23-16 WAKE_ON_NTH_SLOT	WAKE-ON-RADIO Force Wake On Nth Slot If the WAKE_ON_COMPLETE bit is not set in any descriptor, WOR will not awaken the MCU even after a number of good packets are received. Additionally, if WAKE_ON_TIMEOUT is also not set in any descriptor, WOR will not wake up the MCU under any circumstances, which would not be desirable. This register provides a backup method to awaken the MCU, after *N+1* slots have elapsed, where *N* = WAKE_ON_NTH_SLOT[7:0], regardless of whether or not any good packets have been received, and regardless of the setting of the WAKE_ON_* descriptor bits. Applies to Constant-Interval Mode only. (For Timeslot mode, at least one slot *must* have a WAKE_ON_* bit set in its descriptor).
15-0 RECEIVE_TIMEOUT	WAKE-ON-RADIO Receive Timeout For any RX slot, determines how long RX stays on after the descriptor's START_TIME is reached, in microseconds. A timeout is declared if a good packet is not received before the expiration of this time period (START_TIME + RECEIVE_TIMEOUT + WINDOW_WIDENING). Applies to TIMESLOT mode only.

52.4.4.1.1.6.1.4 WAKE-ON-RADIO TIMESTAMP 1 (TIMESTAMP1)

Offset

Register	Offset
TIMESTAMP1	8h

Function

Timestamp captured for a packet received on SLOT 1. During SLOT 1, any valid Access Address or SFD detection will result in the contents of the respective Link Layer's Event Timer being captured into this register at the instant of detection (there is no offset applied). TIMESTAMP1 remains "sticky" until a new AA or SFD detection occurs, during either the same, or a subsequent, SLOT 1.

Note: Timestamp for SLOT 0 is captured into the respective Link Layer's TIMESTAMP register (external to WOR), and can be read from that Link Layer's address space.

Note: If WOR_DEBUG=1, this register instead reads back WOR_ADDBACK[27:0], which is the number of microseconds that the WOR state machine "added back" to the assigned Link Layer's Event Timer, to correct for the amount of time that Link Layer was in DSM (Event Timer frozen). The WOR_ADDBACK readback value applies to the most recently-completed DSM cycle.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	TIMESTAMP1															
W																
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	TIMESTAMP1															
W																
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Fields

Field	Function
31-0 TIMESTAMP1	WAKE-ON-RADIO TIMESTAMP1 Timestamp captured for a packet received on SLOT 1. During SLOT 1, any valid Access Address or SFD detection will result in the contents of the respective Link Layer's Event Timer being captured into this register at the instant of detection (there is no offset applied). TIMESTAMP1 remains "sticky" until a new AA or SFD detection occurs, during either the same, or a subsequent, SLOT 1.

52.4.4.1.1.6.1.5 WAKE-ON-RADIO TIMESTAMP 2 (TIMESTAMP2)

Offset

Register	Offset
TIMESTAMP2	Ch

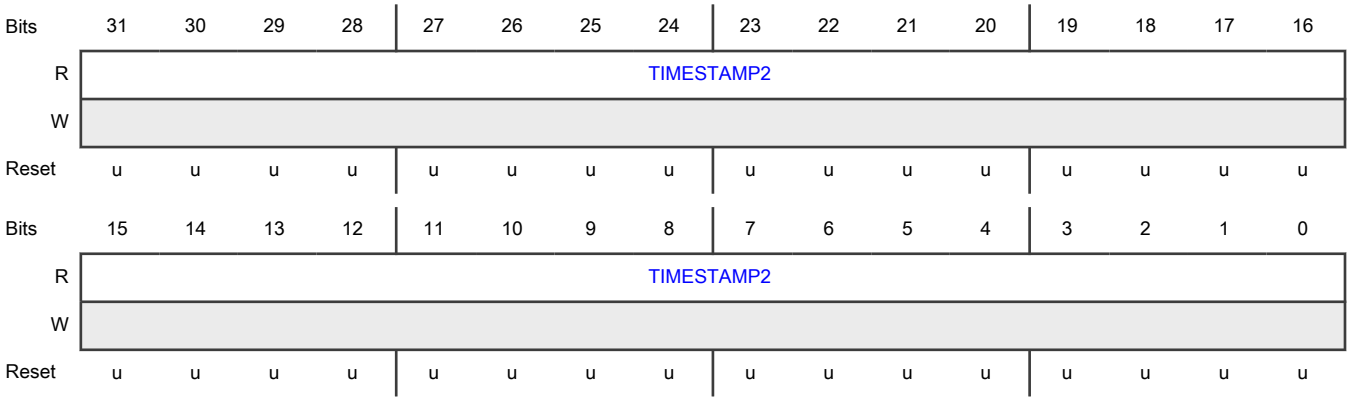
Function

Timestamp captured for a packet received on SLOT 2. During SLOT 2, any valid Access Address or SFD detection will result in the contents of the respective Link Layer's Event Timer being captured into this register at the instant of detection (there is no offset applied). TIMESTAMP2 remains "sticky" until a new AA or SFD detection occurs, during either the same, or a subsequent, SLOT 2.

Note: Timestamp for SLOT 0 is captured into the respective Link Layer's TIMESTAMP register (external to WOR), and can be read from that Link Layer's address space.

Note: If WOR_DEBUG=1, this register instead reads back WW_DSM_ADJUST[23:0], which is the accumulated DSM component of the Window Widening adjustment value that is used to offset the start and end of receive operations during the timeslot.

Diagram



Fields

Field	Function
31-0 TIMESTAMP2	WAKE-ON-RADIO TIMESTAMP2 Timestamp captured for a packet received on SLOT 2. During SLOT 2, any valid Access Address detection or SFD detection will result in the contents of the respective Link Layer's Event Timer being captured into this register at the instant of detection (there is no offset applied). TIMESTAMP2 remains "sticky" until a new AA or SFD detection occurs, during either the same, or a subsequent, SLOT 2.

52.4.4.1.1.6.1.6 WAKE-ON-RADIO TIMESTAMP 3 (TIMESTAMP3)

Offset

Register	Offset
TIMESTAMP3	10h

Function

Timestamp captured for a packet received on SLOT 3. During SLOT 3, any valid Access Address detection or SFD detection will result in the contents of the respective Link Layer's Event Timer being captured into this register at the instant of detection (there is no offset applied). TIMESTAMP3 remains "sticky" until a new AA or SFD detection occurs, during either the same, or a subsequent, SLOT 3.

Note: Timestamp for SLOT 0 is captured into the respective Link Layer's TIMESTAMP register (external to WOR), and can be read from that Link Layer's address space.

Note: If WOR_DEBUG=1, this register instead reads back WW_RUN_ADJUST[19:0], which is the accumulated "run time" component of the Window Widening adjustment value that is used to offset the start and end of receive operations during the timeslot.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	TIMESTAMP3															
W																
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	TIMESTAMP3															
W																
Reset	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

Fields

Field	Function
31-0 TIMESTAMP3	WAKE-ON-RADIO TIMESTAMP3 Timestamp captured for a packet received on SLOT 3. During SLOT 3, any valid Access Address detection or SFD detection will result in the contents of the respective Link Layer's Event Timer being captured into this register at the instant of detection (there is no offset applied). TIMESTAMP3 remains "sticky" until a new AA or SFD detection occurs, during either the same, or a subsequent, SLOT 3.

52.4.4.1.1.6.1.7 WAKE-ON-RADIO STATUS (STATUS)

Offset

Register	Offset
STATUS	14h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	WOR_RX_...	0							WOR_STATE				0	WOR_DSM...	WOR_MAX...	WOR_NO_...
W	W1C															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		SLOT		TIMESTAMP3_STS			TIMESTAMP2_STS			TIMESTAMP1_STS			TIMESTAMP0_STS		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 WOR_RX_FAIL_IRQ	WOR RX Fail Interrupt Flag Will assert when the number of missed slot is equal to RX_SLOT_FAIL_THRESH.
30-24 —	Reserved
23-20 WOR_STATE	WAKE-ON-RADIO Current State This read-only register reflects the instantaneous state of the Wake-On-Radio state vector. A listing of the Wake-On-Radio states, along with the associated state vector, is below: • DISABLED (0) • COMP_DURATION1 (1) • COMP_DURATION2 (2) • COMP_DURATION3 (10) • SLEEP_REQ (3) • IN_DSM (4) • COMP_ADDBACK (5) • COMP_WW (6) • WAIT_SEQ_START (7) • WAIT_SEQ_END (8) • WAIT_RESUME (9)
19 —	Reserved
18 WOR_DSM_EXIT_FLAG	WAKE-ON-RADIO Early DSM Exit Flag This read-only flag indicates that, in the current slot, an event external to the radio has forced an early exit from DSM, before the WOR-computed DSM duration has expired. The WOR_IRQ (WAKE_IRQ) interrupt inside the assigned Link Layer will become set under these conditions, and this flag indicates that the reason for WOR_IRQ was due to an "DSM Early Exit wakeup", as described by the conditions above. The WOR_IRQ will become set, and the MCU awakened, even if the slot descriptor's WAKE_ON_COMPLETE and WAKE_ON_TIMEOUT bits are both set to 0. The WOR state machine is holding in the WAIT_RESUME state, and once software has completed all activities pursuant to the "DSM Early Exit wakeup", software must set WOR_RESUME to advance to the next slot.
17 WOR_MAX_SLOT_FLAG	WAKE-ON-RADIO Maximum Slot Count Reached Flag This read-only flag indicates that, in the current slot, the following conditions have all been met: 1. SCHEDULING_MODE is set to 1 (Constant Interval) 2. WOR_SLOT_COUNT[7:0] (absolute slot number) has matched WAKE_ON_NTH_SLOT[7:0]

Table continues on the next page...

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Field	Function
	The WOR_IRQ (WAKE_IRQ) interrupt inside the assigned Link Layer will become set under these conditions, and this flag indicates that the reason for WOR_IRQ was due to a "Maximum Slot Reached wakeup", as described by the conditions above. The WOR_IRQ will become set, and the MCU awakened, even if the slot descriptor's WAKE_ON_COMPLETE and WAKE_ON_TIMEOUT bits are both set to 0. The WOR state machine is holding in the WAIT_RESUME state, and once software has completed all activities pursuant to the "Maximum Slot Reached wakeup", software must set WOR_RESUME to advance to the next slot
16 WOR_NO_RF_FLAG	WAKE-ON-RADIO NO_RF Slot Flag This read-only flag indicates that, in the current slot, the following conditions have all been met: 1. The slot's descriptor FUNCTION is set to "NO_RF" 2. A DSM cycle has just completed (exited) during the slot 3. The slot's descriptor WAKE_ON_COMPLETE bit was set (or the WOR_SLOT_COUNT matched WAKE_ON_NTH_SLOT), requiring an MCU wakeup. The WOR_IRQ (WAKE_IRQ) interrupt inside the assigned Link Layer will become set under these conditions, and this flag indicates that the reason for WOR_IRQ was due to a "NO_RF wakeup", as described by the conditions above. The WOR state machine is holding in the WAIT_RESUME state, and once software has completed all activities pursuant to the "NO_RF wakeup", software must set WOR_RESUME to advance to the next slot
15-14 —	Reserved
13-12 SLOT	WAKE-ON-RADIO Current Slot This read-only register reflects the instantaneous state of the WOR's SLOT counter, indicating which SLOT is currently in service by the WOR state machine. Software can determine which of the 4 descriptors is currently in effect based on this register.
11-9 TIMESTAMP3_STS	WAKE-ON-RADIO Timestamp 3 Status This read-only register comprises 3 bits which convey information about the validity of the TIMESTAMP3 register contents: **TIMESTAMP3_STS[0]** -- "AA/SFD Status". If set, this bit indicates at least 1 AA or SFD detection occurred during the current, or most recent, SLOT 3 RX operation, and therefore a timestamp, valid or not, was captured into the TIMESTAMP3 register. **TIMESTAMP3_STS[1]** -- "CRC Status". If set, this bit indicates a packet was received which passed CRC verification during the current, or most recent, SLOT 3 RX operation **TIMESTAMP3_STS[2]** -- "Filter Status". If set, this bit indicates a packet was received which passed Packet Filtering rules during the current, or most recent, SLOT 3 RX operation
8-6 TIMESTAMP2_STS	WAKE-ON-RADIO Timestamp 2 Status This read-only register comprises 3 bits which convey information about the validity of the TIMESTAMP2 register contents:

Table continues on the next page...

Table continued from the previous page...

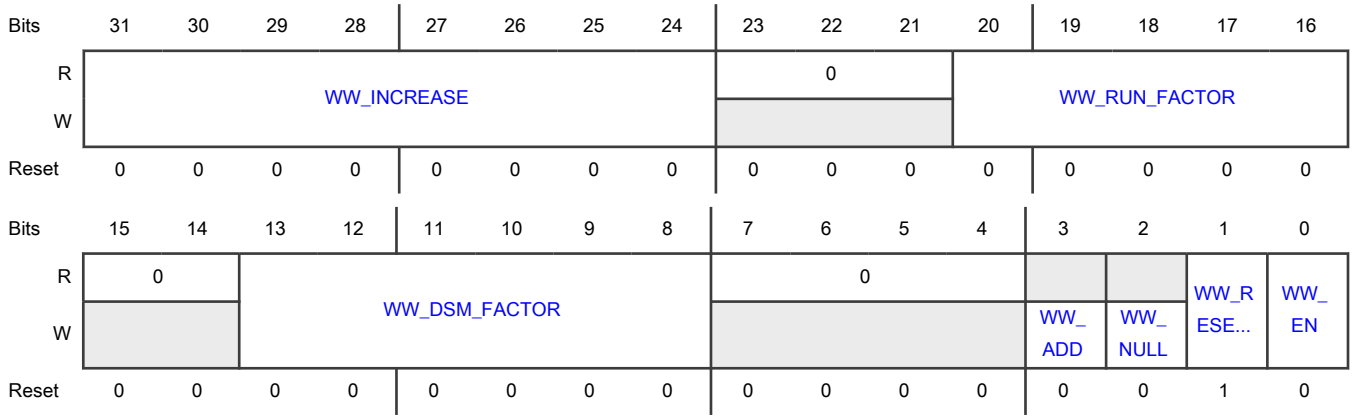
Field	Function
	TIMESTAMP2_STS[0] -- "AA/SFD Status". If set, this bit indicates at least 1 AA or SFD detection occurred during the current, or most recent, SLOT 2 RX operation, and therefore a timestamp, valid or not, was captured into the TIMESTAMP2 register. **TIMESTAMP2_STS[1]** -- "CRC Status". If set, this bit indicates a packet was received which passed CRC verification during the current, or most recent, SLOT 2 RX operation **TIMESTAMP2_STS[2]** -- "Filter Status". If set, this bit indicates a packet was received which passed Packet Filtering rules during the current, or most recent, SLOT 2 RX operation
5-3 TIMESTAMP1_STS	WAKE-ON-RADIO Timestamp 1 Status This read-only register comprises 3 bits which convey information about the validity of the TIMESTAMP1 register contents: **TIMESTAMP1_STS[0]** -- "AA/SFD Status". If set, this bit indicates at least 1 AA or SFD detection occurred during the current, or most recent, SLOT 1 RX operation, and therefore a timestamp, valid or not, was captured into the TIMESTAMP1 register. **TIMESTAMP1_STS[1]** -- "CRC Status". If set, this bit indicates a packet was received which passed CRC verification during the current, or most recent, SLOT 1 RX operation **TIMESTAMP1_STS[2]** -- "Filter Status". If set, this bit indicates a packet was received which passed Packet Filtering rules during the current, or most recent, SLOT 1 RX operation
2-0 TIMESTAMP0_STS	WAKE-ON-RADIO Timestamp 0 Status This read-only register comprises 3 bits which convey information about the validity of the TIMESTAMP0 register contents: **TIMESTAMP0_STS[0]** -- "AA/SFD Status". If set, this bit indicates at least 1 AA or SFD detection occurred during the current, or most recent, SLOT 0 RX operation, and therefore a timestamp, valid or not, was captured into the TIMESTAMP0 register. **TIMESTAMP0_STS[1]** -- "CRC Status". If set, this bit indicates a packet was received which passed CRC verification during the current, or most recent, SLOT 0 RX operation **TIMESTAMP0_STS[2]** -- "Filter Status". If set, this bit indicates a packet was received which passed Packet Filtering rules during the current, or most recent, SLOT 0 RX operation **Note:** TIMESTAMP0 register (timestamp for SLOT 0) is captured into the assigned Link Layer's TIMESTAMP register (external to WOR), and can be read from that Link Layer's address space. However TIMESTAMP0_STS[2:0], which applies to that register, resides in WOR address space.

52.4.4.1.1.6.1.8 WINDOW-WIDENING CONTROL (WW_CTRL)

Offset

Register	Offset
WW_CTRL	18h

Diagram



Fields

Field	Function
31-24 WW_INCREASE	Window-widening Manual Increase Amount This register allows software to increase (add to) the HW-computed window-widening adjustment. This incremental amount is added whenever a 1 is written to the WW_ADD register bit. The units of WW_INCREASE[7:0] are microseconds. It is an unsigned (positive only) addition. This is a one-time only addition (whenever WW_ADD is set), and the window-widening adjustment value continues to accumulate after the increment. The capability to add to the HW-computed adjustment is intended for contingency or debug purposes only, as the HW-computed value should be accurate.
23-21 —	Reserved
20-16 WW_RUN_FACTOR	Window-widening Runtime Factor Determines the rate of Window-widening that applies during RUNTIME (Reference Oscillator On). This setting should be based on the combined Sleep Clock Accuracy (SCA) of the Master + Slave. Each LSB is worth 64ppm of SCA drift. Valid values are 0 -> 16. The lower this factor, the greater the power savings.
15-14 —	Reserved
13-8 WW_DSM_FACTOR	Window-widening DSM Factor WW_DSM_FACTOR[5:0]: Determines the rate of Window-widening that applies during DSM (Reference Oscillator Off). This setting should be based on the combined Sleep Clock Accuracy (SCA) of the Master + Slave. Each LSB is worth 16ppm of combined SCA drift. Valid values are 0 -> 63. The lower this factor, the greater the power savings.
7-4 —	Reserved
3 WW_ADD	Window-widening Add Command

Table continues on the next page...

Table continued from the previous page...

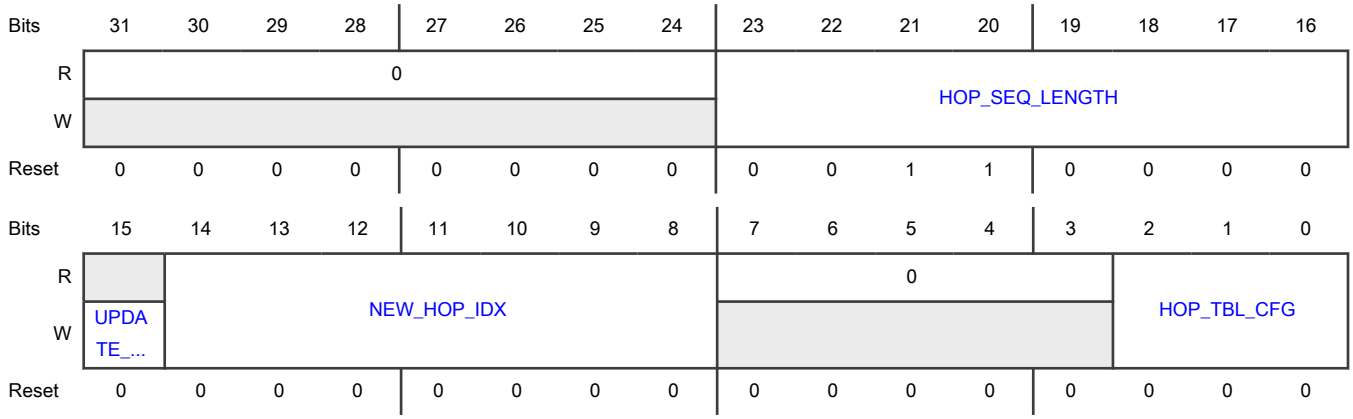
Field	Function
	This bit allows software to increase (add to) the HW-computed window-widening adjustment. The incremental amount is determined by the WW_INCREASE[7:0] register. The capability to add to the HW-computed adjustment is intended for contingency or debug purposes only, as the HW-computed value should be accurate. This bit is write-only. Readback value is always 0. 1: Increase the HW-computed window-widening adjustment by amount WW_INCREASE[7:0]. 0: No effect
2 WW_NULL	Window-widening Null Command This bit allows software to reset the accumulated window-widening adjustment to 0. This bit is write-only. Readback value is always 0. 1: Reset the accumulated window-widening adjustment to 0. 0: No effect.
1 WW_RESET_ON_RX	Window-widening Reset on Received Good Packet Enable a good packet reception to reset the accumulated window-widening adjustment to 0. A good packet is one that passes CRC verification, and passes packet filtering rules. Filtering rules vary by protocol. 1: Allow good packet reception to reset window-widening adjustment. This is the default. 0: Block good packet reception from resetting window-widening adjustment.
0 WW_EN	Window-widening Enable Master Enable for Window Widening. Typically, only slave devices employ window widening. 1: Window Widening is enabled. 0: Window Widening is disabled.

52.4.4.1.1.6.1.9 FREQUENCY HOP CONTROL (HOP_CTRL)

Offset

Register	Offset
HOP_CTRL	1Ch

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 HOP_SEQ_LENGTH	New Hop Table Index The HOP_SEQ_LENGTH[7:0] register determines the number of entries in the WOR Hop Table, regardless of how the table is configured by HOP_TBL_CFG[2:0]. During WOR operation, once the Hop Table Index reaches HOP_SEQ_LENGTH - 1, the next Hop Table Index will wrap to 0. HOP_SEQ_LENGTH must not exceed the table size specified by HOP_TBL_CFG (128 entries).
15 UPDATE_HOP_IDX	Update Hop Table Index Software can jump to a new index (read pointer address) of the WOR Hop Table at any time by writing the desired index to the NEW_HOP_IDX[6:0] register, and setting the UPDATE_HOP_IDX bit to 1. This bit is write-only. Readback value is always 0. 1: Jump to new Hop Table Index pointed to by NEW_HOP_IDX[6:0] 0: No effect
14-8 NEW_HOP_IDX	New Hop Table Index Software can jump to a new index (read pointer address) of the WOR Hop Table at any time by writing the desired index to this register, and setting the UPDATE_HOP_IDX bit.
7-3 —	Reserved
2-0 HOP_TBL_CFG	Hop Table Configuration For maximum flexibility in Frequency Hop scheduling, 4 hop table configurations are defined. The configurations affect: 1. The source of the RF channel information (Link Layer register or WOR Hop Table) 2. How the RF channel information is organized in the WOR Hop Table

Table continues on the next page...

Table continued from the previous page...

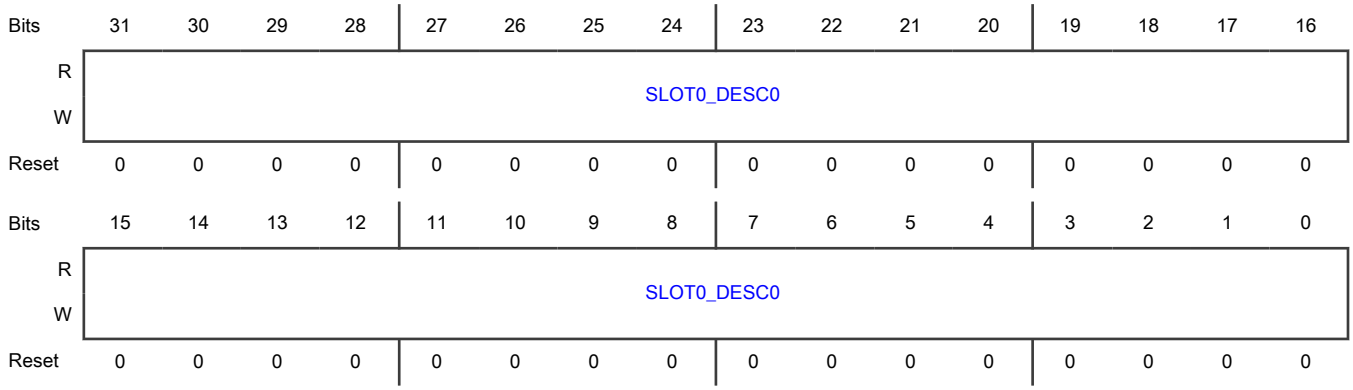
Field	Function
	3. How the hop frequency word is interpreted by the PLL Digital Block Source of RF channel information: 0: Link Layer CHANNEL_NUM register (legacy configuration). The Link Layer is the one assigned by WOR_PROTOCOL register. 1: WOR Hop Table 2: WOR Hop Table 3: WOR Hop Table 4-7: Reserved Hop Table Organization: 0: N/A 1: Table size is 128 entries. Two 7-bit CHANNEL_NUM fields are packed into a 16-bit hop frequency word for RAM storage 2-3: Table size is 128 entries. Each 16-bit hop frequency word in RAM contains a specification for a single RF channel 4-7: Reserved PLL Digital Interpretation of Hop Frequency Word: 0: Lower 7 bits of hop frequency word contain a 7-bit mapped channel (legacy format). 1: Lower 7 bits of hop frequency word contain a 7-bit mapped channel (legacy format). 2-3: See Chapter *PLL Digital* 4-7: Reserved

52.4.4.1.1.6.1.10 SLOT 0 DESCRIPTOR (LSB) (SLOT0_DESC0)

Offset

Register	Offset
SLOT0_DESC0	20h

Diagram



Fields

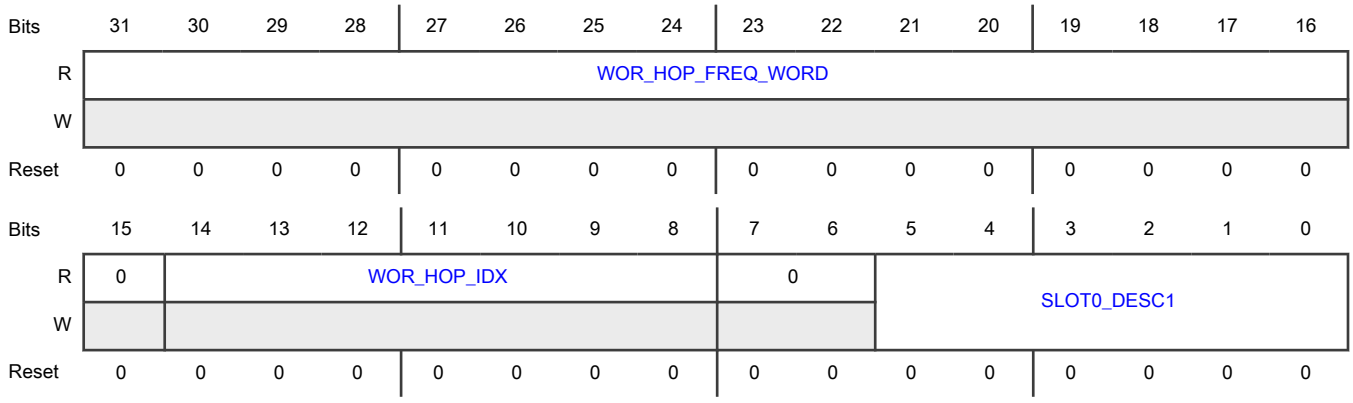
Field	Function
31-0 SLOT0_DESC0	Slot 0 Descriptor (LSB's) This register represents the 32 LSB's of the WOR descriptor for Slot 0

52.4.4.1.1.6.1.11 SLOT 0 DESCRIPTOR (MSB) (SLOT0_DESC1)

Offset

Register	Offset
SLOT0_DESC1	24h

Diagram



Fields

Field	Function
31-16	Current Hop Frequency Word

Table continues on the next page...

Table continued from the previous page...

Field	Function
WOR_HOP_FREQ_WORD	This read-only register reflects the current Hop Frequency Word, formulated by WOR and transmitted to the PLL Digital Block
15 —	Reserved
14-8 WOR_HOP_IDX	Current Hop Table Index This read-only register reflects the current Hop Table Index (read address pointer) into the WOR Hop Table
7-6 —	Reserved
5-0 SLOT0_DESC1	Slot 0 Descriptor (MSB's) This register represents the 6 MSB's of the WOR descriptor for Slot 0

52.4.4.1.1.6.1.12 SLOT 1 DESCRIPTOR (LSB) (SLOT1_DESC0)

Offset

Register	Offset
SLOT1_DESC0	28h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SLOT1_DESC0															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SLOT1_DESC0															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

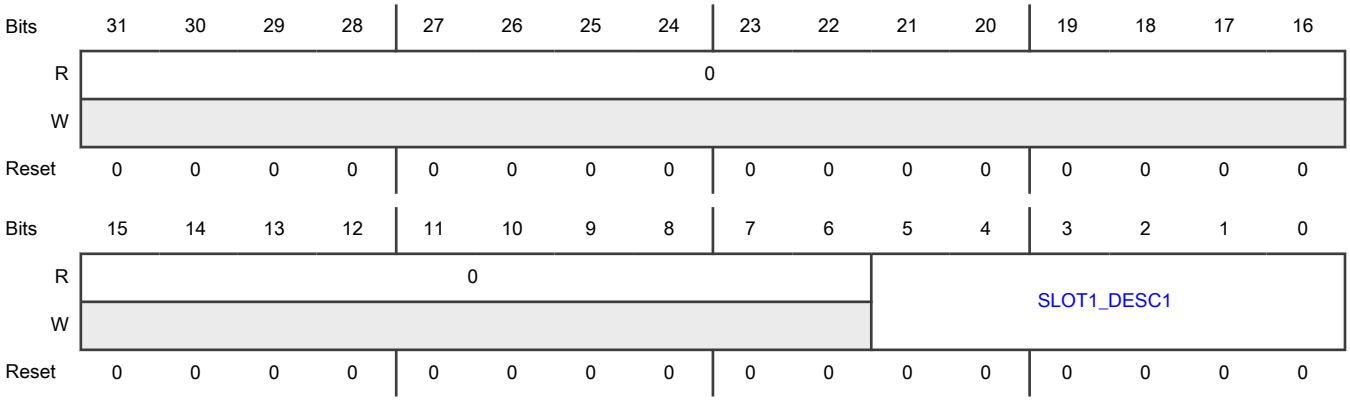
Field	Function
31-0 SLOT1_DESC0	Slot 1 Descriptor (LSB's) This register represents the 32 LSB's of the WOR descriptor for Slot 1

52.4.4.1.1.6.1.13 SLOT 1 DESCRIPTOR (MSB) (SLOT1_DESC1)

Offset

Register	Offset
SLOT1_DESC1	2Ch

Diagram



Fields

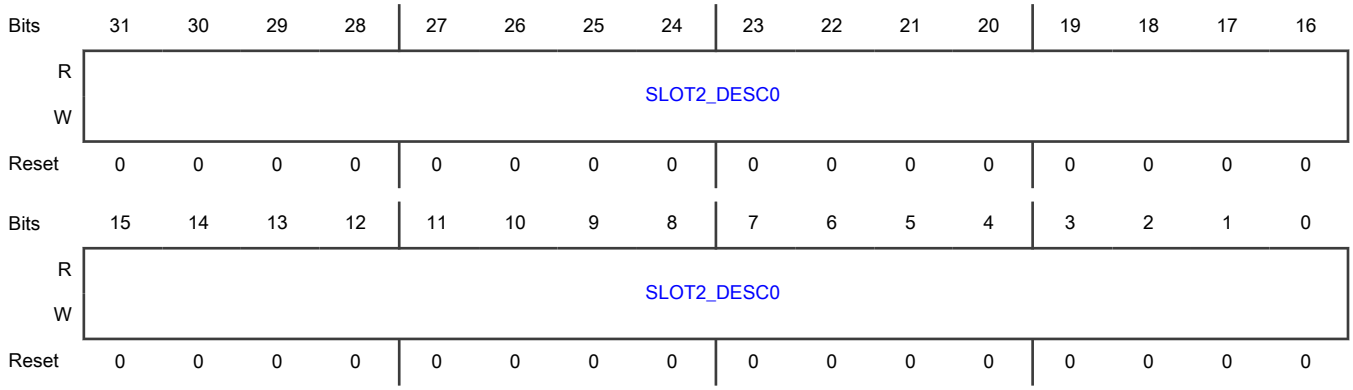
Field	Function
31-6 —	Reserved
5-0 SLOT1_DESC1	Slot 1 Descriptor (MSB's) This register represents the 6 MSB's of the WOR descriptor for Slot 1

52.4.4.1.1.6.1.14 SLOT 2 DESCRIPTOR (LSB) (SLOT2_DESC0)

Offset

Register	Offset
SLOT2_DESC0	30h

Diagram



Fields

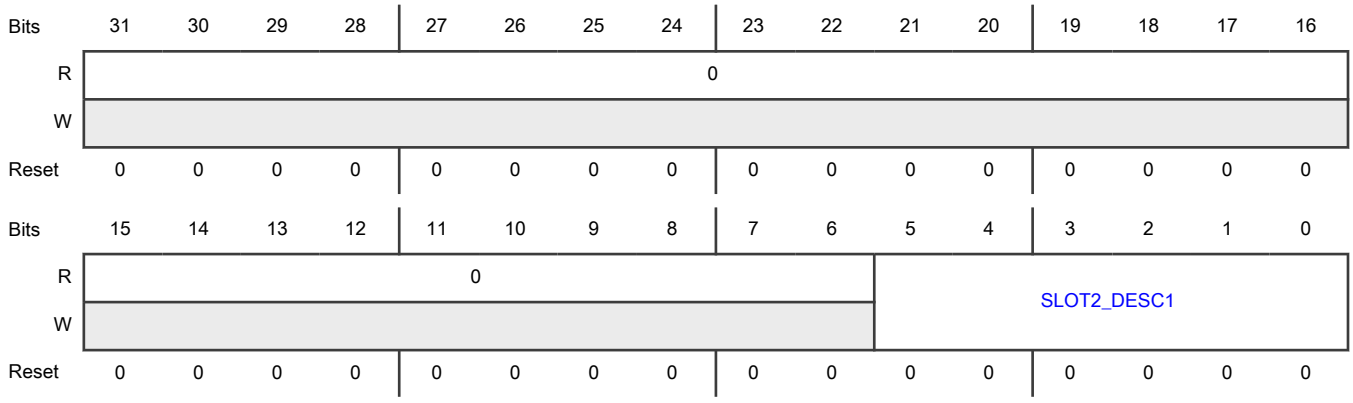
Field	Function
31-0 SLOT2_DESC0	Slot 2 Descriptor (LSB's) This register represents the 32 LSB's of the WOR descriptor for Slot 2

52.4.4.1.1.6.1.15 SLOT 2 DESCRIPTOR (MSB) (SLOT2_DESC1)

Offset

Register	Offset
SLOT2_DESC1	34h

Diagram



Fields

Field	Function
31-6	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
5-0 SLOT2_DESC1	Slot 2 Descriptor (MSB's) This register represents the 6 MSB's of the WOR descriptor for Slot 2

52.4.4.1.1.6.1.16 SLOT 3 DESCRIPTOR (LSB) (SLOT3_DESC0)

Offset

Register	Offset
SLOT3_DESC0	38h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SLOT3_DESC0															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SLOT3_DESC0															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

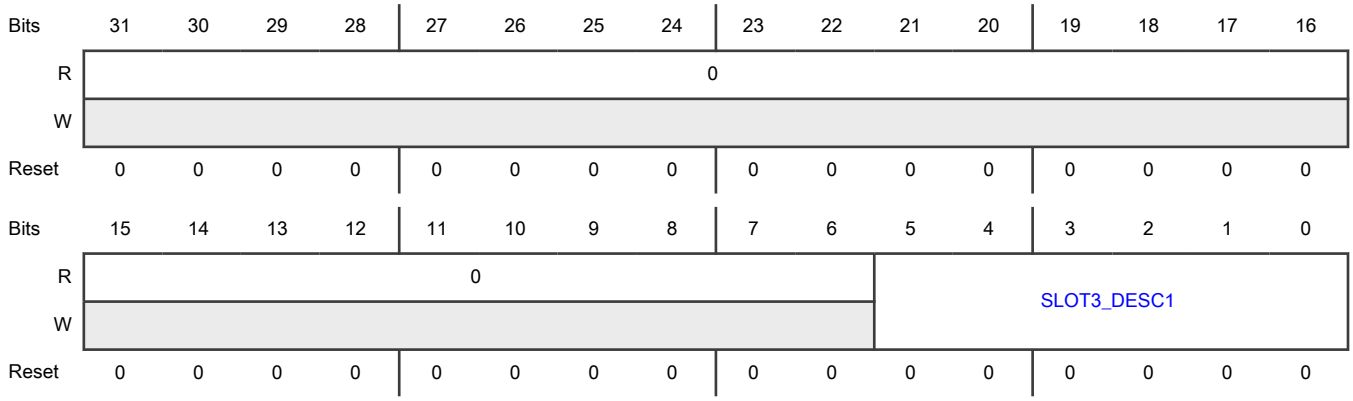
Field	Function
31-0 SLOT3_DESC0	Slot 3 Descriptor (LSB's) This register represents the 32 LSB's of the WOR descriptor for Slot 3

52.4.4.1.1.6.1.17 SLOT 3 DESCRIPTOR (MSB) (SLOT3_DESC1)

Offset

Register	Offset
SLOT3_DESC1	3Ch

Diagram



Fields

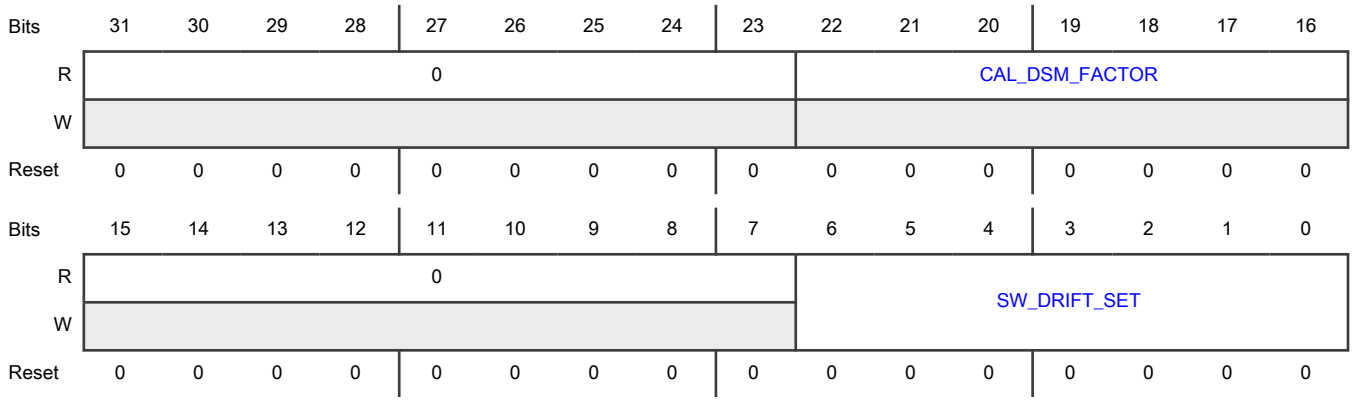
Field	Function
31-6 —	Reserved
5-0 SLOT3_DESC1	Slot 3 Descriptor (MSB's) This register represents the 6 MSB's of the WOR descriptor for Slot 3

52.4.4.1.1.6.1.18 Auto Drift Calculation 1 (AUTO_DRIFT1)

Offset

Register	Offset
AUTO_DRIFT1	40h

Diagram



Fields

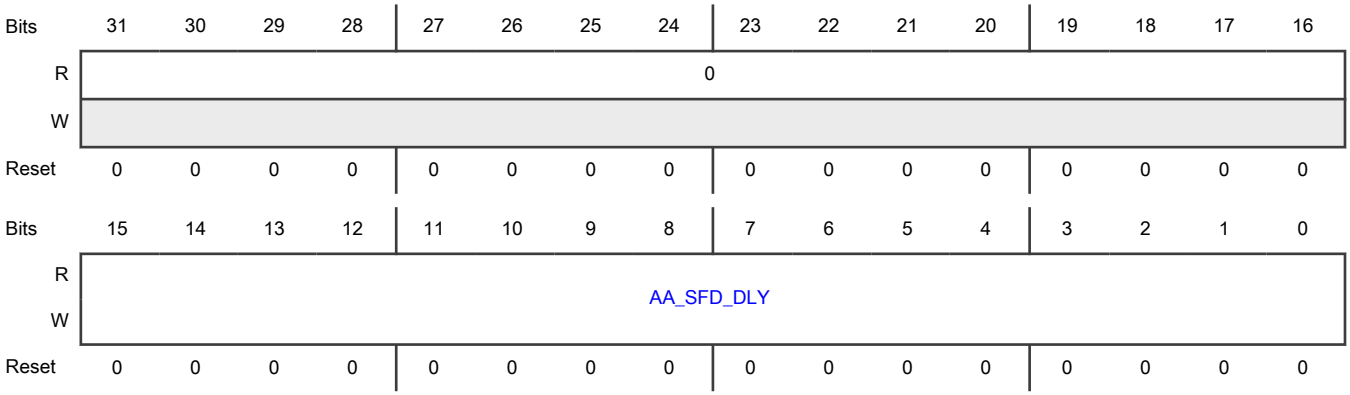
Field	Function
31-23 —	Reserved
22-16 CAL_DSM_FACTOR	Hardware calculated drift. This is a two's complement value. Each LSB is worth 16ppm. Read only.
15-7 —	Reserved
6-0 SW_DRIFT_SET	Software calculated drift. This is a two's complement value. Each LSB is worth 16ppm.

52.4.4.1.1.6.1.19 Auto Drift Calculation 2 (AUTO_DRIFT2)

Offset

Register	Offset
AUTO_DRIFT2	44h

Diagram



Fields

Field	Function
31-16 —	Reserved

Table continues on the next page...

Table continued from the previous page...

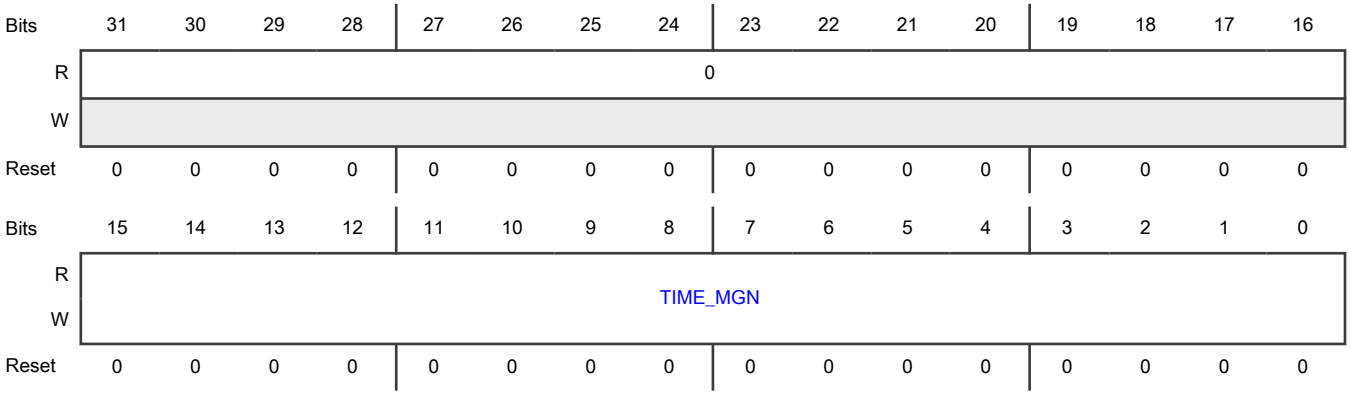
Field	Function
15-0 AA_SFD_DLY	The time duration of Preamble and Sync Address plus the RX warm up duration.

52.4.4.1.1.6.1.20 Auto Drift Calculation 3 (AUTO_DRIFT3)

Offset

Register	Offset
AUTO_DRIFT3	48h

Diagram



Fields

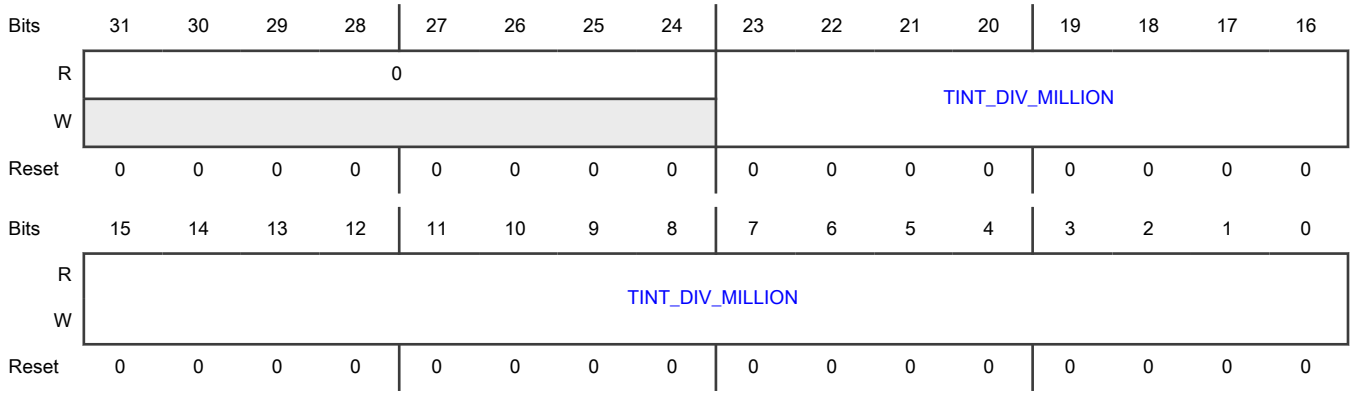
Field	Function
31-16 —	Reserved
15-0 TIME_MGN	The time margin applied to the start time and timeout.

52.4.4.1.1.6.1.21 Auto Drift Calculation 4 (AUTO_DRIFT4)

Offset

Register	Offset
AUTO_DRIFT4	4Ch

Diagram



Fields

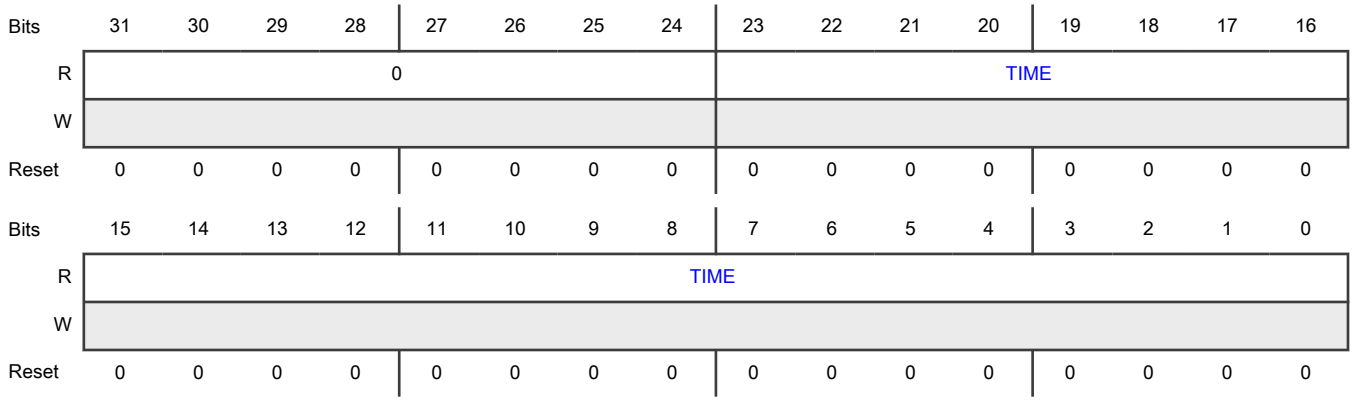
Field	Function
31-24 —	Reserved
23-0 TINT_DIV_MILLION	User programed value to help the hardware to calculate the drift. The value is (2^17 * 1,000,000 / WOR_EVENT_INTERVAL / 16)(rounded)

52.4.4.1.1.6.1.22 Timer Count (TIME)

Offset

Register	Offset
TIME	98h

Diagram



Fields

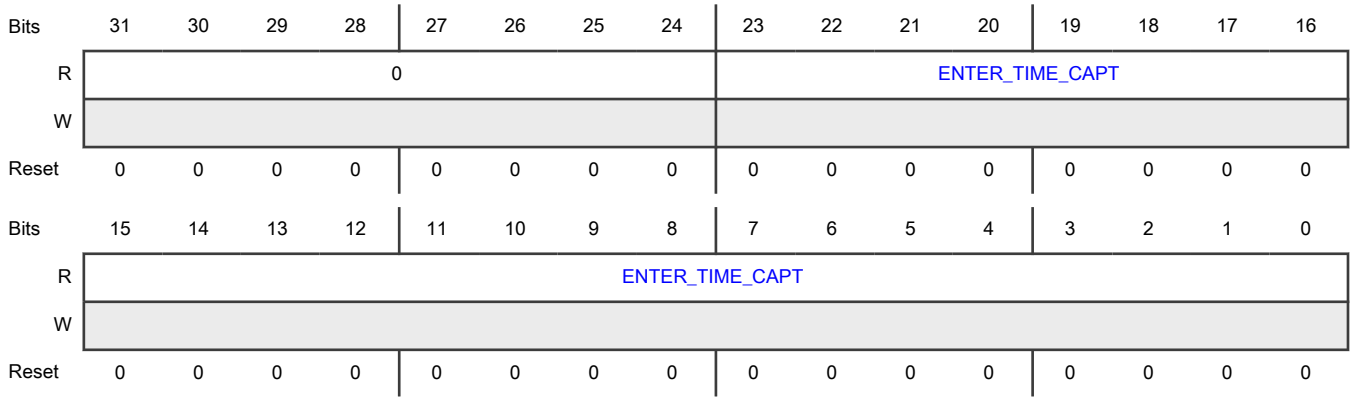
Field	Function
31-24 —	Reserved
23-0 TIME	Current 32kHz reference clock time (used by the MAN low power controller).

52.4.4.1.1.6.1.23 MAN Low Power Entry Time Captured (ENTER_TIME_CAPT)

Offset

Register	Offset
ENTER_TIME_CAPT	9Ch

Diagram



Fields

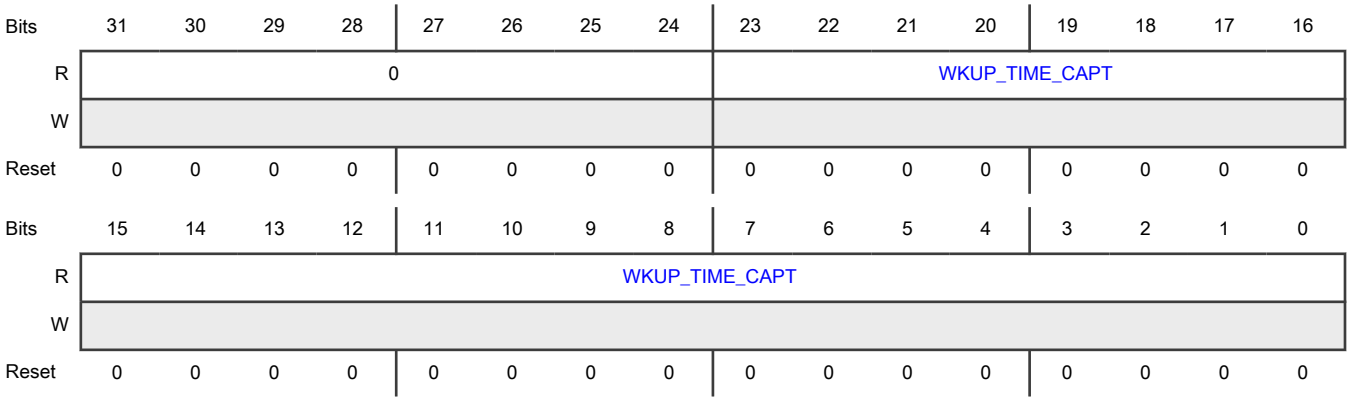
Field	Function
31-24 —	Reserved
23-0 ENTER_TIME_CAPT	Captured Timer count for MAN entry to low power. The value of ENTER_TIME is captured when the man_sleep_req asserts.

52.4.4.1.1.6.1.24 MAN Low Power Wakeup Time Captured (WKUP_TIME_CAPT)

Offset

Register	Offset
WKUP_TIME_CAPT	A0h

Diagram



Fields

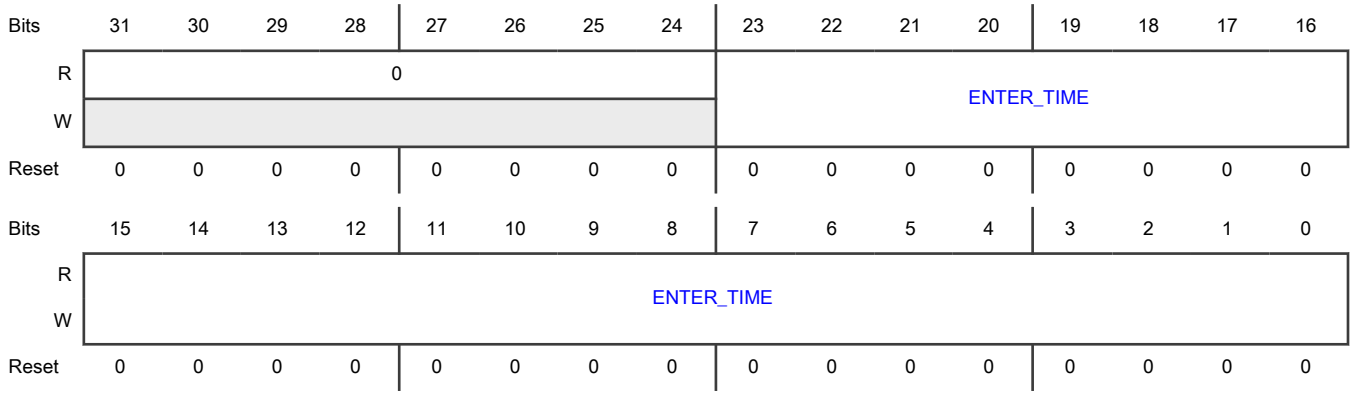
Field	Function
31-24 —	Reserved
23-0 WKUP_TIME_CAPT	Captured Timer count for MAN exit from low power. The value of WKUP_TIME is captured when the man_sleep_req asserts. However, if RFMC's MAN_WKUP bit is set, the value is updated to reflect the early exit time.

52.4.4.1.1.6.1.25 MAN Low Power Entry Time Stamp (ENTER_TIME)

Offset

Register	Offset
ENTER_TIME	A4h

Diagram



Fields

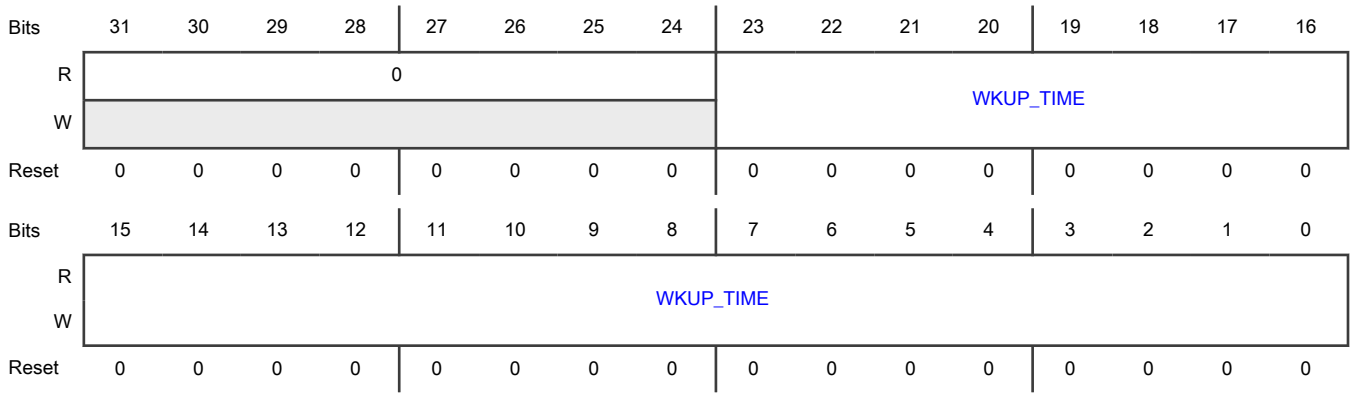
Field	Function
31-24 —	Reserved
23-0 ENTER_TIME	Timer count at which to initiate low power entry by the MAN.

52.4.4.1.1.6.1.26 MAN Low Power Wakeup Time Stamp (WKUP_TIME)

Offset

Register	Offset
WKUP_TIME	A8h

Diagram



Fields

Field	Function
31-24 —	Reserved
23-0 WKUP_TIME	Timer count at which to complete low power wakeup by the MAN.

52.4.4.1.2 Radio Bit Manipulation Engine

52.4.4.1.2.1 Overview

This section provides an introduction to the Radio Bit Manipulation Engine (RBME) module. The RBME module is a group of configurable bit manipulation modules.

52.4.4.1.2.1.1 Block Diagram

52.4.4.1.2.1.1.1 TX-RBME Diagram

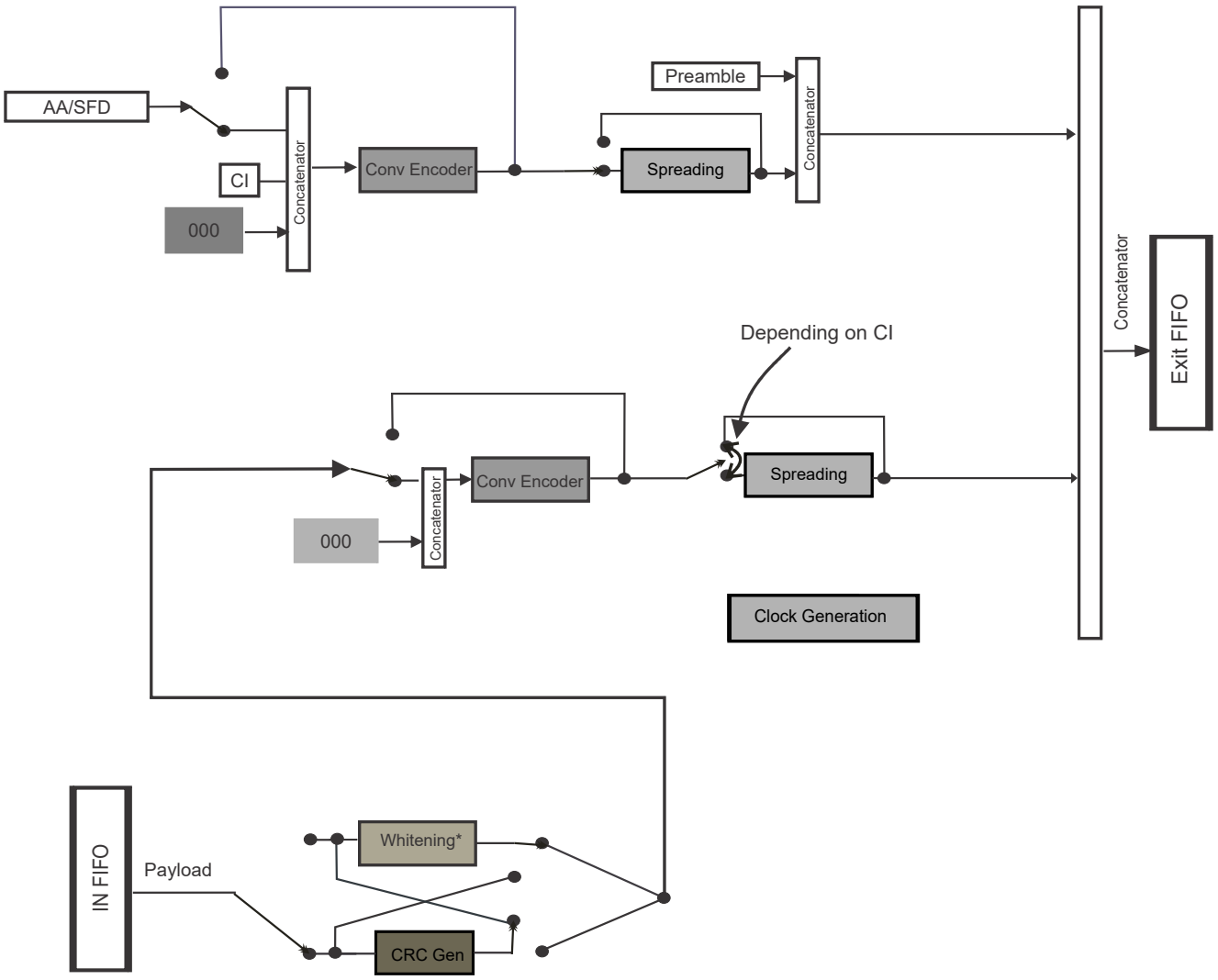


Figure 256. TX Diagram

52.4.4.1.2.1.1.2 RX-RBME Diagram

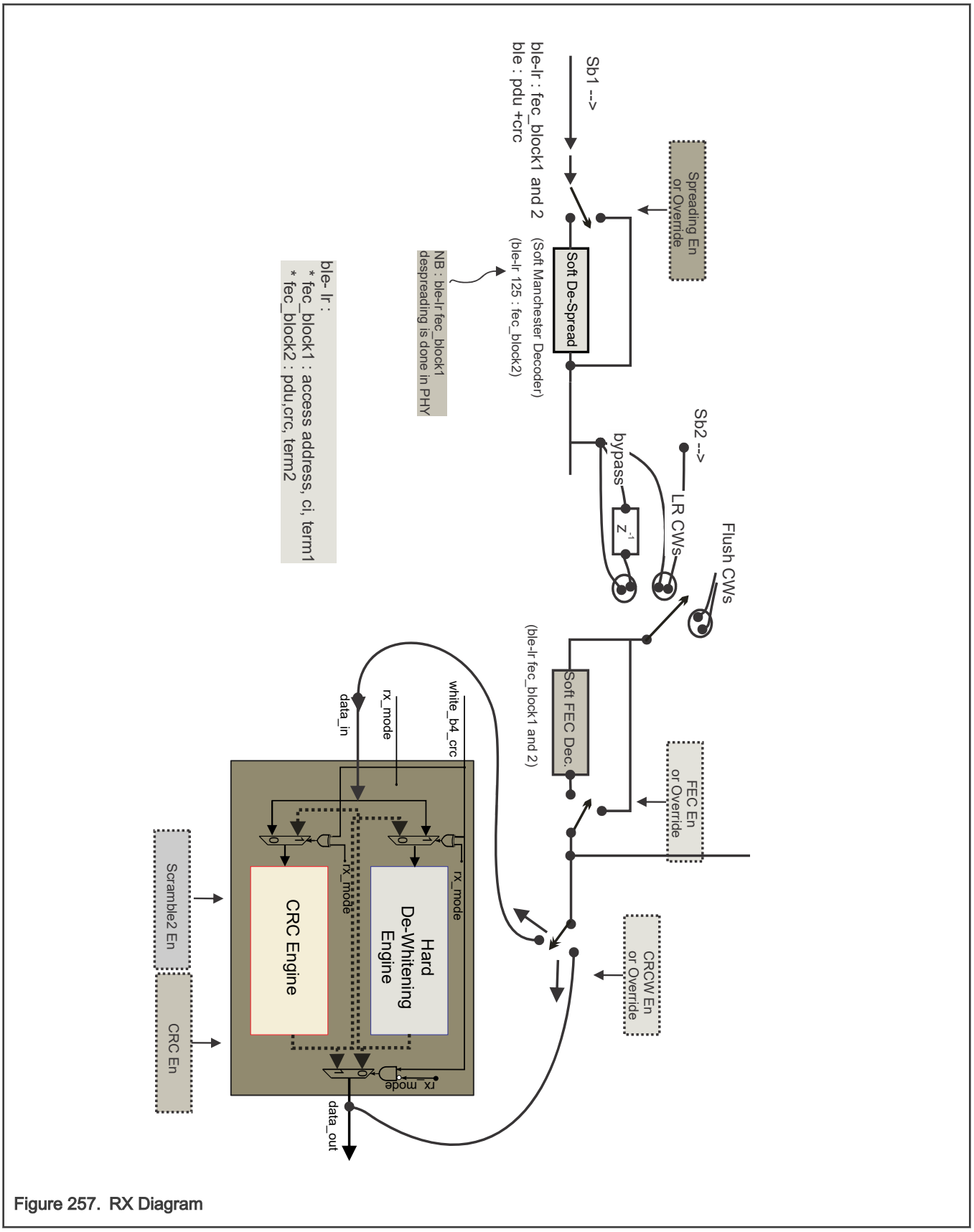


Figure 257. RX Diagram

52.4.4.1.2.1.2 Features

- FEC: Forward Error Correction
  - Support for Bluetooth LE and Bluetooth LE LR
    - Requires a two pass FEC, over the AA+CI and over the payload + CRC
    - These are called FECBlock1 and FECBlock2 respectively
- Spreading
  - Hard Spreader
  - Inclusive of hard Manchester encode and decode
- Configurable CRC and Whiten (CRCW)
  - CRC
    - Supports direct method only
    - Supports input byte reflection
    - Final XOR and checksum byte reflection
    - Multiple CRCs per packet is not currently supported
    - Programmable polynomial and seed values
  - Whitening Block
    - Hard whitening and de-whitening modes only
    - Programmable polynomial and seed values
    - Galois or Fibonacci type LFSR
  - CRC can switch on before or after the second whitening module
- RAM interface
  - Debug
  - Frame processing

NOTE

The RBME is fully functional with GEN-LL, while totally bypassed when 15p4-LL is activated. If the NBU is the active link-layer, the RBME only be enabled for receiving long-range (coded) packets. In this case, the RBME responsible for despreading and do FEC decode. The de-whitening and CRC calculation should be done inside the NBU

52.4.4.1.2.2 Functional description

52.4.4.1.2.2.1 Processing Order

TX-RBME Diagram shows the order of processing for the Transceiver (TX). The Receiver (RX) has the reverse order of processing shown in RX-RBME Diagram. The order of processing and the number of modules involved depends on:

1. The enable register for the block
   - Used to configure a block statically
   - Allows for configurability for a pre-known setup of the RBME
   - All TX modules only require a static enable as the configurations are known in advance
2. Override of the block (RX only)
   - Allows a dynamic override of the block enabling it regardless of the enable register
   - It requires that the appropriate override enable register be asserted

- It does not disable the block: if a block is to be enabled dynamically
  - Set enable register off
  - Set override enable on

3. Bypass of the (RX only)
   - It has the highest priority
   - It is used only internally
   - It is dynamic

52.4.4.1.2.2.1.1 RX Bluetooth LE LR Example

When the Coding Indicator (CI) bits are demodulated and decoded, the mode of Bluetooth LE LR is known. Therefore, dynamic override needs to be used for de-spreading. For this reason, the spreading is disabled and the override is enabled for the RX. Furthermore, the receive for Bluetooth LE LR requires special handling as the FEC is required twice. The following steps describe the RX flow.

1. RBME input mode from link layer has been set to 1 to let RBME prepare for a long range (LR) configuration before AAFound.
2. RBME_en is asserted once AAFound, from the PHY acquisition, has been asserted.
3. After reading the decoded CI bits, the PHY sends a one-bit CI indication.
   - CI_indicator NOT asserted for 125 kbps reception
   - CI_indicator asserted for 500 kips reception
4. The FEC processing must have the packet length from the link layer before the end of the packet for the CRC to be applied correctly. The processing counts the soft bits till Cnt = FECCounter2.
   a. FECCounter2 equals MaxPacketSize register until the LL updates the Frame length
   b. FECCounter2 = FrameLengthBits + NPHRBits + NCRCBits + FineTuneFECFlushBits
      i. FrameLengthBits is the number of bits from the link layer
      ii. NPHRbits = 16 for Bluetooth LE LR
      iii. NCRCbits = length of the CRC
      iv. FineTuneFECFlushBits is a register that allows for customization of the decoder length

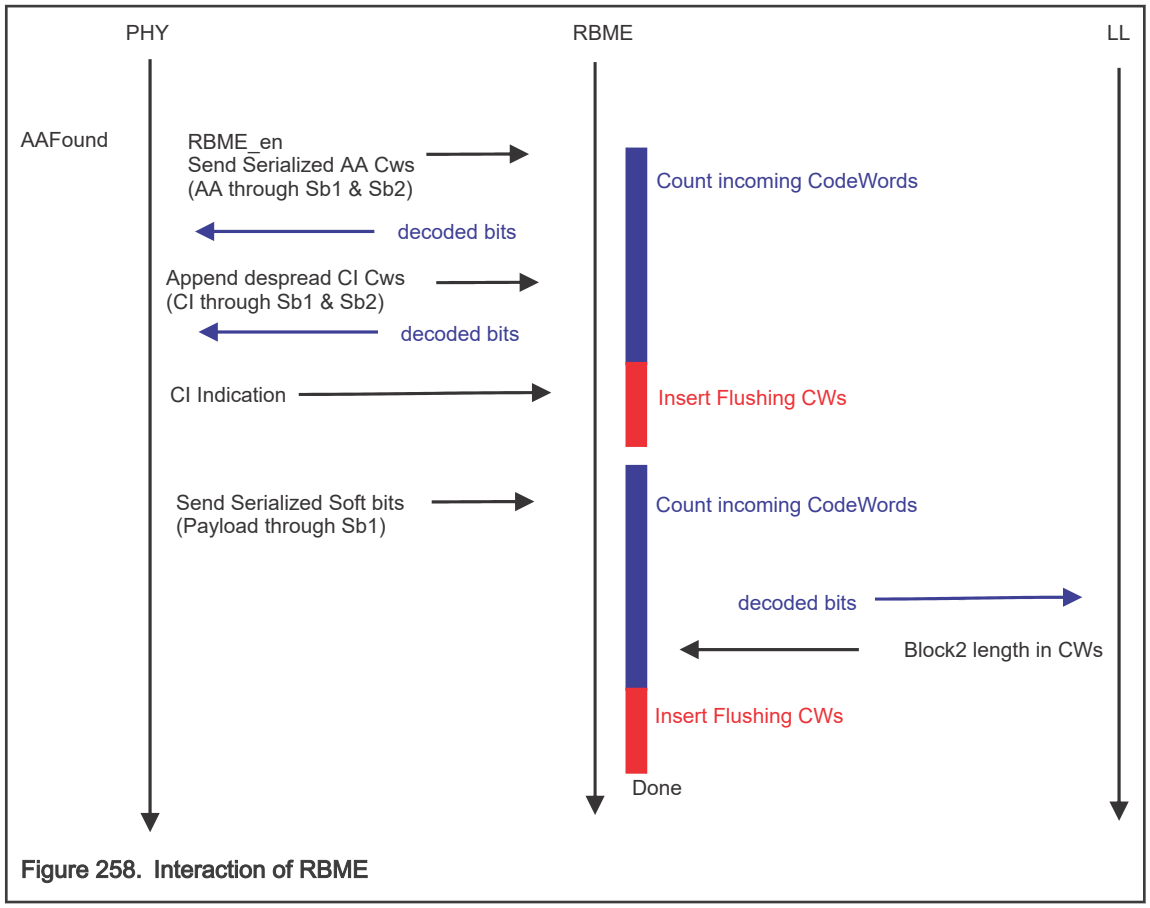


Figure 258. Interaction of RBME

The above figure (Interaction of RBME) shows the interaction among link layer, RBME, and PHY. The following table illustrates the Bluetooth LE LR packet format that RBME RX must account for. Note the separation into FEC Block1 and FEC Block2. Other important aspects are:

- AA+CI are spread with a spreading pattern of length 4
- AA+CI+TERM1 are combined as FECBlock1 as they need to be decoded together
- Header+Payload+CRC+TERM2 are combined as FECBlock2 as they need to be decoded together
- The de-spreading of AA+CI is done in the PHY for speed
- FECBlock2 may or may not need de-spreading depending on whether 125 kbps or 500 kbps are transmitted

Table 446. Standard Bluetooth LE LR Frame Format

10 Octets	4 Octets	2 bits	3 bits	Variable in Octets			24 bits	3 bits
Pre	AA	CI	TERM1	PDU			CRC	TERM2
				Header (16 bits)		Payload		
					Length (8 bits) L0:L7 Payload field length in octets. LSB first	ADV => 1:255 octets Data => 0:251 octets		
	FEC BLOCK 1			FEC BLOCK 2				

52.4.4.1.2.2.1.2 Frame delimiter before CRC Protocol (FCP) Example

An example of FCP frame packet is shown in the table below. It has the distinct characteristic that the Start Frame Delimiter (SFD) is passed through the CRC. This complicates the processing for the RX as there are two possibilities:

1. The ideal SFD is assumed for processing the CRC.
2. The decoded SFD is provided by the PHY.

   RBME assumes option 1, that is, the CRC presumes an ideal SFD. That ideal SFD is injected at the CRC buffer for processing, so no SFD bit errors will ever be caught. Another important feature of FCP is that whitening from a TX perspective is done before the CRC.

Table 447. FCP Frame Packet

1 octet	2 octets	5 octets		Variable in octets (8 -25)	2 octets
		RBME PHR		RBME Payload	
Pre	Net add	Device Address	Control (1 octet)	Data	CRC

52.4.4.1.2.2.2 RBME RAM And Interface

52.4.4.1.2.2.2.1 RAM Interface for RBME

RAM interface for RBME is important for debug and pre/post process frame. The only interrupt of RBME is generated by RAM interface. When packet RAM is filled completely with payload, the interrupt is sent to MCU in case of RAM_IF_IE set. The following figure (RBME TX RAM Interface) shows all the options, however, for simplicity the implementation of the RAM interface is in two developmental stages:

1. RAM-RBME-RAM only

   This interface is the simplest as it presumes that data into RBME and out of RBME comes and returns to the packet RAM.
2. RAM-RBME TX

   This interface writes single bit data from the packet RX RAM into RBME TX. The interface is like that of the generic LL using fast clock implicitly for the data rate and then switching internally to OTA derived clocks. For example, if FEC encoding alone is done, the input buffer is normally read at twice the OTA rate. TX_DIG normally dictates the OTA rate that is desired for the implementation. For the RAM equivalent, the read rate can be higher. The rate of RBME output may be higher than the equivalent OTA rate for the use case but must be smaller or equal to ref_clk/encoding_factor. The values for encoding factor are for example:

   a. For FEC encoding only

   b. 32 if a spreading factor of 16 was required and FEC was also required

   In Step2 of next figure (RBME RX RAM Interface), the data from TX RAM pre-processed is sent to link layer as normal case without RAM interface. Then RBME does the same way as usual.

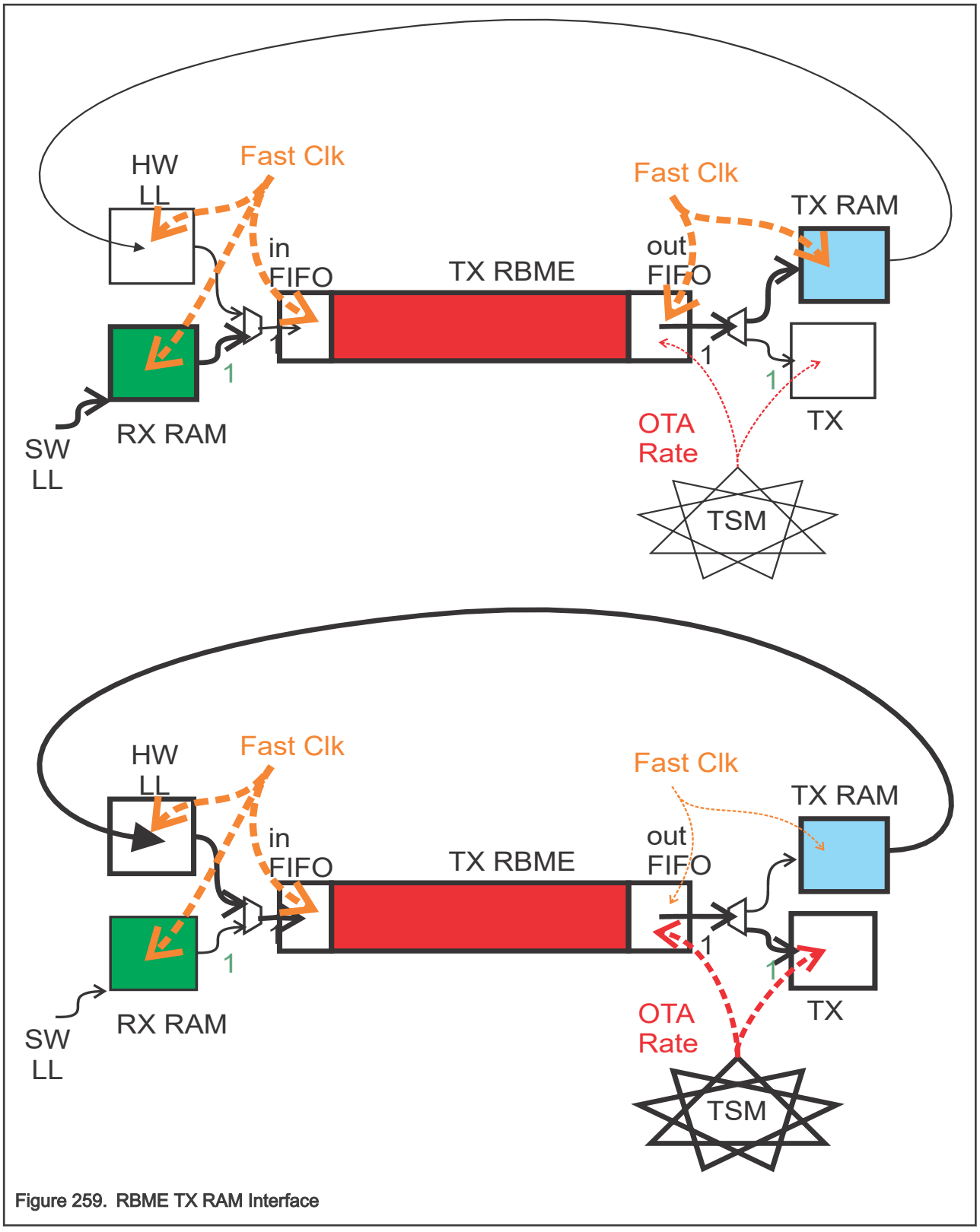


Figure 259. RBME TX RAM Interface

3. RAM-RBME RX

RBME RX processing: PHY ->[Despreading->FEC decoding->CRC & hard de-whitening]->LL Example: unsupported hard de-whitener with a different polynomial, interleaving and FEC plus soft de-spreading and CRC processing can be done in RBME RX.

1. First Pass: Use the PHY to RBME interface to process the data as normal but save the data to TX packet RAM before the de-whitener
    a. FEC decoding is enabled
    b. CRCW is bypassed
    c. Use software processing to do the soft de-whitening data
2. Second-Pass: Use the RAM interface to write 7-bit softbit words into RBME
    a. Do CRC decoding in RBME
    b. Use the RX RAM interface to read the CRC processed hard bit data

NOTE

A bypass from the PHY directly into packet RAM is needed if the de-spreader must be bypassed.

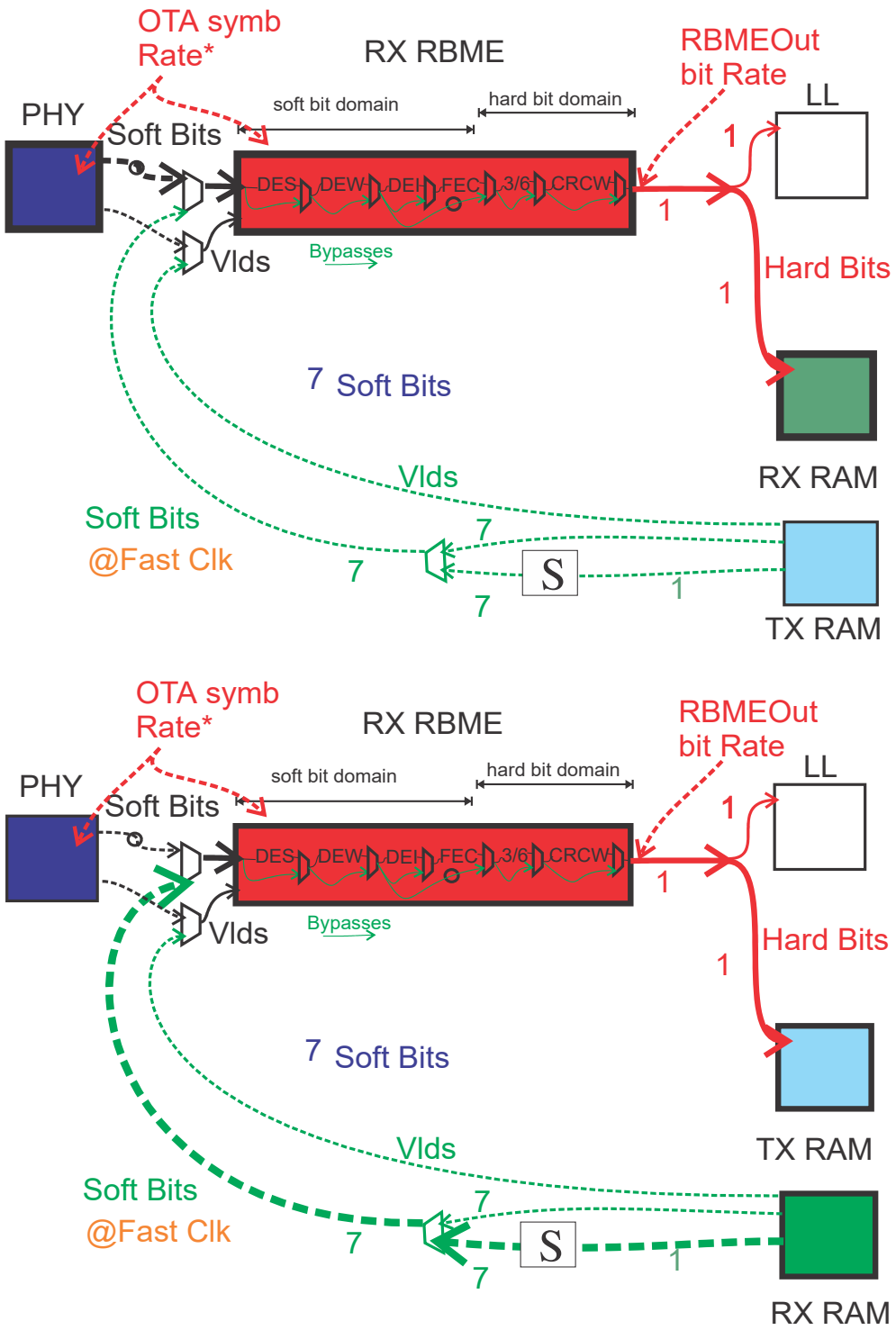


Figure 260. RBME RX RAM Interface

52.4.4.1.2.2.2.2 Internal Interfaces, Word Sizes, and Internal State Machines

For the TX, data and dataVld are single bits; for the RX and before the FEC, the data is in 7-bit words to describe softbits. The data format for CRCW for both TX and RX needs to be Boolean. In terms of clock valid management, every module internally controls its output clock valid (as opposed to a central control). This methodology makes the modules easier to interact with each other. Examples:

1. When bypassing a module, the data valid is equally bypassed.
2. If de-spreading by four is used, the output data valid(s) are four times slower at the output.

The FEC Decoder input is in codeword (CW) pairs. This is normal for a rate ½ FEC. For Bluetooth LE LR, the de-spreading is done at the PHY so that the input to RBME is CW pairs at FrefFreq/2 for speed. This means that a second seven-bit input word needs to be separately added to the input. In summary, the input to the RBME RX is either a seven-bit input or two seven-bit inputs (both associated with the same input data valid signal). For Bluetooth LE LR only, the two seven-bit inputs are expected during the decoding of the AA and CI. For all other cases, there is a single seven-bit input. The RBME may also decode data from external memory, such data are expected to be serialized outside the RBME. The single Sb1 input can be used for this, alternatively, both Sb1 and Sb2 inputs can be used for faster processing. The enable control for a module is tabulated in Table 448. Note that a bypass signal has priority. Block bypasses are internal to the RBME. External override access on the other hand, that is, for the Soft-Whitening module and the FEC module, is allowed as long as the corresponding override enable register is set.

Table 448. RBME Module Enable Truth Table

Enable (Register)	OverrideEnable (Register)	Override	Bypass*	Block Enabled
True	True	True	True	False
True	True	True	False	True
True	True	False	True	False
True	True	False	False	True
True	False	True	True	False
True	False	True	False	True
True	False	False	True	False
True	False	False	False	True
False	True	True	True	False
False	True	True	False	True
False	True	False	True	False
False	True	False	False	False
False	False	True	True	False
False	False	True	False	False
False	False	False	True	False
False	False	False	False	False

NOTE

Bypass signal is used internally, user does not need to program it.

52.4.4.1.2.2.3 FEC

The initial FEC originates from BL5 specifications related to the long-range feature. It is a part of 2.4 GHz Radio IP. The convolutional FEC encoder uses:

1. A non-systematic, non-recursive design
2. Code rate ½ with constraint length 4
3. The generator polynomials are:

$$G0(x) = 1 + x + x^2 + x^3$$

$$G1(x) = 1 + x^2 + x^3$$

52.4.4.1.2.2.3.1 Two-Pass FEC

The FEC encoder and decoder can run twice on a packet. For the TX and Bluetooth LE long range, it must encode the AA, CI + termination bits (FECBlock1), and then encode the payload and CRC (FECBlock2), see section "RX Bluetooth LE LR Example". For the RX, it must decode the two differently. To reduce latency, FECBlock1 is decoded with a fast clock once the AA is detected. FECBlock2 is decoded at the symbol rate.

52.4.4.1.2.2.3.2 TX FEC

FEC Encoder: Bluetooth LE-LR use case A shift register based representation of convolutional encoder is shown in the following figure.

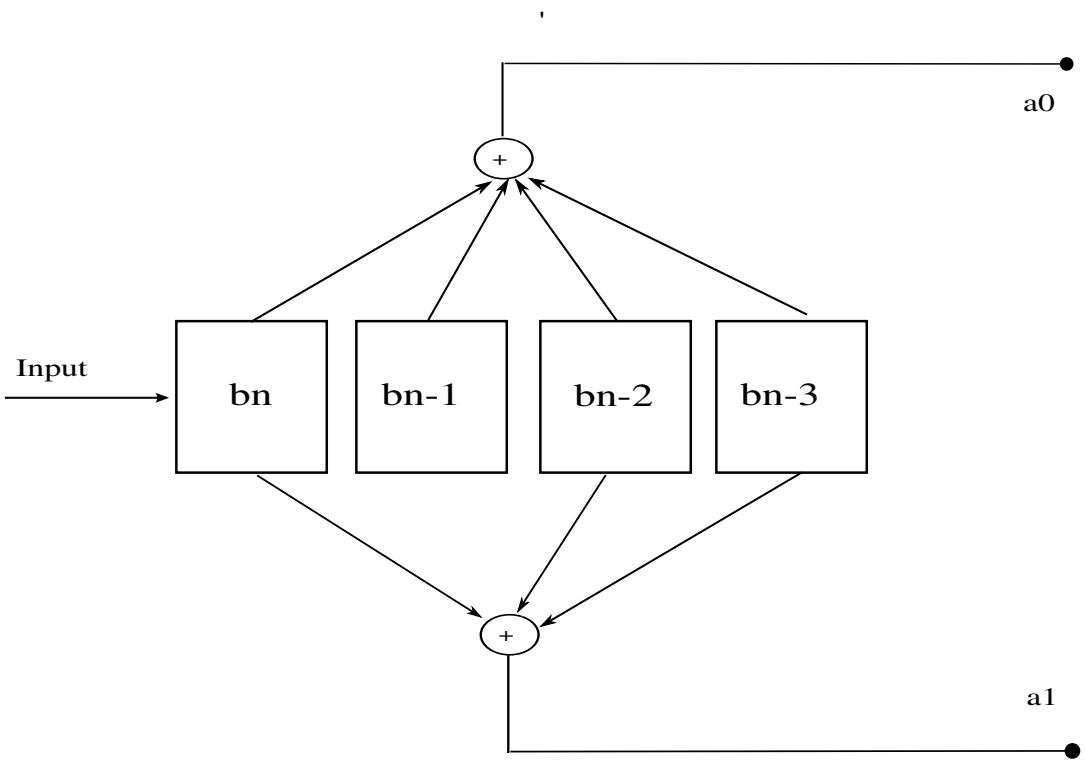


Figure 261. Bluetooth LE-LR FEC Encoder

Where:

- bn denotes the current bit, this is the input for the shift register.
- bn-i (i=1..3) are the previous bits sequence, they are referred to as the state or the memory of the encoder. The encoder produces two bits for each input bit.

The bit from generator polynomial G0 (a0) is transmitted first; the bit from generator polynomial G1 (a1) is transmitted second. The initial state of the convolutional FEC encoder is set to all zeros. An input sequence of three consecutive zeros always brings the convolutional FEC encoder back to its original state. This sequence is known as the termination sequence.

52.4.4.1.2.2.4 Spreader

TX Spreading

The spreading maps each input bit to P output bits (P = 2,4,8,16) symbols. The following table shows an example of Bluetooth LE LR where the choice for M is 4, depending on the coding scheme of protocols in use.

Table 449. Pattern Mapper inputs and outputs for Bluetooth LE LR spreading

Input from FEC encoder	Output sequence when P=1 (no spreading)	Output sequence when P=4
0	0	0011*
1	1	1100*
*The entries in the table are transmitted MSB first		

Manchester encoding is a subset of spreading with just two bits per input bit — see below figure. As the Manchester example illustrates, the clock rates (actually, clock valid signal rates) are affected by the Manchester encoding and decoding. The same applies to the spreader and de-spreader modules but with data rates changing by P = 2, 4, 8 or 16. Up to 16 are necessary to support all the 802.15.4 standards. The use of spreading means that output bits are serialized at P times the rate of the input bits. This is an important consideration as a clock valid on the output must be P times more often. That is, the data rate after the spreader is P times higher than that before the spreader. The data rate after the de-spreader in the RX is up to 16x smaller.

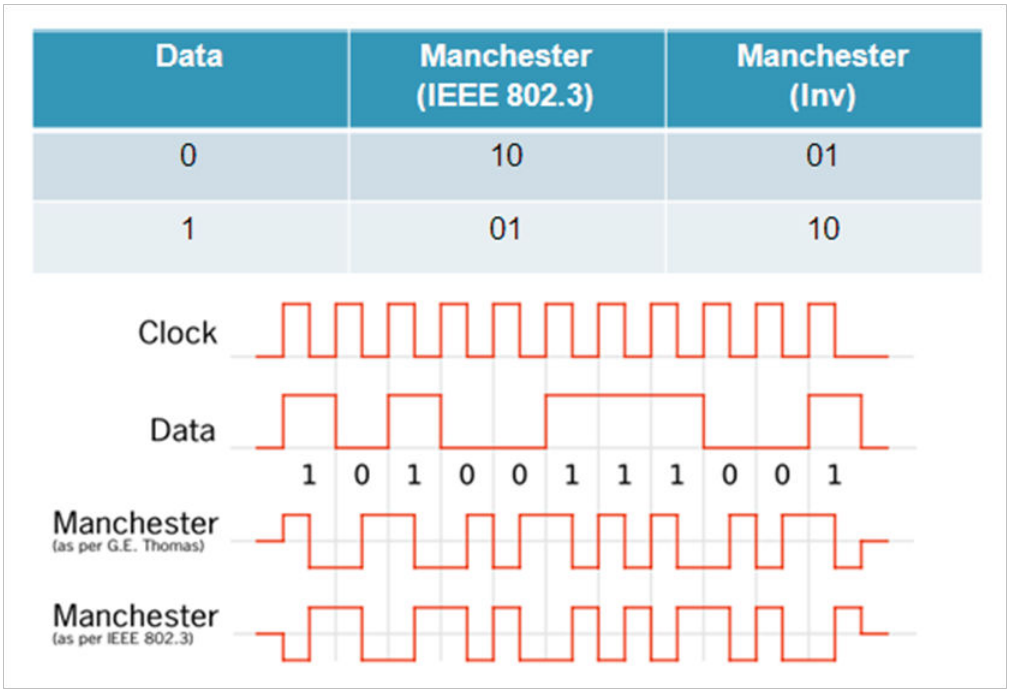


Figure 262. Manchester Encoding option for the Spreading Module

RX DE-Spreading

De-spreading is the dual of the spreading operation. De-spreading means correlating the soft bits provided by the demodulator with the reference sequence. This correlation needs to be done in a timely manner, that is, it has specific timing. For example, with a de-spreading of 4, four samples of the input generate the first output, the next four samples generate the second output and so on. The boundaries of de-spreading are fixed in the PHY.

52.4.4.1.2.2.5 Operation

The CRCW module contains the functionality to perform transmit CRC insertion, receive CRC checking, and data whitening. Additionally, the module can perform data error correction on received packets using the CRC syndrome if configured appropriately.

52.4.4.1.2.2.5.1 CRC Calculation

The CRC value is calculated using a configurable LFSR as depicted in Figure 263. The CRC calculation polynomial value is loaded into register *P*. The seed is loaded into register *SR* at initialization. The result is in register *SR* after all bits have been processed.

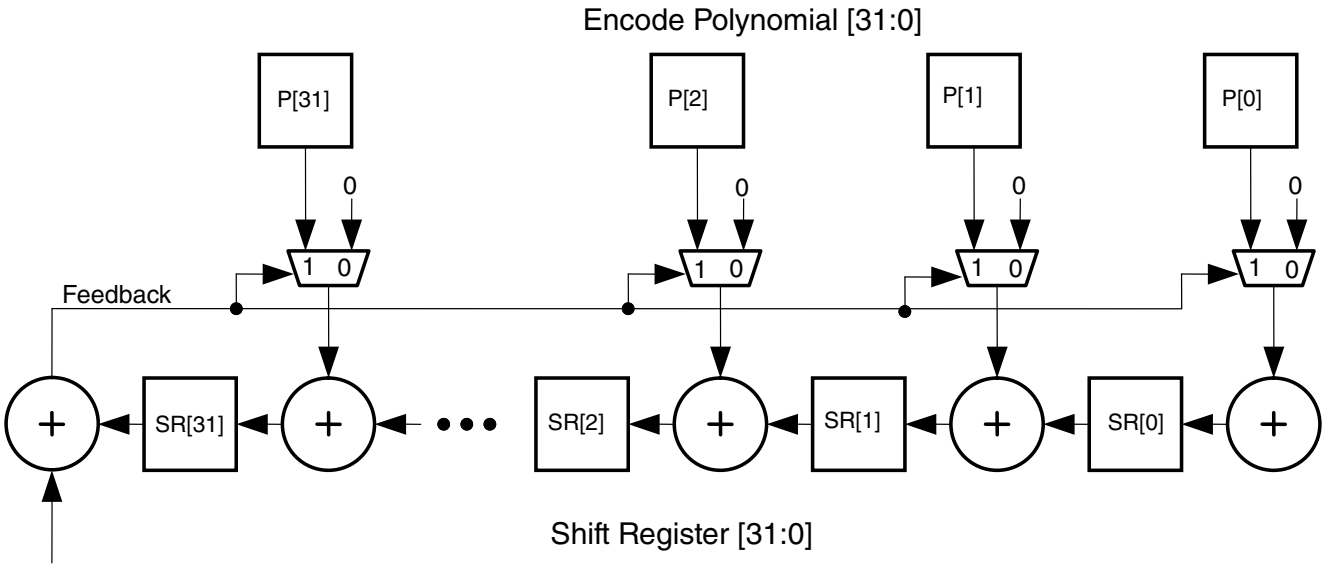
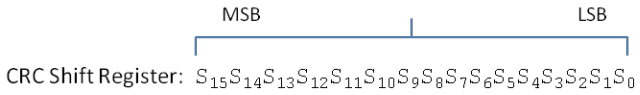


Figure 263. CRC Calculation Shift Register

Data flows from the link layer function to the CRCW module during transmit before being sent to the radio physical layer. All bits in each packet are provided by the link layer function, including placeholder bits for the CRC value. The link layer function marks the CRC calculation start and stop points in the bit stream. The link layer also indicates the start of the CRC placeholder bits. The CRCW module overwrites the placeholder CRC bits with the CRC result, ordered as specified by the configuration options. Figure 264 is a list of example 16-bit CRC output modes.



REF IN	BYTE ORDER	REF OUT	Order of Transmitted Bits (shifted out first ..... shifted out last)
X	0	0	$P_0P_1P_2P_3P_4P_5P_6P_7P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}P_{15}$ $S_{15}S_{14}S_{13}S_{12}S_{11}S_{10}S_9S_8S_7S_6S_5S_4S_3S_2S_1S_0$
X	0	1	$P_0P_1P_2P_3P_4P_5P_6P_7P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}P_{15}$ $S_8S_9S_{10}S_{11}S_{12}S_{13}S_{14}S_{15}S_0S_1S_2S_3S_4S_5S_6S_7$
X	1	0	$P_0P_1P_2P_3P_4P_5P_6P_7P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}P_{15}$ $S_7S_6S_5S_4S_3S_2S_1S_0S_{15}S_{14}S_{13}S_{12}S_{11}S_{10}S_9S_8$
X	1	1	$P_0P_1P_2P_3P_4P_5P_6P_7P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}P_{15}$ $S_0S_1S_2S_3S_4S_5S_6S_7S_8S_9S_{10}S_{11}S_{12}S_{13}S_{14}S_{15}$

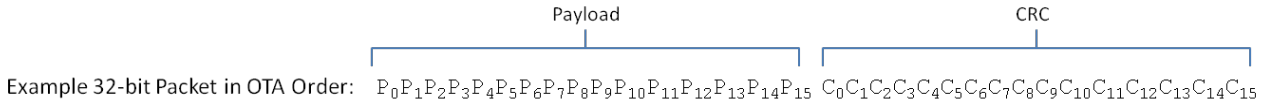
Figure 264. CRC Output Bit Order

52.4.4.1.2.2.5.2 CRC Check

During reception, data flows from the radio physical layer to the CRCW module before being sent to the link layer function. All bits in each packet are provided by the radio physical layer. Just as in transmit, the link layer function marks the CRC calculation start and stop points in the bit stream. The link layer also indicates the start of the received CRC bits.

The CRCW calculates the expected CRC result just as in transmit, but compares the received CRC bits as they arrive, ordered as specified by the configuration options, instead of inserting them into the packet. An early fail signal is asserted if a CRC bit miscompare is detected.

The CRC register contains the expected CRC when either of the *config_crc_byte_order* or *config_crc_ref_in* CRC configuration options are set. The CRC register contains the syndrome of the CRC error calculation when both options are not set.



REF IN	BYTE ORDER	REF OUT	Order of Bits Used in CRC Calculation (shifted in first ..... shifted in last)
0	0	0	$P_0P_1P_2P_3P_4P_5P_6P_7P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}P_{15}$ $C_0C_1C_2C_3C_4C_5C_6C_7C_8C_9C_{10}C_{11}C_{12}C_{13}C_{14}C_{15}$
0	0	1	$P_0P_1P_2P_3P_4P_5P_6P_7P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}P_{15}$ $C_7C_6C_5C_4C_3C_2C_1C_0C_{15}C_{14}C_{13}C_{12}C_{11}C_{10}C_9C_8$
0	1	0	$P_0P_1P_2P_3P_4P_5P_6P_7P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}P_{15}$ $C_8C_9C_{10}C_{11}C_{12}C_{13}C_{14}C_{15}C_0C_1C_2C_3C_4C_5C_6C_7$
0	1	1	$P_0P_1P_2P_3P_4P_5P_6P_7P_8P_9P_{10}P_{11}P_{12}P_{13}P_{14}P_{15}$ $C_{15}C_{14}C_{13}C_{12}C_{11}C_{10}C_9C_8C_7C_6C_5C_4C_3C_2C_1C_0$
1	0	0	$P_7P_6P_5P_4P_3P_2P_1P_0P_{15}P_{14}P_{13}P_{12}P_{11}P_{10}P_9P_8$ $C_0C_1C_2C_3C_4C_5C_6C_7C_8C_9C_{10}C_{11}C_{12}C_{13}C_{14}C_{15}$
1	0	1	$P_7P_6P_5P_4P_3P_2P_1P_0P_{15}P_{14}P_{13}P_{12}P_{11}P_{10}P_9P_8$ $C_7C_6C_5C_4C_3C_2C_1C_0C_{15}C_{14}C_{13}C_{12}C_{11}C_{10}C_9C_8$
1	1	0	$P_7P_6P_5P_4P_3P_2P_1P_0P_{15}P_{14}P_{13}P_{12}P_{11}P_{10}P_9P_8$ $C_8C_9C_{10}C_{11}C_{12}C_{13}C_{14}C_{15}C_0C_1C_2C_3C_4C_5C_6C_7$
1	1	1	$P_7P_6P_5P_4P_3P_2P_1P_0P_{15}P_{14}P_{13}P_{12}P_{11}P_{10}P_9P_8$ $C_{15}C_{14}C_{13}C_{12}C_{11}C_{10}C_9C_8C_7C_6C_5C_4C_3C_2C_1C_0$

Figure 265. CRC Input Bit Order

52.4.4.1.2.2.5.3 Data Whitening

The data whitener behaves identically in both transmit (whiten) and receive (de-whiten) operating modes. The LFSR used in this operation is designed to use either Fibonacci or Galois types of calculations. In either case, the LSB of the shift register is used to whiten each data bit as they are streamed through the CRCW.

An initialization signal for the data whiten logic loads the shift register with the seed value. The initialization signal can be used to re-initialize the shift register during a packet. A protocol-specific state machine controls a signal to mark the start and stop points for data whitening in the data stream.

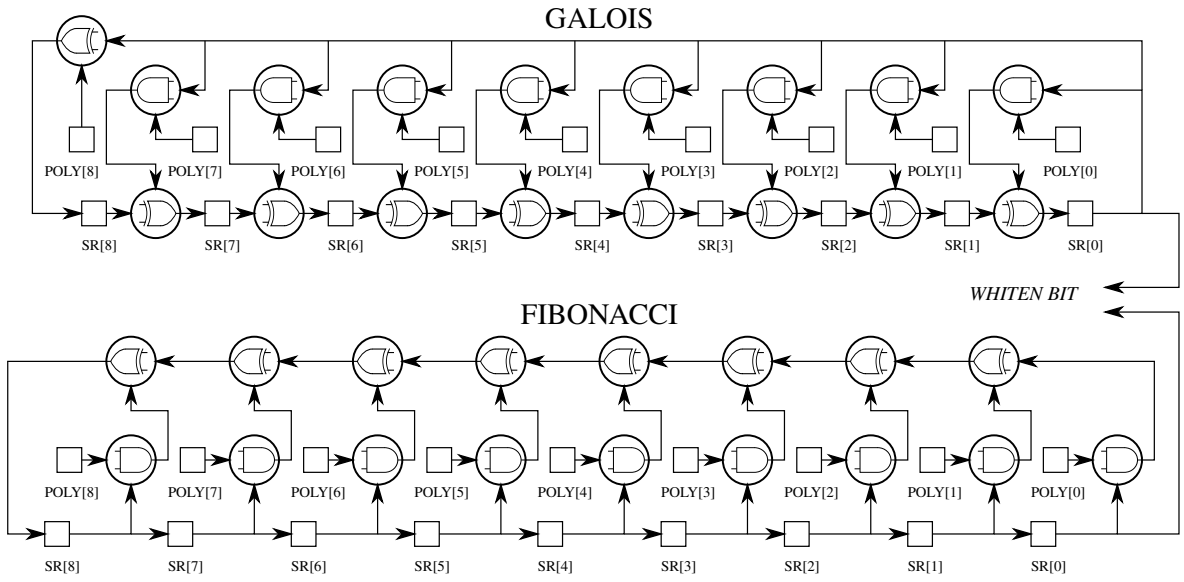


Figure 266. Data Whitening Shift Register

52.4.4.1.2.2.6 Clocking

The RBME has three clock sources: sysclk, radio_symb_clk and ipg_clk_s. The sysclk source is used directly or drives several clock gating inside rbme_cgm module, the radio_symb_clk is gated internally and used by internal blocks, while the ipg_clk_s is only used by the register access logic. The enable signals for clock gating are generated inside the rbme itself.

52.4.4.1.2.2.7 Reset

The RBME has a single asynchronous reset input, named ipg_hard_async_reset_. It clears all the logic inside the module.

52.4.4.1.2.2.8 Interrupts

The RBME block has an interrupt output signal rbme_irq, which indicates that the programmed number of payload bytes has been written to the RAM.

52.4.4.1.2.2.9 DMA

The RBME has no DMA.

52.4.4.1.2.3 Initialization

There is no particular sequence to initialize the Radio BME. The registers must be programmed as described in the Functional Description chapter

52.4.4.1.2.4 Application information

There is no specific procedures to be used by the application.

52.4.4.1.2.5 RBME register descriptions

52.4.4.1.2.5.1 RBME Base Address memory map

RADIO.RBME base address: 48A0_6200h

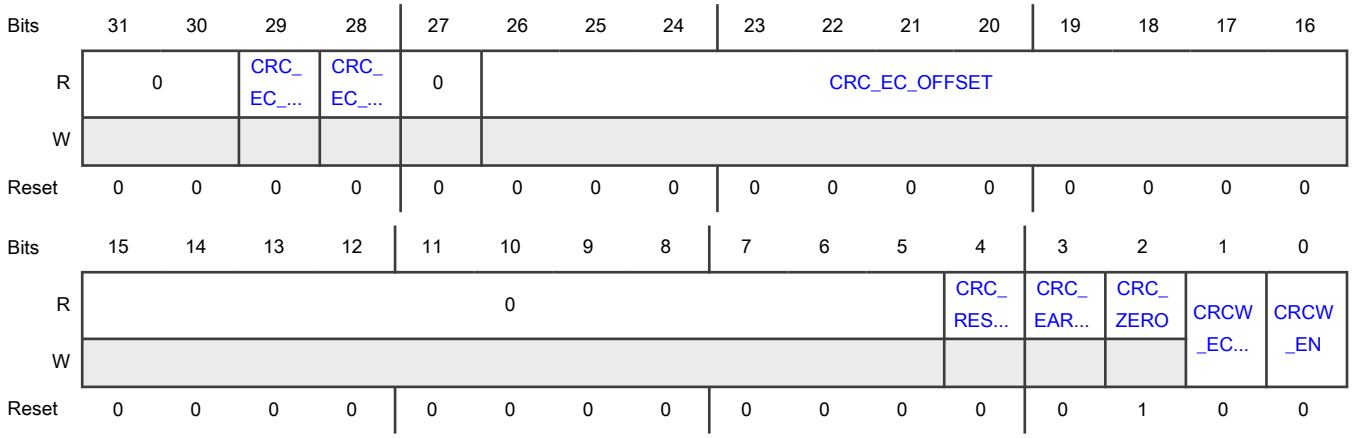
Offset	Register	Width (In bits)	Access	Reset value
0h	CRC/WHITENER CONFIG (CRCW_CFG)	32	RW	0000_0004h
4h	CRC ERROR CORRECTION MASK (CRC_EC_MASK)	32	R	0000_0000h
8h	CRC RESULT (CRC_RES_OUT)	32	R	0000_0000h
Ch	CRC/WHITENER CONFIG 2 (CRCW_CFG2)	32	RW	0000_0000h
10h	CRC CONFIGURATION (CRCW_CFG3)	32	RW	0000_0002h
14h	CRC INITIALIZATION (CRC_INIT)	32	RW	0000_0000h
18h	CRC POLYNOMIAL (CRC_POLY)	32	RW	1021_0000h
1Ch	CRC XOR OUT (CRC_XOR_OUT)	32	RW	0000_0000h
20h	WHITENER CONFIGURATION (WHITEN_CFG)	32	RW	01FF_0918h
24h	WHITENER POLYNOMIAL (WHITEN_POLY)	32	RW	0000_0021h
28h	WHITENER SIZE THRESHOLD (WHITEN_SZ_THR)	32	RW	0000_0800h
2Ch	FEC CONFIG 1 (FEC_CFG1)	32	RW	0000_0300h
30h	RBME SOFT RESET (RBME_RST)	32	RW	0000_0000h
34h	FEC CONFIG 2 (FEC_CFG2)	32	RW	003F_7F10h
3Ch	SPREADER CONFIG (SPREAD_CFG)	32	RW	000C_0200h
40h	WHITEN CONFIG (WHT_CFG)	32	RW	0200_1000h
44h	PACKET SIZE (PKT_SZ)	32	RW	0022_4000h
48h	LENGTH OF PHR CONFIG (CRC_PHR_SZ)	32	RW	0000_0003h
4Ch	FCP SUPPORT CONFIG (FCP_CFG)	32	RW	0000_0000h
50h	FRAME OVERRIDE SIZE (FRAME_OVER_SZ)	32	RW	0000_0000h
54h	OVERRIDE OF FEC BLOCK SIZE (FEC_BSZ_OV_B4SP)	32	RW	0000_0000h
58h	LEG0 CONFIG (LEG0_CFG)	32	RW	F202_DD00h
5Ch	OVERRIDE PAYLOAD (NPAYL_OVER_SZ)	32	RW	0000_0000h
64h	PACKET RAM SOURCE ADDRESS (RAM_S_ADDR)	32	RW	0000_0000h
68h	PACKET RAM DESTINATION ADDRESS (RAM_D_ADDR)	32	RW	0000_0000h
6Ch	PACKET RAM INTERFACE CONFIG (RAM_IF_CFG)	32	RW	0000_0000h

52.4.4.1.2.5.2 CRC/WHITENER CONFIG (CRCW_CFG)

Offset

Register	Offset
CRCW_CFG	0h

Diagram



Fields

Field	Function
31-30 —	Reserved
29 CRC_EC_FAIL	CRC error correction fail This signal is cleared when *crc_init* is asserted. It is set after the completion of a CRC error correction calculation that does not find a valid data correction solution or if error correction was disabled and the CRC check found an error.
28 CRC_EC_DONE	CRC error correction done This signal is cleared when *crc_init* is asserted. It is set after the error correction logic completes processing the syndrome. It is immediately set after a packet is received if no error was detected or if error correction is disabled. Otherwise, it can take up to N system clocks after the packet is received to assert, with N = number of bits used in the CRC calculation, including the CRC value.
27 —	Reserved
26-16 CRC_EC_OFFSET	CRC error correction offset This value provides the byte offset within the data packet to which the CRC error correction mask should be XOR-ed. This value is valid if the *crc_ec_done* signal is asserted and the *crc_ec_fail* signal is not asserted. The offset includes only the bytes used in the CRC calculation, including the CRC value.
15-5 —	Reserved
4 CRC_RES_OUT_VLD	CRC result output valid CRC result output valid
3	CRC error correction fail

Table continues on the next page...

Table continued from the previous page...

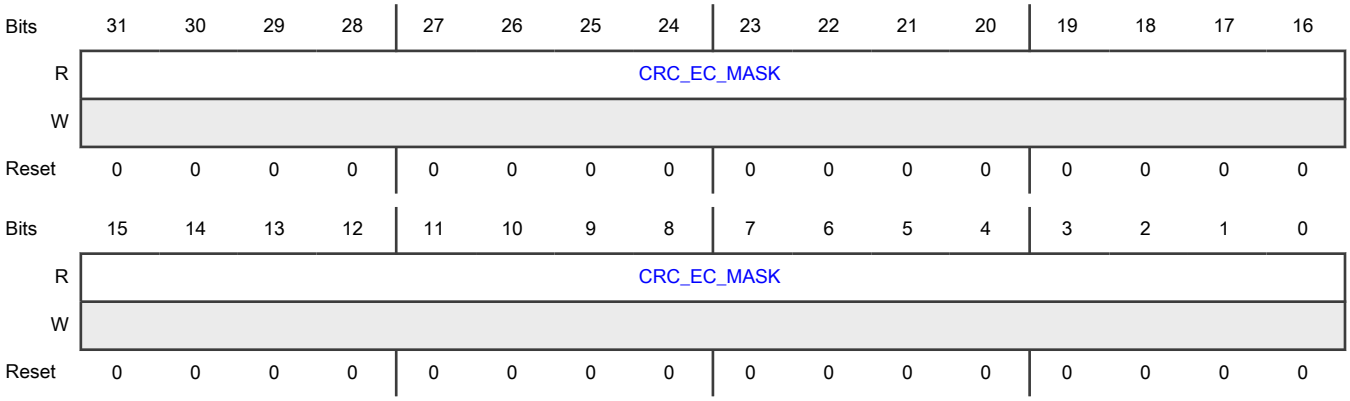
Field	Function
CRC_EARLY_FAIL	This signal is cleared when *crc_init* is asserted. It is set after the completion of a CRC error correction calculation that does not find a valid data correction solution or if error correction was disabled and the CRC check found an error.
2 CRC_ZERO	CRC zero This signal is asserted at any time when the CRC shift register contains a value of zero.
1 CRCW_EC_EN	CRC Error Correction Enable CRC Error Correction Enable
0 CRCW_EN	CRC calculation enable Input data bits loaded with this signal asserted are used in the CRC calculation.

52.4.4.1.2.5.3 CRC ERROR CORRECTION MASK (CRC_EC_MASK)

Offset

Register	Offset
CRC_EC_MASK	4h

Diagram



Fields

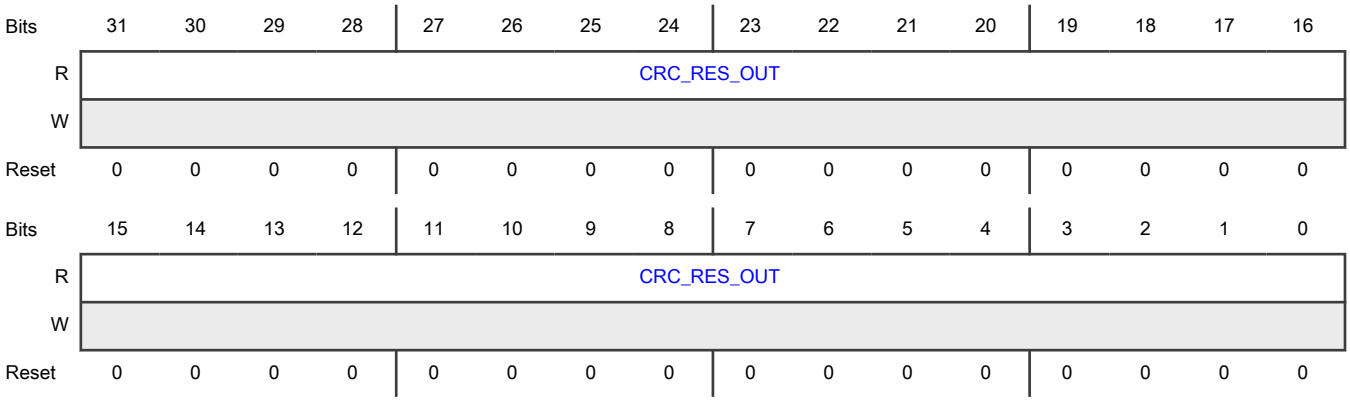
Field	Function
31-0 CRC_EC_MASK	CRC error correction mask This value provides a 32-bit XOR mask that must be applied to the input data packet to correct the burst errors detected by the error correction calculation. This value is valid if the *crc_ec_done* signal is asserted and the *crc_ec_fail* signal is not asserted.

52.4.4.1.2.5.4 CRC RESULT (CRC_RES_OUT)

Offset

Register	Offset
CRC_RES_OUT	8h

Diagram



Fields

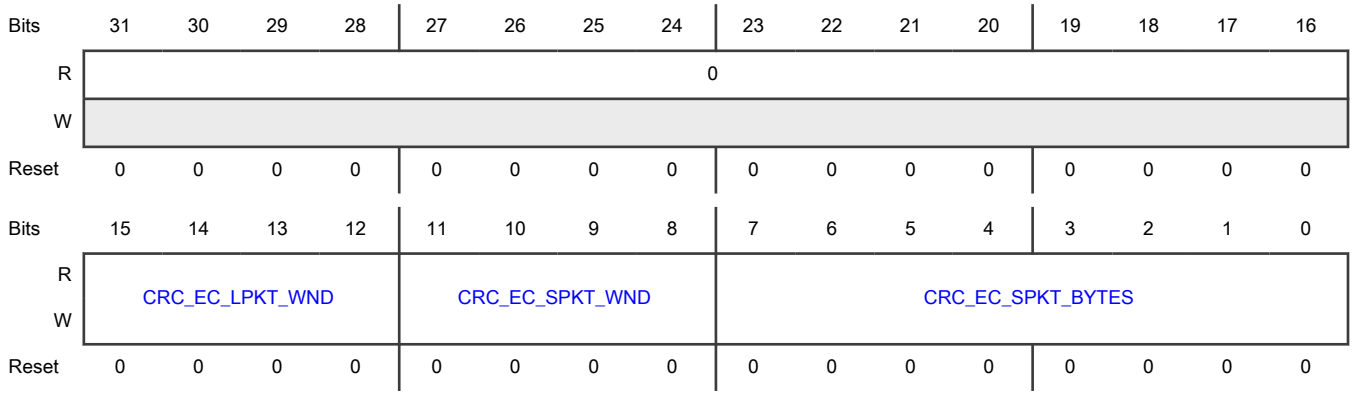
Field	Function
31-0 CRC_RES_OUT	CRC result output This bus provides the instantaneous value of the CRC shift register.

52.4.4.1.2.5.5 CRC/WHITENER CONFIG 2 (CRCW_CFG2)

Offset

Register	Offset
CRCW_CFG2	Ch

Diagram



Fields

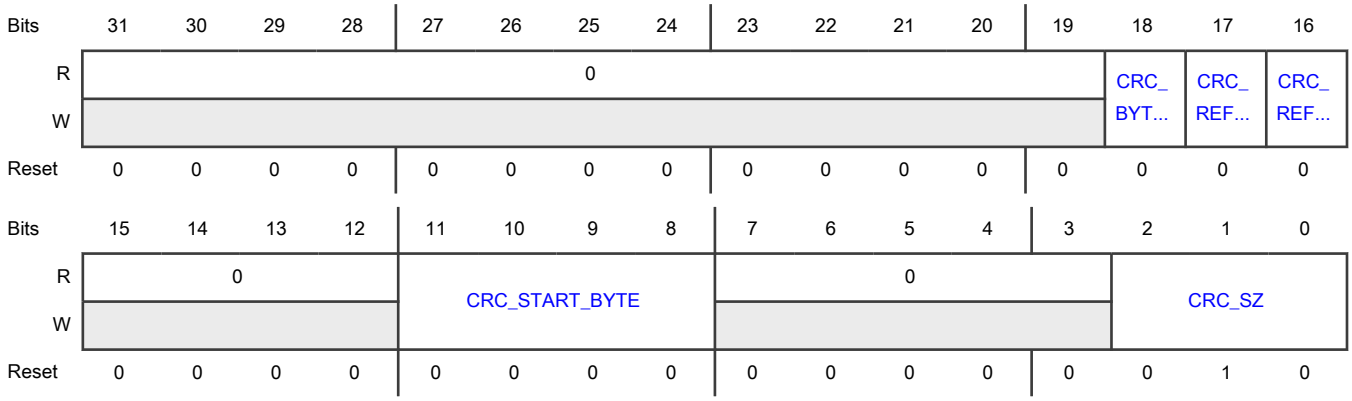
Field	Function
31-16 —	Reserved
15-12 CRC_EC_LPKT_WND	Error correction long packet burst error window This value determines the largest burst error corrected when long packets are processed. A value of zero will disable long packet error correction. The maximum value is 15.
11-8 CRC_EC_SPKT_WND	Error correction short packet burst error window This value determines the largest burst error corrected when short packets are processed. A value of zero will disable short packet error correction. The maximum value is 15.
7-0 CRC_EC_SPKT_BYTES	Error Correction Short Packet Bytes Short packets are defined as those where the number of bytes used in the CRC calculation, including the CRC value, do not exceed this value. The maximum value is 255.

52.4.4.1.2.5.6 CRC CONFIGURATION (CRCW_CFG3)

Offset

Register	Offset
CRCW_CFG3	10h

Diagram



Fields

Field	Function
31-19 —	Reserved
18 CRC_BYTE_ORD	CRC Byte Order 0b - LS Byte First 1b - MS Byte First
17 CRC_REF_OUT	CRC Reflect Out 0b - Does not manipulate CRC result 1b - CRC result is to be reflected bitwise (operated on entire word)
16 CRC_REF_IN	CRC Reflect In 0b - Does not manipulate input data stream 1b - reflect each byte in the input stream bitwise
15-12 —	Reserved
11-8 CRC_START_BYTE	Configure CRC Start Point Starts CRC with this byte position. Byte #0 is the first byte of Sync address.
7-3 —	Reserved
2-0 CRC_SZ	CRC Size (in octets) Number of CRC Octets = CRC_SZ, CRC_SZ from 0 to 4.

52.4.4.1.2.5.7 CRC INITIALIZATION (CRC_INIT)

Offset

Register	Offset
CRC_INIT	14h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	CRC_SEED															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	CRC_SEED															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 CRC_SEED	CRC Seed Value Initial Value for CRC LFSR

52.4.4.1.2.5.8 CRC POLYNOMIAL (CRC_POLY)

Offset

Register	Offset
CRC_POLY	18h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	CRC_POLY															
Reset	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	CRC_POLY															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

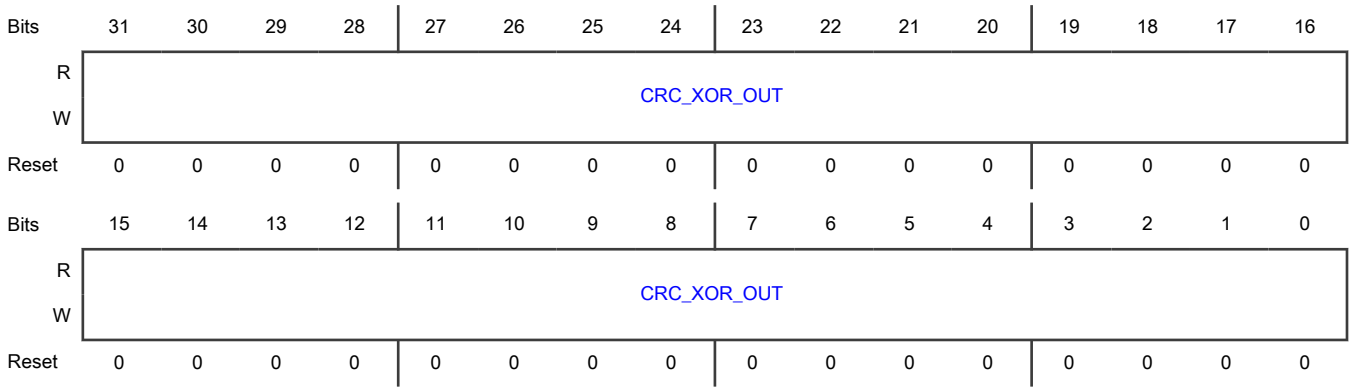
Field	Function
31-0 CRC_POLY	CRC Polynomial.

52.4.4.1.2.5.9 CRC XOR OUT (CRC_XOR_OUT)

Offset

Register	Offset
CRC_XOR_OUT	1Ch

Diagram



Fields

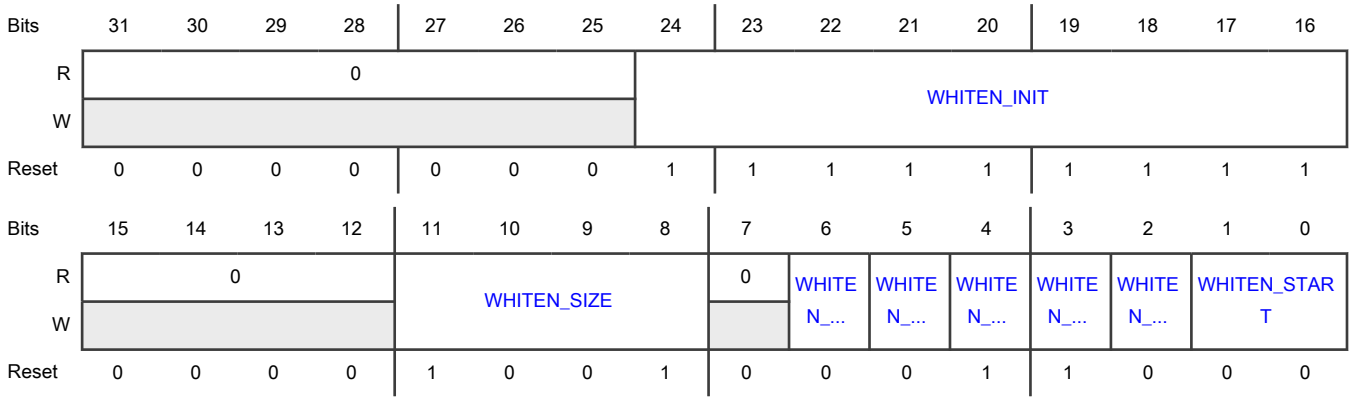
Field	Function
31-0 CRC_XOR_OUT	CRC XOR OUT Register XOR mask for CRC result (for no mask, should be 0)

52.4.4.1.2.5.10 WHITENER CONFIGURATION (WHITEN_CFG)

Offset

Register	Offset
WHITEN_CFG	20h

Diagram



Fields

Field	Function
31-25 —	Reserved
24-16 WHITEN_INIT	Initialization value for whitening/de-whitening
15-12 —	Reserved
11-8 WHITEN_SIZE	Length of Whitener LFSR
7 —	Reserved
6 WHITEN_PAYLOAD_REINIT	Configure for Whitener re-initialization 0b - Does not re-initialize Whitener LFSR at start-of-payload 1b - Re-initialize Whitener LFSR at start-of-payload
5 WHITEN_REF_IN	Whiten Reflect Input The input data stream is reflected, bit-wise, per byte, if this register bit is asserted. Bit 7 becomes bit 0, bit 6 becomes bit 1, etc. This register bit only causes the reflection of the payload data bits as they are used in the whiten calculation and does not cause any change in the output bit order.
4 WHITEN_POLY_TYPE	Whiten Polynomial Type A Fibonacci type LFSR is used with the whiten polynomial if this register bit is asserted. Otherwise, a Galois type LFSR is used.
3	Configure for Whitening-before-CRC Sets the order of Bit Stream Processing for TX and RX.

Table continues on the next page...

Table continued from the previous page...

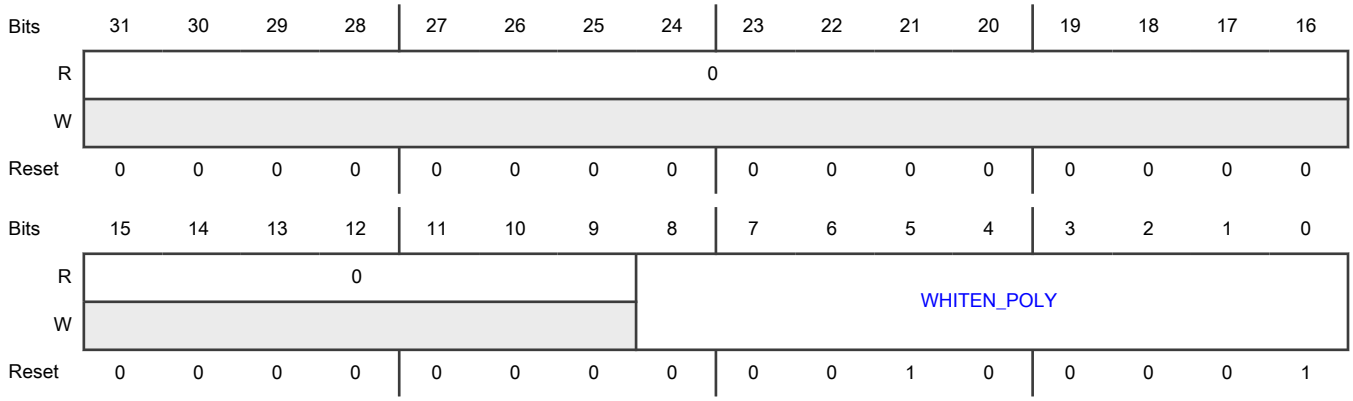
Field	Function
WHITEN_B4_CRC	0b - CRC before whiten/de-whiten 1b - Whiten/de-whiten before CRC
2 WHITEN_END	Configure end-of-whitening 0b - end whiten at end-of-payload 1b - end whiten at end-of-crc
1-0 WHITEN_START	Configure Whitener Start Point 00b - no whitening 01b - start whitening at start-of-H0 10b - start whitening at start-of-H1 but only if LENGTH > WHITEN_SZ_THR 11b - start whitening at start-of-payload but only if LENGTH > WHITEN_SZ_THR

52.4.4.1.2.5.11 WHITENER POLYNOMIAL (WHITEN_POLY)

Offset

Register	Offset
WHITEN_POLY	24h

Diagram



Fields

Field	Function
31-9 —	Reserved

Table continues on the next page...

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Field	Function
8-0 WHITEN_POLY	Whitener Polynomial The 9-bit polynomial used in the whiten calculation. The polynomial value must be right-justified if smaller than 9-bits.

52.4.4.1.2.5.12 WHITENER SIZE THRESHOLD (WHITEN_SZ_THR)

Offset

Register	Offset
WHITEN_SZ_THR	28h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				WHITEN_SZ_THR											
W																
Reset	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Fields

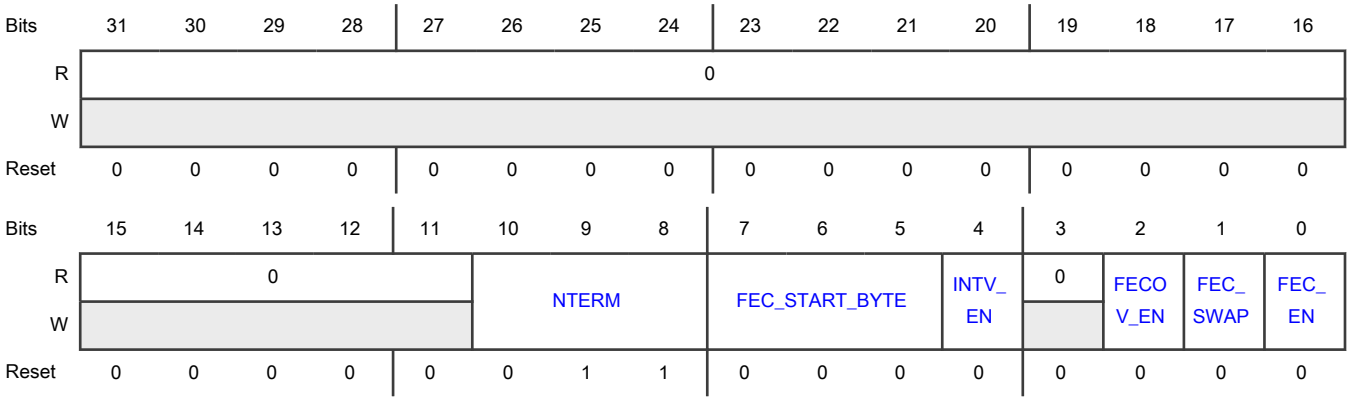
Field	Function
31-12 —	Reserved
11-0 WHITEN_SZ_THR	Whitener Size Threshold Minimum Packet Length (extracted LENGTH field) required to enable whiten. Requires WHITEN_START=2 or 3

52.4.4.1.2.5.13 FEC CONFIG 1 (FEC_CFG1)

Offset

Register	Offset
FEC_CFG1	2Ch

Diagram



Fields

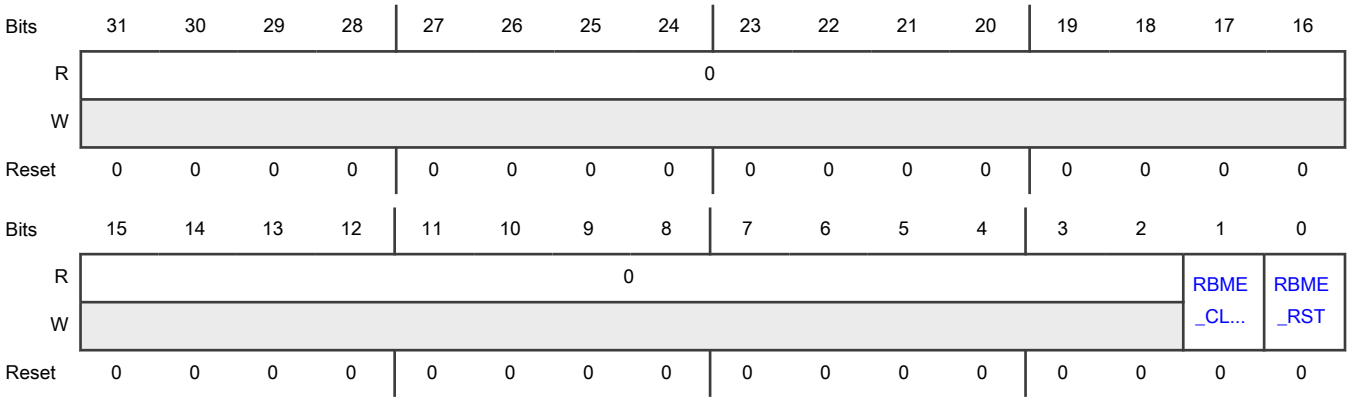
Field	Function
31-11 —	Reserved
10-8 NTERM	Number of term bits Size of term bits, from 0 to 7 bits length can support. In Bluetooth LE, the default value is 3.
7-5 FEC_START_BYTE	FEC Start Byte
4 INTV_EN	Enable interleaver register Should keep 0 for this field
3 —	Reserved
2 FECOV_EN	Enable dynamic override of FEC 0b - Disable FEC override 1b - The override of FEC is only used in Bluetooth LE LR cases, dynamically depending on the LR AA detected
1 FEC_SWAP	FEC output swap Should keep 0 for this field
0 FEC_EN	FEC enable 0b - Disable FEC encoder and decoder 1b - Enable FEC encoder and decoder

52.4.4.1.2.5.14 RBME SOFT RESET (RBME_RST)

Offset

Register	Offset
RBME_RST	30h

Diagram



Fields

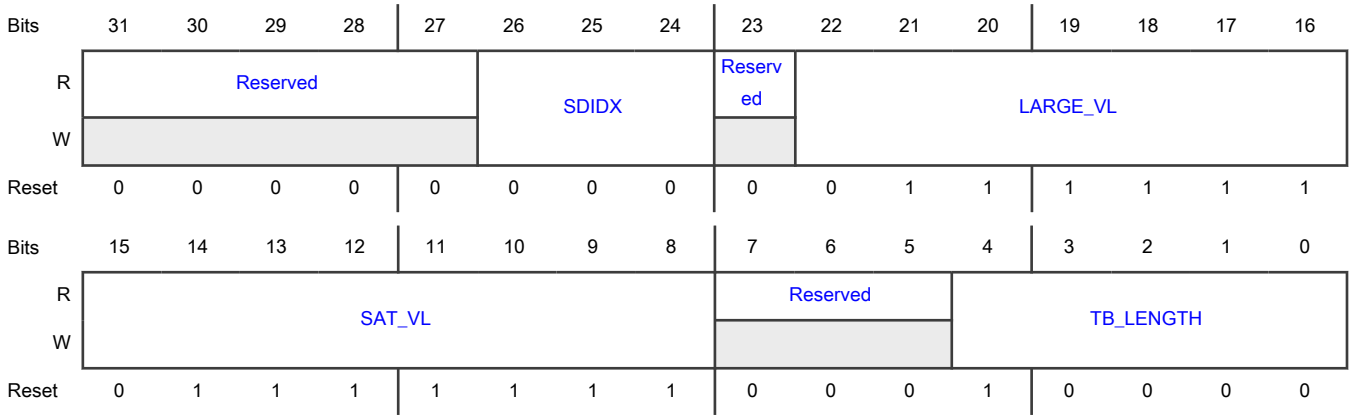
Field	Function
31-2 —	Reserved
1 RBME_CLK_EN_OVRD	RBME Clock Enable override Set this bit to enable RBME internal clock manually.
0 RBME_RST	RBME reset signal 0b - Disable soft reset 1b - Enable soft reset. When this bit is write to 1, the soft reset to RBME happens immediately. Then all internal registers and functions will be reset.

52.4.4.1.2.5.15 FEC CONFIG 2 (FEC_CFG2)

Offset

Register	Offset
FEC_CFG2	34h

Diagram



Fields

Field	Function
31-27 —	Reserved
26-24 SDIDX	Index of startup state. PM(startStIdx)=0 Keep default values in Bluetooth LE mode.
23 —	Reserved
22-16 LARGE_VL	Large value used at startup phase, assigned to the initial PMs. Keep default values in Bluetooth LE mode.
15-8 SAT_VL	Saturation value for PM Keep default values in Bluetooth LE mode.
7-5 —	Reserved
4-0 TB_LENGTH	Trace-back length Viterbi Trace back length from 1 to 16, the longer trace back length will get better BER in lower SNR environment. Keep default values in Bluetooth LE mode.

52.4.4.1.2.5.16 SPREADER CONFIG (SPREAD_CFG)

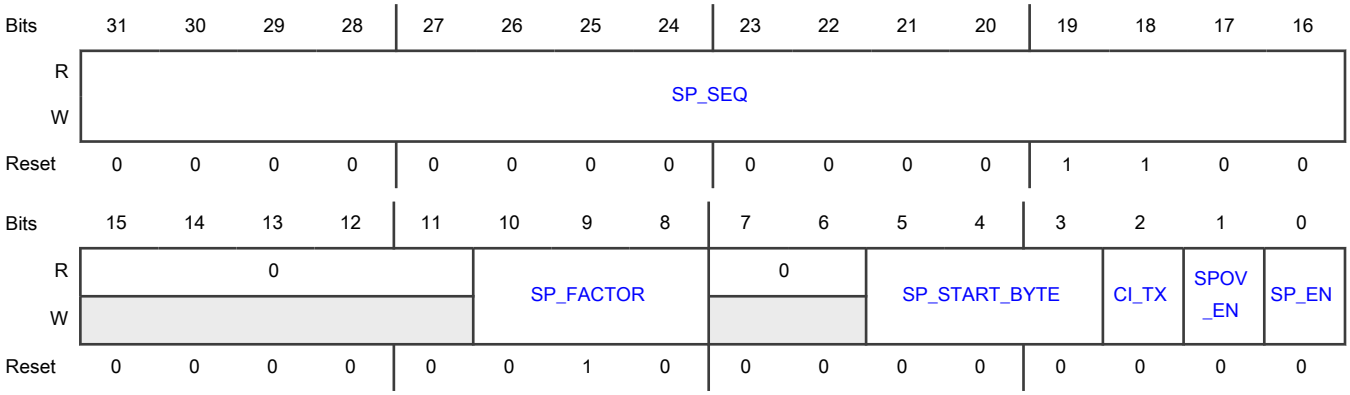
Offset

Register	Offset
SPREAD_CFG	3Ch

Function

Soft/hard spreader/de-spreader config register

Diagram



Fields

Field	Function
31-16 SP_SEQ	Spreading Bit Sequence Bit sequence used for spreading and Manchester encoding
15-11 —	Reserved
10-8 SP_FACTOR	Spreading Factor Spreading and despreading factor selection 000b - Factor = 1(No spreading and despreading) 001b - Factor = 2 010b - Factor = 4 011b - Factor = 8 100b - Factor = 16
7-6 —	Reserved
5-3 SP_START_BYTE	Spread Start Byte
2 CI_TX	Bluetooth LE The CI field determines which coding scheme is used for FEC block 2. It is only used in GENFSK working as active Bluetooth LE link layer TX mode. 0b - FEC Block 2 coded using S=8

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - FEC Block 2 coded using S=2
1 SPOV_EN	Spreader Override Enable Allows overwrite of the spreading, the override is automatically done by hardware in GLL working as active Bluetooth LE link layer. So in normal Bluetooth LE case, there is no need to set this enable bit. 0b - Does not allow active override of the spreading enable 1b - Allows active override of the spreading enable
0 SP_EN	Spreader Enable bit Enable bit for Bluetooth LE spreader or Manchester block. If any protocol has spreader or Manchester function then SP_EN should be enabled. The time for Bluetooth LE 500 or Bluetooth LE 125 spreader is controlled by hardware override. 0b - Disable spreader 1b - Enable spreader

52.4.4.1.2.5.17 WHITEN CONFIG (WHT_CFG)

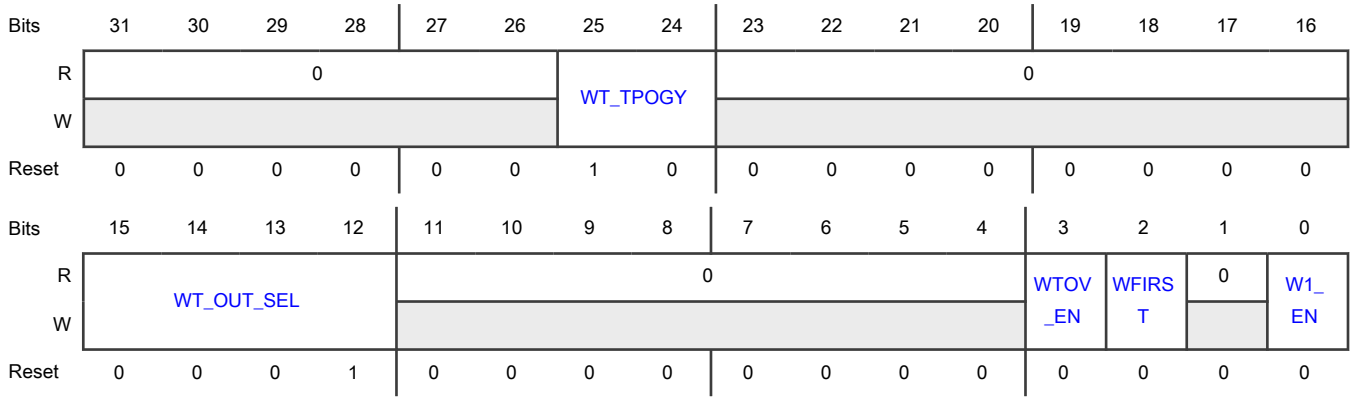
Offset

Register	Offset
WHT_CFG	40h

Function

The WHT_CFG register is used to soft-whiten 1 configuration register.

Diagram



Fields

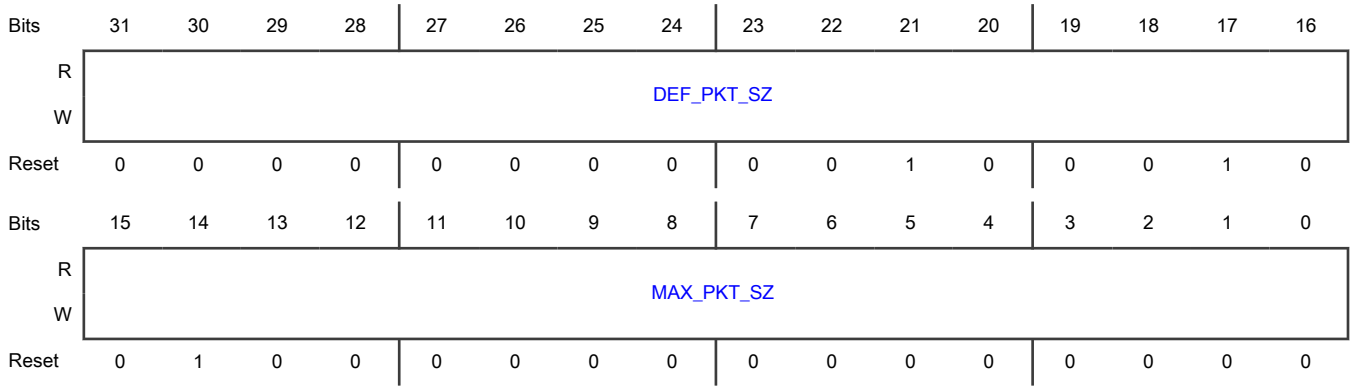
Field	Function
31-26 —	Reserved
25-24 WT_TPOGY	Whiten 1 Polynomial Type Fibonacci =1, Galois = 2, Fibonacci FCP = 3.
23-16 —	Reserved
15-12 WT_OUT_SEL	Selected Output
11-4 —	Reserved
3 WTOV_EN	Allows overwrite of the whitening
2 WFIRST	Whitens before CRC
1 —	Reserved
0 W1_EN	Enable first whitener

52.4.4.1.2.5.18 PACKET SIZE (PKT_SZ)

Offset

Register	Offset
PKT_SZ	44h

Diagram



Fields

Field	Function
31-16 DEF_PKT_SZ	Default Packet Size AA length bits + CI length bits + TERM1 length bits
15-0 MAX_PKT_SZ	Maximum Packet Size In Bits Large value is required as placeholder until the link layer provides the packet length

52.4.4.1.2.5.19 LENGTH OF PHR CONFIG (CRC_PHR_SZ)

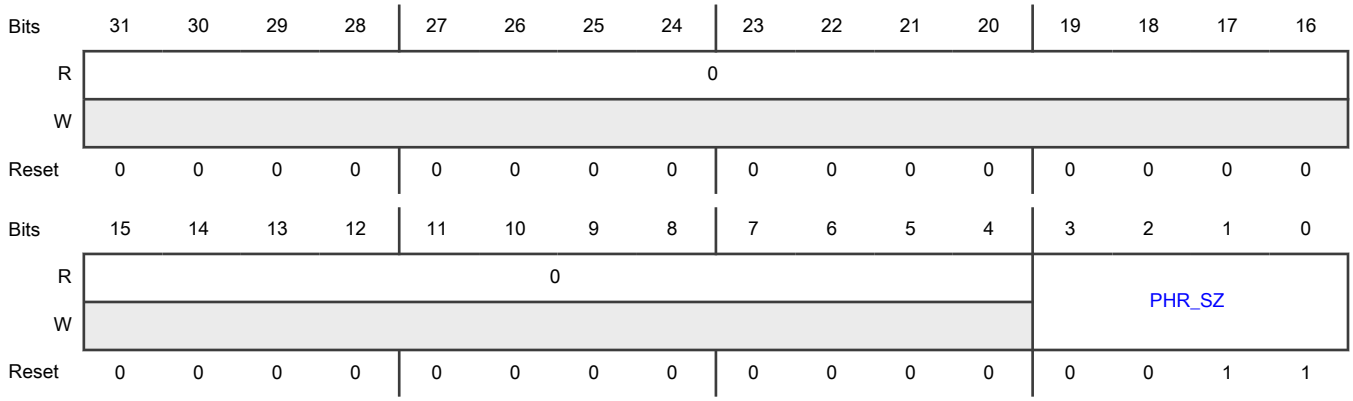
Offset

Register	Offset
CRC_PHR_SZ	48h

Function

Length of PHR in bytes.

Diagram



Fields

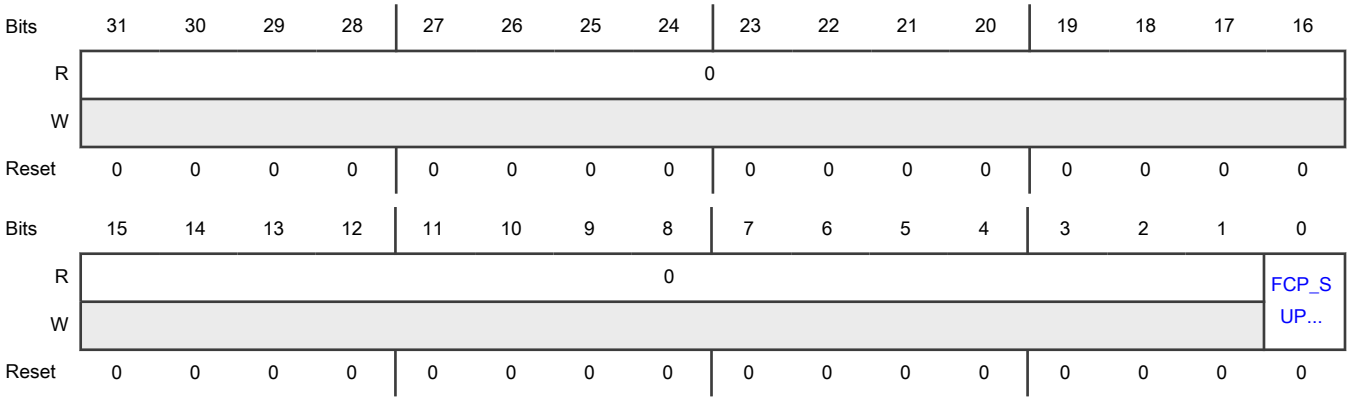
Field	Function
31-4 —	Reserved
3-0 PHR_SZ	PHR Size Config For Bluetooth LE LR mode(either NBU or GEN-LL is activated), this field should be 2. For other protocols, this field has no effect.

52.4.4.1.2.5.20 FCP SUPPORT CONFIG (FCP_CFG)

Offset

Register	Offset
FCP_CFG	4Ch

Diagram



Fields

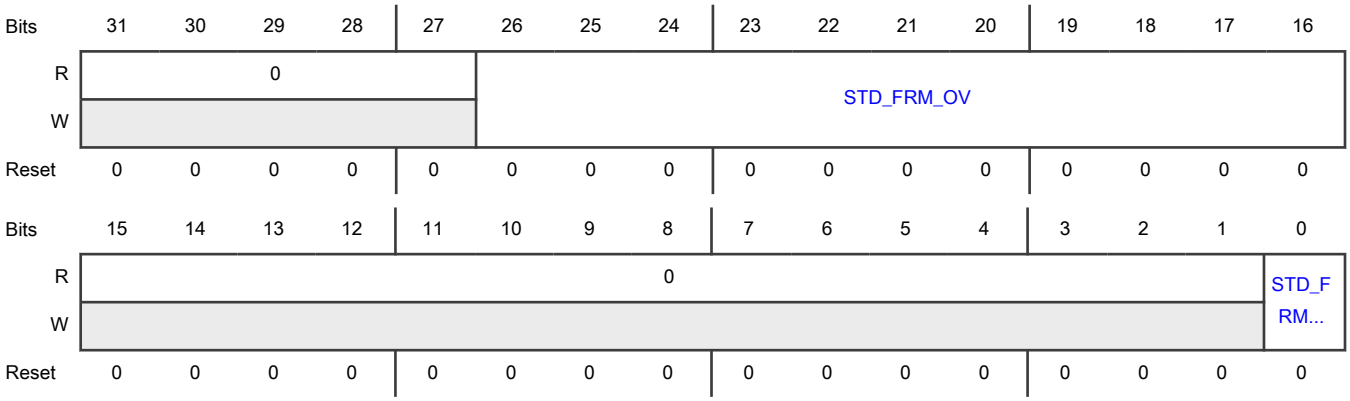
Field	Function
31-1 —	Reserved
0 FCP_SUPPORT	FCP Support 0b - Disable FCP support 1b - Enable FCP support

52.4.4.1.2.5.21 FRAME OVERRIDE SIZE (FRAME_OVER_SZ)

Offset

Register	Offset
FRAME_OVER_SZ	50h

Diagram



Fields

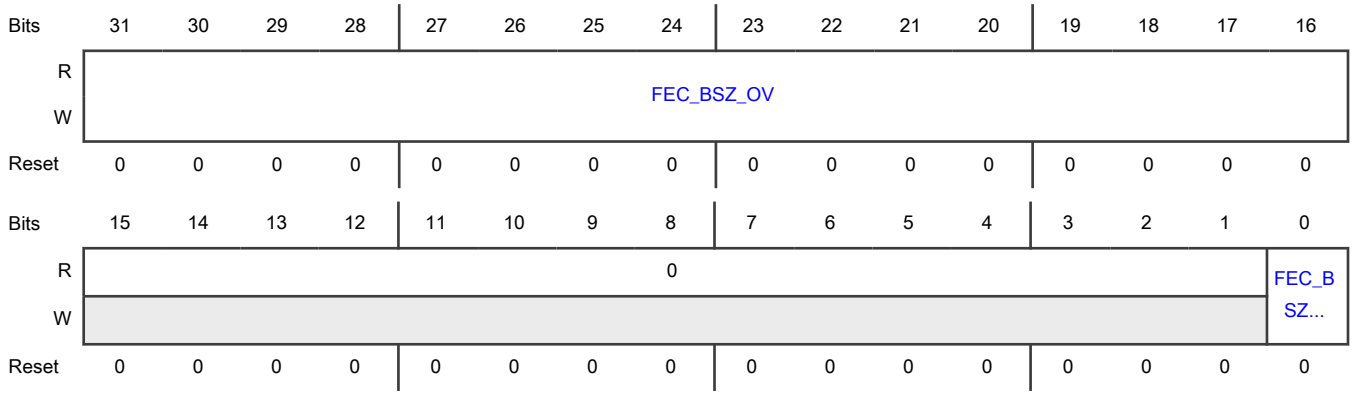
Field	Function
31-27 —	Reserved
26-16 STD_FRM_OV	Value to override the STD frame length (bits)
15-1 —	Reserved
0 STD_FRM_OV_EN	Overrides active STD frame length from link layer enable bit 0b - Disable override active STD frame length from link layer 1b - Enable override active STD frame length from link layer

52.4.4.1.2.5.22 OVERRIDE OF FEC BLOCK SIZE (FEC_BSZ_OV_B4SP)

Offset

Register	Offset
FEC_BSZ_OV_B4SP	54h

Diagram



Fields

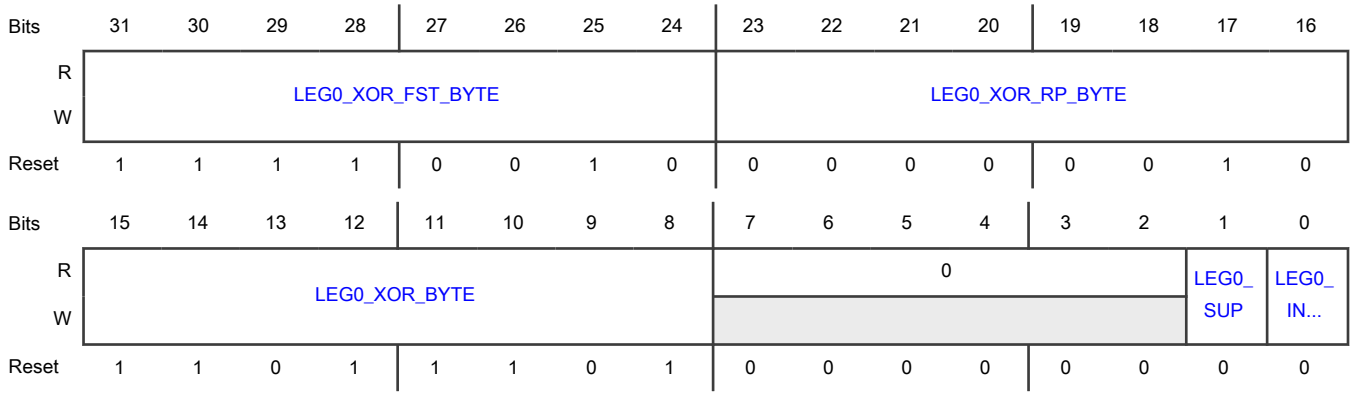
Field	Function
31-16 FEC_BSZ_OV	Value of the override in bits. It is for test purpose.
15-1 —	Reserved
0 FEC_BSZ_OV_B4SP_EN	Override of the FEC block size for data 0b - Disable Override actvie STD frame length from link layer 1b - Enable Override actvie STD frame length from link layer

52.4.4.1.2.5.23 LEG0 CONFIG (LEG0_CFG)

Offset

Register	Offset
LEG0_CFG	58h

Diagram



Fields

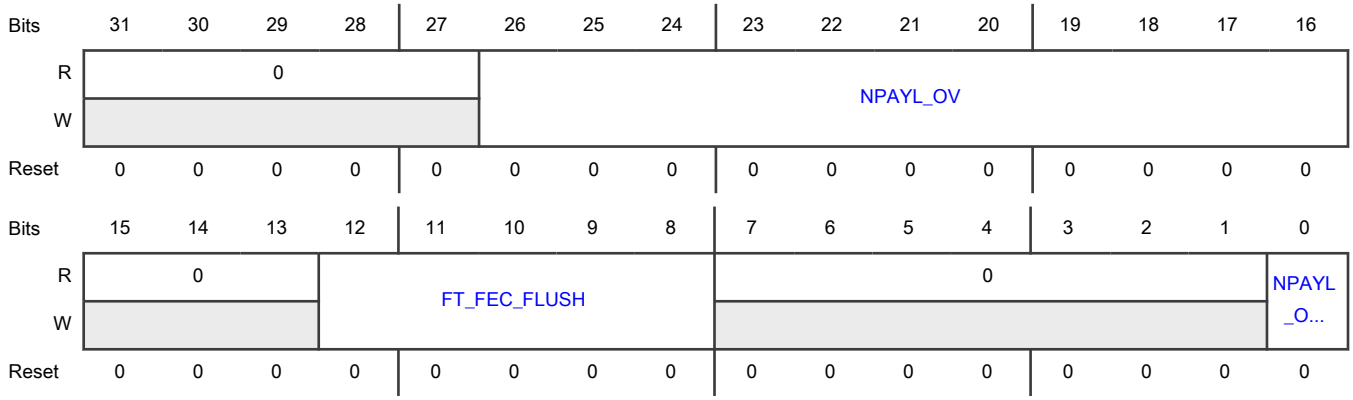
Field	Function
31-24 LEG0_XOR_FST_BYTE	FEC first byte masking
23-16 LEG0_XOR_RP_BYTE	LEG0 repeat bytes masking
15-8 LEG0_XOR_BYTE	LEG0 whitening masking byte
7-2 —	Reserved
1 LEG0_SUP	LEG0 support 0b - Disable LEG0 support 1b - Enable LEG0 support
0 LEG0_INV_EN	Whiten invert enable bit 0b - Disable whiten invert for LEG0 1b - Enable whiten invert for LEG0

52.4.4.1.2.5.24 OVERRIDE PAYLOAD (NPAYL_OVER_SZ)

Offset

Register	Offset
NPAYL_OVER_SZ	5Ch

Diagram



Fields

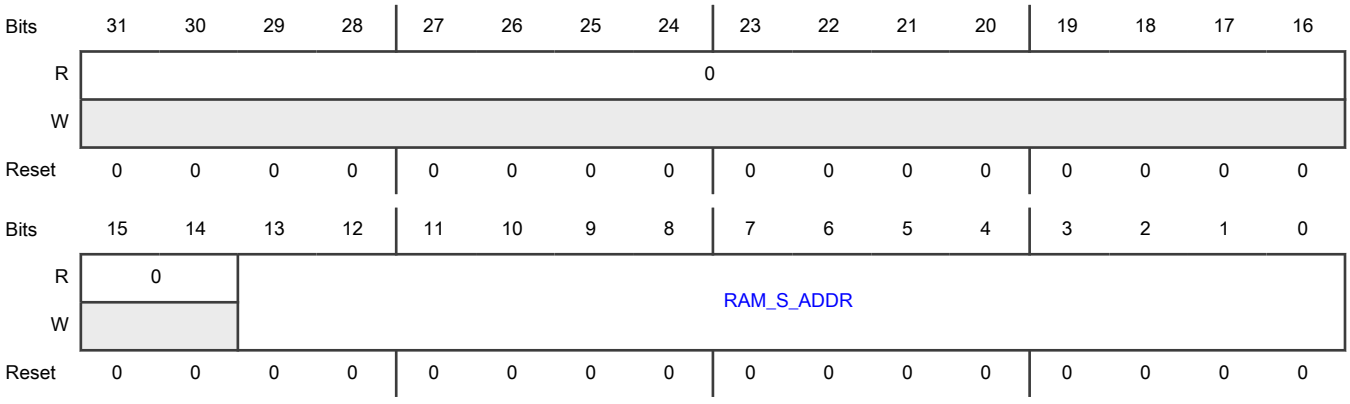
Field	Function
31-27 —	Reserved
26-16 NPAYL_OV	
15-13 —	Reserved
12-8 FT_FEC_FLUSH	Value to override the payload length (bits) For test purpose only
7-1 —	Reserved
0 NPAYL_OV_EN	Override the internal payload length computation 0b - Disable override the internal payload length 1b - Enable override the internal payload length

52.4.4.1.2.5.25 PACKET RAM SOURCE ADDRESS (RAM_S_ADDR)

Offset

Register	Offset
RAM_S_ADDR	64h

Diagram



Fields

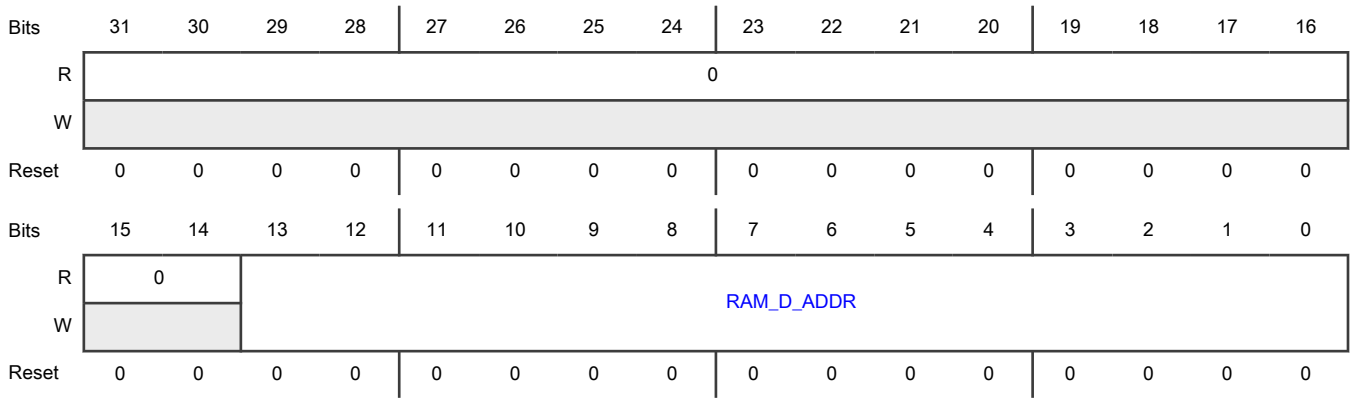
Field	Function
31-14 —	Reserved
13-0 RAM_S_ADDR	Packet RAM source address. This address is ram physical address.

52.4.4.1.2.5.26 PACKET RAM DESTINATION ADDRESS (RAM_D_ADDR)

Offset

Register	Offset
RAM_D_ADDR	68h

Diagram



Fields

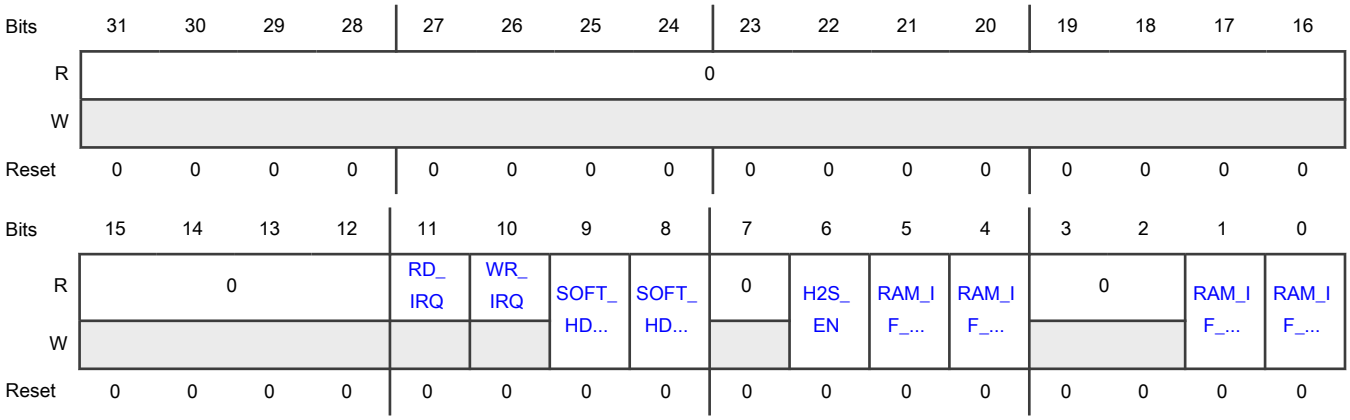
Field	Function
31-14 —	Reserved
13-0 RAM_D_ADDR	Packet RAM destination address, this address is ram physical address.

52.4.4.1.2.5.27 PACKET RAM INTERFACE CONFIG (RAM_IF_CFG)

Offset

Register	Offset
RAM_IF_CFG	6Ch

Diagram



Fields

Field	Function
31-12 —	Reserved
11 RD_IRQ	Read to RAM complete flag 0b - Reading to RAM not complete 1b - Reading to RAM complete
10 WR_IRQ	Write to RAM complete flag 0b - Writing to RAM not complete 1b - Writing to RAM complete
9 SOFT_HD_SEL_WR	Soft and hard bit selection of read operation 0b - Hard bit selection of read operation 1b - Soft bit selection of read operation
8 SOFT_HD_SEL_RD	Soft and hard bit selection of write operation 0b - Hard bit selection of write operation 1b - Soft bit selection of write operation
7	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
6 H2S_EN	Hard bit convert to soft bit enable 0b - Disable hard bit to soft bits conversion 1b - Enable hard bit to soft bits conversion
5 RAM_IF_IC	RAM interface interrupt clear 0b - To do nothing to RAM interface interrupt 1b - To clear RAM interface interrupt
4 RAM_IF_IE	RAM interface interrupt enable bit 0b - Disable RAM interface interrupt 1b - Enable RAM interface interrupt
3-2 —	Reserved
1 RAM_IF_RX_EN	RAM interface RX enable 0b - Disable RAM interface RX 1b - Enable RAM interface RX
0 RAM_IF_TX_EN	RAM interface TX enable bit 0b - Disable RAM interface TX 1b - Enable RAM interface TX

52.4.4.1.3 SFA32K(Signal Frequency Analyser of 32KHz Clock)

52.4.4.1.3.1 Overview

The 32KHz clock source is used as the sleep timer clock source inside RFMC and Bluetooth LE Link Layer. So accuracy of the sleep timer depends on the accuracy of the 32KHz clock in the chip. In order to achieve a higher accuracy 32KHz clock source, the SFA module is used to measure the 32KHz clock source with RF OSC clock. The measurement result can be used by software to calibrate the 32KHz clock source.

The radio SFA module can be configured to measure the 32KHz clock source by a hardware trigger when radio exists from low power mode.

52.4.4.1.3.2 Overview

The Signal Frequency Analyser (SFA) provides functionality to perform measurements of clock frequency, clock period, and time between triggers.

52.4.4.1.3.2.1 Block Diagram

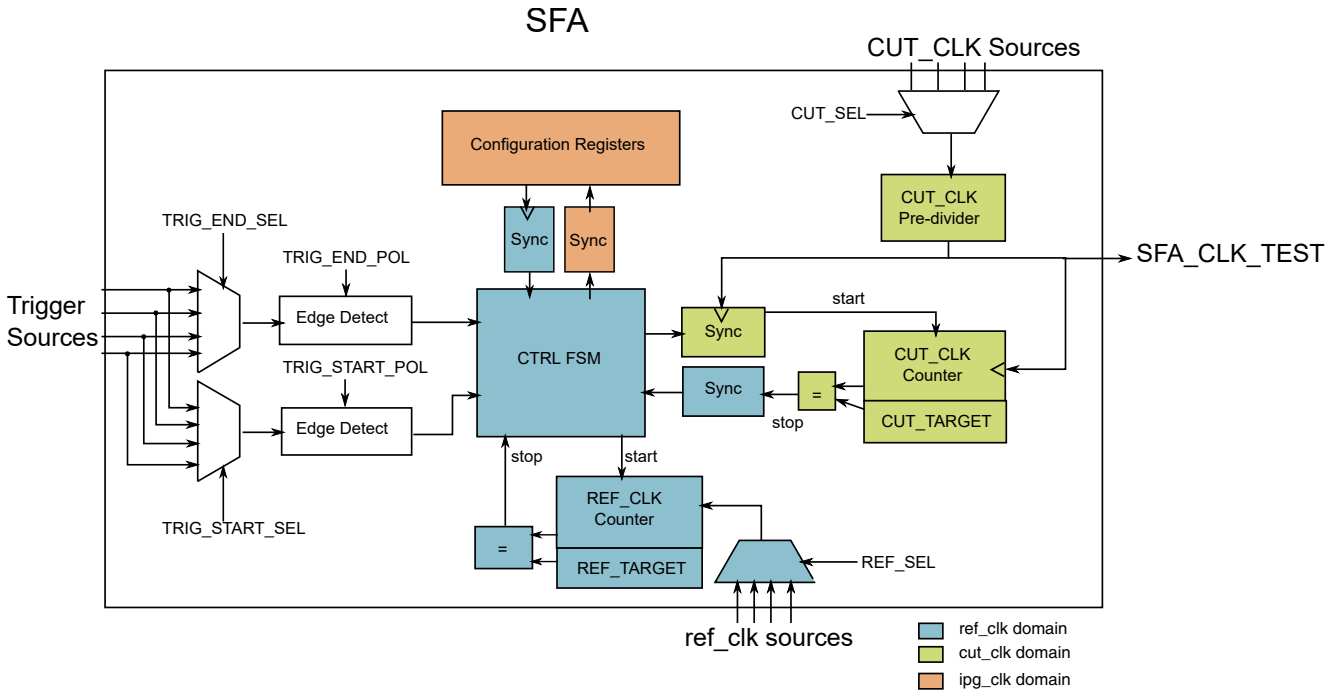


Figure 267. Signal Frequency Analyser Block Diagram

52.4.4.1.3.2.2 Features

The Signal Frequency Analyser includes the following features.

- Two 32-bit counters, one connected to the bus clock (REF clock), which serves as a reference, and the other connected to the clock under test (CUT).
- An 8-bit predivider is provided to divide down the CUT clock.
- A target count register for both the REF clock and CUT clock are provided to stop the counters.
- Trigger measurement mode to analyse the time between 2 edges (with configurable polarity) of either the same or different triggers. Note, the trigger pulse width must be at least 2 ref_clk cycles long to be properly registered.
- Selectable measurement modes to optimize test time by analysing either the frequency (for fast clocks), or the period (for slow clocks) of the CUT clock.
- Selectable sources for reference clock and CUT clock
- Support interrupt for CUT clk freq exceed setting freq limit

52.4.4.1.3.3 Functional Description

The Signal Frequency Analyser can be used to measure frequencies, periods, and time between events. The following use cases demonstrate how these capabilities can be used.

52.4.4.1.3.3.1 Frequency Measurements

The Signal Frequency Analyser can be used to measure the frequency of CUT CLK. The use cases below demonstrate how these capabilities can be used.

In general, either of the following methods may then be used to measure clock frequencies. To measure in frequency mode, register bit CTRL[MODE] must be set to 0x0 or 0x1.

Method 1 (when CUT frequency < REF frequency)(CTRL[MODE] == 0x0):

1. Set CUT and REF count targets
2. Perform a dummy write to REF counter (clears the *COUNT, *STARTED and *STOPPED bits)
3. Poll the CUT_STOPPED bit to make sure it cleared
4. The next step can be completed using 2 different methods depending on the value of CTRL[SFA_TRIG_MEAS_EN]:
    a. SFA_TRIG_MEAS_EN = 0b0

       Perform a dummy write to the CUT counter. This triggers:

        i. REF counter starts counting immediately

        ii. CUT counter starts counting after a ~2 CUT cycle sync delay

    b. SFA_TRIG_MEAS_EN = 0b1

       The SFA will stall processing until the trigger edge selected by CTRL[TRIG_START_SEL] and CTRL[TRIG_START_POL] has been received. Once the trigger has been received, the following sequence will occur:

        i. REF counter starts counting immediately

        ii. CUT counter starts counting after a ~2 CUT cycle sync delay
5. When CUT counter reaches 1, MEAS_STARTED bit asserts after a ~2 REF cycle sync delay
6. Upon assertion of MEAS_STARTED, the REF_COUNT_ST_SAVED (a saved version of the current REF counter, which keeps running) will be written.
7. When CUT counter reaches target, CUT_STOPPED bit asserts after a ~2 REF cycle sync delay
8. Upon assertion of CUT_STOPPED, the REF_COUNT_END_SAVED (which is a saved version of the actual REF counter, which keeps running) will be written.
9. The measurement is considered complete once the REF_STOPPED and CUT_STOPPED bits have been asserted in the CUT_CNT register. The user can either poll the REF_STOPPED and CUT_STOPPED bits or enable SFA_IRQ_EN. If SFA_IRQ_EN is asserted than an interrupt will be issued when the measurement is complete.
10. Calculate CUT frequency by using the difference in the REF_COUNT_END_SAVED and REF_COUNT_ST_SAVED in comparison to the CUT target
11. If the value (REF_COUNT_END_SAVED-REF_COUNT_ST_SAVED) greater than the value setting in REG_HIGH_LIMIT_CNT , it means the measured cut clk frequency is less than minimum limit,if according enable bit is set, the FREQ_LT_MIN_IRQ will be generated
12. If the value (REF_COUNT_END_SAVED-REF_COUNT_ST_SAVED) less than the value setting in REG_LOW_LIMIT_CNT , it means the measured cut clk frequency is greater than maximum limit, if according enable bit is set, the FREQ_GT_MAX_IRQ will be generated

The following two figures represent two possible cases for frequency measurement with CTRL[MODE] = 0x0. The first image illustrates a complete frequency measurement. Note, it is assumed that the user has started the measurement some time before this waveform snapshot was taken. Therefore, the register writes to CUT counter and REF counter are omitted. In this example the CUT target of 0x0000_FFFF is reached before the REF target count is reached. The two significant measurement events occur when MEAS_STARTED is asserted and REF_CNT_STOPPED is asserted.

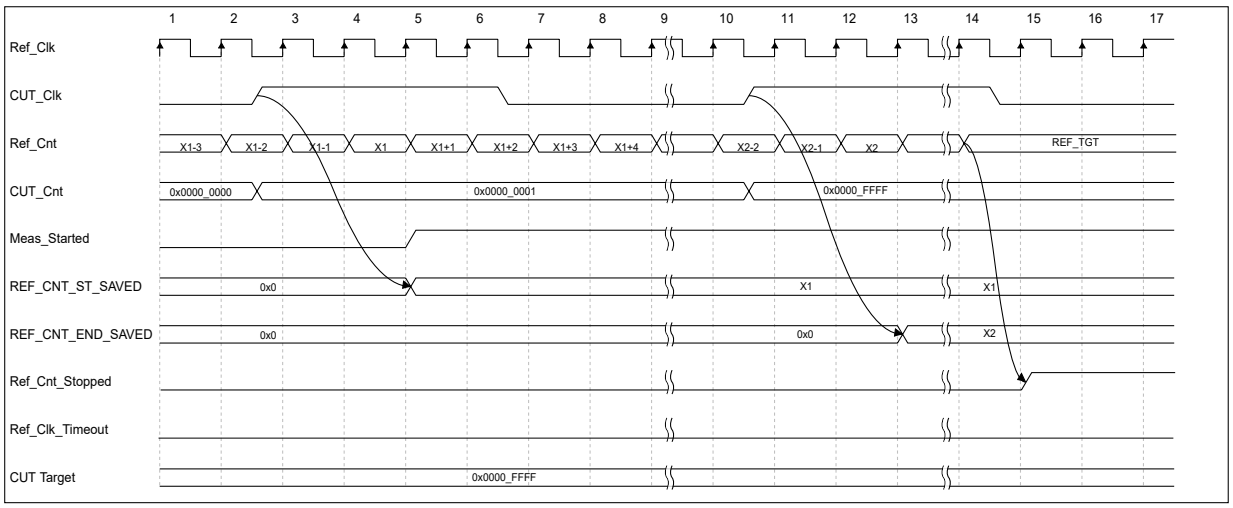


Figure 268. CUT Frequency Measurement with CUT Freq less than REF Freq

The next image illustrates the case when the frequency measurement is unable to be completed before REF_CNT_STOPPED is asserted. This is known as a reference clock timeout. In this example the CUT Target is set to 0x0000_FFFF; however, this value is never reached before REF_CNT = REF_CNT_STOPPED.

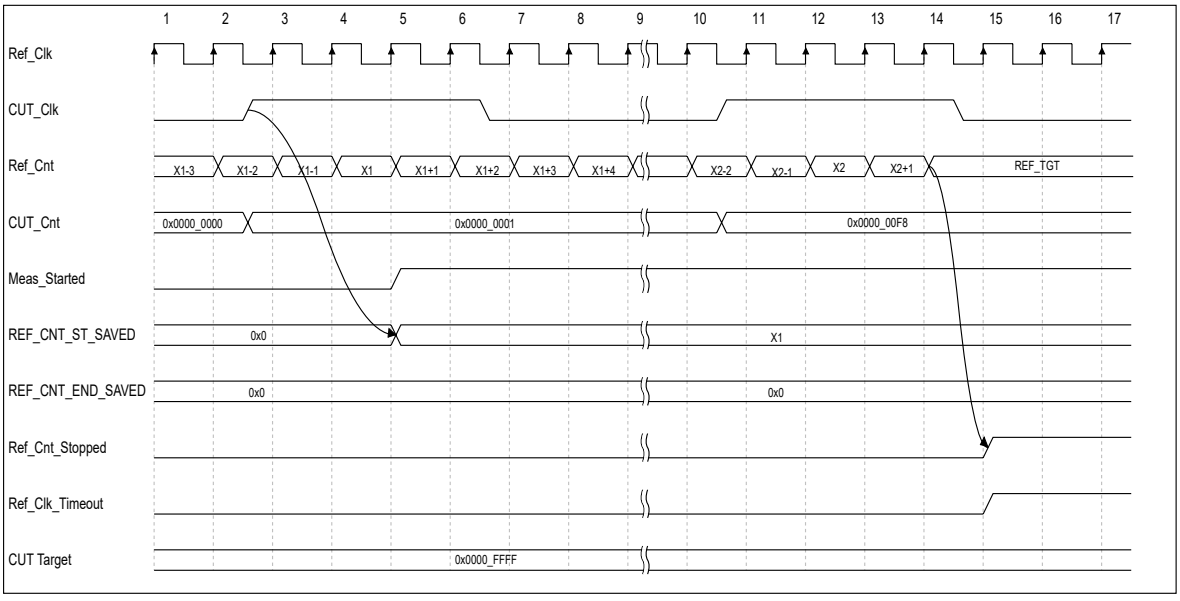


Figure 269. CUT Frequency Measurement Timeout with CUT Freq less than REF Freq

Method 2 (when CUT frequency > REF frequency)(CTRL[MODE] == 0x1):

1. Set CUT and REF count targets (Note: recommend CUT target be set to 0xFFFF_FFFF. There is no CUT_CNT_TIMEOUT flag.)
2. Perform a dummy write to REF counter (clears the *COUNT, *STARTED and *STOPPED bits)
3. Poll the CUT_STOPPED bit to make sure it is clear
4. The next step can be completed using 2 different methods depending on the value of CTRL[SFA_TRIG_MEAS_EN]:
    a. SFA_TRIG_MEAS_EN = 0b0

       Perform a dummy write to the CUT counter. This triggers:

        i. REF counter starts counting immediately

        ii. CUT counter starts counting after a ~2 CUT cycle sync delay

    b. SFA_TRIG_MEAS_EN = 0b1

       The SFA will stall processing until the trigger edge selected by CTRL[TRIG_START_SEL] and CTRL[TRIG_START_POL] has been received. Once the trigger has been received, the following sequence will occur:

        i. REF counter starts counting immediately

        ii. CUT counter starts counting after a ~2 CUT cycle sync delay
5. When REF_COUNT reaches target, the CUT counter stops after a ~2 CUT cycle sync delay, and the CUT_STOPPED bit then sets after a ~2 REF cycle sync delay
6. Calculate CUT frequency by using the CUT_COUNT and REF target
7. To determine when the measurement has been completed, the user can either poll the CUT_STOPPED bit or enable SFA_IRQ_EN. An interrupt will be issued, if SFA_IRQ_EN is asserted and when both CUT_STOPPED and REF_STOPPED are asserted.
8. If the value CUT_CNT is greater than the value setting in CUT_HIGH_LIMIT_CNT , it means the measured cut clk frequency or trigger period is greater than maximum limit. If FREQ_GT_MAX interrupt flag is set, FREQ_GT_MAX IRQ will be generated.
9. If the value CUT_CNT less than the value setting in CUT_LOW_LIMIT_CNT , it means the measured cut clk frequency or trigger period is less than minimum limit, if according enable bit is set, the FREQ_LT_MIN_IRQ will be generated

The following image represents an example frequency measurement with CTRL[MODE] = 0x1. In this case, the CUT frequency should be greater than the REF frequency. This measurement is used to count the number of CUT_CLK cycles that occur in REF_TARGET REF clk cycles. Note that registers REF_CNT_*_SAVED should not be read during this mode. It can be implied that REF_CNT_END_SAVED - REF_CNT_ST_SAVED = REF_TARGET.

When performing a CTRL[MODE] = 0x1 measurement, the CUT_TARGET should be set to the max value to prevent a CUT_TARGET timeout. The measurement will end when REF_CNT reaches the value stored in REF_TARGET. If CUT_TARGET is reached before REF_TARGET is reached, this will indicate an error condition. There is no flag to indicate a CUT_TARGET timeout. This is why CUT_TARGET should be set to the maximum value. The CUT_CNT timeout occurs when CUT_CNT is equal to CUT_TARGET. To detect that the CUT_CNT timeout did not occur, the CUT_CNT register should be less than CUT_TARGET at the end of a CTRL[MODE] = 0x1 measurement. When CUT_CNT is less than CUT_TARGET, the measurement stops when REF_TARGET is met.

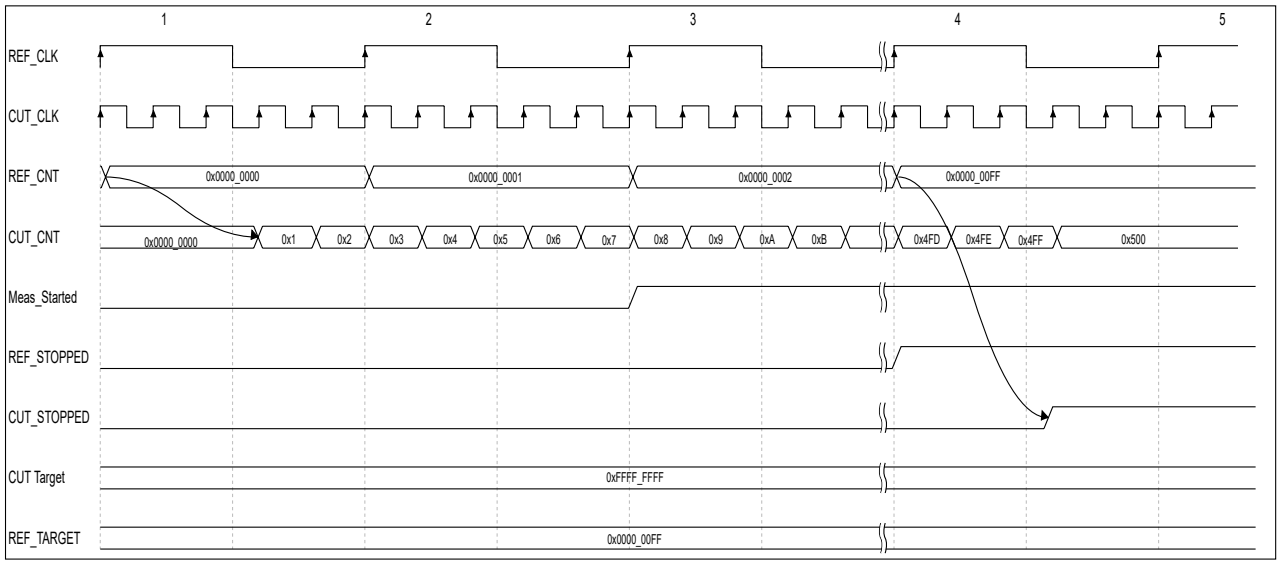


Figure 270. REF Frequency Measurement: CUT Freq greater than REF Freq

52.4.4.1.3.3.2 Clock Period Measurements

The signal frequency analyser has the capability to measure the period of CUT clock. To operate in clock period mode, the register CTRL[MODE] must be set to 0x2. This mode is used to count the number of REF CLK periods which occur during one period of CUT CLK.

Clock Period Measurement (CTRL[MODE] == 0x2). This mode is used to measure the period of CUT clock. It is assumed that CUT frequency < < REF frequency:

1. Select the source of CUT clock with CTRL[CUT_SEL], and configure any CUT pre-divide with CTRL[CUT_PREDIV].
2. Select a value for REF_TARGET. This value acts as a time-out function. The test will always end when REF_CNT == REF_TARGET.
3. Perform a dummy write to the REF counter. This triggers:
    a. REF counter starts counting immediately
    b. All previous counters will be cleared.
4. The MEAS_STARTED bit will indicate when the measurement sequence has begun.
5. The MEAS_STARTED bit is asserted on the first rising edge of the CUT after the dummy write to the REF counter. Upon assertion of MEAS_STARTED, the REF_COUNT_ST_SAVED (which is a saved version of the actual REF counter, which keeps running) will be written with the current REF_CNT value.
6. The REF_STOPPED bit will indicate when the measurement sequence has been completed.
7. Upon completion of one full period measurement (performed from one rising edge to the next rising edge), the REF_COUNT_END_SAVED (which is a saved version of the actual REF counter, which keeps running) will be written with the current value of REF_CNT.
8. Note that REF_STOPPED may be set before the measurement has been completed. This may indicate the REF_CNT reached REF_TARGET before receiving a full period of CUT CLK. In this case, the CNT_STAT[REF_CNT_TIMEOUT] will be set to 0b1 to indicate that a time-out occurred.

9. Calculate the period width by using the difference between the values of REF_CNT_END_SAVED and REF_COUNT_ST_SAVED.
10. To determine when the measurement has been completed, the user can either poll the REF_STOPPED bit or enable SFA_IRQ_EN. If SFA_IRQ_EN is asserted than an interrupt will be issued when REF_STOPPED is asserted.
11. If the value (REF_COUNT_END_SAVED-REF_COUNT_ST_SAVED) greater than the value setting in REG_HIGH_LIMIT_CNT , it means the measured cut clk frequency is less than minimum limit,if according enable bit is set, the FREQ_LT_MIN_IRQ will be generated
12. If the value (REF_COUNT_END_SAVED-REF_COUNT_ST_SAVED) less than the value setting in REG_LOW_LIMIT_CNT , it means the measured cut clk frequency is greater than maximum limit, if according enable bit is set, the FREQ_GT_MAX_IRQ will be generated

Figure 271 illustrates a CUT Clk period measurement cycle. It is assumed this timing diagram occurs sometime after beginning the measurement (dummy write to REF counter) with CTRL[MODE] == 0x2. In addition, it is assumed that SFA_IRQ_EN is asserted. In Figure 271 , the REF_TARGET register was set sufficiently high to receive a full period of CUT before REF_CNT timeout.

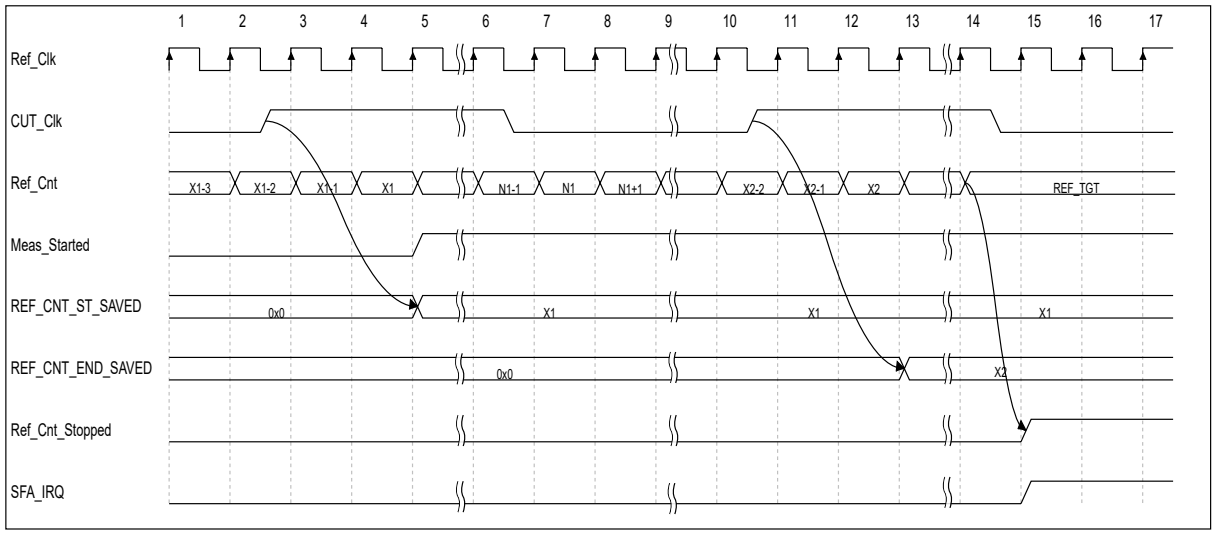


Figure 271. CUT Clk Period Measurement

Figure 272 illustrates what happens when REF_CNT reaches REF_TARGET before the SFA receives a full period of CUT Clk. The result will be an incomplete measurement, and REF_CNT_TIMEOUT will be asserted along with REF_STOPPED.

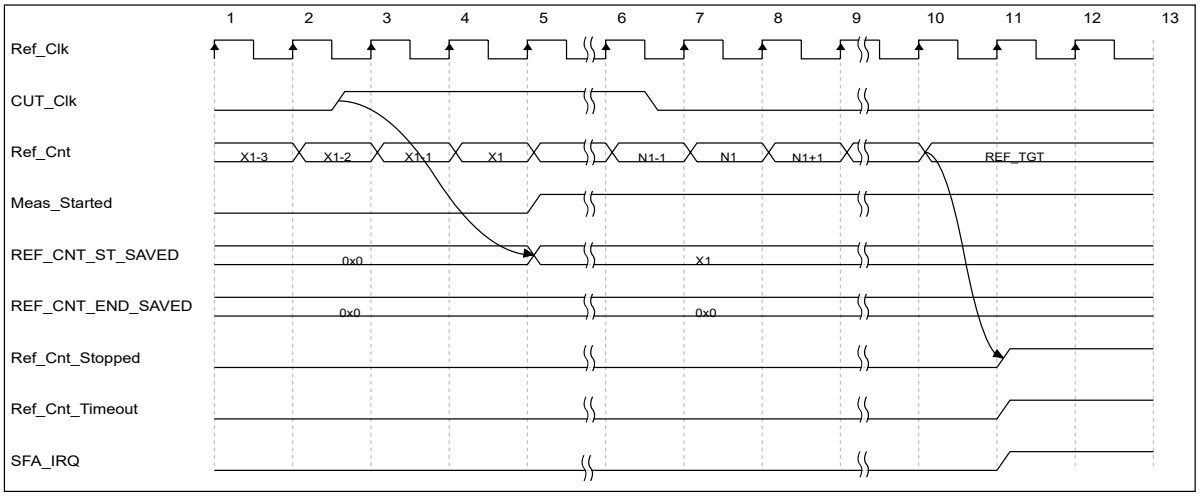


Figure 272. CUT Clk Period Timeout

52.4.4.1.3.3.3 Trigger Based Measurements

Triggered Measurement (CTRL[MODE] == 0x3). This mode is used to measure the time between two signal events. This measurement will count the number of REF clock periods between two triggers. Both the start trigger and end trigger can be selected from a bus interface. To select the start and end triggers, program the CTRL[TRIG_END_SEL] and CTRL[TRIG_START_SEL] fields. In addition, the polarity of each trigger can be selected to begin on rising or falling edge by programming CTRL[TRIG_END_POL] and CTRL[TRIG_START_POL]. It is assumed that the time between edges will be > > REF clock period:

1. Select the signal source which will begin the measurement with CTRL[TRIG_START_SEL].
2. Select a the polarity for TRIG_START_SEL by programming CTRL[TRIG_START_POL]. This will determine if the sequence begins on a rising or falling edge of TRIG_START_SEL.
3. Select both the signal source and edge polarity that will end the measurement, with CTRL[TRIG_END_SEL] and CTRL[TRIG_END_POL].
4. Select a value for REF_TARGET. This value will act as a time-out feature for the current measurement. The measurement will end when REF_CNT = REF_CNT_TARGET.
5. Perform a dummy write to the REF counter. This triggers:
    a. REF counter starts counting immediately
    b. All previous counters will be cleared.
6. The MEAS_STARTED bit will indicate when the selected TRIG_START_SEL edge has been triggered.
7. Upon assertion of MEAS_STARTED, REF_COUNT_ST_SAVED (which is a saved version of the actual REF counter, which keeps running) will be written.
8. The REF_STOPPED bit will indicate when the selected EDGE_COUNT_END edge has been triggered.
9. Upon assertion of REF_STOPPED, REF_CNT_END_SAVED (which is a saved version of the actual REF counter) will be written.
10. Note that REF_STOPPED may be set before the measurement has been completed. This may indicate the REF_TARGET is too low for the required measurement time. In this case, the CNT_STAT[REF_CNT_TIMEOUT] will be set to 0b1 to indicate that either TRIG_END_SEL or TRIG_START_SEL was never received.

11. Calculate the edge to edge time using the difference between the values of REF_COUNT_END_SAVED and REF_CNT_ST_SAVED.
12. To determine when the measurement has been completed, the user can either poll the REF_STOPPED bit or enable SFA_IRQ_EN. If SFA_IRQ_EN is asserted than an interrupt will be issued when REF_STOPPED is asserted.
13. If the value (REF_COUNT_END_SAVED-REF_COUNT_ST_SAVED) greater than the value setting in REG_HIGH_LIMIT_CNT , it means the measured trigger period is greater than maximum limit,if according enable bit is set, the FREQ_LT_MIN_IRQ will be generated
14. If the value (REF_COUNT_END_SAVED-REF_COUNT_ST_SAVED) less than the value setting in REG_LOW_LIMIT_CNT , it means the measured trigger period is less than minimum limit, if according enable bit is set, the FREQ_GT_MAX_IRQ will be generated

The following two waveforms illustrate two possible cases for trigger based measurements. Note that it is assumed that the user completed the above steps 1 through 5 before these waveforms begin. In addition, it is assumed that SFA_IRQ_EN is asserted. The first waveform shows a completed trigger based measurement. The second waveform illustrates a ref counter timeout when attempting to complete a trigger based measurement. Notice the assertion of Ref_Cnt_Timeout upon completing the measurement cycle.

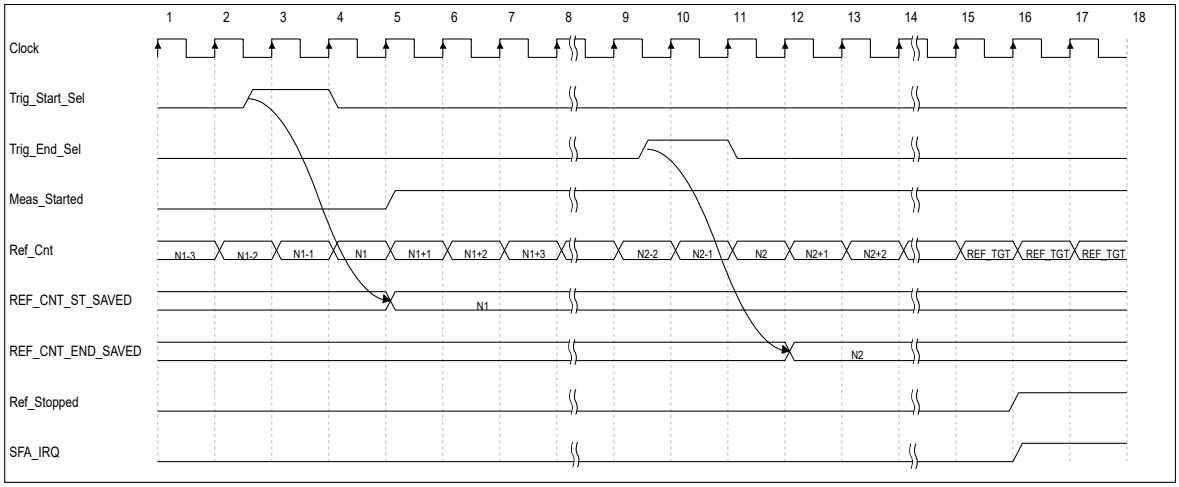


Figure 273. Trigger Based Measurement

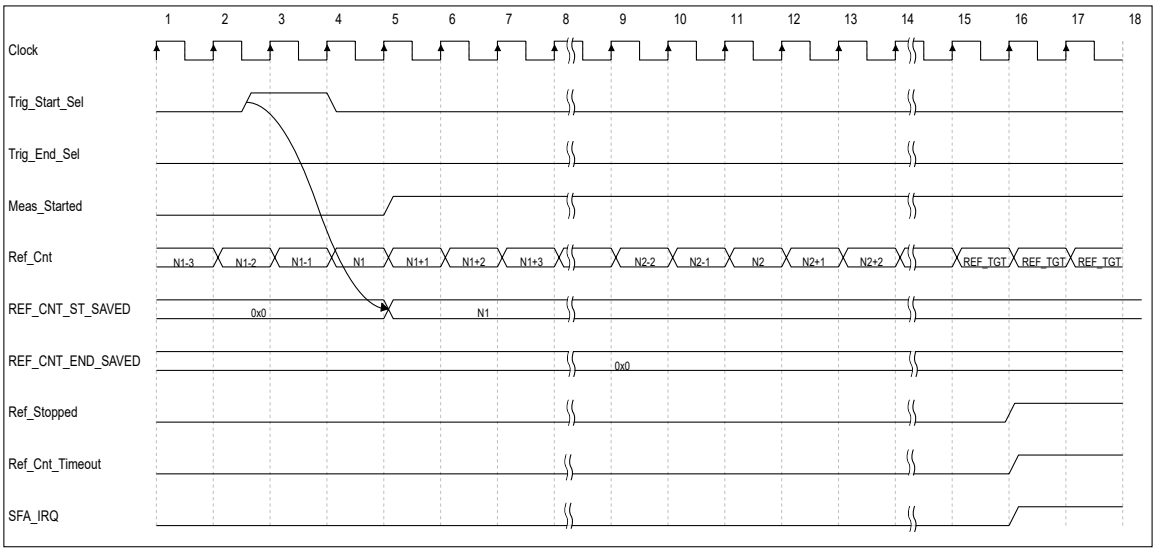


Figure 274. Trigger Based Measurement Timeout

52.4.4.1.3.3.4 Clocking

The SFA has several clock sources, for internal behaviour, register access, and for frequency measurement. Their role during the frequency measurement is covered in the Functional Description chapter. They are listed in the table below:

Table 450. SFA Clocks

Input	Description
ipg_clk	IPS System Bus Clock
ipg_clk_s	IPS System Bus Clock for pmodel
ipt_clk	High Speed TestClock
sfa_clk_inputs	Clocks under Test
sfa_ref_clk_inputs	Clocks for Reference Clock choices

52.4.4.1.3.3.5 Interrupts

This module has single interrupt: ipi_init. This interrupt is asserted when:

- CNT_STAT[4] is set and CTRL [5] is enabled
- CNT_STAT[5] is set and CTRL2[16] is enabled
- CNT_STAT[6] is set and CTRL2[17] is enabled

52.4.4.1.3.4 Memory Map/Register Definition

52.4.4.1.3.4.1 Signal Frequency Analyser register descriptions

52.4.4.1.3.4.1.1 Signal_Frequency_Analyser memory map

RADIO.RF_SFA.RF_SFA base address: 48A0_6300h

Offset	Register	Width (In bits)	Access	Reset value
0h	Signal Frequency Analyser (SFA) Control (CTRL)	32	RW	0000_0000h
8h	Signal Frequency Analyser Count Status Register (CNT_STAT)	32	RW	0000_0000h
Ch	Signal Frequency Analyser Clock Under Test Counter (CUT_CNT)	32	RW	0000_0000h
10h	Signal Frequency Analyser Reference Clock Counter (REF_CNT)	32	RW	0000_0000h
14h	Signal Frequency Analyser Clock Under Test Target Count (CUT_TARGET)	32	RW	FFFF_FFFFh
18h	Signal Frequency Analyser Reference Clock Target Count (REF_TARGET)	32	RW	FFFF_FFFFh
1Ch	Signal Frequency Analyser Reference Clock Count Start Saved Register (REF_CNT_ST_SAVED)	32	R	0000_0000h
20h	Signal Frequency Analyser Reference Clock Count End Saved Register (REF_CNT_END_SAVED)	32	R	0000_0000h
24h	Extended control register for SFA (CTRL2)	32	RW	0000_0000h
28h	Record the low limit reference clock count (REF_LOW_LIMIT_CNT)	32	RW	0000_0000h
2Ch	This register record the low limit of ref clk counter (REF_HIGH_LIMIT_CNT)	32	RW	0000_0000h
30h	Record the CUT clock low limit counter (CUT_LOW_LIMIT_CNT)	32	RW	0000_0000h
34h	Record high limit count of cut clock (CUT_HIGH_LIMIT_CNT)	32	RW	0000_0000h

52.4.4.1.3.4.1.2 Signal Frequency Analyser (SFA) Control (CTRL)

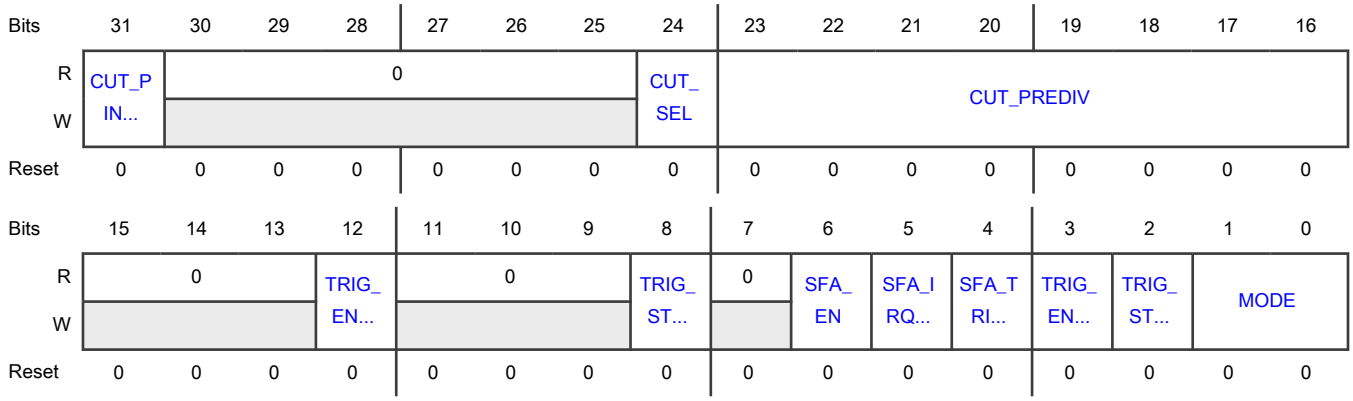
Offset

Register	Offset
CTRL	0h

Function

The SFA Control register contains fields to select both the type of measurement and the signal sources to be measured. The measurement mode will determine whether the SFA performs a frequency, period, or trigger based measurement.

Diagram



Fields

Field	Function
31 CUT_PIN_EN	CUT_PIN_EN This register field controls the connection of the clock under test to an external pin.
30-25 —	Reserved
24 CUT_SEL	CUT_SEL These bits control which SoC clock is connected to the clock under test counter.
23-16 CUT_PREDIV	CUT_PREDIV The CUT_PREDIV 8-bit field provides an integer division of the input CUT signal prior to the CUT counter. Only integer values are implemented and the least significant bit is ignored. 0000_0000b - No Divide 0000_0001b - No Divide 0000_0010b - Divide by 2 0000_0011b - Divide by 2 0000_0100b - Divide by 4 0000_0101b - Divide by 4 0000_0110b - Divide by 6 0000_0111b - Divide by 6 0000_1000b - Divide by 8 0000_1001b - Divide by 8 0000_1010b-1111_1101b - Divide by CUT_PREDIV - CUT_PREDIV%2 1111_1110b - Divide by 254 1111_1111b - Divide by 254

Table continues on the next page...

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Field	Function
15-13 —	Reserved
12 TRIG_END_SEL	Signal MUX For Trigger Based Measurement End This bit selects which signal will be used to commence a trigger based measurement. An edge of this signal will act as a trigger to end the measurement sequence. Either rising edge or falling edge can be selected by programming TRIG_END_POL.
11-9 —	Reserved
8 TRIG_START_SEL	Signal MUX For Trigger Based Measurement Start This bit selects which signal will be used to start an edge to edge measurement. An edge of this signal will act as a trigger to begin the measurement sequence. Either rising edge or falling edge can be selected by programming EDGE_START_POL.
7 —	Reserved
6 SFA_EN	SFA Enable This bit is the general SFA Enable signal. To run any measurement, this signal must be set to 0b1. This signal must be set to 0b0 when modifying any clock inputs, clock divider values, or trigger selects. For example, prior to writing TRIG_END_POL, TRIG_START_POL, TRIG_START_SEL, TRIG_END_SEL, CUT_PREDIV, or CUT_SEL make sure that this bit is set to 0b0. 0b - The SFA is disabled. 1b - The SFA is enabled.
5 SFA_IRQ_EN	SFA Interrupt Enable This signal determines if interrupts are enabled for the SFA. When enabled, an interrupt will be issued upon completion of a measurement. 0b - Interrupts are disabled. 1b - Interrupts are enabled.
4 SFA_TRIG_MEAS_EN	SFA Triggered Measurement Enable The SFA can be triggered to start a new frequency measurement when operating with either MODE = 0x0 or MODE = 0x1. This register field will be inactive if MODE > 0x1. The start trigger will be selected with TRIG_START_SEL and the measurement will begin when the first edge is received with polarity TRIG_START_POL. Note, SFA_EN bit must be set prior to beginning any measurements. The startup process requires a dummy write to the REF_CNT register to enable trigger detection followed by a trigger from the selected source. Refer to section Frequency Measurements for more information. 0b - The measurement will start by default with a dummy write to the REF and CUT counters. 1b - The measurement will start after receiving a dummy write to the REF_CNT followed by receiving the trigger edge selected by TRIG_START_SEL and TRIG_START_POL.

Table continues on the next page...

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Field	Function
3 TRIG_END_POL	Trigger End Polarity This signal determines the polarity of the trigger signal which will end a trigger based measurement. 0b - Rising edge of TRIGER[TRIG_END_SEL] will end the measurement sequence. 1b - Falling edge of TRIGGER[TRIG_END_SEL] will end the measurement sequence.
2 TRIG_START_POL	Trigger Start Polarity This signal determines the polarity of the start signal when measuring in trigger mode. 0b - Rising edge of TRIGGER[TRIG_START_SEL] will begin the measurement sequence. 1b - Falling edge of TRIGGER[TRIG_START_SEL] will begin the measurement sequence.
1-0 MODE	MEASUREMENT MODE Measurement mode determines which type of timing measurement is performed. 00b - Frequency measurement performed with REF frequency > CUT Frequency. 01b - Frequency measurement performed with REF frequency < CUT Frequency. 10b - CUT period measurement performed. 11b - Trigger based measurement performed. Note, each trigger pulse must be held for at least 2 ref_clk cycles.

52.4.4.1.3.4.1.3 Signal Frequency Analyser Count Status Register (CNT_STAT)

Offset

Register	Offset
CNT_STAT	8h

Function

This register returns status flags to indicate the current state of the REF and CUT counters

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0									FREQ_LT...	FREQ_GT...	SFA_IRQ	REF_CNT...	MEAS_ST...	CUT_STO...	REF_STO...
W										W1C	W1C	W1C				
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-7 —	Reserved
6 FREQ_LT_MIN_IRQ	FREQ_LT_MIN interrupt flag FREQ_LT_MIN interrupt flag, it means the cut clk frequency is lower than minimum setting,or trigger measurement period is greater than maximum setting
5 FREQ_GT_MAX_IRQ	FREQ_GT_MAX interrupt flag FREQ_GT_MAX interrupt flag, it means the cut clk frequency is greater than maximum setting,or trigger measurement period is less than minimum setting
4 SFA_IRQ	SFA Interrupt Request This flag indicates that REF_CNT has reached REF_TARGET. More generally, this flag indicates that a measurement has been completed and an interrupt has been issued. Writing a 0x1 to this bit position will clear the interrupt request.
3 REF_CNT_TIMEOUT	Reference Counter Time Out This flag indicates the REF counter reached REF_TARGET before the desired measurement was completed. Every test will commence when REF_CNT == REF_TARGET. For measurement accuracy, this bit should be equal to 0b0 when REF_STOPPED == 0b1. This bit will be cleared on any write to REF_CNT when not performing a measurement.
2 MEAS_STARTED	Measurement Started Flag In frequency measurement mode, this flag indicates when the CUT counter has started counting. Set when CUT counter increments to 1. In period measurement mode, this flag indicates that the first edge of the CUT has been received for period measurement. In edge to edge signal measurement mode, this flag will indicate when TRIGGER[TRIG_START_SEL] has been received for measurement. This event will also push the REF_CNT to the REF_CNT_ST_SAVED register. This flag is only active during CTRL[MODE] == 0x0, 0x2 or 0x3. Cleared on any write to REF_CNT when not performing a measurement.
1 CUT_STOPPED	CUT_STOPPED This flag indicates the CUT counter has stopped counting. Set when either REF or CUT counter has reached its target. Cleared on any write to REF_CNT when not performing a measurement.
0 REF_STOPPED	REF_STOPPED This flag indicates the REF counter has stopped counting. Set when REF counter has reached its target. Cleared on any write to REF_CNT when not performing a measurement. This bit can be polled to indicate when a measurement is complete.

52.4.4.1.3.4.1.4 Signal Frequency Analyser Clock Under Test Counter (CUT_CNT)

Offset

Register	Offset
CUT_CNT	Ch

Function

This register contains the current count of the clock under test. Writes to this register will start the clock under test and reference counters. Counting will stop when either the count matches the contents of the clock under test target count register or when reference counter matches the reference target count register. Note, attempts to read this register before the CUT_STOPPED flag has set will return 0x0000_0000

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	CUT_CNT															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	CUT_CNT															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 CUT_CNT	CUT_CNT Current clock under test count. Writes to this register will start the clock under test and reference counters.

52.4.4.1.3.4.1.5 Signal Frequency Analyser Reference Clock Counter (REF_CNT)

Offset

Register	Offset
REF_CNT	10h

Function

This 32-bit register contains the current count of the reference clock. Writes to this register will clear the clock under test and reference counters. Counting will stop if the count matches the contents of the reference clock target count register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	REF_CNT															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	REF_CNT															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 REF_CNT	REF_CNT Current reference clock count. Writing to this register with any value will clear the clock under test and reference clock count and status flags registers.

52.4.4.1.3.4.1.6 Signal Frequency Analyser Clock Under Test Target Count (CUT_TARGET)

Offset

Register	Offset
CUT_TARGET	14h

Function

This register contains the target count for the clock under test. Both the reference and clock under test count will stop if the clock under test count matches the contents of this register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	CUT_TARGET															
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	CUT_TARGET															
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-0 CUT_TARGET	CUT_TARGET Target count for the clock under test. Note, a measurement of type MODE = 0x0 or 0x1 is not valid if CUT_TARGET = 0x00000000. This value must be set to an integer > 0x0 to perform a valid measurement.

52.4.4.1.3.4.1.7 Signal Frequency Analyser Reference Clock Target Count (REF_TARGET)

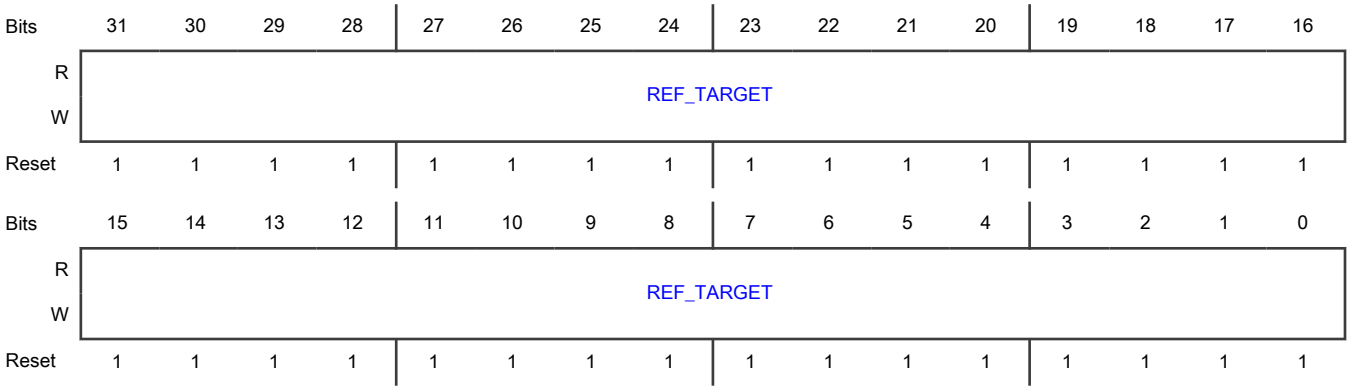
Offset

Register	Offset
REF_TARGET	18h

Function

This register contains the target count for the reference clock. Both the reference and clock under test count will stop if the reference clock count matches the contents of this register.

Diagram



Fields

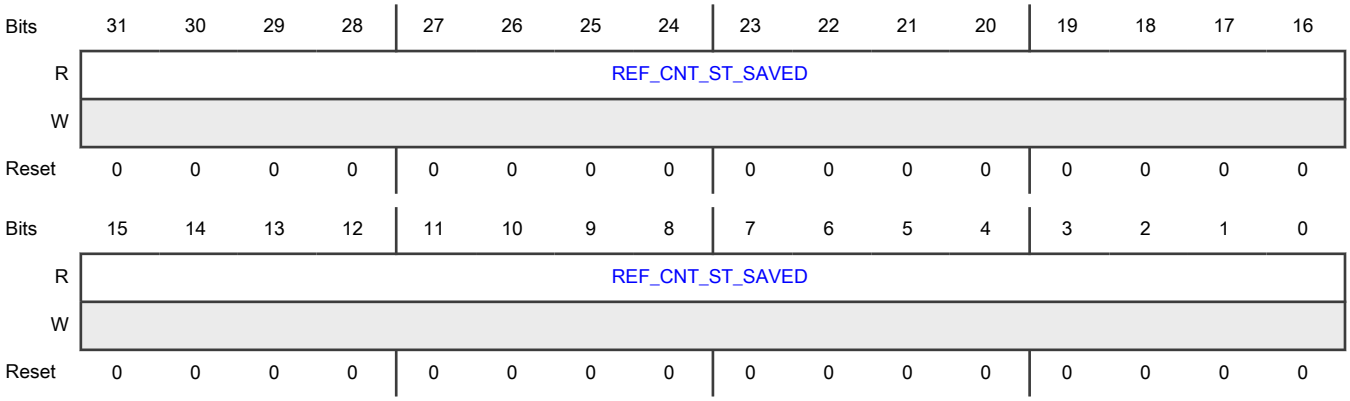
Field	Function
31-0 REF_TARGET	REF_TARGET Target count for the reference clock. Note, a measurement is not valid if REF_TARGET = 0x00000000. This value must be set to an integer > 0x0 to perform a valid measurement.

52.4.4.1.3.4.1.8 Signal Frequency Analyser Reference Clock Count Start Saved Register (REF_CNT_ST_SAVED)

Offset

Register	Offset
REF_CNT_ST_SAVED	1Ch

Diagram



Fields

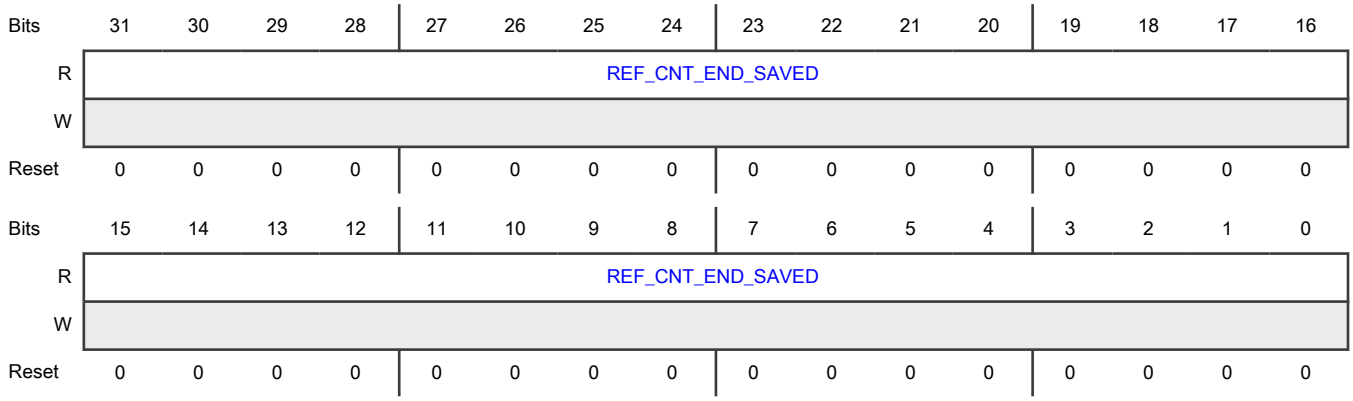
Field	Function
31-0 REF_CNT_ST_SAVED	REF_CNT_ST_SAVED Saved reference clock counter. This register is loaded with the current value of REF_CNT on assertion of the MEAS_STARTED flag. Note, during frequency measurements with CTRL[MODE] = 0x1, this register will be unused. It is assumed that the REF CNT start will be 0x0. This register is cleared on any write to REF_CNT when not performing a measurement.

52.4.4.1.3.4.1.9 Signal Frequency Analyser Reference Clock Count End Saved Register (REF_CNT_END_SAVED)

Offset

Register	Offset
REF_CNT_END_SAVED	20h

Diagram



Fields

Field	Function
31-0 REF_CNT_END_SAVED	REF_CNT_END_SAVED Saved reference clock counter. This register is loaded with the current value of REF_CNT on assertion of either the CUT_STOPPED or REF_STOPPED flags. Note, during frequency measurements with CTRL[MODE] = 0x1, this register will be unused. It is assumed that the REF_CNT_END will be equal to REF_TARGET. Cleared on any write to REF_CNT when not performing a measurement.

52.4.4.1.3.4.1.10 Extended control register for SFA (CTRL2)

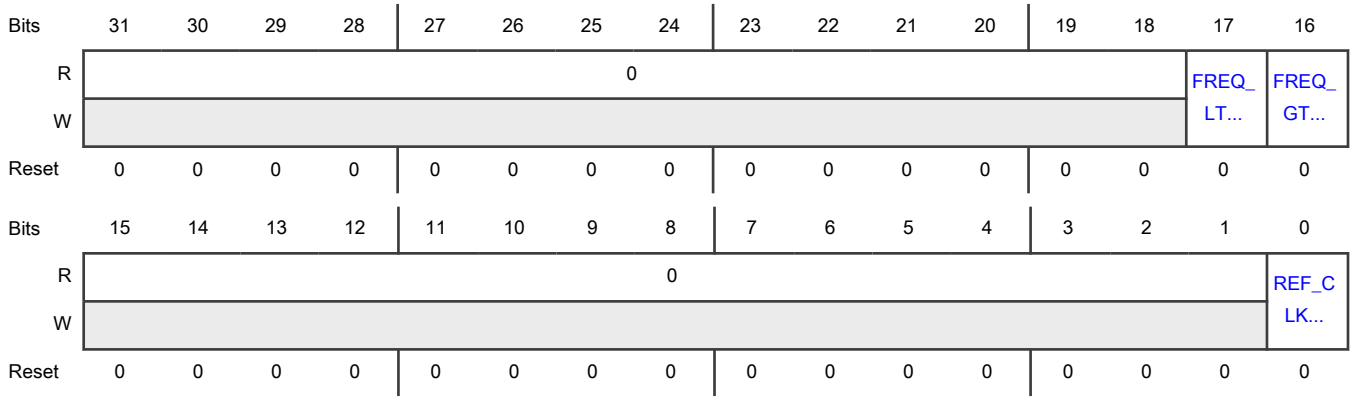
Offset

Register	Offset
CTRL2	24h

Function

This register an extended control register for SFA

Diagram



Fields

Field	Function
31-18 —	Reserved
17 FREQ_LT_MIN_IRQ_EN	FREQ_LT_MIN interrupt enable This bit used to enable FREQ_LT_MIN interrupt.
16 FREQ_GT_MAX_IRQ_EN	FREQ_GT_MAX interrupt enable This bit used to enable FREQ_GT_MAX interrupt.
15-1 —	Reserved
0 REF_CLK_SEL	Reference clock select These bits control which SoC clock is connected to the reference clock.

52.4.4.1.3.4.1.11 Record the low limit reference clock count (REF_LOW_LIMIT_CNT)

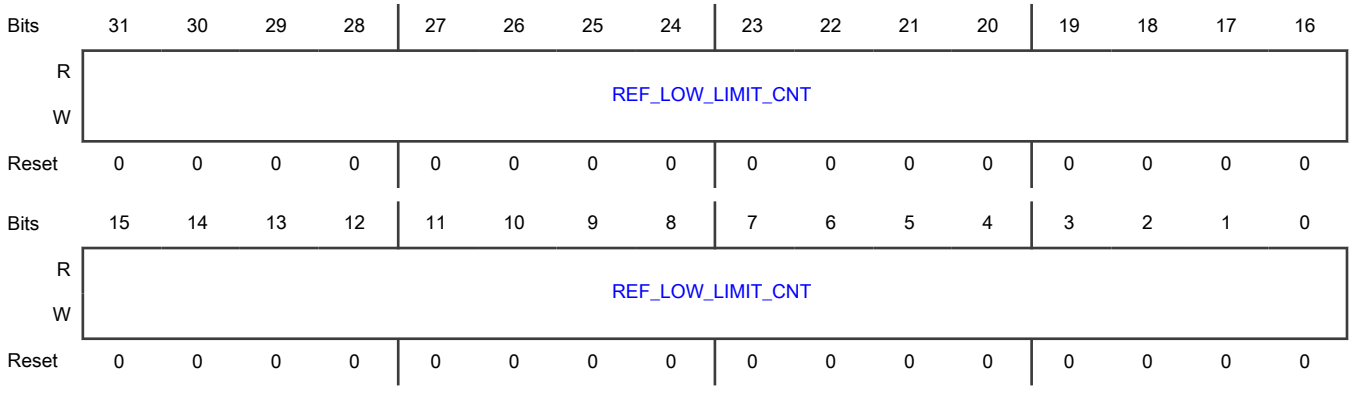
Offset

Register	Offset
REF_LOW_LIMIT_CNT	28h

Function

Record the low limit reference clock count.

Diagram



Fields

Field	Function
31-0 REF_LOW_LIMIT_CNT	Low limit reference clock count value Low limit reference clock count value. If reference clock counter number in measure period is less than this value. Then FREQ_GT_MAX interrupt will generate if according enable bit is set.

52.4.4.1.3.4.1.12 This register record the low limit of ref clk counter (REF_HIGH_LIMIT_CNT)

Offset

Register	Offset
REF_HIGH_LIMIT_CNT	2Ch

Function
This register record the low limit of ref clk counter.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	REF_HIGH_LIMIT_CNT															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	REF_HIGH_LIMIT_CNT															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 REF_HIGH_LIMIT_CNT	High limit reference clock count value High limit reference clock count value. If reference clock counter number in measure period is greater than this value. Then FREQ_LT_MIN interrupt will generate if according enable bit is set.

52.4.4.1.3.4.1.13 Record the CUT clock low limit counter (CUT_LOW_LIMIT_CNT)

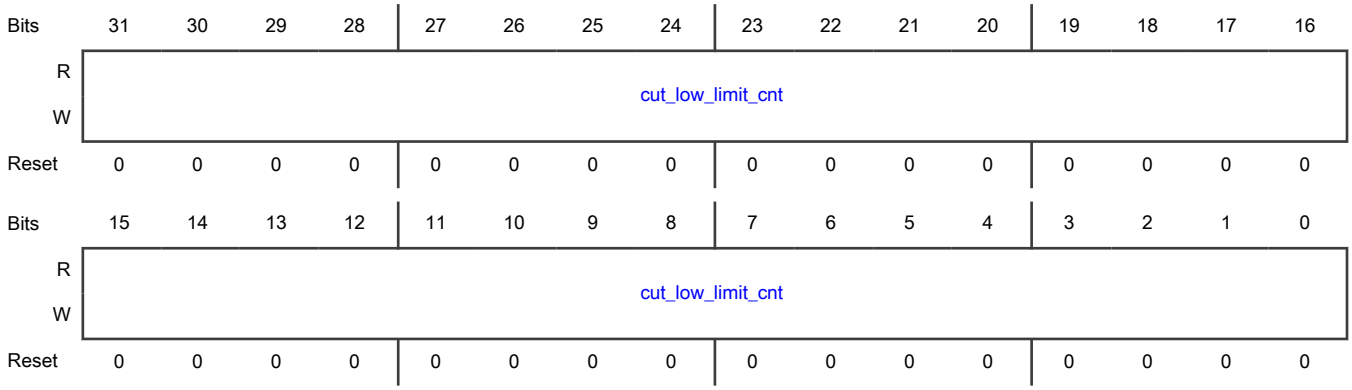
Offset

Register	Offset
CUT_LOW_LIMIT_CNT	30h

Function

Record the CUT clock low limit counter. This register is only used when CTRL.MODE=0x01

Diagram



Fields

Field	Function
31-0 cut_low_limit_cnt	Low limit cut clock count value Low limit cut clock count value. If cut clock counter number in measure period is less than this value. Then FREQ_LT_MIN interrupt will generate if according enable bit is set.

52.4.4.1.3.4.1.14 Record high limit count of cut clock (CUT_HIGH_LIMIT_CNT)

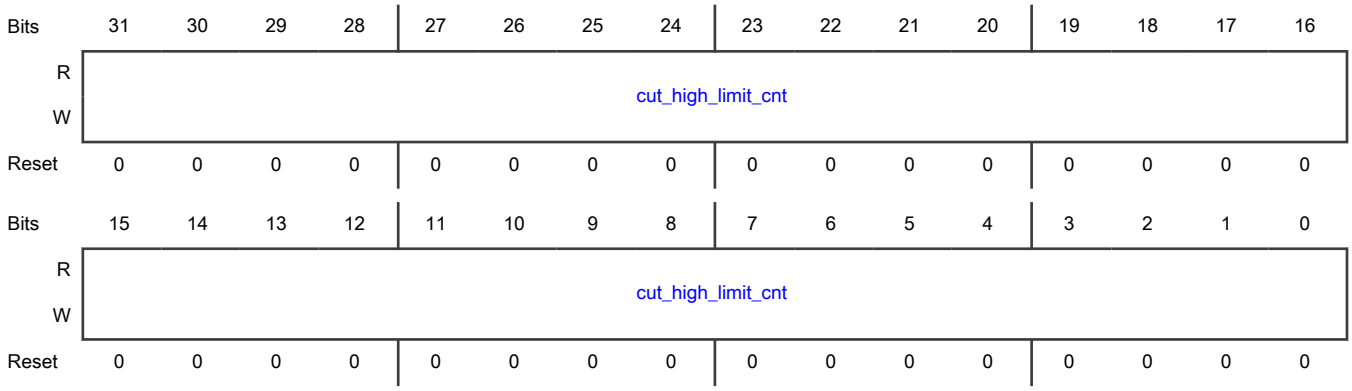
Offset

Register	Offset
CUT_HIGH_LIMIT_CNT	34h

Function

Record high limit count of cut clock. This register is only used when CTRL.MODE=0x01

Diagram



Fields

Field	Function
31-0 cut_high_limit_cnt	High limit cut clock count value High limit cut clock count value. If cut clock counter number in measure period is greater than this value. Then FREQ_GT_MAX interrupt will generate if according enable bit is set.

52.4.4.1.4 Basic Radio Integrated Crypto (BRIC)

52.4.4.1.4.1 BRIC

52.4.4.1.4.1.1 Overview

The Basic Radio Integrated Crypto (BRIC) module is a wrapper, with control logic around the Low Tier Crypto (LTC) block and PKB (Private Key Bus) Slave that interfaces with EdgeLock Secure Enclave. This module provides the legacy interface (IPS + DMA) to the LTC module, contains additional logic to enable direct hardware interfacing for simple AES functions and a PKB interface with the EdgeLock Secure Enclave to receive KEYS securely over the PKB interface. Essentially, the logic takes control of the IPS interface so that another HW entity can easily interface.

The BRIC module allows for legacy behavior of the LTC. The IPS bus and relevant DMA signals are brought out to be used by the system. When in isolated mode, the control of these signals comes from the internal logic using a dedicated hardware interface. For example, RPA checking can be performed by a direct hardware connection as opposed to using a bus master to interface with the LTC.

52.4.4.1.4.1.1.1 Block Diagram

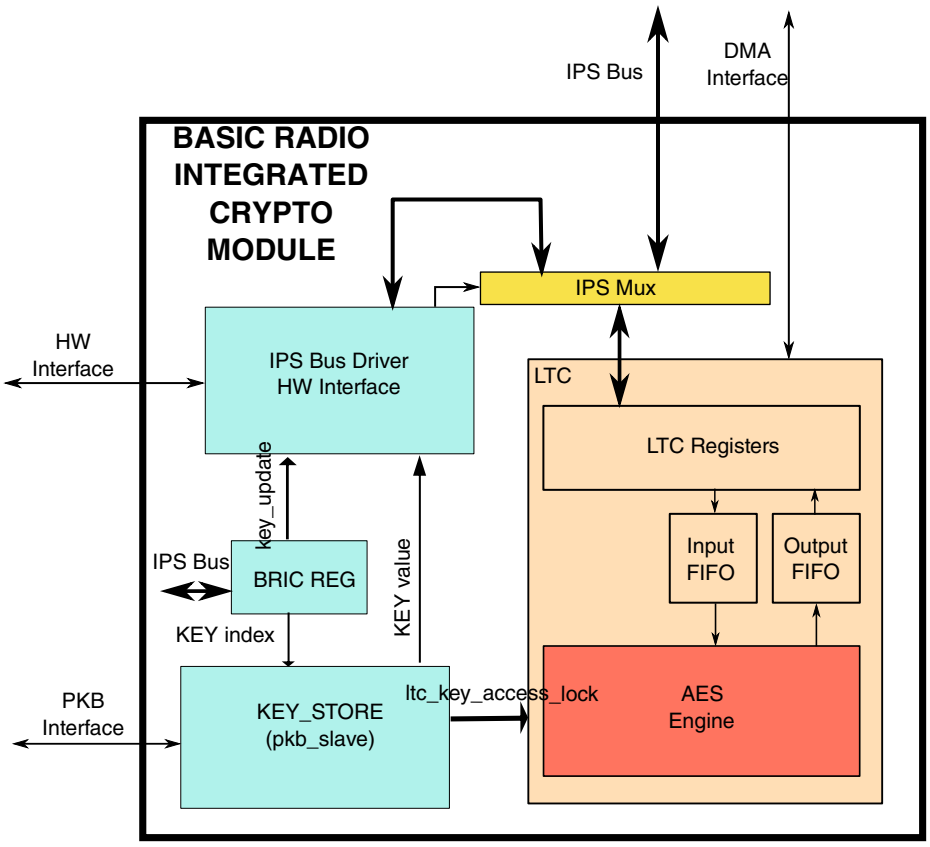


Figure 275. BRIC Block Diagram

52.4.4.1.4.1.1.2 Features

- Supports all LTC functions (See LTC block guide)
- IPS and DMA interface for use by the system as needed
- Dedicated HW interface that overrides the IPS interface
- HW interface simplified for easy integration
- PKB Slave that interfaces directly with EdgeLock Secure Enclave for secure KEY Transfer
- No RAM footprint

52.4.4.1.4.1.2 Functional Description

The BRIC module provides following functionalities:

- Legacy LTC mode
- Hardware Interface mode
- Secure key transfer

52.4.4.1.4.1.2.1 Legacy LTC mode

If the HW interface mode is not selected. The BRIC module simply passes through the IPS and DMA signals. Is this configuration the core, or any bus master for that matter, can access the LTC in the traditional manner and use its capabilities as described in the LTC block guide.

52.4.4.1.4.1.2.2 Hardware interface mode

If the HW interface is selected, the BRIC module will take over control of the LTC.

The first part of this is to check that no process is pending by checking the AB bit in LTC_STA. If this bit is clear, the IPS module enable is then checked to confirm that no accesses are in progress on the IPS bus. When the module enable is low, the xfr_wait will be asserted until the HW interface is disabled. This will effectively block any bus master from accessing the LTC until the HW interface has completed its activity. **NOTE: There is a possibility that SW could be interrupted while configuring the LTC. The BRIC module will not maintain such configuration and SW should take care to resolve this situation if it happens by re-configuring.**

In addition to blocking the system IPS bus, the DMA signals will also be blocked to avoid any spurious requests during HW interface operation. This completes the interface isolation and hi_ready will be asserted. Once the external interfaces have been isolated as per above, the HW interface will begin operation according to the following sequence (HWM indicates HW master below):

1. HWM waits for hi_ready = 0
2. HWM asserts lock_bric for continuous BRIC access for multiple key resolution
3. HWM sets key_in[127:0] and prand[23:0] to desired values
4. HWM asserts hi_mode
5. BRIC uses key_in[127:0] and prand[23:0] to configure and execute ah(key_in,prand) using the LTC as per the Bluetooth Low Energy privacy specification.
6. BRIC sets resultant hash value on hash[23:0] when the LTC is complete, then asserts hash_comp.
7. HWM waits until hash_comp is asserted
8. HWM captures the hash
9. HWM repeats steps **3-8** as needed
10. HWM de-asserts lock_bric

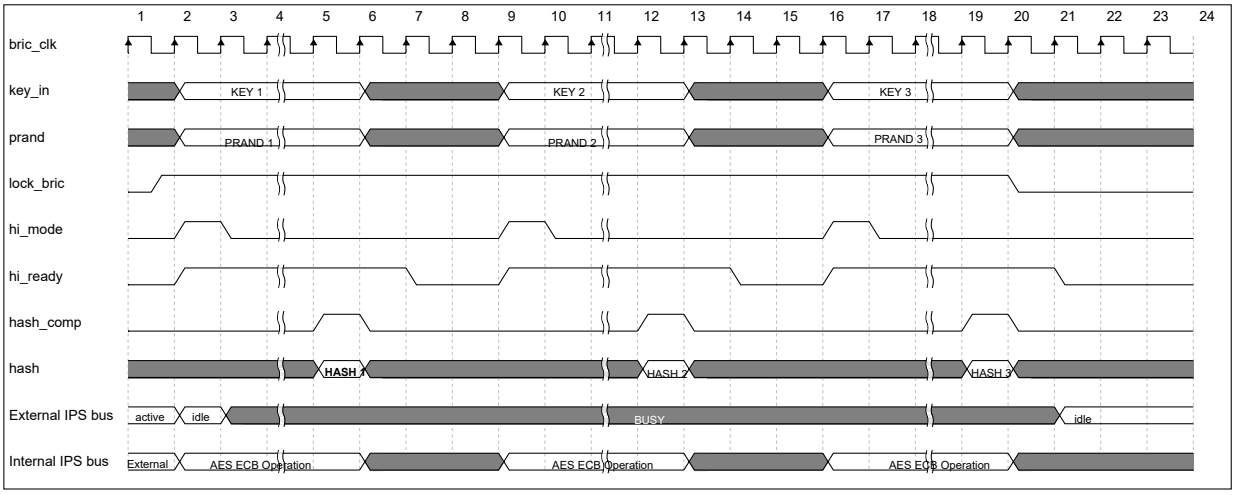


Figure 276. Multiple RPA hash generation

52.4.4.1.4.1.2.3 Software Access during HW mode

To avoid any unexpected results due to software access through IPS bus during HW mode the following response methods are implemented.

IPS_XFR_WAIT is asserted through out the HW mode to inform that SW that BRIC is busy. Hence any SW access will have to wait till the HW access is over.

IPS_XFR_ERR is asserted whenever there is a SW access during ongoing HW mode. This is to avoid SW waiting for longer time till the end of HW operation.

Both the above signal behavior can be controlled individually through register bits in BRIC_CONFIG register.

A few SW-HW access scenarios are listed in below timing diagrams.

1. HW request is asserted while SW access is ongoing - HW waits for SW access to be over
2. SW access start and HW request at the same clock - HW waits for SW access to be over
3. SW access during HW mode - respond with WAIT/ERROR/WAIT & ERROR based on the configuration

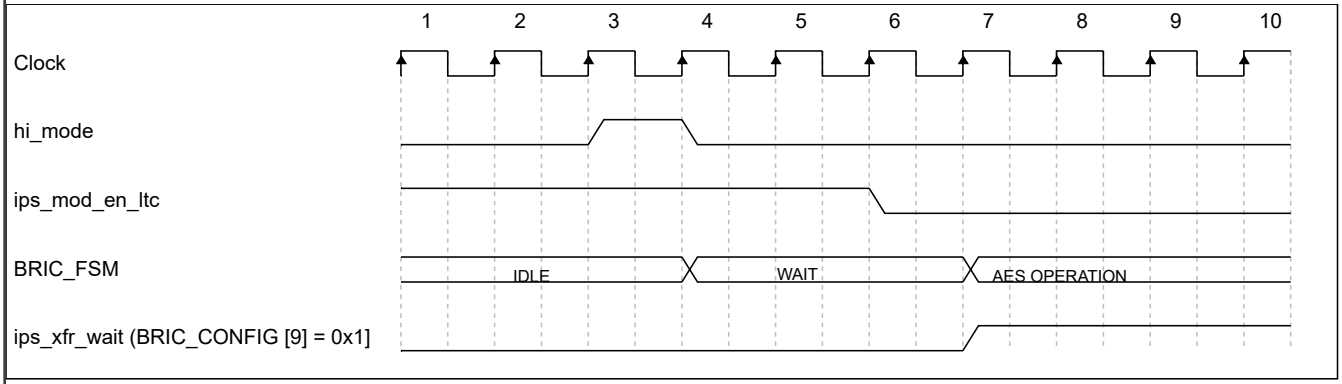


Figure 277. HW request asserted during SW access

Figure 278. SW access and HW request at same clock

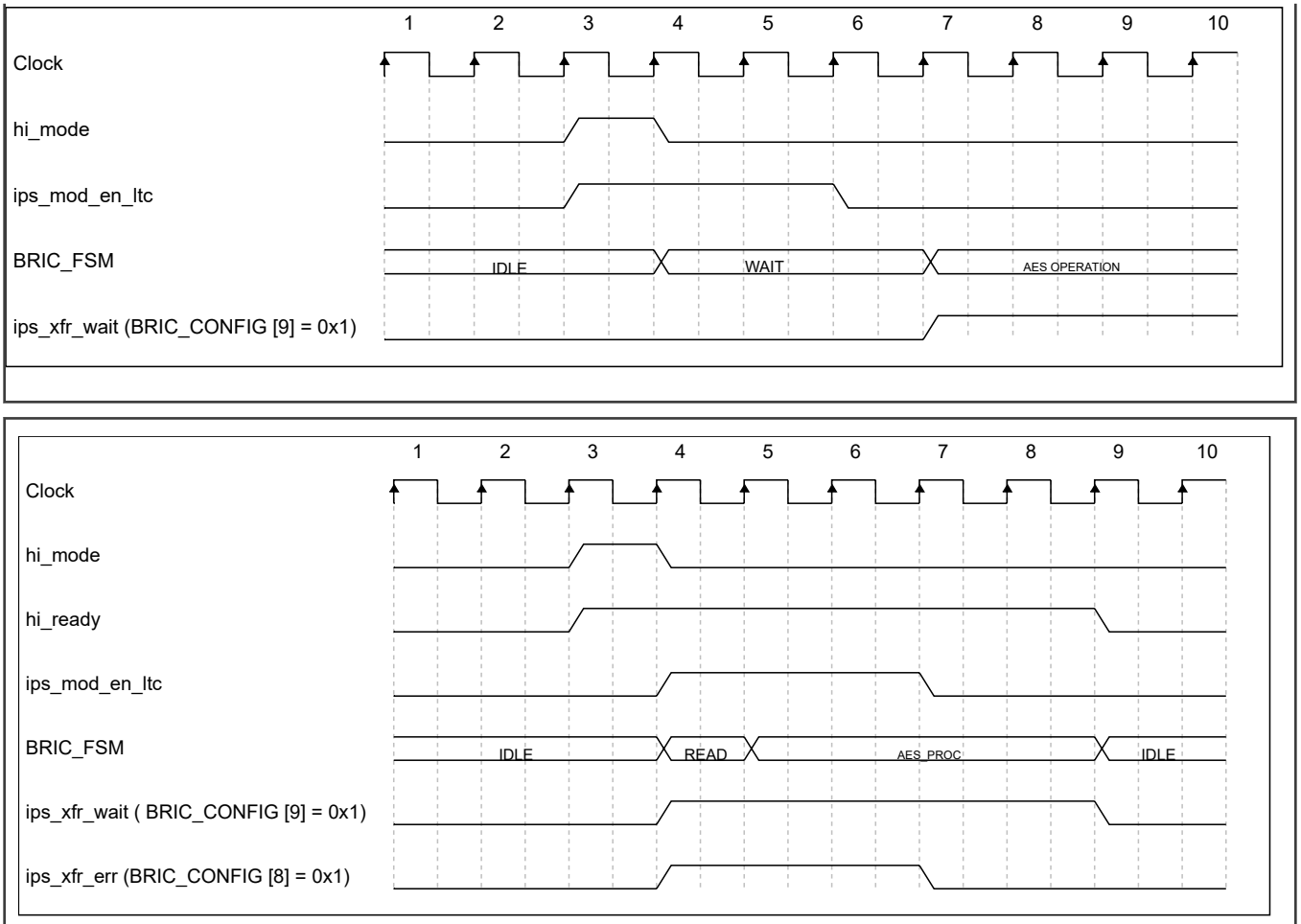


Figure 279. SW access during HW mode

52.4.4.1.4.1.2.4 Secure KEY transfer

The PKB master (EdgeLock Secure Enclave) can write the KEY securely over a PKB interface to any of the two KEY registers present in the BRIC. Any one of these KEYs (transferred over PKB interface) can be selectively transferred to the LTC by writing the index 0/1 to the KEY_INDEX_REGISTER.

The BRIC key_store module can accept and store two 128 bit keys from security module over the secure PKB interface. The written KEYs are no more readable from BRIC.

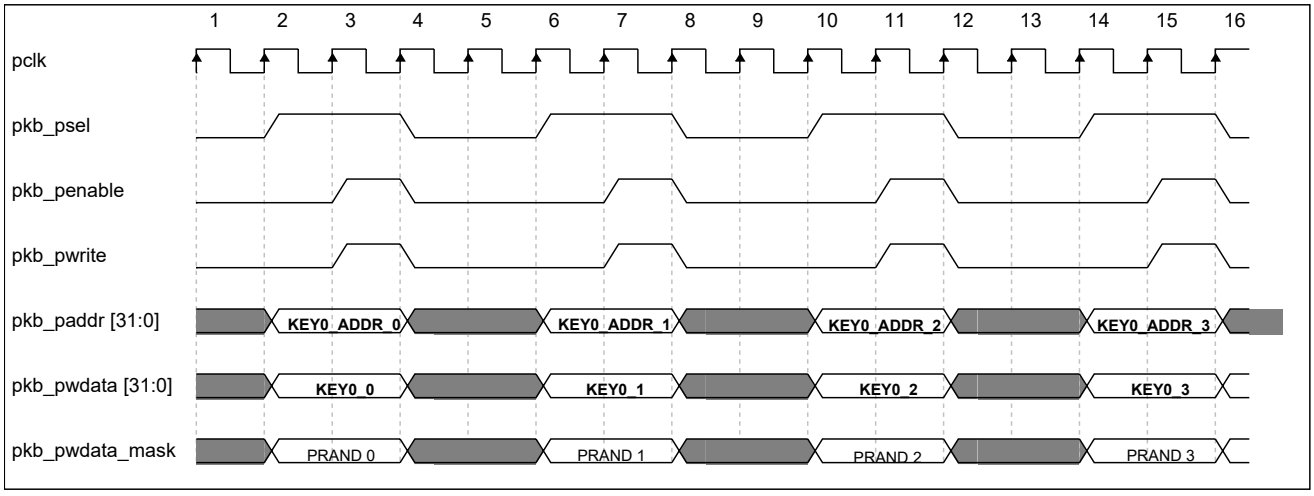


Figure 280. KEY write through PKB

Once KEYs are written by the security IP t to the BRIC the processor can initiate a KEY transfer by writing a valid value to the BRIC KEY_INDEX register. The below transactions indicate the steps involved in transferring a KEY from PKB master (security IP) to LTC module.

1. Write KEY value to BRIC key_store module through PKB interface securely. PKB bus is write only.
2. To transfer the KEY from BRIC key_store to LTC update the KEY_INDEX register with intended value
3. KEY_INDEX register update triggers KEY value write to LTC through the HW IPS interface

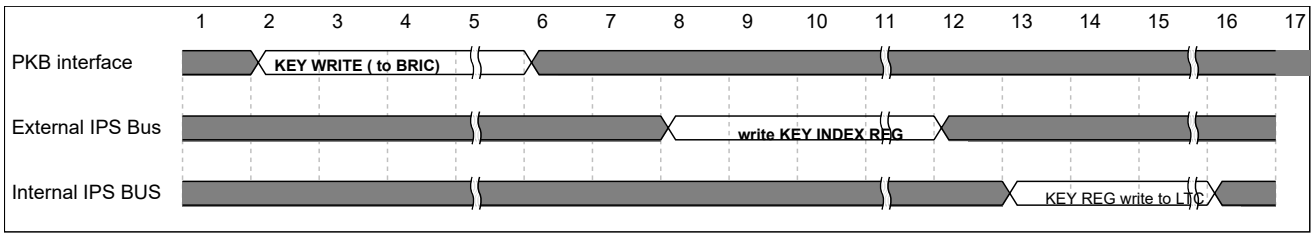


Figure 281. PKB KEY transfer to LTC

52.4.4.1.4.1.2.5 LTC KEY read access

LTC legacy module has a provision to disable the KEY read access by asserting the input signal "ltc_key_access_lock". In the BRIC this input signal has to be tied to "high" (KEY read is locked/disabled) always. To ensure a read path for the LTC KEY for special requirements like debug a different method is implemented and available for the debug software. This is by writing a key value of all 1's to KEY0 REGISTER or KEY1 REGISTER in the BRIC key store through the PKB interface. The KEY register in LTC will be readable as long as the value is retained in any of the KEYx Registers.

52.4.4.1.4.1.2.6 Clocking

The BRIC has two clock sources, for internal logic, register access and peripheral PKB interface. They are listed in the table below:

Table 451. BRIC Clocks

Input	Description
ipg_clk	IPS System Bus Clock - for internal logic and register access
pclk	Peripheral Clock - to access PKB Interface

52.4.4.1.4.1.2.7 Interrupts

The LTC interrupt is passed through to the BRIC output in all modes of operation except HW interface mode.

During HW interface mode the LTC module generates a done_interrupt once encryption is complete. BRIC state machine clears this interrupt internally and hence this interrupt is masked from the output during HW interface mode.

52.4.4.1.4.1.3 Initialization

There is no particular sequence to initialize the BRIC.

52.4.4.1.4.1.4 External Signal Descriptions

Signal	Width	I/O	Function
ipg_clk	1	I	IP Bus Clock, Free-running
ipg_hard_async_reset_b	1	I	asynchronous HW reset
ipt_se_gatedclk	1	I	Scan enable for gated clocks
ipg_soft_reset	1	I	synchrounous soft reset
ipg_stop	1	I	IPG stop mode
ipg_sop_ack	1	O	IPG stop acknowledge
bric_busy	1	O	BRIC/LTC busy
IPS Bus Interface			
ips_module_en	1	I	IPS module enable
ips_rwb	1	I	IPS read/write
ips_addr [15:0]	16	I	IPS address
ips_wdata [31:0]	32	I	IPS write data
ips_byte_en [3:0]	4	I	IPS byte enable
ips_rdata [31:0]	32	O	IPS read data
ips_xfr_wait	1	O	IPS transfer wait
ips_xfr_err	1	O	IPS transfer error
DMA/Interrupt			
ipd_done_idata	1	I	IPD done in data
ipd_done_odata	1	I	IPD done out data
ipd_req_idata	1	O	IPD request in data
ipd_req_odata	1	O	IPD request out data
ipi_bric_int	1	O	Interrupt
Direct HW Interface			
key_in [127:0]	128	I	Key input
prand [23:0]	24	I	PRAND input for creating hash
hash [23:0]	24	O	Hash output from AES

Table continues on the next page...

Table continued from the previous page...

Signal	Width	I/O	Function
lock_bric	1	I	Lock LTC IPS interface for direct Hardware access (Multiple RPA resolution) • **0 :** Legacy IP interface can be used to access LTC • **1 :** Legacy IPS bus disabled, direct HW Interface is active
hi_mode	1	I	Request hash operation (high pulse of one clock cycle) through Hardware interface. key_in and prand inputs has to be valid at the time of assertion hi_mode. hi_ready will be 1 while a hash operation is performed. • **0 :** Legacy IPS interface is available, HW Interface is not • **1 :** IPS bus disabled, direct HW Interface to be used
hi_ready	1	O	HW interface ready • **0 :** HW Interface ready to accept command, safe to change hi_mode • **1 :** HW Interface busy, no inputs should be changed
hash_req	1	I	Not used
hash_comp	1	O	Hash operation complete. Asserts for one clock cycle when 'hash' is valid and can be read.
Private Key Bus (PKB) Interface			
pkb_psel	1	I	PKB APB select
pkb_penable	1	I	PKB APB Enable
pkb_paddr	32	I	PKB APB address
pkb_pwrite	1	I	PKB APB write enable (1= write, read not supported)
pkb_pwdata	32	I	PKB APB write data
pkb_pwdata_mask	32	I	PKB APB write data mask
pkb_pready	1	O	PKB APB ready
pkb_pslverr	1	O	PKB APB slave error

52.4.4.1.4.1.5 Memory Map and register definition

The BRIC memory map and register description is included in the following section.

52.4.4.1.4.1.5.1 BRIC register descriptions

52.4.4.1.4.1.5.1.1 BRIC Base Address memory map

RADIO.BRIC base address: 48A0_6700h

Offset	Register	Width (In bits)	Access	Reset value
0h - Ch	KEY0 Registers (PKB) (KEY0_0 - KEY0_3)	32	W	0000_0000h
10h - 1Ch	KEY1 Registers (PKB) (KEY1_0 - KEY1_3)	32	W	0000_0000h
20h	BRIC CONFIG register (BRIC_CONFIG)	32	RW	0000_0200h

52.4.4.1.4.1.5.1.2 KEY0 Registers (PKB) (KEY0_0 - KEY0_3)

Offset

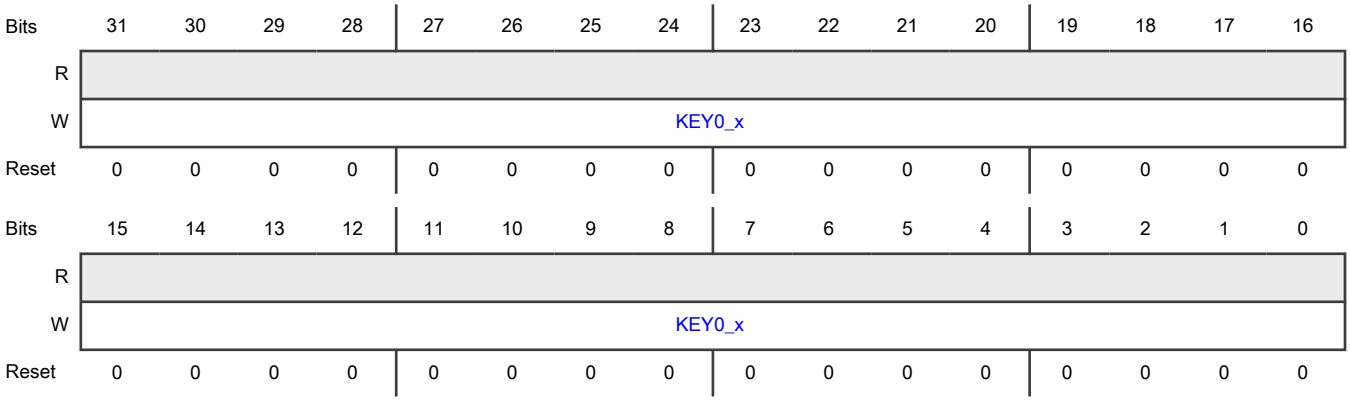
Register	Offset
KEY0_0	0h
KEY0_1	4h
KEY0_2	8h
KEY0_3	Ch

Function

The KEY0 Register normally holds the left-aligned key for the internal crypto engine written by the EdgeLock Secure Enclave. The MSB "KEY0_3" is in offset 0Ch. The Key is 128 bits in length and is written as four PKB masked write access.

The value in the Key0 Register can be transferred to the crypto engine by writing the KEY_INDEX_CONFIG register with value 00h.

Diagram



Fields

Field	Function
31-0 KEY0_x	KEY0 written through PKB interface

52.4.4.1.4.1.5.1.3 KEY1 Registers (PKB) (KEY1_0 - KEY1_3)

Offset

Register	Offset
KEY1_0	10h
KEY1_1	14h
KEY1_2	18h
KEY1_3	1Ch

Function

The KEY1 Register normally holds the left-aligned key for the internal crypto engine written by the EdgeLock Secure Enclave. The MSB "KEY1_3" is in offset 1Ch. The Key is 128 bits in length and is written as four PKB masked write access.

The value in the "KEY1" Register can be transferred to the crypto engine by writing the KEY_INDEX register with value 01h.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R																
W	KEY1_x															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R																
W	KEY1_x															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 KEY1_x	KEY1 written through PKB interface

52.4.4.1.4.1.5.1.4 BRIC CONFIG register (BRIC_CONFIG)

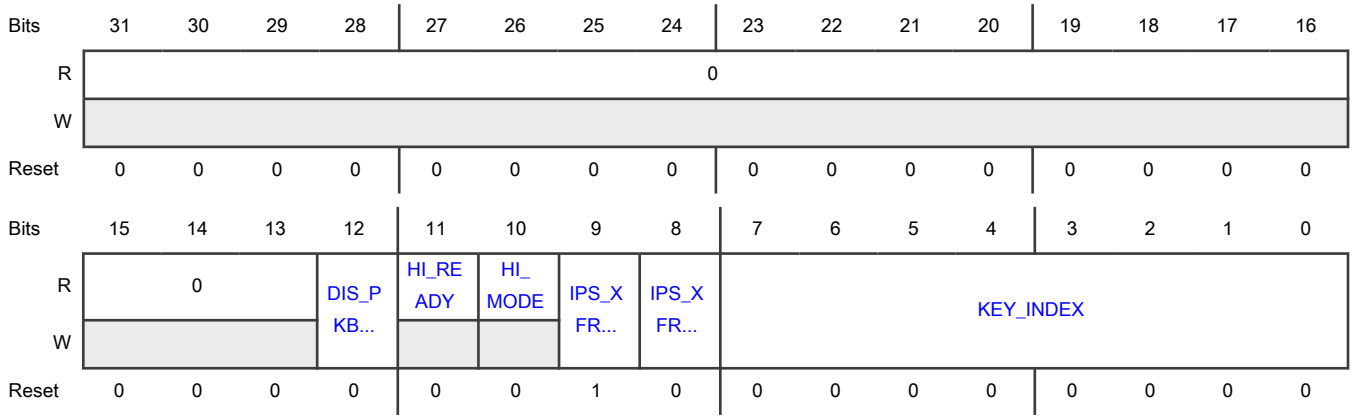
Offset

Register	Offset
BRIC_CONFIG	20h

Function

Configuration and Status register in BRIC

Diagram



Fields

Field	Function
31-13 —	This bit is reserved and should not be set.
12 DIS_PKB_ERR_RESP	Disable (0x1) PKB error response (Error response will be forced to zero)
11 HI_READY	Indicates HW mode is in progress and any SW access during this time is responded with an IPS_ERROR or IPS_WAIT depending on the configuration
10 HI_MODE	Indicates HW mode request to BRIC is active. BRIC may be in HW mode or waiting for a SW access to be over to start the HW mode when this bit is 0x1
9 IPS_XFR_WAIT_EN	Enable (0x1) ips_xfr_wait generation on IPS access during HW mode
8 IPS_XFR_ERR_EN	Enable (0x1) ips_xfr_err generation on IPS access during HW mode
7-0 KEY_INDEX	KEY INDEX KEY INDEX value for selecting the KEY from the PKB slave key array to be transferred to LTC. Writing this field with a valid value (0x0 or 0x1) triggers the KEY transfer from the PKB Slave KEY array to the LTC. To initiate KEY transfer to LTC a write has to be done to this register even if there is no change in KEY value

52.4.4.1.4.2 LTC

52.4.4.1.4.2.1 LP Trusted Cryptography Block Diagram

LP Trusted Cryptography is an architecture that allows multiple cryptographic hardware accelerator engines to be instantiated and share common registers. This version of LTC only supports AES. The following figure presents a top-level diagram of the LP Trusted Cryptography module with an AES engine.

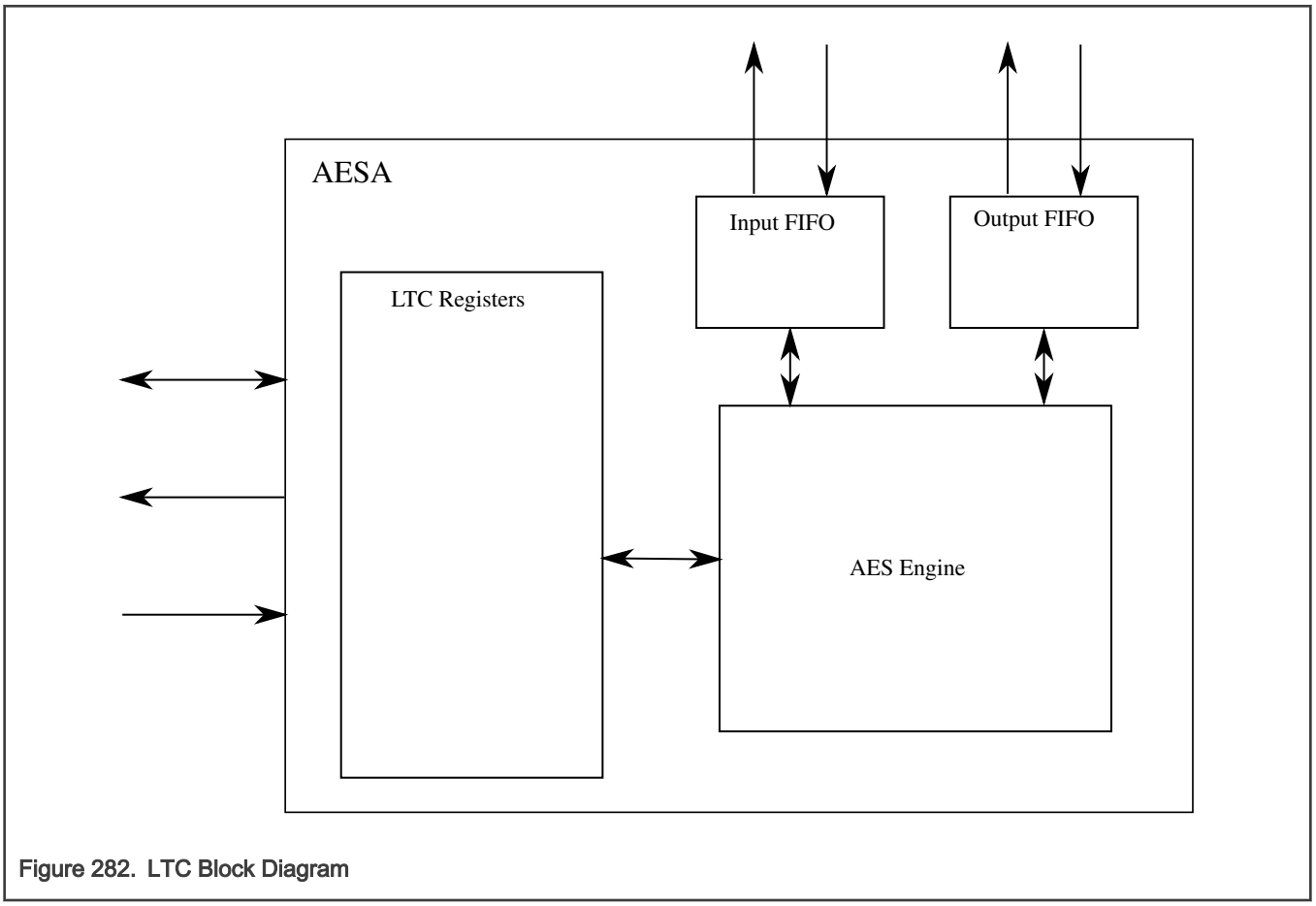


Figure 282. LTC Block Diagram

52.4.4.1.4.2.2 Feature summary

LTC includes the following:

- Cryptographic authentication
  - Message authentication codes (MAC)
    - AES-CMAC
    - AES-XCBC-MAC
  - ICV checking
- Authenticated encryption algorithms
  - AES-CCM (counter with CBC-MAC)
- Symmetric key block ciphers
  - AES (128-bit keys)
  - Cipher modes
    - ECB, CBC, CTR, OFB, CFB128 for AES

52.4.4.1.4.2.3 functionality

52.4.4.1.4.2.3.1 Differences between the AES encrypt and decrypt keys

The decrypt form of the key is different from the encrypt form of the key, because AES successively modifies the cryptographic key during the steps of the cryptographic operation. The decryption operation yields the correct result only if the modified form of the key (the decrypt key) is used at the beginning of the decryption operation. Unless told otherwise (via the DK bit in the Mode Register), AES assumes that a key loaded from memory is the encrypt key, that is, the form appropriate for encryption. If a decryption operation is specified and DK = 0, AES first goes through the steps required to derive the decrypt key from the encrypt key, and then performs the decryption operation. If a decryption operation is specified and DK = 1, the steps required to derive the decrypt key are skipped and the decryption operation is performed immediately, significantly improving performance for small data blocks.

Note that the difference between the encrypt key and the decrypt key must be taken into account when sharing keys between jobs. When an AES decryption job loads a key from memory, it is probably an encrypt key, so the DK bit in the Mode Register should be set to 0 so that AES derives the decrypt key from the encrypt key before beginning the decryption operation. But when a subsequent AES decryption job shares the key from a previous decryption job, the key that is shared is a decrypt key. In that case, the DK bit should be set to 1, which tells AES to skip the key derivation steps. If DK were set to 0 in this case, the decrypt key would be modified as if it were an encrypt key, and consequently, the wrong key value would be used in the decryption operation.

52.4.4.1.4.2.3.2 AESA modes of operation

The following modes are supported by AESA:

- Electronic codebook (ECB)
- Cipher block chaining (CBC)
- Output feedback (OFB)
- 128-bit cipher feedback (CFB128)
- Counter (CTR)
- Extended cipher block chaining message authentication code (XCBC-MAC)
- Cipher-based MAC (CMAC)
- CTR and CBC-MAC (CCM)

AES modes can be classified into these categories:

- Confidentiality (ECB, CBC, CTR, OFB, CFB128)
- Authenticated Confidentiality (CCM)
- Authentication (XCBC-MAC, CMAC)

CBC mode can also be viewed as an authentication mode when used to encrypt data, because it provides CBC-MAC in the context registers.

52.4.4.1.4.2.3.3 AESA use of registers

Note the following regarding the AESA's use of registers:

- For all modes, if AESA is selected and the mode code written to the Mode Register does not correspond to any of the implemented AES modes, the illegal-mode error is generated.
- If ICV-only jobs are created (no data or no additional data to be processed, only ICV to be checked) in modes that support ICV check, the ICV_TEST mode bit should be set, and the AS mode field should be programmed to Update.

52.4.4.1.4.2.3.4 AES ECB mode

The electronic codebook (ECB) mode is a confidentiality mode that features, for a given key, the assignment of a fixed, ciphertext block to each plaintext block, analogous to the assignment of code words in a codebook. In ECB encryption, the forward cipher

function is applied directly and independently to each block of the plaintext. The resulting sequence of output blocks is the ciphertext. In ECB decryption, the inverse cipher function is applied directly and independently to each block of the ciphertext. The resulting sequence of output blocks is the plaintext.

52.4.4.1.4.2.3.4.1 AES ECB mode use of the Mode Register

AES ECB mode uses the Mode Register as follows:

- The Encrypt (ENC) field should be 1 for ECB encryption and 0 for ECB decryption.
- The Algorithm State (AS) field is not used in ECB mode.
- The Additional Algorithm Information (AAI) field must be set with value 20h that activates ECB mode. Setting the MSB in the AAI field (interpreted as the Decrypt Key or DK bit for AES operations) specifies that the key loaded to the Key Register is the decryption form of the key, rather than the encryption form of the key. If DK = 0, when a decryption operation is requested LTC processes the content of the Key Register to yield the decryption form of the key. If DK = 1, LTC skips this processing. The illegal-mode error is generated if DK = 1 and ENC=1.
- The Algorithm (ALG) field is used to activate AES by setting it to 10h .

52.4.4.1.4.2.3.4.2 AES ECB mode use of the Context Register

The AES ECB mode does not use Context Registers.

52.4.4.1.4.2.3.4.3 AES ECB Mode use of the Data Size Register

The length of the message to be processed in bytes must be written to the Data Size register. If this value is not divisible by 16, the Data Size error is generated.

52.4.4.1.4.2.3.4.4 AES ECB Mode use of the Key Register

ECB keys must be written to the Key Register and can have 16 bytes.

52.4.4.1.4.2.3.4.5 AES ECB Mode use of the Key Size Register

The number of bytes in the ECB key must be written to the Key Size register by the time that MODE and DATA SIZE have been written.

52.4.4.1.4.2.3.5 AES CBC, OFB, CFB128 modes

The CBC, OFB, CFB128 modes are considered together because of their similarities and are described in this table.

Table 452. AES CBC, OFB, CFB128 modes

Name	Abbreviation	Function
Cipher-Block Chaining mode	CBC	Confidentiality mode whose encryption process features the combining ("chaining") of the plaintext blocks with the previous ciphertext blocks. The CBC mode requires an IV (Initialization Vector) to combine with the first plaintext block **NOTE** CBC mode uses both forward and inverse AES cipher. OFB and CFB use only forward AES cipher.
Cipher FeedBack mode (128-bit)	CFB128	Confidentiality mode that features the feedback of successive ciphertext segments into the input blocks of the forward cipher to generate output blocks that are exclusive-ORed with the plaintext to produce the ciphertext,

Table continues on the next page...

Table 452. AES CBC, OFB, CFB128 modes (continued)

Name	Abbreviation	Function
		and vice versa. The CFB mode requires an IV as the initial input block. AESA implements 128-bit CFB mode where every ciphertext/plaintext block must have 128 bits.
Output FeedBack mode	OFB	Confidentiality mode that features the iteration of the forward cipher on an IV to generate a sequence of output blocks that are exclusive-ORed with the plaintext to produce the ciphertext, and vice versa. The OFB mode requires IV. The last block of OFB input data can have fewer than 16 bytes.

52.4.4.1.4.2.3.5.1 AES CBC, OFB, and CFB128 modes use of the Mode Register

The AES CBC, OFB, and CFB128 modes use the Mode Register as follows:

- The Encrypt (ENC) field should be 1 for encryption and 0 for decryption, except for OFB mode in which this bit is not used.
- The ICV/TEST bit is not used in these modes.
- The Algorithm State (AS) field is used only in CBC mode to prevent IV update in the context for the last data block when set to "Finalize" (2h).
- The Additional Algorithm Information (AAI) field defines which mode is used for processing. For CBC, OFB, and CFB128, these values are 10h, 40h, and 30h, respectively.
- The Algorithm (ALG) field is used to activate AES by setting it to .

52.4.4.1.4.2.3.5.2 AES CBC, OFB, and CFB128 modes use of the Context Register

The AES CBC, OFB, and CFB128 modes use the Context Register as follows:

- AES CBC, OFB, and CFB all use the Context Registers to provide IV, which is updated with every processed block of a message. When a message is split into chunks and processed in multiple sessions, the IV must be saved and later restored for the next chunk to be processed correctly. At the end of CBC processing, IV is also the MAC of the message.
- If the AS field of the Mode Register is set to Finalize (2h) or Initialize/Finalize (3h) in the CBC mode, the last IV update is not written to the context. This enables CBC encryption to effectively perform ECB encryption transformation of a single-block message located in the context in place of IV, and with an all-zero block provided as input data through the FIFO without overwriting the context.

Table 453. Context usage in CBC, OFB, CFB mode

Context Word	Definition
0	IV [127:96]
1	IV [95:64]
2	IV [63:32]
3	IV [31:0]

52.4.4.1.4.2.3.5.3 AES CBC, OFB, and CFB128 modes use of the Data Size Register

The AES CBC, OFB, and CFB128 modes use the Data Size Register as follows:

- The byte length of the message to be processed must be written to the Data Size Register.

- The first write to this register initiates processing. This register can also be written during processing, in which case the value written is accumulated to the current state of the register.
- After the Data Size Register is written for the last time, its value must be divisible by 16 in CBC and CFB128 modes, otherwise the data-size error is generated.
- Only OFB decrements the value in this register with every processed block.

52.4.4.1.4.2.3.5.4 AES CBC, OFB, and CFB128 mode use of the Key Register

The AES CBC, OFB, and CFB128 modes uses the Key Register as follows:

- A CBC, OFB, or CFB key must be written to the Key Register.
- Keys can have 16 bytes.

52.4.4.1.4.2.3.5.5 AES CBC, OFB, and CFB128 modes use of the Key Size Register

The AES CBC, OFB, and CFB128 modes use the Key Size Register as follows:

- The number of bytes in a key must be written to the Key Size register.
- Any value other than 16 causes a key-size error to be generated.

52.4.4.1.4.2.3.6 AES CTR mode

The counter (CTR) mode is a confidentiality mode that features the application of the forward cipher to a set of input blocks, called counters, to produce a sequence of output blocks that are exclusive-ORed with the plaintext to produce the ciphertext, and vice versa. Note that the counter value must be unique for each data block that is encrypted with the same key. LTC uses a 128-bit counter to ensure that the counter value will not overflow and wrap around.

NOTE

It is the user's responsibility to ensure that the same key value is not used again following a reset.

52.4.4.1.4.2.3.6.1 AES CTR mode use of the Mode Register

The AES CTR mode uses the Mode Register as follows:

- The Additional Algorithm Information (AAI) field should be set to 00h to activate CTR mode.
- The Algorithm State (AS) field when set to "Finalize" (2h) prevents counter update in the context for the last data block.
- The Algorithm (ALG) field is used to activate AES by setting it to .

52.4.4.1.4.2.3.6.2 AES CTR mode use of the Context Register

The AES CTR mode uses the Context Register as follows:

- CTR uses context words 4, 5, 6 and 7 to provide initial counter value (CTR0). This value is incremented with the modulo specified in the Mode Register with every processed block of a message. When a message is split into chunks and processed in multiple sessions, the CTR0 field of context has to be saved and later restored for the next chunk to be processed correctly.
- If the AS field of the Mode Register is set to Finalize (2h) or Initialize/Finalize (3h) in the CTR mode, the last counter update is not written to the context. This enables CTR encryption to effectively perform ECB encryption transformation of a single-block message located in the context words 4, 5, 6 and 7 in place of CTR0 and with all-zero block provided as input data through the FIFO without overwriting the context.

Table 454. Context usage in CTR mode

Context Word	Initial-input definition	Context-switching definition
0	-	-
1	-	-
2	-	-
3	-	-
4	CTR0 [127:96]	CTRi [127:96]
5	CTR0 [95:64]	CTRi [95:64]
6	CTR0 [63:32]	CTRi [63:32]
7	CTR0 [31:0]	CTRi [31:0]

52.4.4.1.4.2.3.6.3 AES CTR mode use of the Data Size Register

The byte-length of the message to be processed must be written to the Data Size register. CTR decrements the value in this register with every processed block.

52.4.4.1.4.2.3.6.4 AES CTR mode use of the Key Register

- CTR key must be written to the Key Register.
- The Key Register can have 16 bytes.

52.4.4.1.4.2.3.6.5 AES CTR mode use of the Key Size Register

The number of bytes in a key must be written to the Key Size register. Any value other than 16 will cause Key Size error to be generated.

52.4.4.1.4.2.3.7 AES XCBC-MAC and CMAC modes

The AES XCBC-MAC and CMAC modes are described together because of their similarities. They are extensions of the AES CBC mode that produces a key-dependent, one--way hash (or message authentication code (MAC)) in a secure fashion across messages of varying lengths. They also provide data-integrity and data-origin authentication regarding the original message source.

52.4.4.1.4.2.3.7.1 AES XCBC-MAC and CMAC modes use of the Mode Register

The AES XCBC-MAC and CMAC modes use the Mode Register as follows:

- The Encrypt (ENC) bit is ignored.
- The ICV_TEST bit must be set for computed MAC to be compared with the received MAC. The received MAC must be written to the Input Data FIFO after message data. If this bit is not set, XCBC-MAC and CMAC do not expect received ICV to be supplied after message data.
- The Algorithm State (AS) field is defined for XCBC-MAC as shown in this table.

Table 455. Mode Register[AS] operation selections in AES XCBC-MAC

Operation	Description
INITIALIZE	Message is processed in multiple sessions and the current session is the first one. During initialization, derived keys K3 and K2 that are XOR-ed with the last message block are computed and stored in the context to be used in the last processing session. The derived key K1 used as an AES key is computed and written back to the Key Register over the original key
INITIALIZE/FINALIZE	Message is processed in a single XCBC session and the final MAC is computed
UPDATE	Message is processed in multiple sessions and the current session is neither the first nor the last. Derived keys K2 and K3 are provided in the context and the derived key K1 is provided in the Key Register. If decryption is requested, and data size is not written or is set to 0, and ICV_TEST bit is 1 - AS = UPDATE means that Check ICV (CICV) job is requested. The CICV-only job does not process any data, it just pops received ICV/MAC from the Input Data FIFO, and compares it to the computed MAC that is restored with the rest of the context from the previous session.
FINALIZE	Message is processed in multiple sessions and the current session is the last one. Derived keys K2 and K3 are provided in the context and the derived key K1 is provided in the Key Register. The final MAC is computed

- The Algorithm State (AS) field is defined for CMAC as shown in this table.

Table 456. Mode Register[AS] operation selections in CMAC

Operation	Function
INITIALIZE	Message is processed in multiple sessions and the current session is the first one. During initialization, the constant L = E(K, 0) is computed as encrypted block of zeros using key K and stored in the context to be used in the last processing session for derivation of keys K1 and K2. One of these keys will be XOR-ed with the last message block.
INITIALIZE/ FINALIZE	Message is processed in a single session and the final MAC is computed
UPDATE	Message is processed in multiple sessions and the current session is neither the first nor the last. The constant L used for key derivation is provided in the context. If decryption is requested, and data size is not written or is set to 0, and ICV_TEST:w bit is 1 - AS = UPDATE means that Check ICV (CICV) job is requested. The CICV-only job does not process any data, it just pops received ICV/MAC from the Input Data FIFO, and compares it to the computed MAC that is restored with the rest of the context from the previous session
FINALIZE	Message is processed in multiple sessions and the current session is the last one. The constant L used for key derivation is provided in the context. The final MAC is computed

- If the AS field is not set to either "Initialize/Finalize" or "Finalize" and the ICV_TEST bit is set to 1, the illegal-mode error is generated, except for CICV-only jobs.
- The Additional Algorithm Information (AAI) field must be set to 70h for XCBC and 60h for CMAC to be activated.
- The Algorithm (ALG) field is used to activate AES by setting it to .

52.4.4.1.4.2.3.7.2 AES XCBC-MAC and CMAC Modes use of the Context Register

The AES XCBC-MAC and CMAC modes use the Context Register as follows:

- No data needs to be provided in the context when starting a new XCBC or CMAC session.
- The computed MAC and the derived keys K2 and K3 are written back to the context by XCBC.
- The computed MAC and the constant L = E(K,0), computed as encrypted block of zeros using key K, are written back to the context by CMAC.
- When a message is split into chunks and processed in multiple sessions, these values need to be saved before context switch and restored before the next chunk of a message is to be processed. At the end of message processing the first 4 words of the context contain the MAC value.

Table 457. Context usage in XCBC-MAC and CMAC modes

Mode	Context Word	Context-switching definition	Final-result definition
XCBC-MAC	0	MAC[127:96]	MAC[127:96]
	1	MAC[95:64]	MAC[95:64]
	2	MAC[63:32]	MAC[63:32]
	3	MAC[31:0]	MAC[31:0]
	4	K3[127:96]	-
	5	K3[95:64]	-
	6	K3[63:32]	-
	7	K3[31:0]	-
	8	K2[127:96]	-
	9	K2[95:64]	-
	10	K2[63:32]	-
	11	K2[31:0]	-
CMAC	0	MAC[127:96]	MAC[127:96]
	1	MAC[95:64]	MAC[95:64]
	2	MAC[63:32]	MAC[63:32]
	3	MAC[31:0]	MAC[31:0]
	4	L[127:96]	-
	5	L[95:64]	-
	6	L[63:32]	-
	7	L[31:0]	-

52.4.4.1.4.2.3.7.3 AES XCBC-MAC and CMAC modes use of the ICV Size Register

The AES XCBC-MAC and CMAC modes use the ICV Size Register as follows:

- This register is used to provide received ICV/MAC byte-size.
- The computed ICV/MAC written to the context in the XCBC mode is always 16 bytes.
- In CMAC mode, this register determines also the computed MAC size-the remaining bytes are cleared.
- Supported values for ICV size are 4 to 16 bytes. If this register is 0, the size of ICV is 16 bytes.

52.4.4.1.4.2.3.7.4 AES XCBC-MAC and CMAC modes use of the Data Size Register

The AES XCBC-MAC and CMAC modes use the Data Size Register as follows:

- The byte-length of the message to be processed must be written to the Data Size register.
- XCBC-MAC and CMAC decrement the value in this register with every processed block.

52.4.4.1.4.2.3.7.5 AES XCBC-MAC and CMAC modes use of the Key Register

The AES XCBC-MAC and CMAC modes use the Key Register as follows:

- The key must be written to this register.
- For XCBC-MAC, if the AS mode field is set to either "Initialize" or "Initialize/Finalize", it is the original XCBC key (K) that must be written here. Otherwise, the derived key (K1) must be restored to this register. CMAC only uses original key K as an AES key.

52.4.4.1.4.2.3.7.6 AES XCBC-MAC and CMAC modes use of the Key Size Register

The AES XCBC-MAC and CMAC modes use the Key Size Register as follows:

- The total number of key bytes must be written to the Key Size register.
- For XCBC-MAC, any value other than 16 causes a key-size error to be generated. For CMAC, this error is generated only if any value other than 16 is written.

52.4.4.1.4.2.3.7.7 ICV checking in AES XCBC-MAC and CMAC modes

Automatic ICV checking is enabled by setting the ICV bit of the Mode Register to 1. When ICV is set to 1, the AS mode field must be set to either "Finalize" or "Initialize/Finalize"; otherwise the illegal-mode error is generated, except for CICV-only (Check-ICV-only) jobs.

The received ICV must be provided on the FIFO after the message data. The FIFO data type must be set to ICV when it is put on the FIFO. The size of the received and computed ICV is provided in the ICV Size register.

If the ICV check detects a mismatch between the decrypted received ICV and the computed ICV, the ICV error is generated.

52.4.4.1.4.2.3.8 AESA CCM and CCM* mode

CCM and CCM* consists of two related processes: generation encryption and decryption verification, which combine two cryptographic primitives: counter mode encryption (CTR) and cipher-block chaining based authentication (CBC-MAC). Only the forward cipher function of the block cipher algorithm is used within these primitives. Note that the counter value must be unique for each data block that is encrypted with the same key. LTC uses a 128-bit counter to ensure that the counter value does not overflow and wrap around.

NOTE

It is the user's responsibility to ensure that the same key value is not used again following a reset.

52.4.4.1.4.2.3.8.1 Generation encryption

A cipher-block chaining is applied to the payload, the associated data (AAD), and the nonce to generate a message authentication code (MAC); then counter mode encryption is applied to the MAC and the payload to transform them into an unreadable form, called the ciphertext. Thus, CCM generation encryption expands the size of the payload by the size of the MAC.

52.4.4.1.4.2.3.8.2 Decryption verification

Counter-mode decryption is applied to the purported ciphertext to recover the MAC and the corresponding payload; then cipher block chaining is applied to the payload, the received associated data, and the received nonce to verify the correctness of the MAC.

52.4.4.1.4.2.3.8.3 AES CCM and CCM* mode use of the Mode Register

The AES CCM and CCM* mode uses the Mode Register as follows:

- The Encrypt (ENC) bit must be set to 1 for encryption and 0 for decryption.
- The ICV_TEST bit must be set for CCM and CCM* to compare computed MAC with the received MAC when decryption is requested.
- The received MAC must be written to the input-data FIFO after message data.
- Setting the ICV_TEST bit causes the received MAC to be decrypted and compared with the computed MAC.
- The number of MSBs to be compared is defined by the MAC size in the CCM IV (B_0) as described in the CCM and CCM* specification.
- If the AS field is set to FINALIZE, but ICV = 0, AESA does not expect received ICV to be put on the input-data FIFO. In that case, MAC is computed and truncated to the specified size for decryption.
- For encryption, the computed MAC is encrypted and truncated to size. The illegal-mode error is generated if ICV = 1 and ENC = 1.
- If ICV = 1 and the decrypted received MAC do not match computed MAC, the ICV error is generated.
- The Algorithm State (AS) field is defined for CCM as follows:

Table 458. Mode Register[AS] operation selections in AES CCM

Operation	Description
INITIALIZE	Message is processed in multiple sessions and the current session is the first one. During initialization, the initial counter CTR0 is encrypted in the CTR mode and the B0 is processed with the CBC-MAC mode. The resulting values are stored in the context. Also, the size of MAC is decoded from B0 and written to the context. This AS setting must be used whenever the first part (or whole) AAD is being processed
INITIALIZE/ FINALIZE	Message is processed in a single CCM session and the final MAC is computed and encrypted. The initial counter CTR0 and B0 must be provided in the context
UPDATE	Message is processed in multiple sessions and the current session is neither the first nor the last. All context data is restored from the previous session and the key is written to the Key Register. If decryption is requested, and data size is not written or is set to 0, and ICV_TEST bit is 1 - AS=UPDATE means that a CICV-only job is requested. The CICV-only job does not process any data, it just pops received ICV/MAC from the Input Data FIFO, decrypts it and compares it to the computed MAC that is restored with the rest of the context from the previous session
FINALIZE	Message is processed in multiple sessions and the current session is the last one. All context data is restored from the previous session and the key is written to the Key Register. The final MAC is computed and encrypted

- Whenever AS is set to Initialize or Initialize/Finalize, context registers must be zero.
- If the AS field is not set to either Initialize/Finalize or Finalize and the ICV_TEST bit is set to 1, the illegal-mode error is generated. This does not apply in case when only ICV check is requested as described for AS = UPDATE.
- The Additional Algorithm Information (AAI) field must be set to 80h for CCM or CCM* to be activated.
- The Algorithm (ALG) field is used to activate AES by setting it to .

52.4.4.1.4.2.3.8.4 AES CCM and CCM* mode use of the Context Register

The AES CCM and CCM* mode uses the Context Register as follows:

- B0 and the initial counter CTR0 must be provided in the context before the first chunk of the message is to be processed. During initialization, the initial counter CTR0 is encrypted in the CTR mode and B0 (which functions like a CBC-MAC IV in CCM) is processed with the CBC-MAC mode. The resulting values are stored in the context. Also, the size of MAC is decoded from B0 and written to context word 13.
- If there is AAD, the first block of it defines its size, and that value is decoded and written to context word 12. All of the context data must be restored before the next chunk of the message is to be processed in multi-session processing.
- For CCM encryption, the ICV (encrypted final MAC) is written to context words 8, 9, 10 and 11. For CCM decryption, the ICV (received MAC), which is always encrypted, is decrypted to words 8, 9, 10 and 11. The final computed MAC is written (in clear) to words 0, 1, 2 and 3.

Table 459. Context usage in CCM and CCM* mode encryption

Context Word	Initial-input definition	Intermediate definition	Final-output definition
0	B0[127:96]	intermediate MAC state	MAC[127:96]
1	B0[95:64]	intermediate MAC state	MAC[95:64]
2	B0[63:32]	intermediate MAC state	MAC[63:32]
3	B0[31:0]	intermediate MAC state	MAC[31:0]
4	CTR0[127:96]	CTR[127:96]	-
5	CTR0[95:64]	CTR[95:64]	-
6	CTR0[63:32]	CTR[63:32]	-
7	CTR0[31:0]	CTR[31:0]	-
8	-	E(CTR0)[127:96][1]	E(MAC)[127:96]
9	-	E(CTR0)[95:64][1]	E(MAC)[95:64]
10	-	E(CTR0)[63:32][1]	E(MAC)[63:32]
11	-	E(CTR0)[31:0][1]	E(MAC)[31:0]
12	-	AAD Presence Flag[31], Zero[30:16], AAD size[15:0]	-
13	-	Zero[31:3], Encoded MAC size[2:0]	-

1. E(x) means encrypted x

Table 460. Context usage in CCM and CCM* mode decryption

Context Word	Initial-input definition	Context-switching Definition	Final-result definition
0	B0[127:96]	intermediate MAC state	MAC[127:96]

Table continues on the next page...

Table 460. Context usage in CCM and CCM* mode decryption (continued)

Context Word	Initial-input definition	Context-switching Definition	Final-result definition
1	B0[95:64]	intermediate MAC state	MAC[95:64]
2	B0[63:32]	intermediate MAC state	MAC[63:32]
3	B0[31:0]	intermediate MAC state	MAC[31:0]
4	CTR0[127:96]	CTR[127:96]	-
5	CTR0[95:64]	CTR[95:64]	-
6	CTR0[63:32]	CTR[63:32]	-
7	CTR0[31:0]	CTR[31:0]	-
8	-	E(CTR0)[127:96]	Decrypted Received MAC[127:96]
9	-	E(CTR0)[95:64]	Decrypted Received MAC[95:64]
10	-	E(CTR0)[63:32]	Decrypted Received MAC[63:32]
11	-	E(CTR0)[31:0]	Decrypted Received MAC[31:0]
12	-	AAD Presence Flag[31], Zero[30:16], AAD size[15:0]	-
13	-	Zero[31:3], Encoded MAC size[2:0]	-

52.4.4.1.4.2.3.8.5 AES CCM and CCM* mode use of the Data Size Register

The AES CCM and CCM* mode uses the Data Size Register as follows:

- The byte-length of the message to be processed must be written to the Data Size register.
- CCM decrements the value in this register with every processed block.
- The content of the Data Size register must be divisible by 16 after the last write to it if the AS mode field is set to either "Update" or "Initialize". Otherwise, the data-size error is generated. In other words, message splitting can be done only on a 16-byte boundary.

52.4.4.1.4.2.3.8.6 AES CCM and CCM* mode use of the Key Register

CCM and CCM* key must be written to this register; it is always an encryption key.

52.4.4.1.4.2.3.8.7 AES CCM and CCM* mode use of the Key Size Register

The AES CCM and CCM* mode uses the Key Size Register as follows:

- The total number of key bytes must be written to the Key Size register.
- Any value other than 16 causes a key-size error to be generated.

52.4.4.1.4.2.3.8.8 AES CCM and CCM* mode use of the ICV check

The AES CCM and CCM* mode uses ICV checking as follows:

- Automatic ICV checking is enabled by setting the ICV_TEST bit of the Mode Register to 1. When ICV is set to 1, the AS mode field must be set to either "Finalize" or "Initialize/Finalize"-otherwise the illegal-mode error is generated, unless data size is 0 indicating ICV check is only requested. Also, if ICV = 1, the ENC bit must be 0.
- The received ICV must be provided on the input data FIFO after the message data. In CCM, received ICV is always encrypted. The size of the received and computed ICV is for CCM encoded in the B0.
- If the ICV check detects mismatch between the decrypted received ICV and the computed ICV, the ICV error is generated.

52.4.4.1.4.2.4 Standalone AES Examples

Example AES ECB Operation:

1. Write key to Primary Key Register.
2. Write key size to Primary Key Size Register. (00000010h)
3. Write Mode to Primary Mode Register. (0010020Dh)
4. Write Size of data to encrypt/decrypt to Data Size Register.
5. Write data into the Input FIFO.
6. Read data from the Output FIFO.
7. Interrupt is generated after final word is pushed to output FIFO.

Example AES CTR Operation:

1. Write key to Primary Key Register.
2. Write key size to Primary Key Size Register. (00000010h)
3. Write initial counter value to Context Words 4-7 in the Context Register.
4. Write Mode to Primary Mode Register. (0010020Dh)
5. Write Size of data to encrypt/decrypt to Data Size Register.
6. Write data into the Input FIFO.
7. Read data from the Output FIFO.
8. Interrupt is generated after final word is pushed to output FIFO.

Example AES CCM or CCM* Operation:

1. Write key to Primary Key Register.
2. Write key size to Primary Key Size Register. (00000010h)
3. Write B0 value to Context Words 0-3 in the Context Register.
4. Write initial counter value to Context Words 4-7 in the Context Register.
5. Write Mode to Primary Mode Register. (0010080Dh) CCM and CCM* both use the same mode value.
    - CCM and CCM* both use the same mode value.
6. Write Size of Authentication Only Data to the AAD Size Register.
7. Write Authentication Only data to the Input FIFO.
    - Authentication data needs to be padded to a 16 byte boundary with zeros.
    - For example if there is 8 bytes of AAD then (00000008h) should be written to AAD Size register and 8 bytes of AAD data followed by 8 bytes of Zero should be written into the Input FIFO.
8. Write Size of data to encrypt/decrypt and authenticate to Data Size Register.

9. Write data into the Input FIFO.
10. Read data from the Output FIFO.
11. Interrupt is generated after final word is pushed to output FIFO.
12. Read MAC from Context Registers
    - MAC is read from Context Registers 0-3.
    - Encrypted MAC is read from Context Registers 8-11.

Example AES CCM or CCM* Authentication Only Operation:

1. Write key to Primary Key Register.
2. Write key size to Primary Key Size Register. (00000010h)
3. Write B0 value to Context Words 0-3 in the Context Register.
4. Write initial counter value to Context Words 4-7 in the Context Register.
5. Write Mode to Primary Mode Register. (0010080Dh).
    - CCM and CCM* both use the same mode value.
6. Write Size of Authentication Only Data to the AAD Size Register.
    - The AL bit needs to be set in the AAD Size Register. This tells the AES core engine that it will recieve only Authentication Data. Note for encryption only the mechanism is handled automatically.
7. Write Authentication Only data to the Input FIFO.
    - Authentication data needs to be padded to a 16 byte boundary with zeros.
    - For example if there is 8 bytes of AAD then (00000008h) should be written to AAD Size register and 8 bytes of AAD data followed by 8 bytes of Zero should be written into the Input FIFO.
8. Write data into the Input FIFO.
9. Interrupt is generated after final word is processed from input FIFO.
10. Read MAC from Context Registers
    - MAC is read from Context Registers 0-3.
    - Encrypted MAC is read from Context Registers 8-11.

Example AES CCM or CCM* Encryption Only Operation:

1. Write key to Primary Key Register.
2. Write key size to Primary Key Size Register. (00000010h)
3. Write B0 value to Context Words 0-3 in the Context Register.
4. Write initial counter value to Context Words 4-7 in the Context Register.
5. Write Mode to Primary Mode Register. (0010080Dh).
    - CCM and CCM* both use the same mode value.
6. Write Size of data to encrypt/decrypt to Data Size Register.
7. Write data into the Input FIFO.
8. Read data from the Output FIFO.
9. Interrupt is generated after final word is pushed into the output FIFO.

Writing and Reading Data from the FIFOs:

1. Writing and reading by polling operations.

- The FIFO Status Register(LTCFIFOSTA) shows the number of entries in both the input and output FIFOs. It also shows when the FIFOs are full.
- The input FIFO supports 0x32bit entries.
- The output FIFO supports 4x32bit entries.
- Whenever there is space in the input FIFO the user can write a word into the Input FIFO.
- Whenever there is a word in the output FIFO then the user can read a word from the Output FIFO.

2. Writing and reading FIFOs by DMA operations.
   - The on chip DMA will handle all reads and writes of the FIFOs.
   - The IDE and ODE bits in the Control Register must be written to enable the DMA handshake.
     - IDE will enable dma transfers to the input FIFO when there is space available.
     - ODE will enable dma transfers from the output FIFO when there are words in the FIFO.
   - The on chip DMA should then be programmed to write data to the input FIFO and read data from the output FIFO.

52.4.4.1.4.2.5 LTC register descriptions

All reads of write-only addresses always return zero. Writes to read-only addresses are ignored. LTC will generate a transfer error whenever an undefined address is read or written to on the register bus. Although many of the LTC registers hold more than 32 bits, the register addresses shown in the Memory Map below represent how these registers are accessed over the register bus as 32-bit words.

NOTE

The reset value of some registers differs between different versions of LTC. To ensure driver compatibility across different versions of LTC, when updating fields within registers, the registers should first be read, the required fields updated, and then the register should be written. This will avoid inadvertently changing the settings of other fields in the same register.

52.4.4.1.4.2.5.1 LTC memory map

RADIO.LTC base address: 48A0_6800h

Offset	Register	Width (In bits)	Access	Reset value
0h	Mode Register (MD)	32	RW	0000_0000h
8h	Key Size Register (KS)	32	W	0000_0010h
10h	Data Size Register (DS)	32	RW	0000_0000h
18h	ICV Size Register (ICVS)	32	RW	0000_0000h
30h	Command Register (COM)	32	W	0000_0000h
34h	Control Register (CTL)	32	RW	0000_0000h
40h	Clear Written Register (CW)	32	W	0000_0000h
48h	Status Register (STA)	32	RW	0000_0000h
4Ch	Error Status Register (ESTA)	32	R	0000_0000h
58h	AAD Size Register (AADSZ)	32	RW	0000_0000h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
100h - 134h	Context Register (CTX_0 - CTX_13)	32	RW	0000_0000h
200h - 20Ch	Key Registers (KEY_0 - KEY_3)	32	RW	0000_0000h
4F0h	Version ID Register (VID1)	32	R	0034_0100h
4F4h	Version ID 2 Register (VID2)	32	R	0000_0101h
4F8h	CHA Version ID Register (CHAVID)	32	R	0000_0050h
7C0h	FIFO Status Register (FIFOSTA)	32	R	0000_0000h
7E0h	Input Data FIFO (IFIFO)	32	W	0000_0000h
7F0h	Output Data FIFO (OFIFO)	32	R	0000_0000h

52.4.4.1.4.2.5.2 Mode Register (MD)

Offset

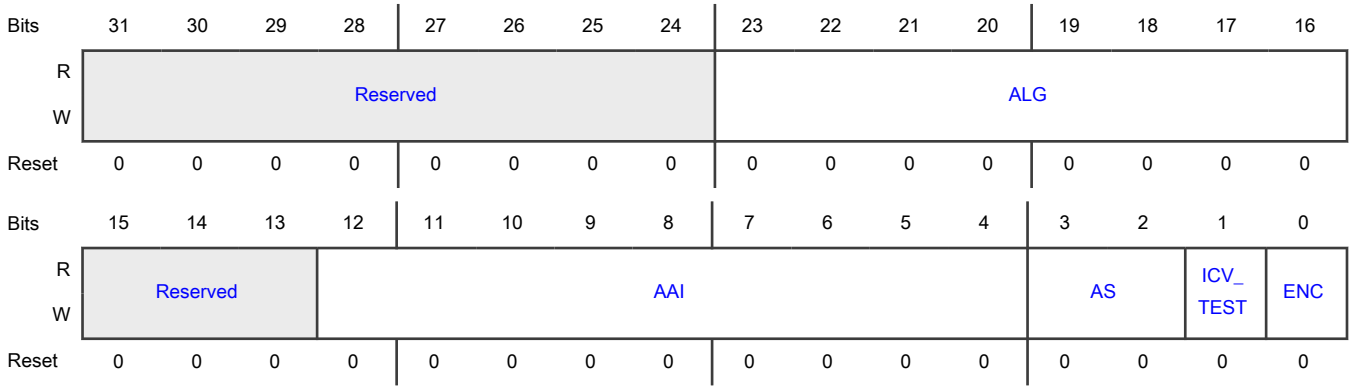
Register	Offset
MD	0h

Function

The Mode Register is used to tell the cryptographic engines which operation is being requested. The interpretation of this register will be unique for each CHA.

This section defines the format of the Mode Register when used with non-public-key algorithms and non-RNG operations.

Diagram



Fields

Field	Function
31-24 —	Reserved Must be 0.
23-16 ALG	Algorithm This field specifies which algorithm is being selected. 0001_0000b - AES
15-13 —	Reserved Must be 0.
12-4 AAI	Additional Algorithm information This field contains additional mode information that is associated with the algorithm that is being executed. See also the section describing the appropriate CHA. **NOTE** Some algorithms do not require additional algorithm information and in those cases this field should be all 0s.

Table 461. AAI Interpretation for AES Modes

[For AES the MSB of AAI is the DK (Decrypt Key) bit.]				
Code [1]	Interpretation		Code[1]	Interpretation
00h	CTR (mod 2^{128})		80h	CCM, CCM*
10h	CBC		90h	Reserved
20h	ECB		A0h	Reserved
30h	CFB		B0h	Reserved
40h	OFB		C0h	Reserved
50h	Reserved		D0h	Reserved
60h	CMAC		E0h	Reserved
70h	XCBC-MAC		F0h	Reserved
			12h	CBC-CS2
Setting the DK bit (i.e. ORing 100h with any AES code above) causes Key Register to be loaded with the AES Decrypt key, rather than the AES Encrypt key.				

1. The codes are mutually exclusive (i.e. they cannot be ORed with each other).

Field	Function
3-2 AS	Algorithm State This field defines the state of the algorithm that is being executed. This may not be used by every algorithm. 00b - Update 01b - Initialize 10b - Finalize 11b - Initialize/Finalize
1 ICV_TEST	ICV Checking This bit selects whether the current algorithm should compare the known ICV versus the calculated ICV. This bit should only be used in modes that support ICV checking. Setting bit with non supported algorithms could cause the hardware to hang. 0 - Don't compare 1 - Compare
0 ENC	Encrypt/Decrypt. This bit selects encryption or decryption. 0b - Decrypt. 1b - Encrypt.

52.4.4.1.4.2.5.3 Key Size Register (KS)

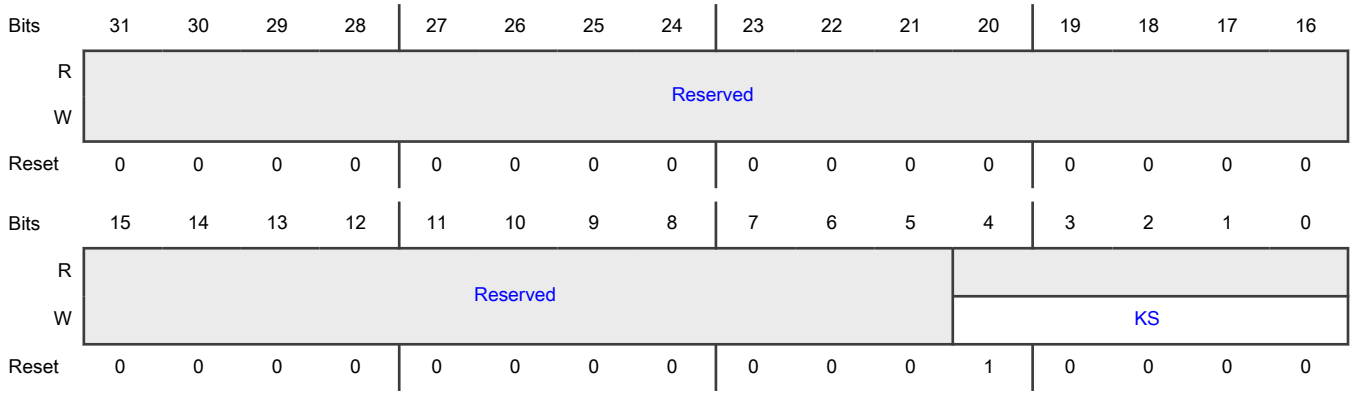
Offset

Register	Offset
KS	8h

Function

The Key Size Register is used to tell the crypto engine(AES) the size of the key that was loaded into the Key Register. The Key Size Register must be written after the key is written into the Key Register. Writing to the Key Size Register will prevent the user from modifying the Key Register. Only 16 byte keys are supported so this register will always read 16 bytes. This register is still required to be written to indicate to the AES engine that the key was loaded.

Diagram



Fields

Field	Function
31-5 —	Reserved
4-0 KS	Key Size This is the size of a Key measured in bytes

52.4.4.1.4.2.5.4 Data Size Register (DS)

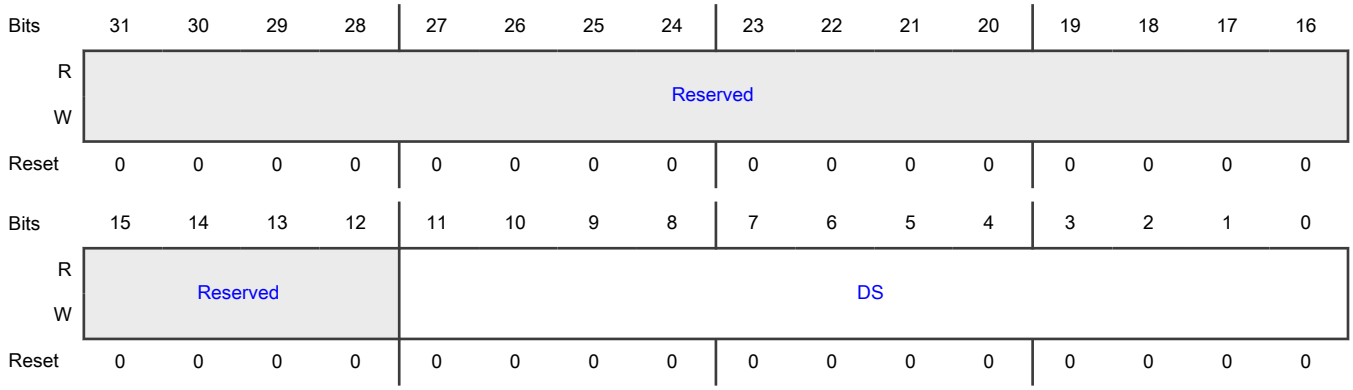
Offset

Register	Offset
DS	10h

Function

The Data Size Register is used to tell a crypto engine the amount of data in bytes that will be loaded into the Input Data FIFO. Note that writing to the AAD Size Register (AADSZ) , will cause this register to also update. This register is additive and any write to this register will be added to the current value in the register. For example, if the DS field currently has the value 16, writing 2 to the least-significant half of the Data Size register (i.e. the DS field) will result in a value of 18 in the DS field. Care should be taken to not overflow the register. Overflowing the register can result in a hang condition. Note that AES decrements this register, so reading the register may return a value less than sum of the values that were written into it. This register is cleared whenever a key is decrypted or encrypted.

Diagram



Fields

Field	Function
31-12 —	Reserved
11-0 DS	Data Size This is the number of whole bytes of data that will be consumed by the CHA. Note that writing the AAD Size Register will result in this register also being written to.

52.4.4.1.4.2.5.5 ICV Size Register (ICVS)

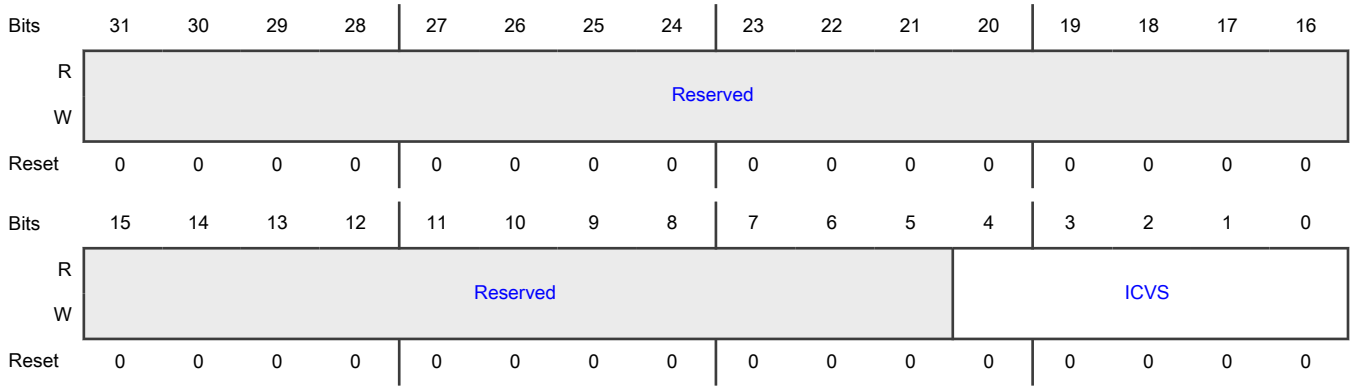
Offset

Register	Offset
ICVS	18h

Function

The ICV Size Register indicates how much of the last block of ICV is valid when performing AES integrity check modes (e.g. AES-CMAC, AES-XCBC-MAC). This register must be written prior to the corresponding word of data being consumed by AES. In practical terms, this means the register must be written prior to the corresponding data being written to the Input Data FIFO.

Diagram



Fields

Field	Function
31-5 —	Reserved
4-0 ICVS	ICV Size, in Bytes

52.4.4.1.4.2.5.6 Command Register (COM)

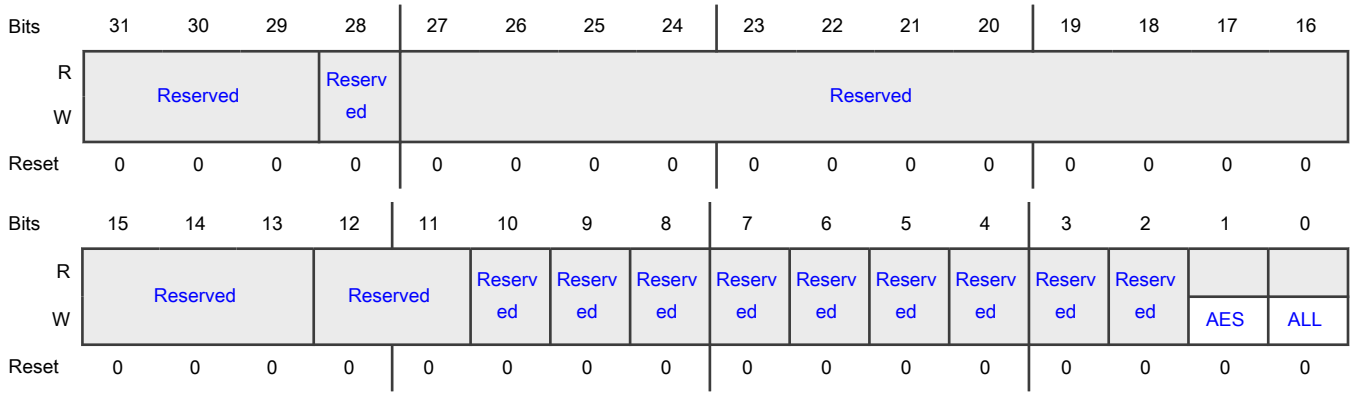
Offset

Register	Offset
COM	30h

Function

The Command Register is used to send control signals to the Crypto Engines.

Diagram



Fields

Field	Function
31-29 —	Reserved To preserve software compatibility with other versions of LTC, 0 should be written to all reserved bits.
28 —	Reserved
27-13 —	Reserved
12-11 —	Reserved
10 —	Reserved
9 —	Reserved
8 —	Reserved
7 —	Reserved
6 —	Reserved
5 —	Reserved
4 —	Reserved
3 —	Reserved
2 —	Reserved
1 AES	Reset AESA Writing a 1 to this bit resets the AES Accelerator core engine. 0b - Do Not Reset

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - Reset AES Accelerator
0 ALL	Reset All Internal Logic Writing to this bit will reset all accelerator engines and as well as all the internal registers. 0b - Do Not Reset 1b - Reset all CHAs in use by this CCB. This should be done at the end of every operation to make sure the engine is cleared of all data and ready for next command.

52.4.4.1.4.2.5.7 Control Register (CTL)

Offset

Register	Offset
CTL	34h

Function

This register is used for some of the internal controls of the LTC block.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	KAL	Reserved	Reserved						COS	CIS	KOS	KIS	Reserved		OFS	IFS
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	Reserved		OFR	OFE	Reserved		IFR	IFE	Reserved			Reserved	Reserved			IM
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 KAL	Key Register Access Lock Read access to the key register is blocked. Any reads of the key register will only return zero. Once this bit is set, it can only be cleared by hard reset. 0b - Key Register is readable. 1b - Key Register is not readable.

Table continues on the next page...

Table continued from the previous page...

Field	Function
30 —	Reserved
29-24 —	Reserved
23 COS	Context Register Output Byte Swap Byte swap all data that is read from the context register. Data is byte swapped only within a single word. 0b - Do Not Byte Swap Data. 1b - Byte Swap Data.
22 CIS	Context Register Input Byte Swap Byte swap all data that is written to the context register. Data is byte swapped only within a single word. 0b - Do Not Byte Swap Data. 1b - Byte Swap Data.
21 KOS	Key Register Output Byte Swap Byte swap all data that is read from the key register. Data is byte swapped only within a single word. 0b - Do Not Byte Swap Data. 1b - Byte Swap Data.
20 KIS	Key Register Input Byte Swap Byte swap all data that is written to the key register. Data is byte swapped only within a single word. 0b - Do Not Byte Swap Data. 1b - Byte Swap Data.
19-18 —	Reserved
17 OFS	Output FIFO Byte Swap Byte swap all data that is read from the Onput FIFO. 0b - Do Not Byte Swap Data. 1b - Byte Swap Data.
16 IFS	Input FIFO Byte Swap Byte swap all data that is written to the Input FIFO. 0b - Do Not Byte Swap Data. 1b - Byte Swap Data.
15-14	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
13 OFR	Output FIFO DMA Request Size The DMA request logic will only request data if the OUTPUT FIFO has enough data to satisfy the request. 0b - DMA request size is 1 entry. 1b - DMA request size is 4 entries.
12 OFE	Output FIFO DMA Enable 0b - DMA Request and Done signals disabled for the Output FIFO. 1b - DMA Request and Done signals enabled for the Output FIFO.
11-10 —	Reserved
9 IFR	Input FIFO DMA Request Size The DMA request logic will only request data if the INPUT FIFO has enough space for the request size. 0b - DMA request size is 1 entry. (4 bytes) 1b - DMA request size is 0 entries. (0 bytes)
8 IFE	Input FIFO DMA Enable 0b - DMA Request and Done signals disabled for the Input FIFO. 1b - DMA Request and Done signals enabled for the Input FIFO.
7-5 —	Reserved
4 —	Reserved
3-1 —	Reserved
0 IM	Interrupt Mask Once this bit is set, it can only be cleared by hard reset. 0b - Interrupt not masked. 1b - Interrupt masked

52.4.4.1.4.2.5.8 Clear Written Register (CW)

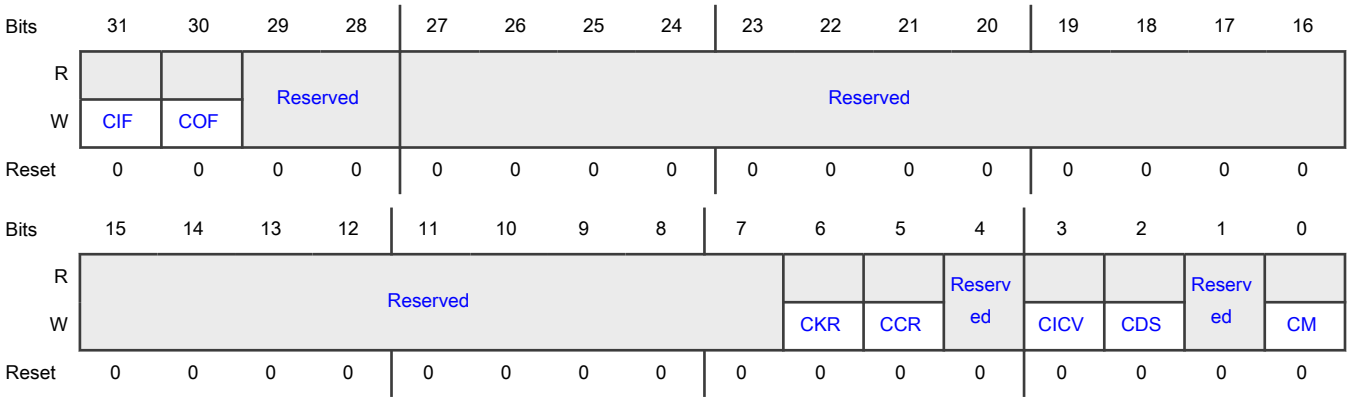
Offset

Register	Offset
CW	40h

Function

The Clear Written Register is used to clear many of the internal registers. All fields of this register are self-clearing.

Diagram



Fields

Field	Function
31 CIF	Clear Input FIFO Writing a 1 to this bit causes the Input Data FIFO reset and reset level to empty.
30 COF	Clear Output FIFO Writing a 1 to this bit causes the Output FIFO to be cleared.
29-28 —	Reserved
27-16 —	Reserved
15-7 —	Reserved
6 CKR	Clear the Key Register Writing a one to this bit causes the Key and Key Size Registers to be cleared.
5 CCR	Clear the Context Register Writing a one to this bit causes the Context Register to be cleared.

Table continues on the next page...

Table continued from the previous page...

Field	Function
4 —	Reserved
3 CICV	Clear the ICV Size Register Writing a one to this bit causes the ICV Size Register to be cleared.
2 CDS	Clear the Data Size Register Writing a one to this bit causes the Data Size Register to be cleared. This clears AAD Size as well.
1 —	Reserved
0 CM	Clear the Mode Register Writing a one to this bit causes the Mode Register to be cleared.

52.4.4.1.4.2.5.9 Status Register (STA)

Offset

Register	Offset
STA	48h

Function

The Status Register shows the status of the internal Crypto engine and its internal registers.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	Reserved	Reserved			Reserved			Reserved	Reserved			EI	Reserved			DI
W																W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved			Reserved		Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	AB	Reserved
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>31
—</td><td>Reserved</td></tr>
<tr><td>30-28
—</td><td>Reserved</td></tr>
<tr><td>27-25
—</td><td>Reserved</td></tr>
<tr><td>24
—</td><td>Reserved</td></tr>
<tr><td>23-21
—</td><td>Reserved</td></tr>
<tr><td>20
EI</td><td>Internal Error
An Error has been asserted. This error can only be cleared by resetting LTC with etiher an async reset or writing to the proper bit in the Command Register.
0b - No Error.
1b - Error Occurred. Details of the Error can be found in the Error Status Register.</td></tr>
<tr><td>19-17
—</td><td>Reserved</td></tr>
<tr><td>16
DI</td><td>LTC Interrupt
The Interrupt has been asserted indicating that either the operation has completed successfully or ended in error.
<table>
<tr><th>Value</th><th>Read</th><th>Write</th></tr>
<tr><td>0</td><td>No Interrupt</td><td>No change</td></tr>
<tr><td>1</td><td>Interrupt asserted</td><td>Clear the Interrupt</td></tr>
</table></td></tr>
<tr><td>15-13
—</td><td>Reserved</td></tr>
<tr><td>12-11
—</td><td>Reserved</td></tr>
<tr><td>10
—</td><td>Reserved</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function
9 —	Reserved
8 —	Reserved
7 —	Reserved
6 —	Reserved
5 —	Reserved
4 —	Reserved
3 —	Reserved
2 —	Reserved
1 AB	AESA Busy This bit indicates that the AES Accelertor is busy. The CHA can either be busy processing data or resetting. 0b - AESA Idle 1b - AESA Busy.
0 —	Reserved

52.4.4.1.4.2.5.10 Error Status Register (ESTA)

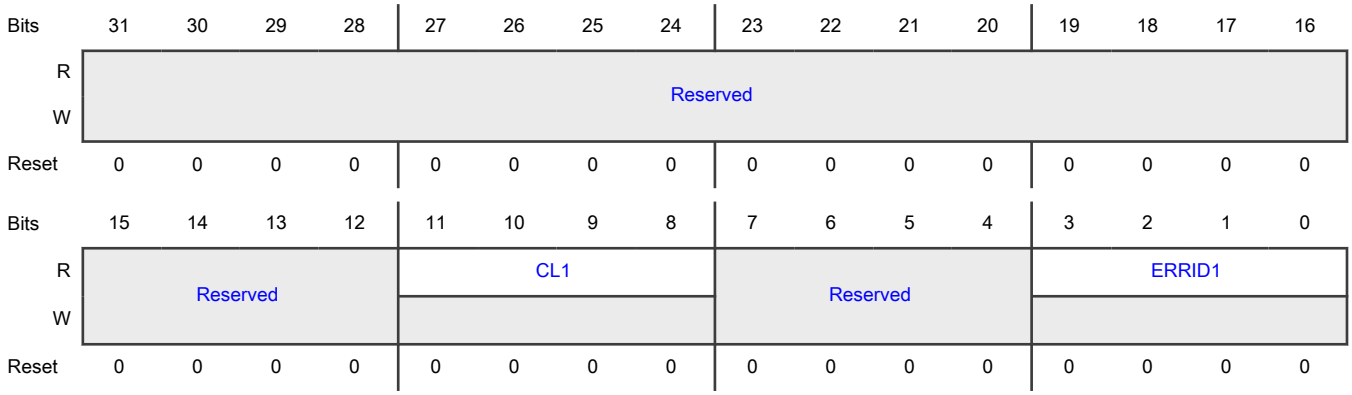
Offset

Register	Offset
ESTA	4Ch

Function

The Error Register shows the status of the internal Crypto Engine and its internal registers.

Diagram



Fields

Field	Function
31-12 —	Reserved
11-8 CL1	algorithms The algorithms field indicates which algorithm is asserting an error. Others reserved 0000b - General Error 0001b - AES
7-4 —	Reserved
3-0 ERRID1	Error ID 1 These bits indicate the type of error that was found while processing the Descriptor. The Algorithm that is associated with the error can be found in the CL1 field. Others reserved. 0001b - Mode Error 0010b - Data Size Error 0011b - Key Size Error 0110b - Data Arrived out of Sequence Error 1010b - ICV Check Failed 1011b - Internal Hardware Failure 1100b - CCM AAD Size Error (either 1. AAD flag in B0 =1 and no AAD type provided, 2. AAD flag in B0 = 0 and AAD povided, or 3. AAD flag in B0 =1 and not enough AAD provided - expecting more based on AAD size.) 1111b - Invalid Crypto Engine Selected

52.4.4.1.4.2.5.11 AAD Size Register (AADSZ)

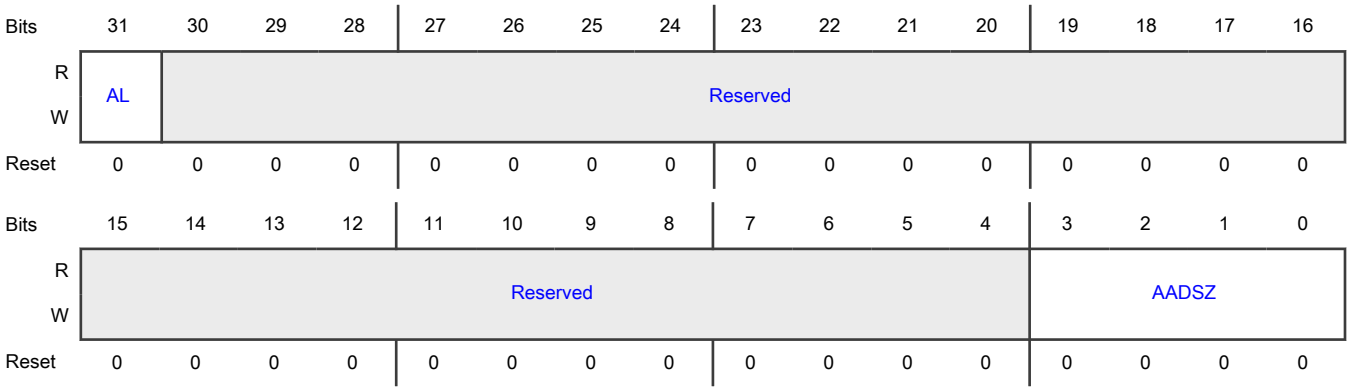
Offset

Register	Offset
AADSZ	58h

Function

The AAD Size Register is used by AESA to determine how much of the last block of AAD is valid. The write to this register should be the entire size of the AAD as it is also added directly to the Data Size Register. The size added to the Data Size Register is the AAD size rounded up to the next 16 byte boundary. For instance, a size of 20 bytes written to the AAD size register will cause 32 bytes to be added to the Data Size Register. The size stored in the AADSZ field represents the number of bytes valid in the final block of AAD. However, the entire size of AAD should be written to the AAD Size Register (AADSZ) Register address location. When authentication only is being done then the AL bit needs to be written to tell the AES engine that this is the last of the data.

Diagram



Fields

Field	Function
31 AL	AAD Last Only AAD data will be written into the Input FIFO.
30-4 —	Reserved
3-0 AADSZ	AAD size in Bytes, mod 16

52.4.4.1.4.2.5.12 Context Register (CTX_0 - CTX_13)

Offset

For a = 0 to 13:

Register	Offset
CTX_a	100h + (a × 4h)

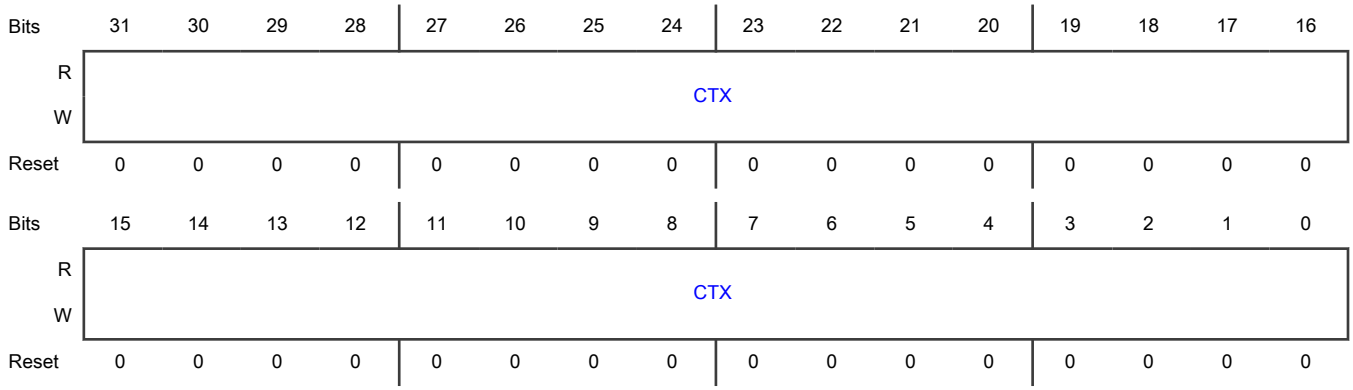
Function

The Context Register holds the context for the internal crypto engine. This register is 448 bits in length. The IP bus write to the Context Register is accessible only as full-word reads or writes to fourteen 32-bit registers. The MSB is located at offset 0100h with respect to the register page.

The bit assignments of this register are dependent on the algorithm, and in some cases the mode of that algorithm. See the appropriate section for the Context Register format used for that algorithm:

- AES ECB: Section AES ECB mode use of the Context Register
- AES CBC: Section AES CBC, OFB, and CFB128 modes use of the Context Register
- AES CTR: Section AES CTR mode use of the Context Register
- AES CCM: Section AES CCM and CCM* mode use of the Context Register

Diagram



Fields

Field	Function
31-0 CTX	CTX

52.4.4.1.4.2.5.13 Key Registers (KEY_0 - KEY_3)

Offset

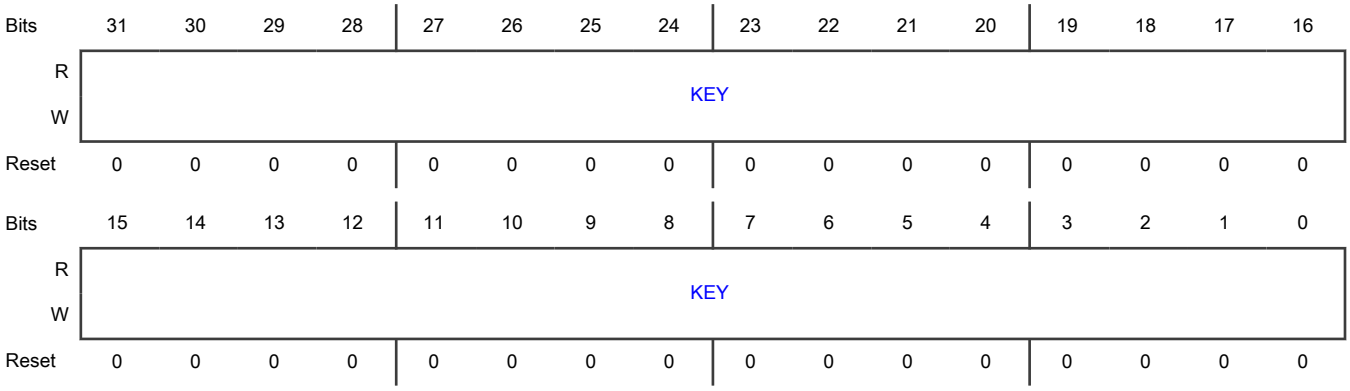
Register	Offset
KEY_0	200h
KEY_1	204h
KEY_2	208h
KEY_3	20Ch

Function

The Key Register normally holds the left-aligned key for the internal crypto engine. The MSB is in offset 200h. The Key Register is 128 bits in length. The IP bus write to the Key Register is accessible only as full-word reads or writes to four 32-bit registers.

Before the value in the Key Register can be used in a cryptographic operation, the size of the key must be written into the Key Size Register. Once the Key Size Register has been written, the Key Register cannot be written again until the Key Size Register has been cleared.

Diagram



Fields

Field	Function
31-0 KEY	KEY

52.4.4.1.4.2.5.14 Version ID Register (VID1)

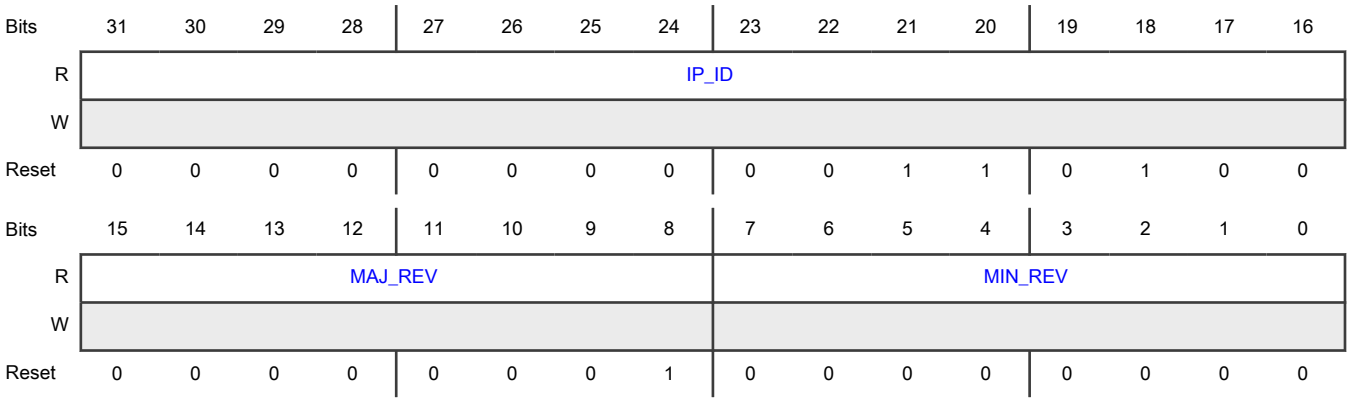
Offset

Register	Offset
VID1	4F0h

Function

This register contains the ID for LTC and major and minor revision numbers.

Diagram



Fields

Field	Function
31-16 IP_ID	Unique string used to identify which version of the module is in HW ID(0x0034).
15-8 MAJ_REV	Major revision number.
7-0 MIN_REV	Minor revision number.

52.4.4.1.4.2.5.15 Version ID 2 Register (VID2)

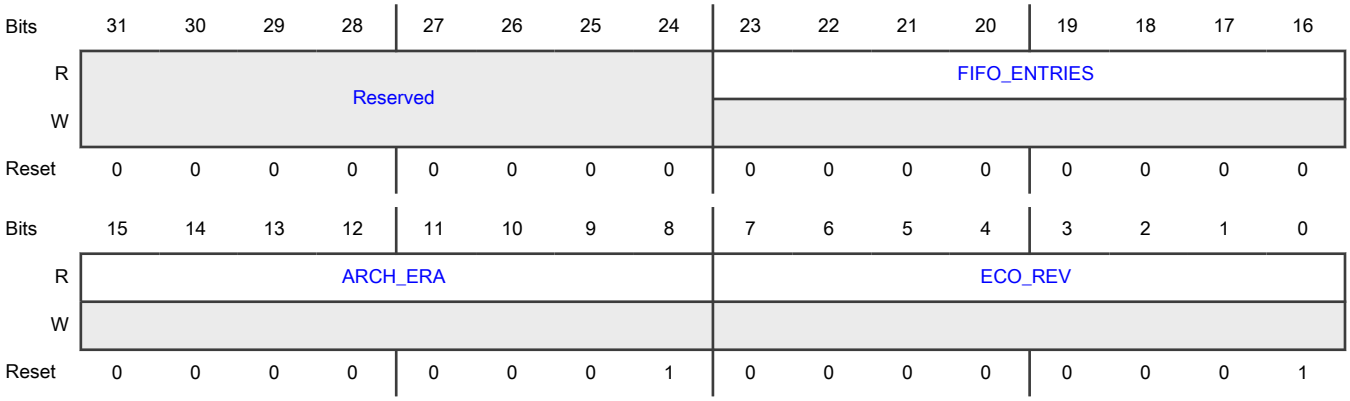
Offset

Register	Offset
VID2	4F4h

Function

This register contains the architectural era and eco revision numbers. It also contains the number of Input FIFO entries.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16	FIFO Entries

Table continues on the next page...

Table continued from the previous page...

Field	Function
FIFO_ENTRIES	This field represents the total number of entries (4 bytes per entry) in the Input FIFO.
15-8 ARCH_ERA	Architectural ERA.
7-0 ECO_REV	ECO revision number.

52.4.4.1.4.2.5.16 CHA Version ID Register (CHAVID)

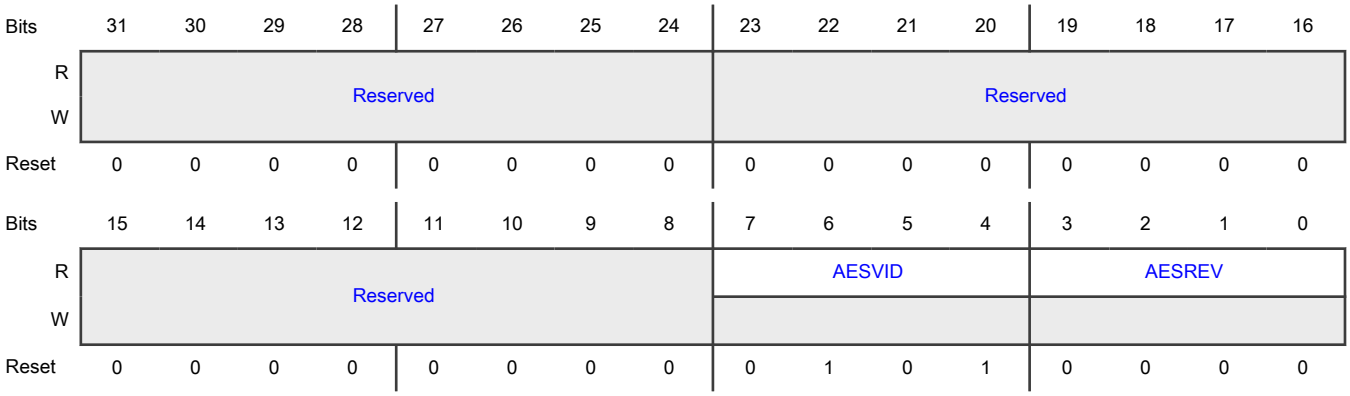
Offset

Register	Offset
CHAVID	4F8h

Function

This register contains the Version ID and Revision Number for the CHAs contained within LTC.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
15-8 —	Reserved
7-4 AESVID	AES Version ID
3-0 AESREV	AES Revision Number

52.4.4.1.4.2.5.17 FIFO Status Register (FIFOSTA)

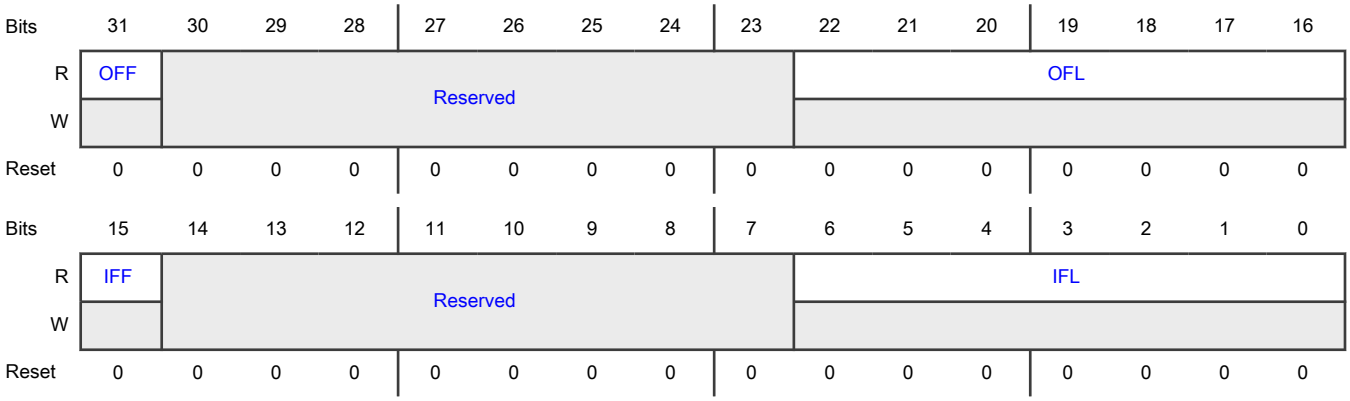
Offset

Register	Offset
FIFOSTA	7C0h

Function

The FIFO Status shows the current levels of the Input and Output FIFO.

Diagram



Fields

Field	Function
31 OFF	Output FIFO Full The Output FIFO is full and should not be written to.
30-23	Reserved

Table continues on the next page...

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Field	Function
—	
22-16 OFL	Output FIFO Level These bits indicate the current number of entries in the Output FIFO.
15 IFF	Input FIFO Full The Input FIFO is full and should not be written to.
14-7 —	Reserved
6-0 IFL	Input FIFO Level These bits indicate the current number of entries in the Input FIFO. An Entry is 4 bytes.

52.4.4.1.4.2.5.18 Input Data FIFO (IFIFO)

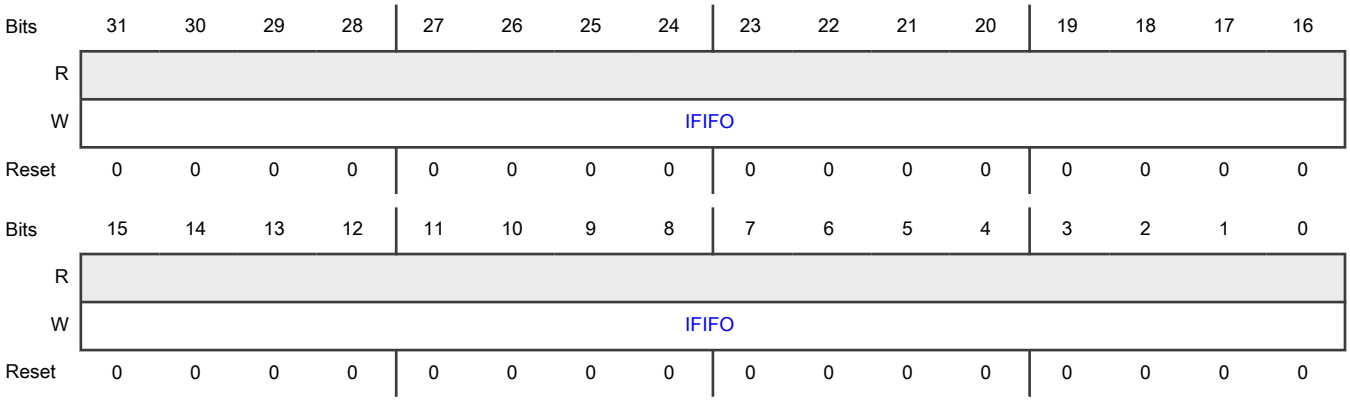
Offset

Register	Offset
IFIFO	7E0h

Function

Data to be processed by the various crypto engines is first pushed into the Input Data FIFO. The Input Data FIFO does not support byte enables. All data should be word aligned. The IFIFO is 0 entries deep, and each entry is four bytes. Care must be used to not overflow the Input Data FIFO. A Write to the Input Data FIFO when FIFOSTA[IFF] is set will cause a bus error. Reads from this address will always return 0x0.

Diagram



Fields

Field	Function
31-0 IFIFO	IFIFO

52.4.4.1.4.2.5.19 Output Data FIFO (OFIFO)

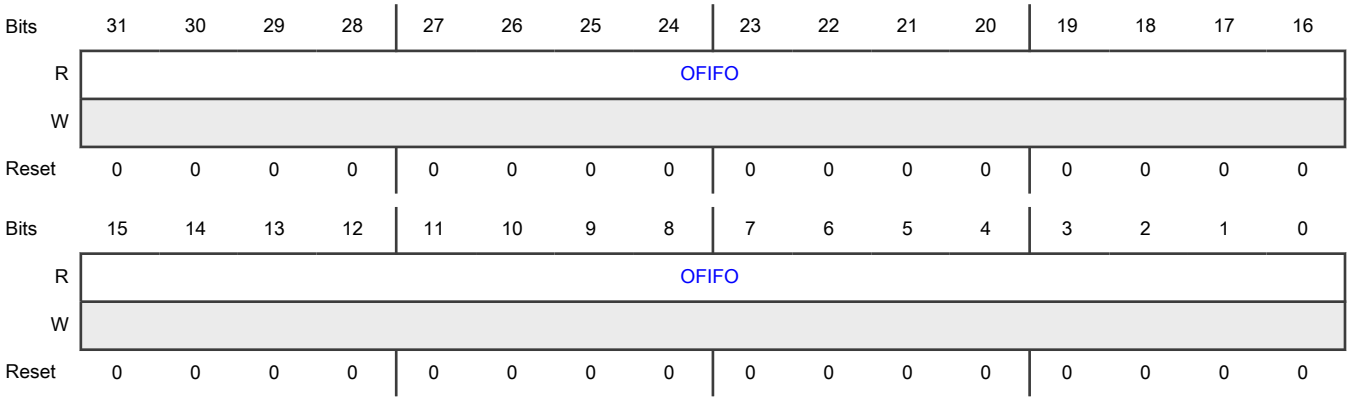
Offset

Register	Offset
OFIFO	7F0h

Function

Data that is output from the AES is pushed into the Output Data FIFO. The OFIFO is 4 entries deep, and each entry is four bytes. During normal operation, the AES will never overflow the Output Data FIFO. Writes to this register are ignored.

Diagram



Fields

Field	Function
31-0 OFIFO	Output FIFO

52.4.4.1.5 WiFi Coexistence Interface

The 2.4GHz radio architecture supports a flexible coexistence interface that enables the narrowband (NB) radio (e.g., Bluetooth, IEEE 802.15.4 and proprietary protocols) to coexist in the same space as a WiFi radio, which shares the same frequency band, or a different IC, with which active synchronization may be required to reduce either power consumption from battery or reduce electro-magnetic interference (EMI). As a simplification, this section primarily showcases the coexistence capabilities of the NB 2.4GHz radio in the context of WiFi radio coexistence. Note that an inter-processor communication (IPC) channel using a serial bus may also be used to augment the capabilities of the HW coexistence interface.

Typical coexistence schemes between a Bluetooth and WiFi designate the WiFi transceiver as the master, and the 2.4GHz transceiver as the slave. However in some cases, an application profile may dictate the opposite. The coexistence strategy is to prevent both the NB 2.4GHz radio and the WiFi radio from transmitting simultaneously; a configuration option exists to prevent the NB 2.4GHz radio from reception when the WiFi radio owns the RF channel. Yet another implementation choice is for the two radios to indicate the nature of their RF activity allowing the coexistence scheme to allow for simultaneous reception on both radios as well as other options when NB and WiFi channels have adequate separation.

52.4.4.1.5.1 Coexistence Pin Definition

The WiFi coexistence pins are described in the following table.

WiFi Coexist Function	Pin Direction	Pin Description
RF_ACTIVE (REQUEST)	O	An output which is asserted prior to any Radio event and remains asserted for the duration of the event.
RF_STATUS (DIRECTION)	O	An output which indicates when the Radio is in an RX or TX event, software can also control this signal directly.
RF_PRIORITY	O	An output which indicates to the external WiFi device that the Radio event is a high priority and it needs access to the 2.4 GHz antenna.
RF_NOT_ALLOWED (!GRANT)	I	External signal which causes the internal Radio to cease radio activity.
RF_TX_CONF	I	Signal from an external Radio which indicates the availability of the 2.4 GHz antenna to the internal Radio. Note that this signal is not connected to the Radio hardware. Radio software can use any interrupt-capable GPIO which the application assigns for this function.

Behavioral control information for the radio pins is provided below. Refer also to Radio Coexistence/FEM/LANT Connections which illustrates how the signals are connected and muxed in the radio.

52.4.4.1.5.1.1 RF_NOT_ALLOWED Behavioral Control

The WiFi IC generates a signal, RF_NOT_ALLOWED. If this signal is asserted, then 2.4GHz radio does not perform any communication. When this signal is de-asserted, then 2.4GHz radio is free to perform communications. In case when the signal RF_NOT_ALLOWED is asserted when 2.4GHz radio has already initiated the transmission/reception of a packet then the 2.4GHz radio must stop its activity immediately. Note that a software override of the RF_NOT_ALLOWED signal is also supported by the radio, which can be used for debug as well as enabling the capability to abort radio activity under software control (based on application layer arbitration between a multi-radio system).

The table below describes register bits in the RFMC and RADIO_MISC to enable, control and provide status for RF_NOT_ALLOWED

Field	Type	Description
RFNA_IBE[2:0]	RW	RFMC bitfield to select which (among several) SOC pin to use for RF_NOT_ALLOWED function
RF_NOT_ALLOWED_EN[3:0]	RW	RADIO_MISC (COEX_CTRL register) bitfield to choose which link layers will receive RF_NOT_ALLOWED signal
RF_NOT_ALLOWED_ASSERTED	W1C	RADIO_MISC (COEX_CTRL register) bitfield sets on assertion of RF_NOT_ALLOWED, cleared only by software.
RF_NOT_ALLOWED	R	RADIO_MISC (COEX_CTRL register) bitfield reflects the raw state of the selected RF_NOT_ALLOWED SOC pin

Table continues on the next page...

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RF_NOT_ALLOWED_OVRD_EN	RW	RADIO_MISC (COEX_CTRL register) bitfield. If set, allows software to control the RF_NOT_ALLOWED signal to the link layers via the RF_NOT_ALLOWED_OVRD bitfield
RF_NOT_ALLOWED_OVRD	RW	RADIO_MISC (COEX_CTRL register) bitfield. If RF_NOT_ALLOWED_OVRD_EN is set, the RF_NOT_ALLOWED signal to the link layers is driven with the value of the RF_NOT_ALLOWED_OVRD bitfield
RF_NOT_ALLOWED_INV	RW	RADIO_MISC (COEX_CTRL register) bitfield. If set, the selected RF_NOT_ALLOWED pin is inverted before being used as the RF_NOT_ALLOWED signal to the link layers

52.4.4.1.5.1.2 RF_ACTIVE Behavioral Control

The NB radio provides the RF_ACTIVE (REQUEST) output to request coexistence access. This signal can be generated by either the TSM, one of the link layers, or the RFMC.

The table below describes register bits in the TSM, RFMC and RADIO_MISC to enable, control, and provide status for RF_ACTIVE. Refer to the link layer chapters for information on their REQUEST output.

Field	Type	Description
RF_ACTIVE_RX_HI[7:0]	RW	TSM bitfield to control when TSM RF_ACTIVE asserts in the RX sequence
RF_ACTIVE_RX_LO[7:0]	RW	TSM bitfield to control when TSM RF_ACTIVE de-asserts in the RX sequence
RF_ACTIVE_TX_HI[7:0]	RW	TSM bitfield to control when TSM RF_ACTIVE asserts in the TX sequence
RF_ACTIVE_TX_LO[7:0]	RW	TSM bitfield to control when TSM RF_ACTIVE de-asserts in the TX sequence
TSM_RF_ACTIVE_OVRD_EN	RW	TSM bitfield to provide override enable for TSM RF_ACTIVE output
TSM_RF_ACTIVE_OVRD	RW	TSM bitfield to provide override value for TSM RF_ACTIVE output
TSM_SPARE1_EXTEND[7:0]	RW	TSM bitfield to control when how long TSM RF_ACTIVE remains asserted after end of RX or TX sequence. This is intended to close any gaps which may occur between consecutive RX/TX or TX/RX operations
COEX_SEL	RW	RADIO_MISC (COEX_CTRL register) bitfield to select whether the TSM outputs (RF_ACTIVE, RF_STATUS, RF_PRIORITY) or the active Link Layer's outputs are input to the RFMC.
RFACT_SRC[1:0]	RW	RFMC bitfield to select whether RF_ACTIVE radio output is driven by RFMC (2'b00), TSM/LL output from the COEX_SEL mux (2'b01), or Bluetooth LE bt_clk_req signal (2'b10)
RFACT_WKUP_DLY[5:0]	RW	RFMC bitfield. If RFACT_SRC=2'b00, this configures number of 32kHz reference clocks following enable of the XO to assert the RF_ACTIVE pin for a MAN/WOR/Bluetooth LE wakeup event.
RFACT_IDIS	RW	RFMC bitfield. If RFACT_SRC=2'b00, this selects whether the RF_ACTIVE radio output de-asserts when the TSM becomes idle
RFACT_EN	RW	RFMC bitfield. If RFACT_SRC=2'b00, the RF_ACTIVE radio output is asserted while this bit is set

Table continues on the next page...

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RFACT_FLAG	W1C	RFMC bitfield. Sets when the RF_ACTIVE radio output asserts
RFACT_IE	RW	RFMC bitfield. If set, the RFMC will generate an interrupt to CM33 when the RF_ACTIVE radio output asserts

52.4.4.1.5.1.3 RF_STATUS Behavioral Control

The NB radio provides the RF_STATUS (DIRECTION) output to indicate when the radio is in an RX or TX event. This signal can be generated by either the TSM or the active link layers.

The table below describes register bits in the TSM and RADIO_MISC to enable and control RF_STATUS. Refer to the link layer chapters for information on their DIRECTION output.

Field	Type	Description
RF_STATUS_RX_HI[7:0]	RW	TSM bitfield to control when TSM RF_STATUS asserts in the RX sequence
RF_STATUS_RX_LO[7:0]	RW	TSM bitfield to control when TSM RF_STATUS de-asserts in the RX sequence
RF_STATUS_TX_HI[7:0]	RW	TSM bitfield to control when TSM RF_STATUS asserts in the TX sequence
RF_STATUS_TX_LO[7:0]	RW	TSM bitfield to control when TSM RF_STATUS de-asserts in the TX sequence
TSM_RF_STATUS_OVRD_EN	RW	TSM bitfield to provide override enable for TSM RF_STATUS output
TSM_RF_STATUS_OVRD	RW	TSM bitfield to provide override value for TSM RF_STATUS output
COEX_SEL	RW	RADIO_MISC (COEX_CTRL register) bitfield to select whether the TSM outputs (RF_ACTIVE, RF_STATUS, RF_PRIORITY) or the active Link Layer's outputs are input to the RFMC.

52.4.4.1.5.1.4 RF_PRIORITY Behavioral Control

The NB radio provides the RF_PRIORITY[1:0] outputs to indicate the radio access priority. This signal can be generated by either the TSM or the active link layers. Note that if the TSM is chosen, then RF_PRIORITY[1] is always 0.

The table below describes register bits in the TSM and RADIO_MISC to enable and control RF_PRIORITY. Refer to the link layer chapters for information on their PRIORITY output.

Field	Type	Description
RF_PRIORITY_RX_HI[7:0]	RW	TSM bitfield to control when TSM RF_PRIORITY asserts in the RX sequence
RF_PRIORITY_RX_LO[7:0]	RW	TSM bitfield to control when TSM RF_PRIORITY de-asserts in the RX sequence
RF_PRIORITY_TX_HI[7:0]	RW	TSM bitfield to control when TSM RF_PRIORITY asserts in the TX sequence
RF_PRIORITY_TX_LO[7:0]	RW	TSM bitfield to control when TSM RF_PRIORITY de-asserts in the TX sequence
TSM_RF_PRIORITY_OVRD_EN	RW	TSM bitfield to provide override enable for TSM RF_PRIORITY output
TSM_RF_PRIORITY_OVRD	RW	TSM bitfield to provide override value for TSM RF_PRIORITY output

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COEX_SEL	RW	RADIO_MISC (COEX_CTRL register) bitfield to select whether the TSM outputs (RF_ACTIVE, RF_STATUS, RF_PRIORITY) or the active Link Layer's outputs are input to the RFMC.

52.4.4.1.5.2 Coexistence Signaling Options

The figure below illustrates a number of Bluetooth & WiFi coexistence signaling (adapted from WiFi alliance documentation). The interface definition between the two radio has evolved over time targeting improved spectral and antenna control efficiency. Most modern BT & WiFi interfaces utilize 3 or more signals.

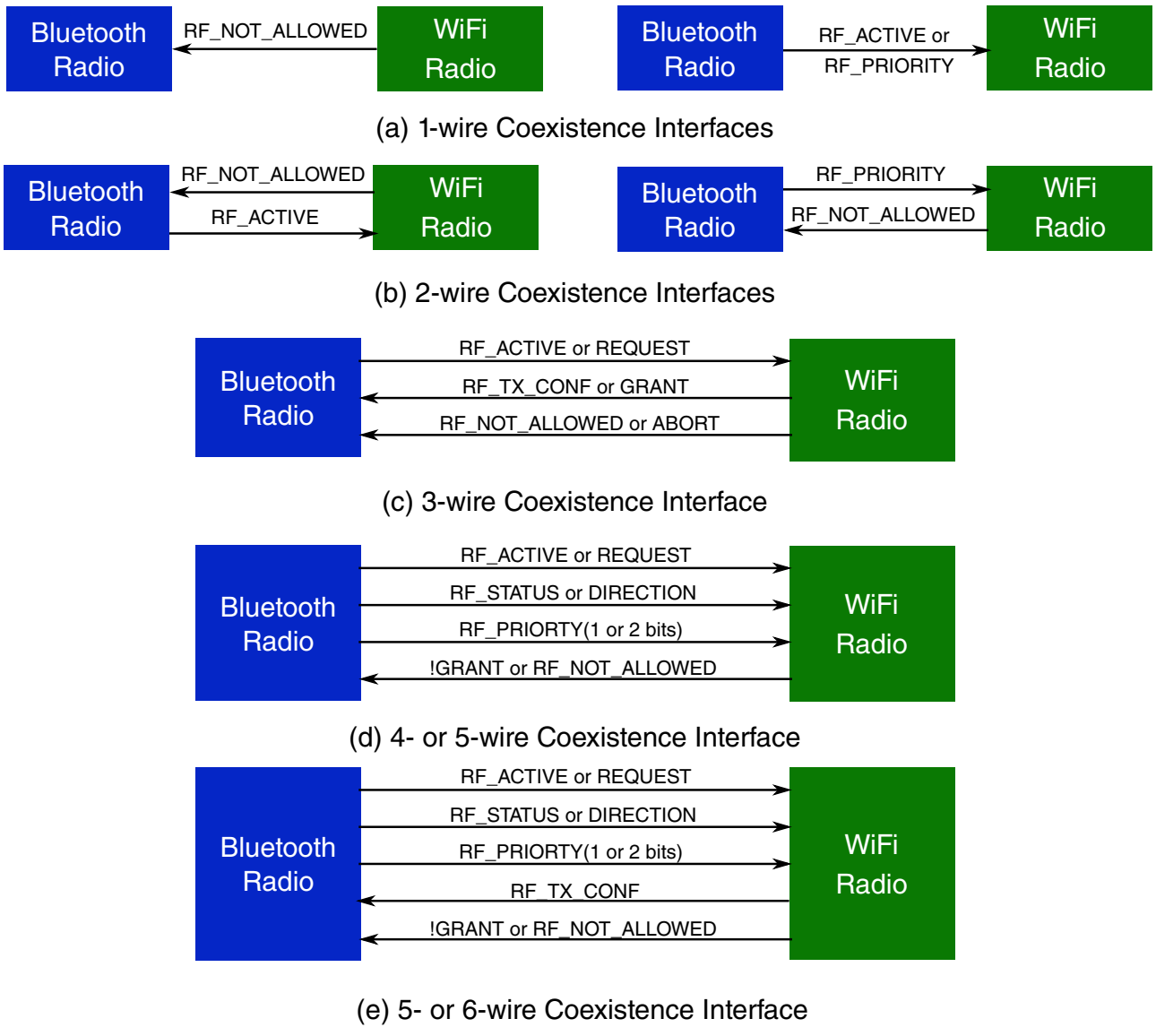

Figure 283. Coexistence signaling options between Bluetooth-LE and WiFi Radios

52.4.4.1.5.3 Example Coexistence Pin Mapping

The table below shows example mapping of legacy coexistence signals supported by the NB 2.4GHz radio for a few WiFi radios available in the market.

WiFi Co-existence Use Case	RF_ACTIVE	RF_STATUS	RF Priority	RF_NOT_ALLOWED	RF_TX_CONF	WiFi SoC
Direction	Output	Output	Output	Input	Input	
Functionality	Indicates a Radio Event; Needs to stay asserted during a radio event; Deasserted if RF_NOT_ALLOW ED==1	Indicates RX/TX event. Optionally RF_Priority signal can be mixed on it	Specifies RF_ACTIVE priority to an external traffic arbiter	Indicates an external command for the NB radio to cease radio activity	Indicates grant of antenna to TX; Need to sample if RF_priority requested; can be any GPIO	
1-Wire Interface, WLAN is Master				X		
1-Wire Interface, BT is Master	X					
2-Wire Interface, Cross Signaling between BT and WLAN	X			X		
2-Wire Interface, BT Priority and WLAN TX Signaling			X		X	
3-Wire: Third Party Interface	X			X	X	Broadcom, CSR
3-wire: Request, Grant and Status	X	X			X	BRCM43XX; Nokia 3-wire option
3-wire: Qualcomm	X		X	O	X	QCOM Dakota chipset
4-wire: Request, Grant, Status and Freq (Nokia 4-wire option)	X	X	X		X	BCM89xx; Nokia 4-wire option
4-wire: CSR Interface	X	X	X	O	X	CSR-BC41Bxx
4-wire: Phillips Interface	X	X		X	X	

52.4.4.1.6 Radio Coexistence/FEM/LANT Connections

The Radio provides flexible mux configuration for 4 coexistence outputs, 4 FEM control outputs and 4 Localization outputs. The detailed connections are shown in below diagram.

NOTE

For the Bluetooth LE use case using the NBU: once asserted the bt_grant_n input should remain asserted until 10us after the bt_request has been de-asserted.

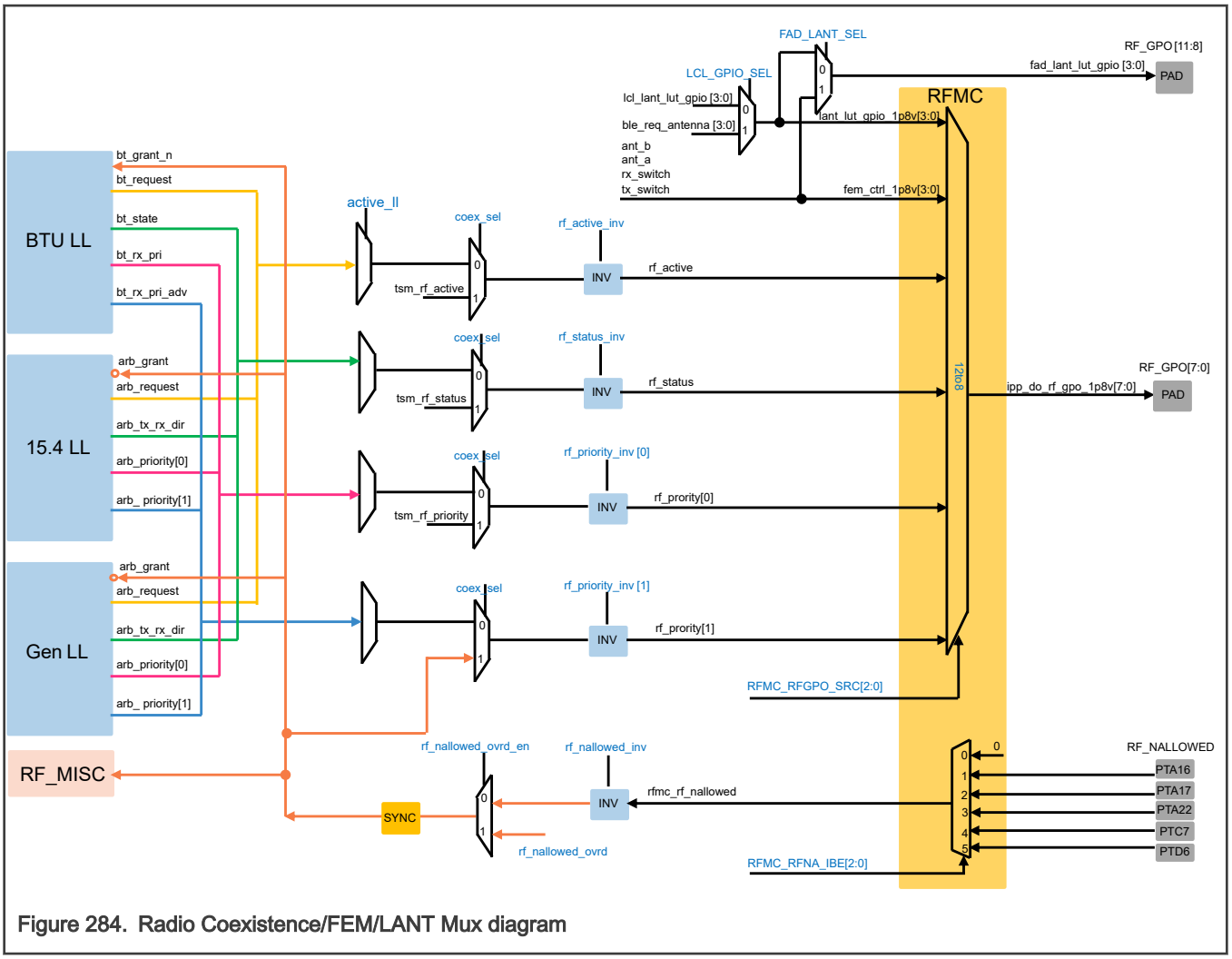

Figure 284. Radio Coexistence/FEM/LANT Mux diagram

52.4.4.2 Transceiver

52.4.4.2.1 Overview

The transceiver is built to support concurrent transmit and receive operations in the 2.4Ghz bands. The PHY layer supports the following protocols :

- Bluetooth Low Energy (BLE) and Channel Sounding
- IEEE 802.15.4 (Zigbee, Thread …)
- Generic FSK

The arbitration between protocols is managed by software through Link Layers.

52.4.4.2.1.1 Block diagram

The transceiver uses a constant envelope direct launch transmitter and a low IF quadrature receiver. A high level figure illustrating the digital and analog components and their hierarchy is shown below.

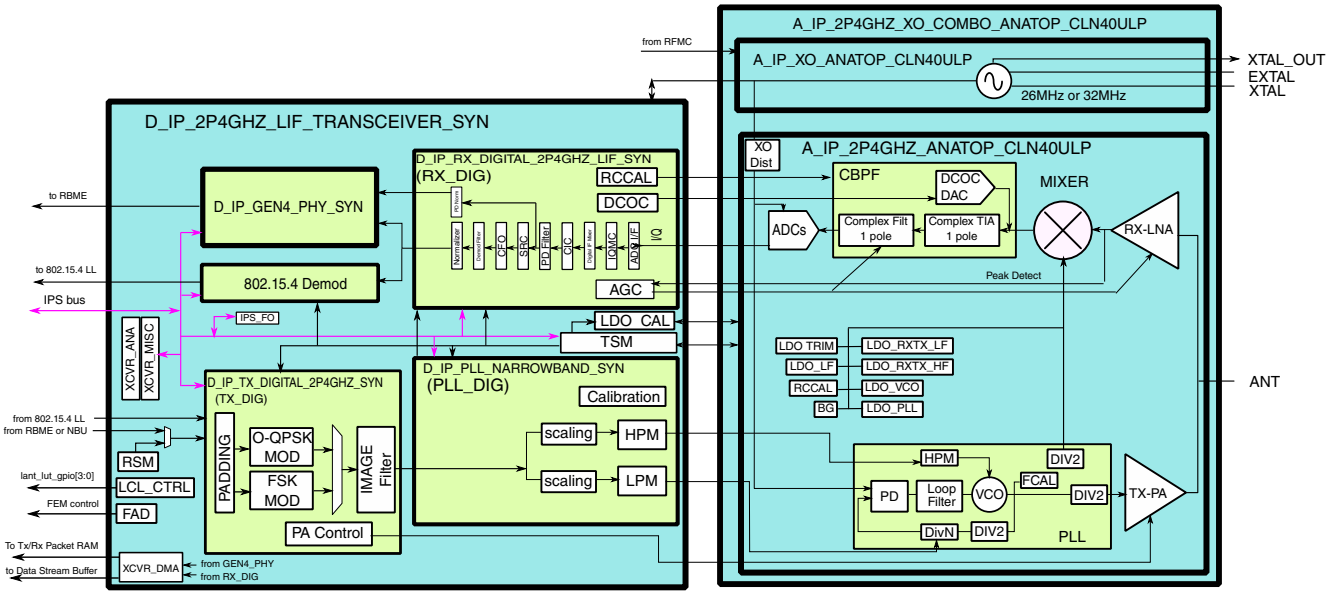

Figure 285. Transceiver Hierarchy

52.4.4.2.1.2 Features

The digital part of the transceiver is split in several sub-modules:

- Transmitter digital module
- Receiver digital module
- PLL digital module
- Zigbee PHY
- 2.4GHz FSK PHY
- Transceiver sequence manager (TSM)
- DMA
- Localization control module (LCL)
- Ranging sequence manager (RSM)
- LDO calibration

52.4.4.2.2 Functional description

52.4.4.2.2.1 Transmitter Digital Module (TX_DIG)

52.4.4.2.2.1.1 Overview

The Transmitter Digital (TX_DIG) processes the Transmission Data from the RF Protocol Link Layers and presents the processed data to the PLL Frequency Synthesizer as the Baseband Frequency Word.

PFC_en (Phase to Frequency Conversion) is set when zigbee symbols are to be transmitted.

52.4.4.2.2.1.1.1 Block diagram

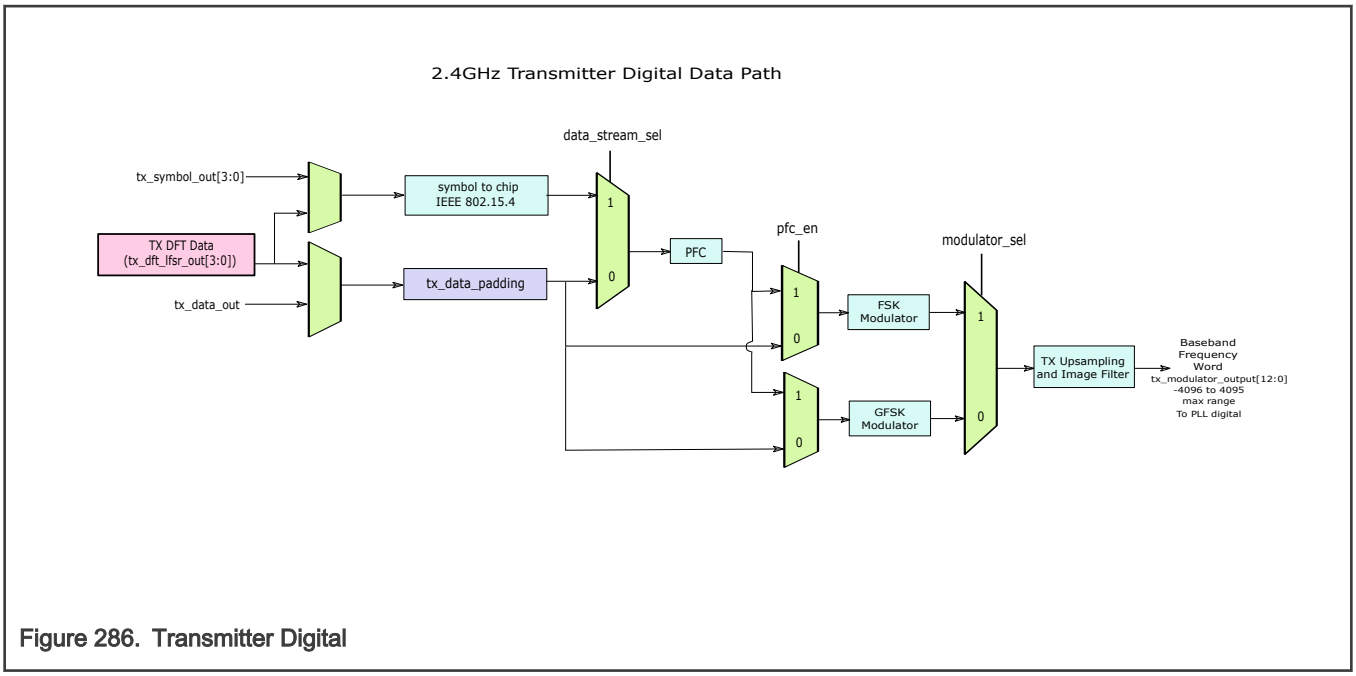

Figure 286. Transmitter Digital

modulator_sel	pfc_en	data_stream_sel	modulation type
0	0	-	GFSK
0	1	0	Invalid
1	0	-	FSK
1	1	0	MSK
1	1	1	OQPSK

52.4.4.2.2.1.1.2 Features

52.4.4.2.2.1.1.2.1 Modulation Types

Modulation Type [1]	Data/Chip Rate (kbps) [2]	BT Product [3]	Modulation Index	Symbol Time (us)	Max Frequency Deviation (kHz)
GMSK/ GFSK,BT=0.5, h=0.5	2000	0.5	0.5	0.5	500
	1000	0.5	0.5	1	250
	500	0.5	0.5	2	125
	250	0.5	0.5	4	62.5
GFSK, BT=0.5, h=0.32	2000	0.5	0.32	0.5	320
	1000	0.5	0.32	1	160
	500	0.5	0.32	2	80
	250	0.5	0.32	4	40
GFSK, BT=0.5, h=0.7	2000	0.5	0.7	0.5	700

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	1000	0.5	0.7	1	350
	500	0.5	0.7	2	175
	250	0.5	0.7	4	87.5
GFSK, BT=0.5, h=1.0	2000	0.5	1	0.5	1000
	1000	0.5	1	1	500
	500	0.5	1	2	250
	250	0.5	1	4	125
GMSK, BT=0.3	2000	0.3	0.5	0.5	300
	1000	0.3	0.5	1	150
	500	0.3	0.5	2	75
	250	0.3	0.5	4	37.5
GMSK, BT=0.7	2000	0.7	0.5	0.5	700
	1000	0.7	0.5	1	350
	500	0.7	0.5	2	175
	250	0.7	0.5	4	87.5
Generic MSK	2000	NA	0.5	0.5	500
	1000	NA	0.5	1	250
	500	NA	0.5	2	125
	250	NA	0.5	4	62.5
Generic FSK	2000	NA	0.5	0.5	500
	1000	NA	0.5	1	250
	500	NA	0.5	2	125
	250	NA	0.5	4	62.5
OQPSK/Zigbee	2000	NA	0.5	0.5	500
	1000	NA	0.5	1	250
	500	NA	0.5	2	125
	250	NA	0.5	4	62.5

1. Modulation Type is set using TXDIG:MODULATION_TYPE.
2. Data Rate is set using XCVR_CTRL:DATA_RATE[2:0].
3. Bandwidth Time Product is changed by reprogramming the GFSK Gaussian Filter coefficients.

52.4.4.2.2.1.1.2.2 Data Rates

For other Radio protocols, the Transit Data Rate is set by the DATA_RATE bits in the XCVR_CTRL register.

The supported data rates are shown in the table below.

Table 462. Transmitter Data Rates

XCVR_CTRL: DATA_RATE[2:0] Identifies the data rate at the output of the PHY	TX Data Rate
000	2Mbps
001	1Mbps
010	500Kbps
011	250Kbps
100-111	Reserved

52.4.4.2.2.1.1.2.3 Over-Sampling

The TX Digital uses an Oversample Clock to process the transmission data.

The GFSK, GMSK, and MSK Oversample Ratios are summarized below.

Table 463. Oversample Ratios for GFSK, GMSK, and MSK Modulations

TX Data Rate (kb/s)	Ref Clk Freq (MHz)	OSR Ref Clk Divider	OSR Clk Rate (MHz)	Data Oversample Rate
2000	32	2	16	8
1000	32	4	8	8
500	32	8	4	8
250	32	16	2	8
2000	26	1	26	13
1000	26	2	13	13
500	26	4	6.5	13
250	26	8	3.25	13

52.4.4.2.2.1.1.2.4 Frequency Word Adjust

The Transmitter has a frequency adjustment register, FREQ_WORD_ADJ, which is used as a signed 9-bit number that is added to the TX Digital output before it is presented to the PLL as the baseband frequency word. This allows the baseband frequency word to be adjusted, or skewed, by a range of -512 to +511.

This frequency adjustment is applied to the final modulation word from any source (GFSK, FSK, DFT) and there is no protection from a math overflow. So the baseband frequency word range of -4096 to 4095 must be considered when adding this frequency word adjustment.

52.4.4.2.2.1.2 Functional description

52.4.4.2.2.1.2.1 Data Pre-Processing

Before the Transmission Data is processed by the GFSK or FSK Modulators, it can be inverted, and it can also have additional preamble-like data pre-pended.

52.4.4.2.2.1.2.1.1 Data Polarity

The Transmission Data that is received by the TX Digital module is mapped to a positive frequency deviation if the data is a 1, and is mapped to a negative frequency deviation if the data is a 0

This mapping can be reversed by setting the TX_CAPTURE_POL register bit.

52.4.4.2.2.1.2.1.2 Data Padding

Transmission Data Padding is done to avoid abrupt steps in On-Air frequency modulation and thereby minimize spectral transients during the transition from a low Power Amplifier setting to a high Power Amplifier setting prior to protocol data packet transmission.

The abrupt step in modulation is avoided by pre-pending frequency words onto the front end of the actual preamble transmission. The Power Amplifier ramp-up is done while modulating these additional frequency words, and then the modulating power ramp-up smoothly transitions into the packet transmission at the Target Power level.

The data-padding starts right after TxDig_en and is applied to the Tx modulator before and during PA ramp-up as well as PA settling time(PAD_DLY plus PA_PUP_ADJ).

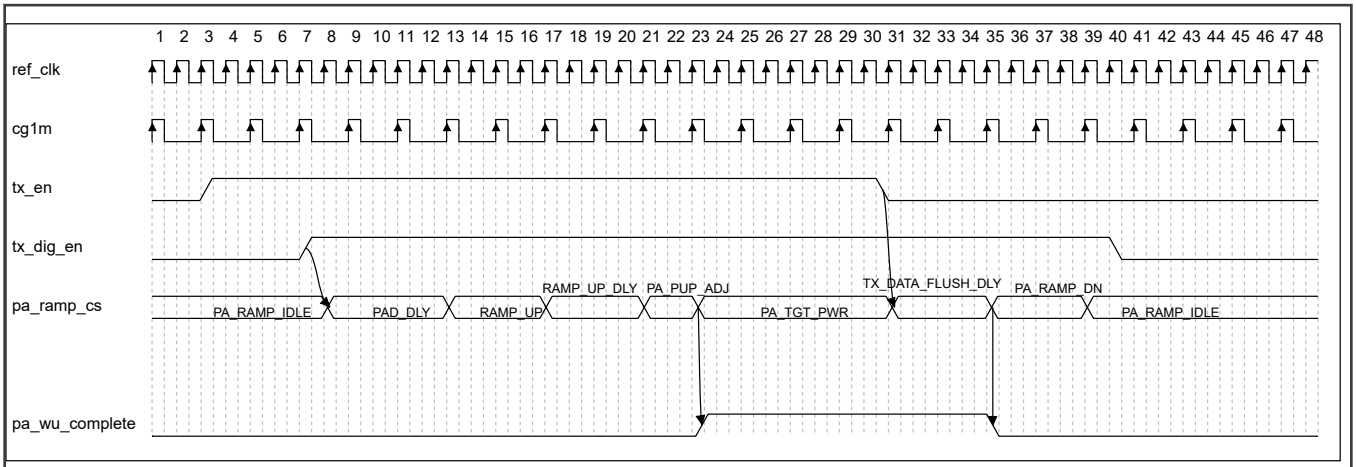


Figure 287. TX padding

There are basically three data padding steps:

- PAD_DLY, if enabled, it adds symbols before rampup.
- RAMP_UP_DLY, smooth transitions to the target power level.
- PA_PUP_ADJ, additional settling time, 2 times ref_clk cycles.
- TX_DATA_FLUSH_DLY, if enabled, it adds symbols before it starts ramping down.

DATA_PADDING_CTRL[PAD_DLY_EN],

- 1'b0, Pad delay is disabled.
- 1'b1:, Pad delay is enabled, and will insert 0-0-0-0... or 1-1-1-1..., based on data_padding_en settings.

DATA_PADDING_CTRL_1[RAMP_UP_DLY]

- It adds the number of cycles after PA ramp-up is completed, up to 31 cg1m cycles.

Table 464. Data Padding Selection

DATA_PADDING_EN[1:0]	Frequency word to PLL
00	13'h000
01	data_pad_pfdev
10	data_pad_mfdev
11	Reserved

52.4.4.2.2.1.2.1.3 Power Amplifier Ramping

PA ramping is included in the 2p4, to prevent abrupt transitions in PA (power amplifier) power, that could cause unwanted spectral transients. During a TX sequence, PA ramping gradually ramps up PA power, between a programmable minimum, and the TX target power. The trajectory of the ramp is programmable, and ramping takes place over the course of 1, 2, or 4us (programmable).

During ramp-down of the Power Amplifier the TX Digital holds the TX Modulation Data at the final value until power reaches the minimum level.

Please refer to the section Power Amplifier Ramping in the Transceiver Sequence Manager chapter for more details.

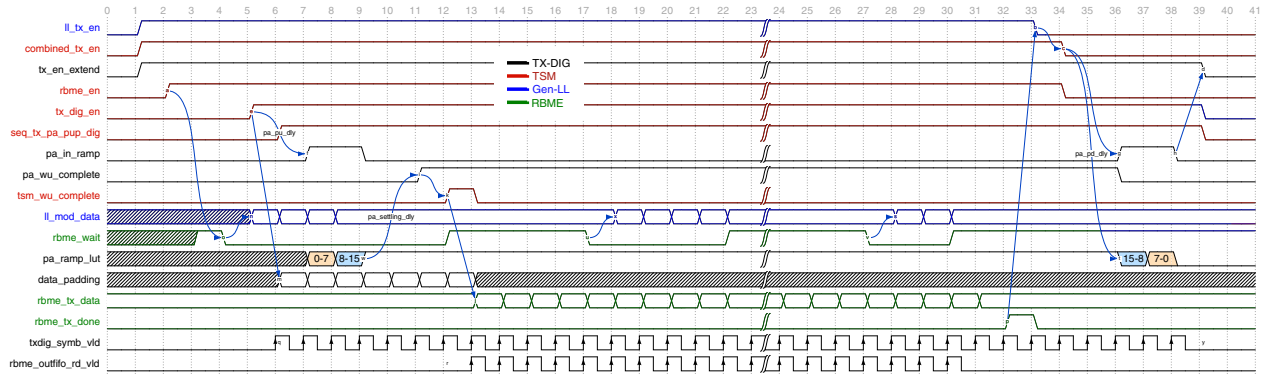


Figure 288. Power Amplifier Ramping

52.4.4.2.2.1.2.2 TX Warmup

When a Link Layer asserts *source*_tx_en (or software sets the FORCE_TX_EN bit) to start a TX burst, the TSM TX warmup sequence will begin. Near the end of the TSM TX warmup sequence, a TSM timing signal (tx_dig_en) will signal to the TXDIG to ramp-up the PA and start sending TX data.

The TXDIG warmup time is the time from tx_dig_en TSM signal assertion to when the TX is ready to send bits on air, which is the assertion of pa_wu_complete by the TXDIG.

The TXDIG warmup time depends on the following:

- pa_ramp_pad
- pa_ramp_up
- pa_ramp_settle (ramp_up_dly+pa_pup_adj)

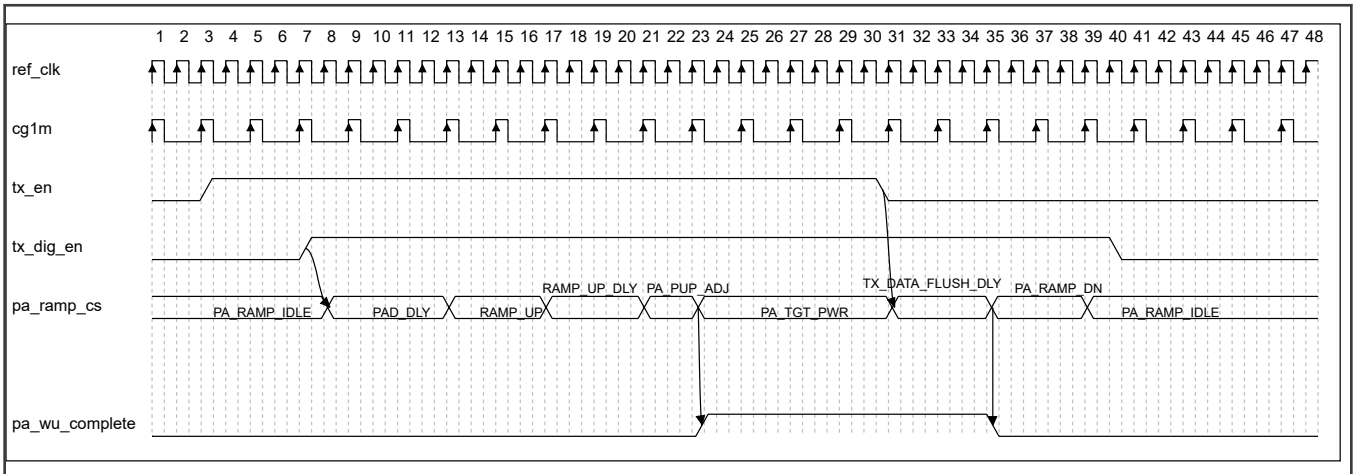


Figure 289. TX warmup delay

So the total TX warmup delay is composed of the following:

- pa_ramp_pad: DATA_PADDING_CTRL[PAD_DLY], in cg1m cycles ,padding before ramp-up (0 if PAD_DLY_EN=0)
- pa_ramp_up: PA_CTRL[PA_RAMP_SEL], 0us, 1us, 2us, or 4us.
- pa_ramp_settle:
  - ramp_up_dly : DATA_PADDING_CTRL_1[RAMP_UP_DLY], number of cg1m cycles plus
  - pa_pup_adj : DATA_PADDING_CTRL[PA_PUP_ADJ], 2 times the number of ref_clk cycles.

52.4.4.2.2.1.2.3 PA Ramping

PA ramping is included in the TXDig, to prevent abrupt transitions in PA (power amplifier) power that could cause unwanted spectral transients. During a TX sequence, PA ramping gradually ramps up PA power, between a programmable minimum, and the TX target power. The trajectory of the ramp is programmable, and ramping takes place over the course of 16 steps, 16 times the bit rate.

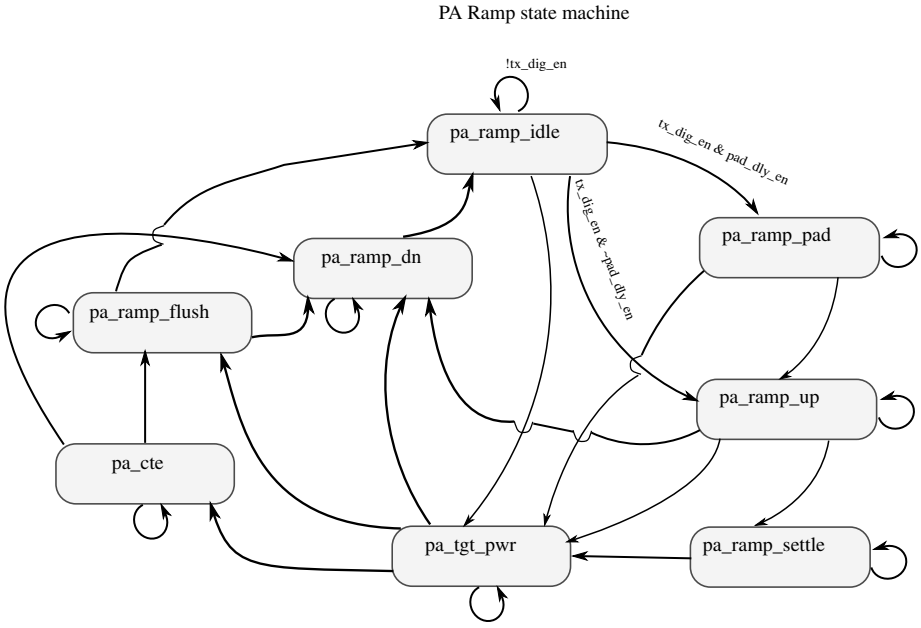


Figure 290. PA Ramp state machine

All fields used below for PA Ramping are contained in PA_CTRL register.

During a TX sequence, PA ramping is triggered by a low-to-high transition of tx_dig_en. At assertion of tx_dig_en the TX Dig will enable the PA, with a minimum power level determined by the lowest power level which is 0 according to a 16-deep pre-programmed register table (PA_RAMP_TBL table). After that, power level will increment according to the table. Incrementing will occur at 16 times the bit rate. At each ramp step, PA power level will be taken from the next entry in the PA_RAMP Table, from 0-15.

After the 16th and final ramp step, PA power level will be the selected target power in PA_TGT_POWER[5:0]. The target power will remain in effect for the duration of the packet transmission.

The overall time for ramping is determined by PA_RAMP_SEL[1:0] (no ramping/1us/2us/4us). For further explanations of PA Ramping , v_ramp_dur will be used to indicate the duration of ramping.

PA_RAMP_SEL[1:0]	v_ramp_dur
0x0	No ramping

Table continues on the next page...

Table continued from the previous page...

PA_RAMP_SEL[1:0]	v_ramp_dur
0x1	1us
0x2	2us
0x3	4us

3 Functional modes can be identified below (they depend on PA_RAMP_SEL) :

- Ramping LUT mode : classical digital ramping, default mode
- Ramping with Linear Interpolation : PA_RAMP_DIG_INTERP_EN bit to enable .
- Ramping with Analog Control :
  - PA_RAMP_ANA_EN bit to enable.
  - PA_RAMP_ANA_IDX[3:0] to select the index from which Analog control will jump over to target power.
  - PA_RAMP_ANA_IDX_TYPE to enable invert mechanism during ramp down.
  - PA_RAMP_HOLD[2:0] to add extra delay before cutting PA after ramp down (1us granularity).

Linear interpolation mode and analog mode will control more accurately the PA ramping and limit RF transmission transients.

Next sections below will describe these 3 modes :

52.4.4.2.2.1.2.3.1 Digital Ramping without Interpolation

PA_RAMP_DIG_INTERP_EN = 0 & PA_RAMP_ANA_EN = 0

This is the default modefor PA Ramping.

It ramps by crossing PA power levels (PA_RAMP table) until reaching target-power level.

52.4.4.2.2.1.2.3.2 Digital Ramping with Interpolation

PA_RAMP_DIG_INTERP_EN = 1 & PA_RAMP_ANA_EN = 0

This is a new mode that adds linear interpolation to existing PA_ramp table. It will bring some improvement to manage spurious in RF emission.

Linear Interpolation is a Mathematical Technique to estimate intermediate values between PA power levels (until reaching target-power level) in a straight-line method. It helps to smoothly adjust ramping and achieves a gradual ramp (up or down) to ensure optimal performance.

The intermediate values given by interpolation introduce a v_ramp_interp, which is a factor that depends on PA_RAMP_SEL.

The number of levels of power becomes : 16*v_ramp_interp , with :

PA_RAMP_SEL[1:0]	v_ramp_interp
0x0	No ramping
0x1	2
0x2	4
0x3	4

52.4.4.2.2.1.2.3.3 Analog Ramping

To enable this feature in the analog block, it is necessary to program the TX_DAC_PA[PA_SMOOTHER_EN] register to one, and then play with different current levels with TX_DAC_PA[PA_SMOOTHER_CUR], which will vary the speed (settling time) of the analog ramp.

To enable the feature in the digital block, program the following values:

PA_RAMP_DIG_INTERP_EN = 0 & PA_RAMP_ANA_EN = 1

This will disable Digital Interpolation when analog ramping is in use.

52.4.4.2.2.1.2.4 GFSK Modulator
52.4.4.2.2.1.2.4.1 Gaussian Filter

GFSK Modulation is implemented using a Gaussian filter and a lookup table to implement the various reference frequencies, data rates, and modulation index values.

The Gaussian filter is a symmetric 16-tap FIR filter with 9-bit quantized coefficients and supports reference frequencies of 32 and 26 MHz at oversampling ratios of 8 and 13 respectively. There are 2 sets of pre-programmed filter coefficients available as shown in the table below.

Table 465. Gaussian Filter Coefficients BT=0.5

Tap Number(s)	32 MHz Ref	26 MHz Ref
0	9'h001	9'h017
1	9'h004	9'h029
2	9'h00d	9'h044
3	9'h029	9'h067
4	9'h063	9'h090
5	9'h0c0	9'h0ba
6	9'h12c	9'h0dc
7	9'h176	9'h0ef
8	9'h176	9'h0ef
9	9'h12c	9'h0dc
10	9'h0c0	9'h0ba
11	9'h063	9'h090
12	9'h029	9'h067
13	9'h00d	9'h044
14	9'h004	9'h029
15	9'h001	9'h017

The pre-programmed filter coefficients can be manually overridden using the gfsk_coeff_man bit to disable the GFSK Filter Lookup Table. In this case the filter coefficients will be taken from the TX GFSK Filter Coefficients register.

The following tables show the coefficients for BT=0.7 and BT=0.3

Table 466. Gaussian Filter Coefficients BT=0.7

Table continues on the next page...

Table 466. Gaussian Filter Coefficients BT=0.7 (continued)

Tap Number(s)	32 MHz Ref	26 MHz Ref
0	9'h000 (0)	9'h003 (3)
1	9'h000 (0)	9'h00A (10)
2	9'h001 (1)	9'h01B (27)
3	9'h007 (7)	9'h03E (62)
4	9'h025 (37)	9'h079 (121)
5	9'h08A (138)	9'h0C6 (198)
6	9'h14A (330)	9'h114 (276)
7	9'h1FE (510)	9'h145 (325)
8	9'h1FE (510)	9'h145 (325)
9	9'h14A (330)	9'h114 (276)
10	9'h08A (138)	9'h0C6 (198)
11	9'h025 (37)	9'h079 (121)
12	9'h007 (7)	9'h03E (62)
13	9'h001 (1)	9'h01B (27)
14	9'h000 (0)	9'h00A (10)
15	9'h000 (0)	9'h003 (3)

Table 467. Gaussian Filter Coefficients BT=0.3

Tap Number(s)	32 MHz Ref	26 MHz Ref
0	9'h019 (25)	9'h048 (72)
1	9'h02C (44)	9'h059 (89)
2	9'h046 (70)	9'h06B (107)
3	9'h069 (105)	9'h07D (125)
4	9'h091 (145)	9'h08D (141)
5	9'h0B8 (184)	9'h09A (154)
6	9'h0D8 (216)	9'h0A4 (164)
7	9'h0EA (234)	9'h0A9 (169)
8	9'h0EA (234)	9'h0A9 (169)
9	9'h0D8 (216)	9'h0A4 (164)
10	9'h0B8 (184)	9'h09A (154)
11	9'h091 (145)	9'h08D (141)
12	9'h069 (105)	9'h07D (125)

Table continues on the next page...

Table 467. Gaussian Filter Coefficients BT=0.3 (continued)

13	9'h046 (70)	9'h06B (107)
14	9'h02C (44)	9'h059 (89)
15	9'h019 (25)	9'h048 (72)

Table 468. Gaussian Filter Coefficients BT=2.0

Tap Number(s)	32 MHz Ref	26 MHz Ref
0	9'h000 (0)	9'h000 (0)
1	9'h000 (0)	9'h000 (0)
2	9'h000 (0)	9'h000 (0)
3	9'h000 (0)	9'h000 (0)
4	9'h000 (0)	9'h000 (0)
5	9'h000 (0)	9'h007 (7)
6	9'h00E (14)	9'h068 (104)
7	9'h1F1 (497)	9'h191 (401)
8	9'h1F1 (497)	9'h191 (401)
9	9'h00E (14)	9'h068 (104)
10	9'h000 (0)	9'h007 (7)
11	9'h000 (0)	9'h000 (0)
12	9'h000 (0)	9'h000 (0)
13	9'h000 (0)	9'h000 (0)
14	9'h000 (0)	9'h000 (0)
15	9'h000 (0)	9'h000 (0)

52.4.4.2.2.1.2.4.2 On-Air Frequency Deviation

By default, the GFSK Modulator presents the modulation word to the PLL starting with the Negative Frequency Deviation, this results in the PLL going On-Air at the Carrier Frequency minus the frequency deviation.

The GFSK Modulator can instead be configured to begin modulating at Zero Frequency Deviation, allowing the PLL to go On-Air at the Carrier Frequency. This configuration is used if the ZERO_FDEV bit in the TX Digital Control register is set.

52.4.4.2.2.1.2.5 FSK Modulator

52.4.4.2.2.1.2.5.1 FSK Modulation Word

The default FSK Modulation mapping translates the chips/bits to a frequency modulation of +Frequency Deviation/PLL Minimum Modulation Step for a data 1, and -Frequency Deviation/PLL Minimum Modulation Step for a data 0.

For a 32 MHz reference clock with a PLL Minimum Modulation Step Size of 244.14 Hz, the default FSK Modulation mapping translates to a +/- 500 kHz peak Frequency Deviation, which is a PLL Baseband Frequency Word of +2047/-2047.

52.4.4.2.2.1.2.5.2 802.15.4 Modes, DFT only.

In Gen4p5, the 802.15.4 mode is only implemented for DFT. No Symbol to chip is implemented, only Phase to Frequency Conversion takes place.

To enable 802.15.4 DFT mode the following settings are needed:

- data_stream_sel = 1'b0.
- radio_dft_mode = 4'b0010: for DFT pattern register.

  or radio_dft_mode = 4'b0011: for DFT LFSR register.
- pfc_en = 1'b1.
- modulator_sel = 1'b1.

52.4.4.2.2.1.2.5.3 FSK Modulator

The FSK Modulation is implemented by mapping directly to a frequency modulation.

For most cases, mFdev is equal to minus Fdev.

Fdev = mod_index * Symbol_Rate/2 * TX_Scale.

TX_Scale = LO_DIV/PLL_Scale

PLL_Scale = 2^PLL_Scale_exp

PLL_Scale_exp = floor(log2(LO_Div))

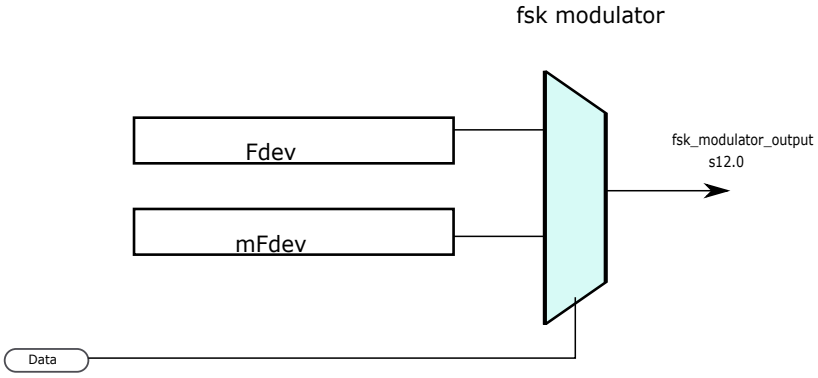


Figure 291. FSK Transmit Modulator

52.4.4.2.2.1.2.6 Data Post-Processing

After the Transmission Data is processed by the GFSK or FSK Modulators, it can be post-processed to remove TX modulation images.

52.4.4.2.2.1.2.6.1 Sample/Hold Images

Power efficient constant envelope transmit modulation is done at a multiple of the symbol clock (Over-Sample Rate), which is chosen as a fraction of the RF Osc reference clock frequency. The transmit modulation signal is then converted to the reference clock rate, at which it is presented to the PLL as the modulation word. This sample/hold (or zero-order hold, ZOH) operation results in TX modulation images that repeat at the fractional reference clock rate at used.

These modulation images are automatically filtered by the sinc ZOH transfer function and the integration (i.e., 1/s) operation of the VCO. These inherent filtering operations result in these modulation images not violating any of the transmit modulation frequency mask. However, to provide additional spectral margin to support using an external power amplifier to boost the transmit power, an image suppression set of FIR filters has been included in the transmit path to suppress the transmit sample/hold images by at least an additional 20 dB.

The transmit image filters are enabled by default in GFSK and GMSK modes and not enabled in IEEE 802.15.4 and MSK modulation modes, but their usage can be overridden using the TX_IMAGE_FILTER_OVRD_EN bit.

52.4.4.2.2.1.2.6.2 Image Filters

The Transmitter uses up to three image filters, by default they are enabled based upon the modulation type and data rate as shown below. There is an option to override the individual filters by programming: sync0_filter_en, sync1_filter_en, and image_fir_filter_en.

Table 469. Default Transmit Image Filter Usage

Ref Clk Freq (MHz)	ModulationType; Data Rate	TX Image Sync0	TX Image Sync1	TX Image FIR
32	GFSK/GMSK; 2000 kbps	0	0	1
32	GFSK/GMSK; 1000 kbps	1	1	1
32	GFSK/GMSK; 500 kbps	1	1	1
32	GFSK/GMSK; 250 kbps	1	1	1
26	GFSK/GMSK; 2000 kbps	0	0	1
26	GFSK/GMSK; 1000 kbps	0	1	1
26	GFSK/GMSK; 500 kbps	1	1	1
26	GFSK/GMSK; 250 kbps	1	1	1
32/26	FSK/MSK Modes; All data rates	0	0	0

52.4.4.2.2.1.2.6.3 Image Filters Frequency Response

The frequency response of the TX image suppression filters and the reduction in the level of TX images for the 1 Mbps GMSK (Bluetooth LE) with the FIR filter are demonstrated in the plots below.

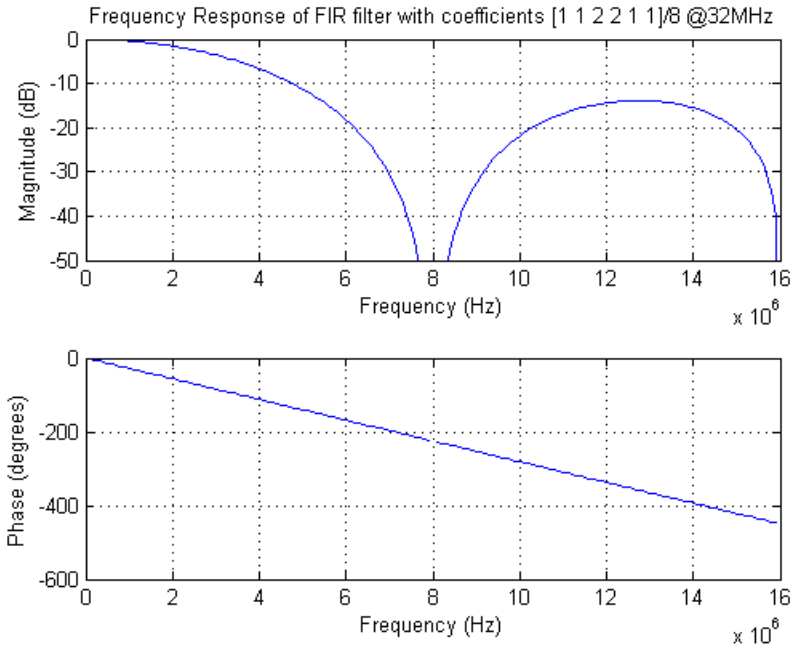


Figure 292. Frequency response of the 6-Tap FIR Transmit Image Suppression filter

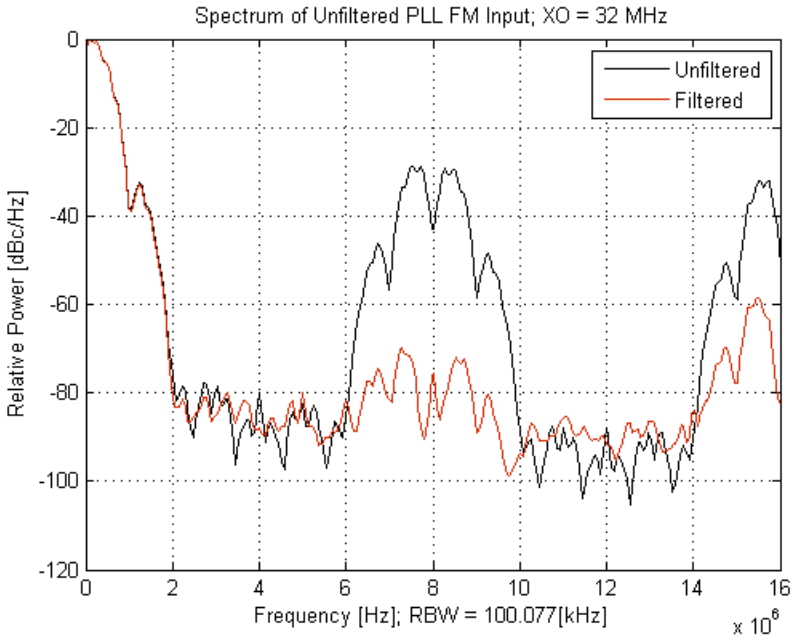


Figure 293. Comparison of Transmit Modulation Images at the PLL Input for Bluetooth LE

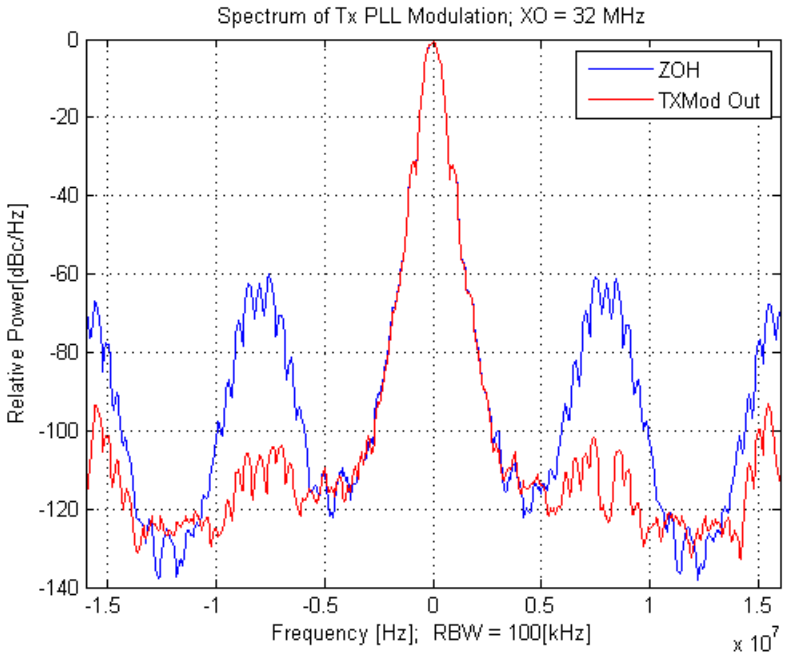


Figure 294. Comparison of Transmit Modulation Images at the PLL Output for Bluetooth LE (1 Mbps GMSK)

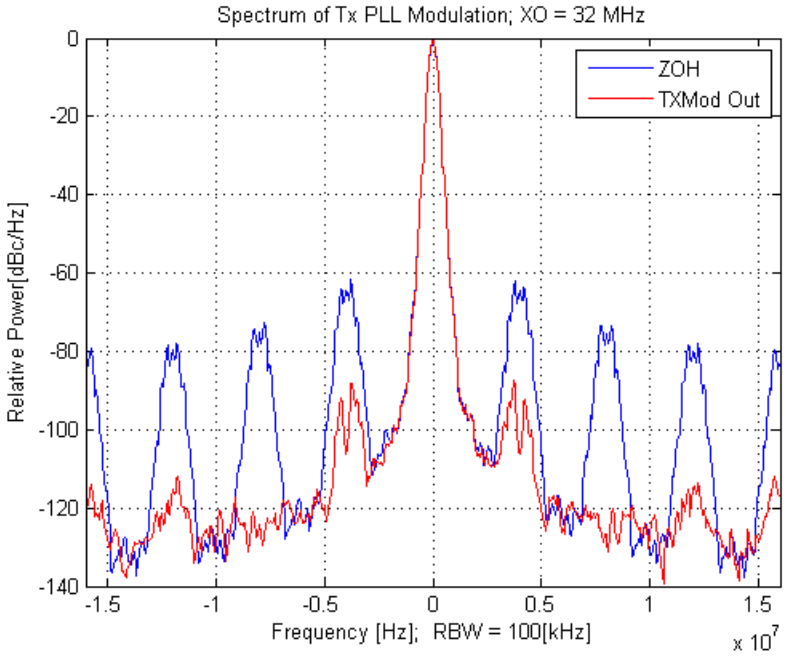


Figure 295. Comparison of Transmit Modulation Images at the PLL Output for 500 kbps GMSK

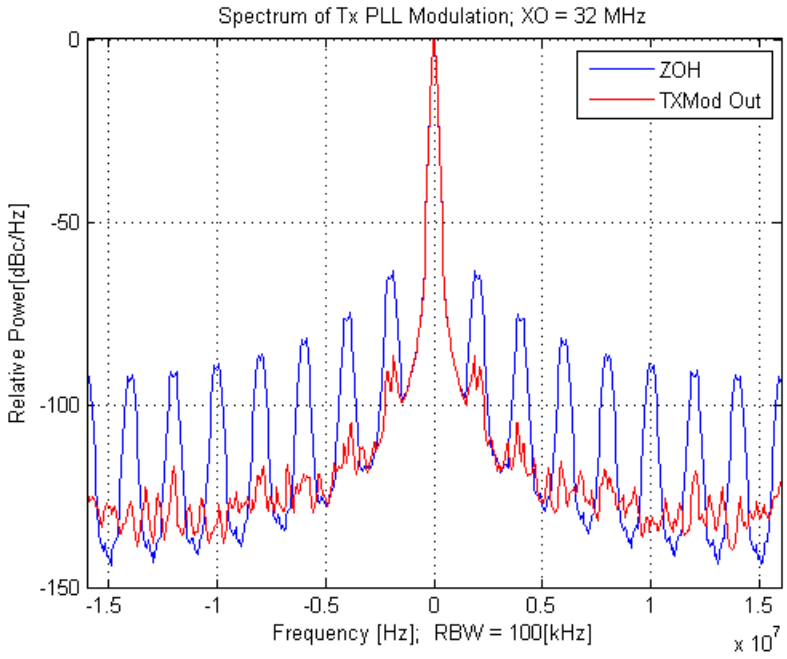


Figure 296. Comparison of Transmit Modulation Images at the PLL Output for 250 kbps GMSK

52.4.4.2.2.1.2.7 CTE (Continuous Tone Extension)

In Bluetooth LE 5.1, Constant Tone Extension (CTE) consists of a constantly modulated series of unwhitened 1 symbols (however TX_DIG 2p4 has the option to transmit 0 symbols as well). The Constant Tone Extension is not included in CRC or MIC calculations and it follows the CRC transmission in the packet. The Constant Tone Extension has a variable length with a minimum duration of 16us.

For direction finding applications, CTE is transmitted during various phases of the programmed antenna switching pattern that compromises of the guard period, the reference period and the switching/sampling slots.

- The Localization Control Module (lcl_ctrl) asserts tx_cte_on (based on cte_dur).
- When tx_en deasserts, TX_DIG looks at the state of tx_cte_on.

  If deasserted, the pa_ramp_cs behaves normally, it will go through the data flush state if a value other than zero is programmed, then it will ramp down.

  If tx_cte_on is asserted, then the pa_ramp_cs state machine keeps the state at target power, then it transmits 0 if CTE_DATA = 1'b0 or 1 if CTE_DATA = 1'b1 (DATA_PADDING_CTRL[4]).

  When tx_cte_on is deasserted, then the state machine behaves as normal: it will go through data flush if a value other than zero is programmed and then it will enter ramp down.

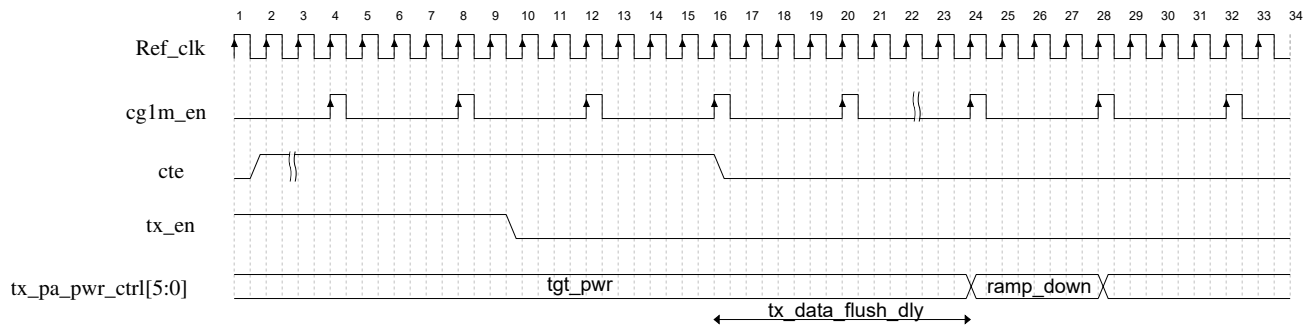


Figure 297. CTE

52.4.4.2.2.1.2.8 Clocking

The TX_DIG uses two clocks, the 26 or 32MHz RF reference clock (ref_clk), and the IPS gated clock (ips_clk) that has been synchronized to the RF reference clock. All programming model registers are clocked by the IPS clock. All other registers are clocked by the RF reference clock.

52.4.4.2.2.1.2.9 Reset

All TX_DIG registers that require a reset are reset by a global asynchronous reset. In addition, a software reset from 2P4Ghz XCVR can reset all TX_DIG modules except TX_DIG control register module.

52.4.4.2.2.1.2.10 Interrupts

This module has no interrupts.

52.4.4.2.2.1.2.11 DMA

There is no DMA associated with this TX_DIG module.

52.4.4.2.2.1.3 External signals

Table 470. Signal description

Signal Name	Direction	Description
ipg_hard_async_reset_b	Input	Hardware asynchronous reset
soft_reset	Input	Software reset
ref_clk	Input	Reference clock
ips_clk	Input	IPS clock
tx_data_out	Input	BLE stream input
tx_symbol_out[3:0]	Input	Zigbee stream input
tx_modulator_output[12:0]	Output	Baseband frequency word for PLL modulation
tx_pa_pwr_ctrl[5:0]	Output	Power amplifier command

52.4.4.2.2.1.4 Initialization

1. Choose correct signal path for TX modulation:
    a. TXDIG_CTRL[MODULATOR_SEL] set to 0 for GFSK or set to 1 for FSK.
    b. TXDIG_CTRL[PFC_EN] set to 1 for phase to frequency conversion or set to 0 if not required.

c. TXDIG_CTRL[DATA_STREAM_SEL] set to 0 for tx_data_padding path or set to 1 for symbol_to_chip path.

2. Enter frequency deviation values:
   a. For FSK:
      i. For 1 Mb/s case: FSK_CTRL[FSK_FDEV_0] and FSK_CTRL[FSK_FDEV_1].
      ii. For 2 Mb/s case: DATARATE_CONFIG_FSK_CTRL[DATARATE_CONFIG_FSK_FDEV0] and DATARATE_CONFIG_FSK_CTRL[DATARATE_CONFIG_FSK_FDEV1].
   b. For GFSK:
      i. For 1 Mb/s case: GFSK_CTRL[GFSK_FDEV].
      ii. For 2 Mb/s case: DATARATE_CONFIG_GFSK_CTRL[DATARATE_CONFIG_GFSK_FDEV].
3. Choose power amplifier (PA) target source:
   a. If PA value is set by link layer, set PA_CTRL[TGT_PWR_SRC] to 1. Please note that whatever is the Link Layer (BLE, Zigbee or GenericFSK), only the 6 LSB of its PA target power related register will be used to program the target power at the PA controller.
   b. If PA value is not set by link layer, set PA_CTRL[TGT_PWR_SRC] to 0 and choose target value with PA_CTRL[PA_TGT_POWER].

52.4.4.2.2.1.5 Application information

The procedures to use this TX_DIG module are described in the sub_chapters and register definition.

52.4.4.2.2.1.6 Register descriptions

The Transmitter Digital memory map and detailed descriptions of all its registers are as follows.

52.4.4.2.2.1.6.1 XCVR_TX_DIG register descriptions

52.4.4.2.2.1.6.1.1 XCVR_TX_DIG_REGS memory map

RADIO.XCVR_TX_DIG base address: 48A0_7200h

Offset	Register	Width (In bits)	Access	Reset value
0h	TXDIG_CTRL (TXDIG_CTRL)	32	RW	0000_0000h
4h	DATA_PADDING_CTRL (DATA_PADDING_CTRL)	32	RW	0000_0010h
8h	DATA_PADDING_CTRL_1 (DATA_PADDING_CTRL_1)	32	RW	0000_1000h
Ch	DATA_PADDING_CTRL_2 (DATA_PADDING_CTRL_2)	32	RW	0000_0000h
10h	FSK_CTRL (FSK_CTRL)	32	RW	0800_1800h
14h	GFSK_CTRL (GFSK_CTRL)	32	RW	0000_0000h
18h	GFSK_COEFF_0_1 (GFSK_COEFF_0_1)	32	RW	0000_0000h
1Ch	GFSK_COEFF_2_3 (GFSK_COEFF_2_3)	32	RW	0000_0000h
20h	GFSK_COEFF_4_5 (GFSK_COEFF_4_5)	32	RW	0000_0000h
24h	GFSK_COEFF_6_7 (GFSK_COEFF_6_7)	32	RW	0000_0000h
28h	IMAGE_FILTER_CTRL (IMAGE_FILTER_CTRL)	32	RW	0000_0000h

Table continues on the next page...

Table continued from the previous page...

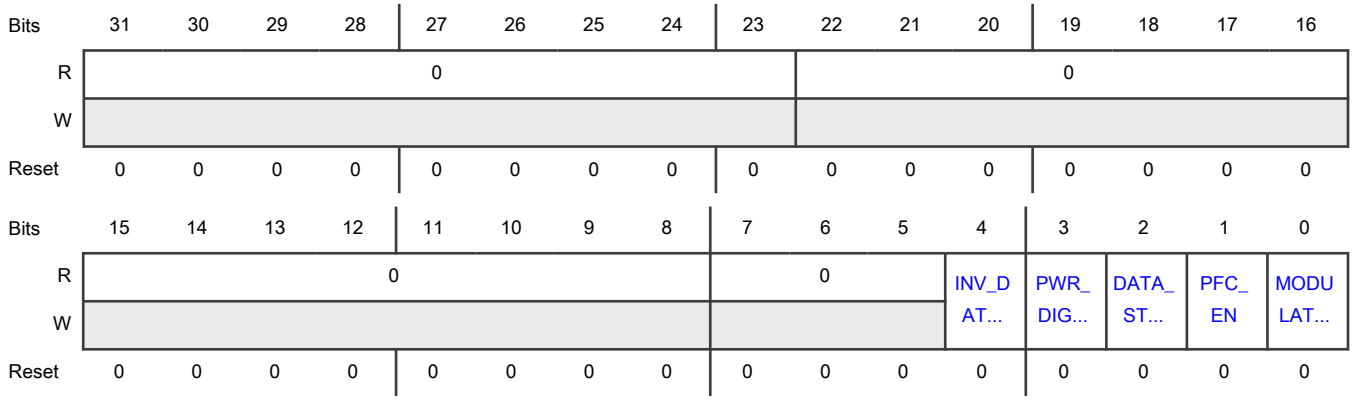
Offset	Register	Width (In bits)	Access	Reset value
2Ch	PA_CTRL (PA_CTRL)	32	RW	0000_003Eh
30h	PA_RAMP_TBL0 (PA_RAMP_TBL0)	32	RW	0604_0201h
34h	PA_RAMP_TBL1 (PA_RAMP_TBL1)	32	RW	1410_0C09h
38h	PA_RAMP_TBL2 (PA_RAMP_TBL2)	32	RW	2621_1C18h
3Ch	PA_RAMP_TBL3 (PA_RAMP_TBL3)	32	RW	3C38_322Ch
40h	SWITCH_TX_CTRL (SWITCH_TX_CTRL)	32	RW	0000_0000h
44h	RF_DFT_TX_CTRL0 (RF_DFT_TX_CTRL0)	32	RW	0000_0000h
48h	RF_DFT_TX_CTRL1 (RF_DFT_TX_CTRL1)	32	RW	2101_FFFFh
4Ch	RF_DFT_TX_CTRL2 (RF_DFT_TX_CTRL2)	32	RW	0000_0000h
50h	RF_DFT_PATTERN (RF_DFT_PATTERN)	32	RW	0000_0000h
54h	DATARATE_CONFIG_FSK_CTRL (DATARATE_CONFIG_FSK_CTRL)	32	RW	0000_0000h
58h	DATARATE_CONFIG_GFSK_CTRL (DATARATE_CONFIG_GFSK_CTRL)	32	RW	0000_0000h
5Ch	DATARATE_CONFIG_FILTER_CTRL (DATARATE_CONFIG_FILTER_CTRL)	32	RW	0000_0000h

52.4.4.2.2.1.6.1.2 TXDIG_CTRL (TXDIG_CTRL)

Offset

Register	Offset
TXDIG_CTRL	0h

Diagram



Fields

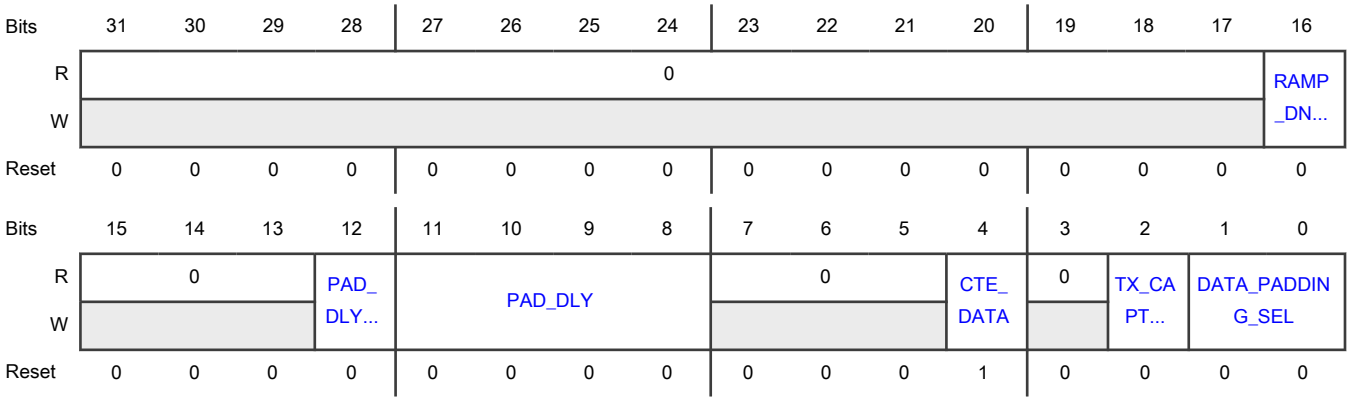
Field	Function
31-23 —	Reserved
22-8 —	Reserved
7-5 —	Reserved
4 INV_DATA_OUT	INV_DATA_OUT Inverts the data out.
3 PWR_DIG_STOP	PWR_DIG_STOP Possibility to set pa_pwr to 0 when tx_dig_en is inactive 1'b0: let the default pwr before enabling tx_dig_en 1'b1: set pa_pwr to 0 before enabling tx_dig_en
2 DATA_STREAM_SEL	DATA_STREAM_SEL Selects between symbol_to_chip and tx_data_padding. 1'b0: tx_data_padding 1'b1: symbol_to_chip
1 PFC_EN	PFC_EN Selects between the output of data_stream and tx_data_padding. PFC_en (Phase to Frequency Conversion) is set when zigbee symbols are to be transmitted. The frequency modulation (FM) information is obtained by differentiating the phase using a delay of 1 symbol (for Zigbee is a 1-chip delay) . 1'b0: tx_data_padding 1'b1: data_stream
0 MODULATOR_SEL	MODULATOR_SEL Selects between GFSK and FSK modulator. 1'b0: GFSK 1'b1: FSK

52.4.4.2.2.1.6.1.3 DATA_PADDING_CTRL (DATA_PADDING_CTRL)

Offset

Register	Offset
DATA_PADDING_CTRL	4h

Diagram



Fields

Field	Function
31-17 —	Reserved
16 RAMP_DN_PAD_EN	RAMP_DN_PAD_EN Enables padding during ramp-down.
15-13 —	Reserved
12 PAD_DLY_EN	PAD_DLY_EN Enable padding before ramp-up.
11-8 PAD_DLY	PAD_DLY Number of Cg1m cycles of padding before ramp-up.
7-5 —	Reserved
4 CTE_DATA	CTE_DATA When CTE (Continuous Tone Extension) selects the data to be transmitted. 1'b0: Transmit 0. 1'b1: Transmit 1.

Table continues on the next page...

Table continued from the previous page...

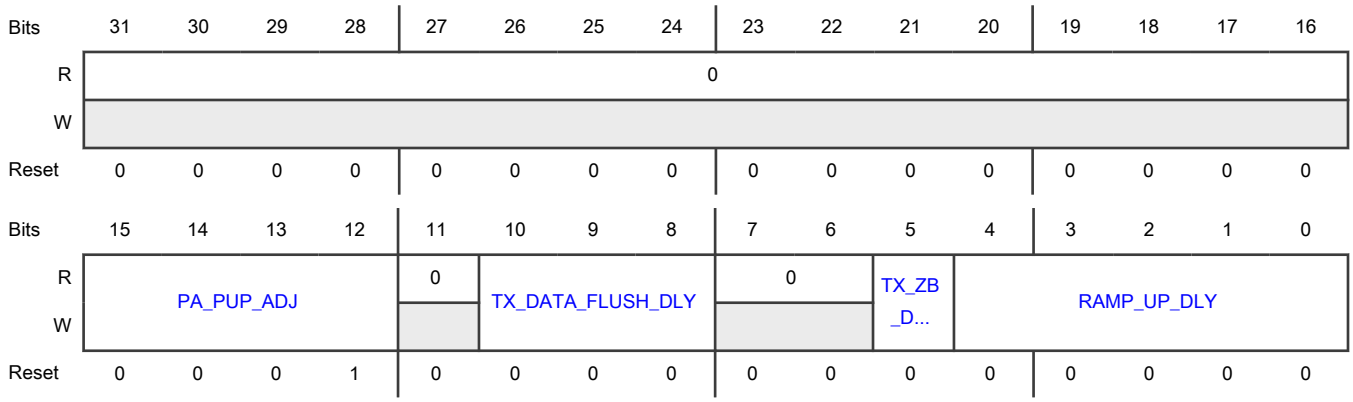
Field	Function
3 —	Reserved
2 TX_CAPTURE_POL	TX_CAPTURE_POL Inverts the polarity of the transmit data. 1'b0: Do not invert transmit data. 1'b1: Invert transmit data.
1-0 DATA_PADDING_SEL	DATA_PADDING_SEL Selects data to be used during padding. 2'b00: 0x0000 is sent to the PLL as frequency word (baseband). 2'b01: DATA_PAD_PFDEV is sent to the PLL (1). 2'b10: DATA_PAD_MFDEV is sent to the PLL (0). 2'b11: Reserved.

52.4.4.2.2.1.6.1.4 DATA_PADDING_CTRL_1 (DATA_PADDING_CTRL_1)

Offset

Register	Offset
DATA_PADDING_CTRL_1	8h

Diagram



Fields

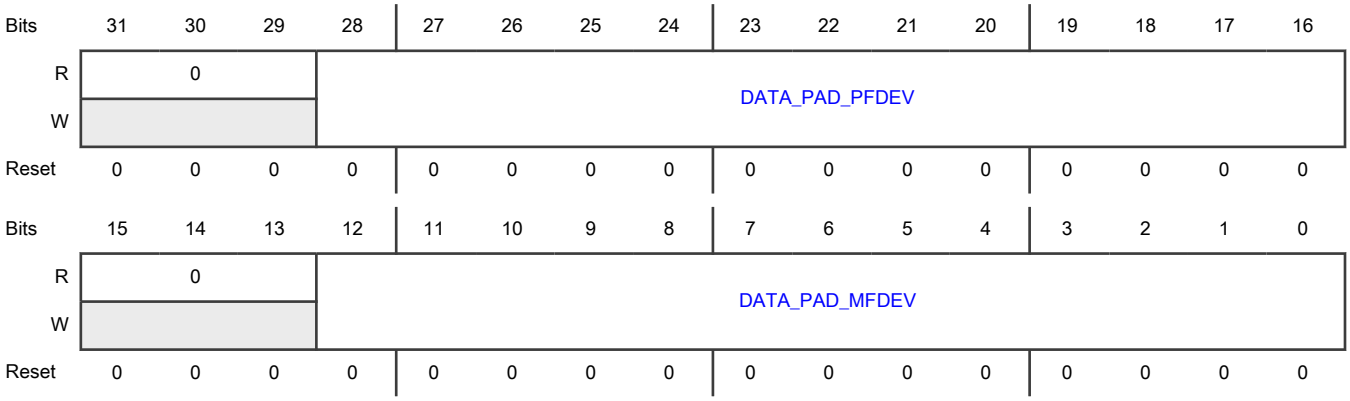
Field	Function
31-16 —	Reserved
15-12 PA_PUP_ADJ	PA_PUP_ADJ PA Power Up Adjust. This field tells the TX_DIG to assert tx_pa_pup after tx_dig_en is set, then waits for 2 times the number of ref clk cycles programmed in this field (2*PA_PUP_ADJ) before the PA_RAMP state machine enters the RAMP_UP state. If PAD_DLY_EN is set and PAD_DLY is different than zero, the TX_DIG pads for the number of cg1m cycles specified by PAD_DLY, then it asserts tx_pa_pup and waits for the number of ref clk cycles programmed (2xPA_PUP_ADJ) before entering RAMP_UP state.
11 —	Reserved
10-8 TX_DATA_FLUSH_DLY	TX_DATA_FLUSH_DLY TX Data Flush Delay This registers tells the number of cycles (Cg1m) to wait after tx_en de-asserts before ramp-down.
7-6 —	Reserved
5 TX_ZB_DATA_PADDING_EN	TX_ZB_DATA_PADDING_EN Delay ZB TX data transmission by 8us 1'b0: No delay 1'b1: 8us Delay
4-0 RAMP_UP_DLY	RAMP_UP_DLY This registers indicates the number of cycles (cg1m) to wait after ramp-up before asserting pu_complete, if PA_PUP_ADJ is non zero, assertion of pu_complete takes place after 2 times the number of ref_clk cycles programmed in PA_PUP_ADJ after RAMP_UP_DLY. (ready to start receiving data from the link layer).

52.4.4.2.2.1.6.1.5 DATA_PADDING_CTRL_2 (DATA_PADDING_CTRL_2)

Offset

Register	Offset
DATA_PADDING_CTRL_2	Ch

Diagram



Fields

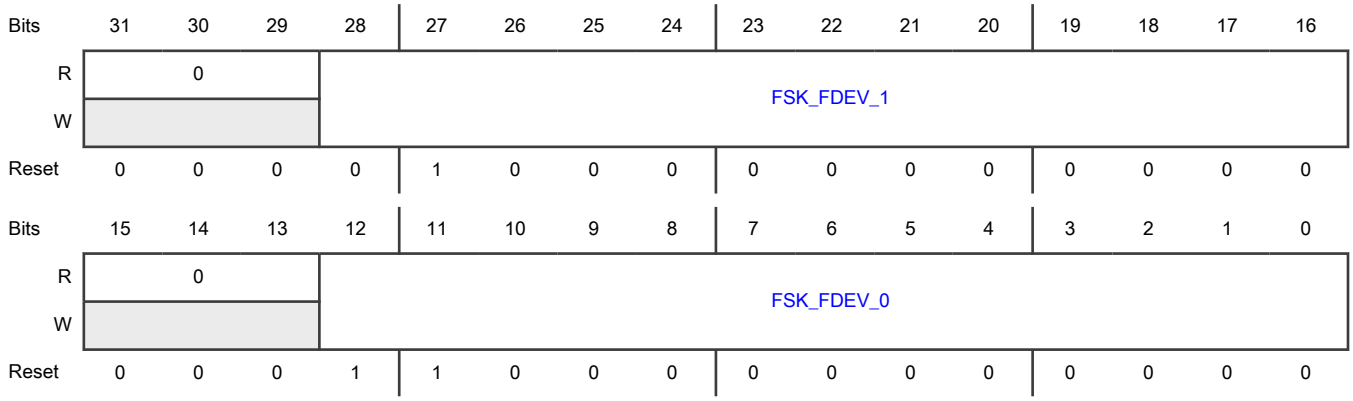
Field	Function
31-29 —	Reserved
28-16 DATA_PAD_PFDEV	DATA_PAD_PFDEV This register indicates the +1 signed frequency word, represented in 2's complement, to be used during padding.
15-13 —	Reserved
12-0 DATA_PAD_MFDEV	DATA_PAD_MFDEV This register indicates the -1 signed frequency word, represented in 2's complement, to be used during padding.

52.4.4.2.2.1.6.1.6 FSK_CTRL (FSK_CTRL)

Offset

Register	Offset
FSK_CTRL	10h

Diagram



Fields

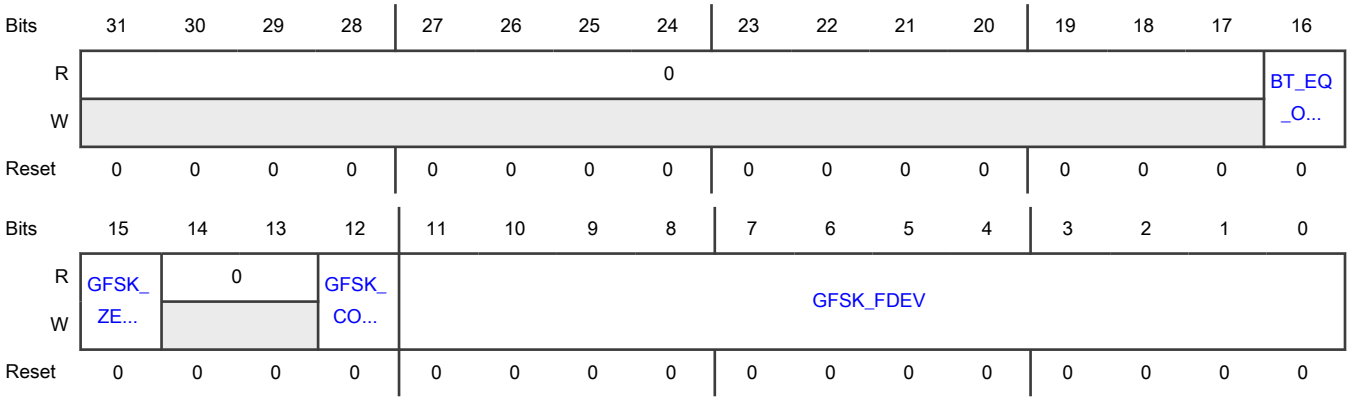
Field	Function
31-29 —	Reserved
28-16 FSK_FDEV_1	FSK_FDEV_1 Signed frequency word, represented in 2's complement, for a 1.
15-13 —	Reserved
12-0 FSK_FDEV_0	FSK_FDEV_0 Signed frequency word, represented in 2's complement, for a 0.

52.4.4.2.2.1.6.1.7 GFSK_CTRL (GFSK_CTRL)

Offset

Register	Offset
GFSK_CTRL	14h

Diagram



Fields

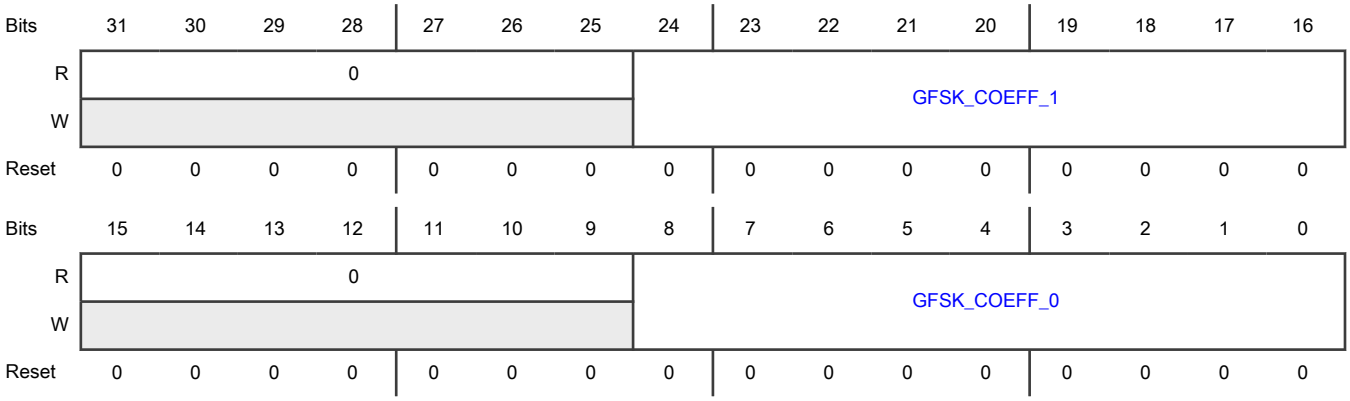
Field	Function
31-17 —	Reserved
16 BT_EQ_OR_GTR_ONE	BT_EQ_OR_GTR_ONE Indicates if the BT product is equal or grater than 1. Used to enable BT>= logic.
15 GFSK_ZERO_FDEV_EN	GFSK_ZERO_FDEV_EN If this bit is set, then in Gaussian Modulation modes the modulation will start at the Carrier frequency.
14-13 —	Reserved
12 GFSK_COEFF_MAN	GFSK_COEFF_MAN Enables manual selection of GFSK coefficients.
11-0 GFSK_FDEV	GFSK_FDEV GFSK frequency word, unsigned.

52.4.4.2.2.1.6.1.8 GFSK_COEFF_0_1 (GFSK_COEFF_0_1)

Offset

Register	Offset
GFSK_COEFF_0_1	18h

Diagram



Fields

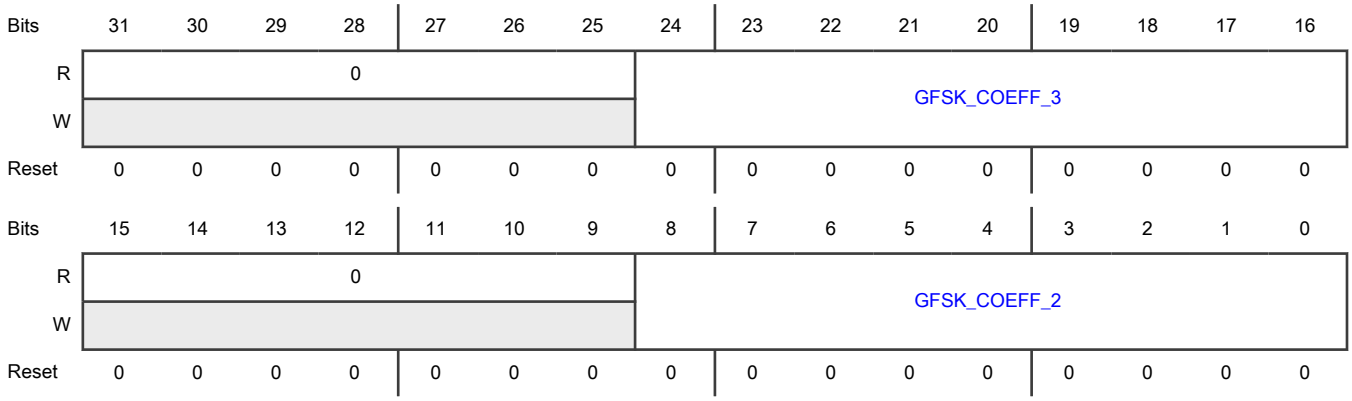
Field	Function
31-25 —	Reserved
24-16 GFSK_COEFF_1	GFSK_COEFF_1 GFSK_COEFF_1[8:0] GFSK filter coefficient 1, format u9.0
15-9 —	Reserved
8-0 GFSK_COEFF_0	GFSK_COEFF_0 GFSK_COEFF_0[8:0] GFSK filter coefficient 0, format u9.0

52.4.4.2.2.1.6.1.9 GFSK_COEFF_2_3 (GFSK_COEFF_2_3)

Offset

Register	Offset
GFSK_COEFF_2_3	1Ch

Diagram



Fields

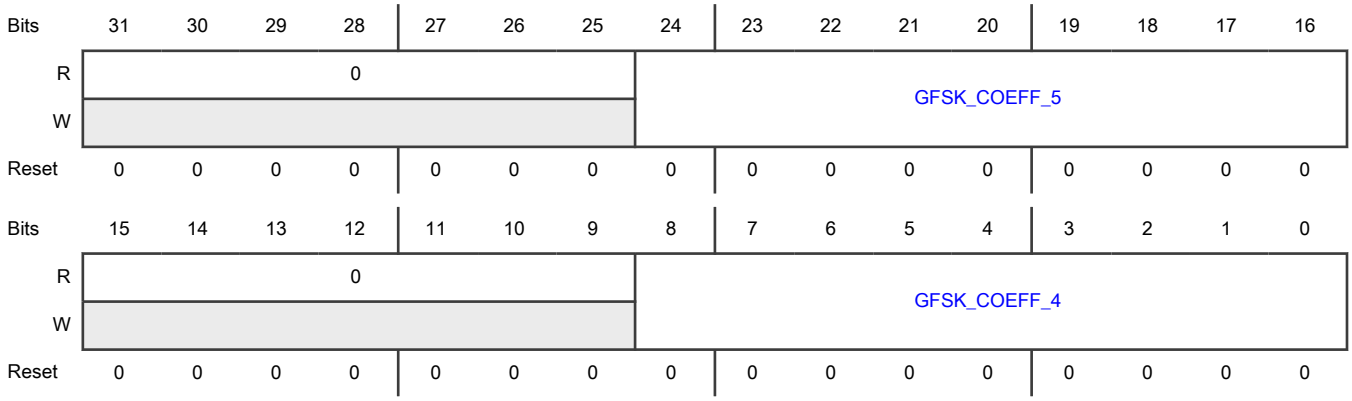
Field	Function
31-25 —	Reserved
24-16 GFSK_COEFF_3	GFSK_COEFF_3 GFSK_COEFF_3[8:0] GFSK filter coefficient 3, format u9.0
15-9 —	Reserved
8-0 GFSK_COEFF_2	GFSK_COEFF_2 GFSK_COEFF_2[8:0] GFSK filter coefficient 2, format u9.0

52.4.4.2.2.1.6.1.10 GFSK_COEFF_4_5 (GFSK_COEFF_4_5)

Offset

Register	Offset
GFSK_COEFF_4_5	20h

Diagram



Fields

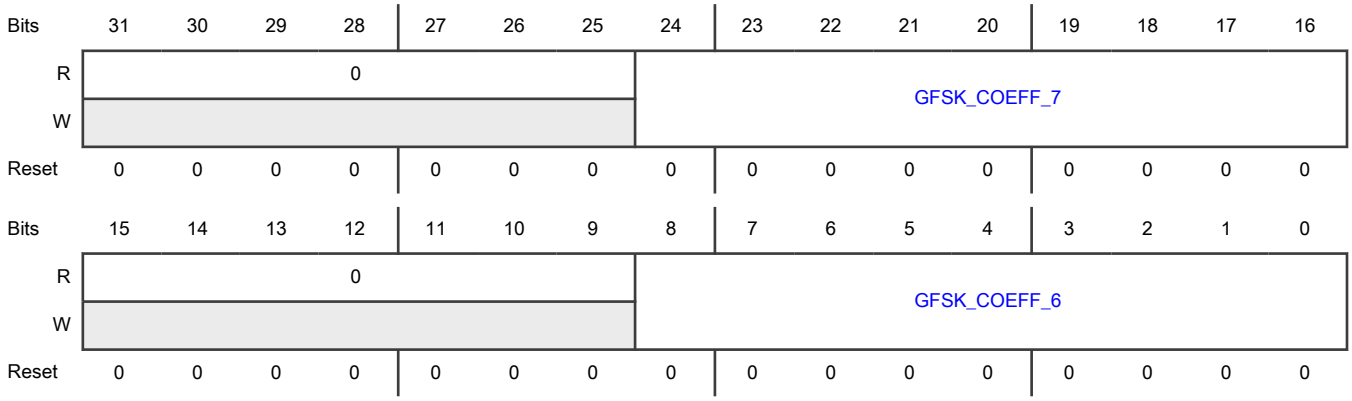
Field	Function
31-25 —	Reserved
24-16 GFSK_COEFF_5	GFSK_COEFF_5 GFSK_COEFF_5[8:0] GFSK filter coefficient 5, format u9.0
15-9 —	Reserved
8-0 GFSK_COEFF_4	GFSK_COEFF_4 GFSK_COEFF_4[8:0] GFSK filter coefficient 4, format u9.0

52.4.4.2.2.1.6.1.11 GFSK_COEFF_6_7 (GFSK_COEFF_6_7)

Offset

Register	Offset
GFSK_COEFF_6_7	24h

Diagram



Fields

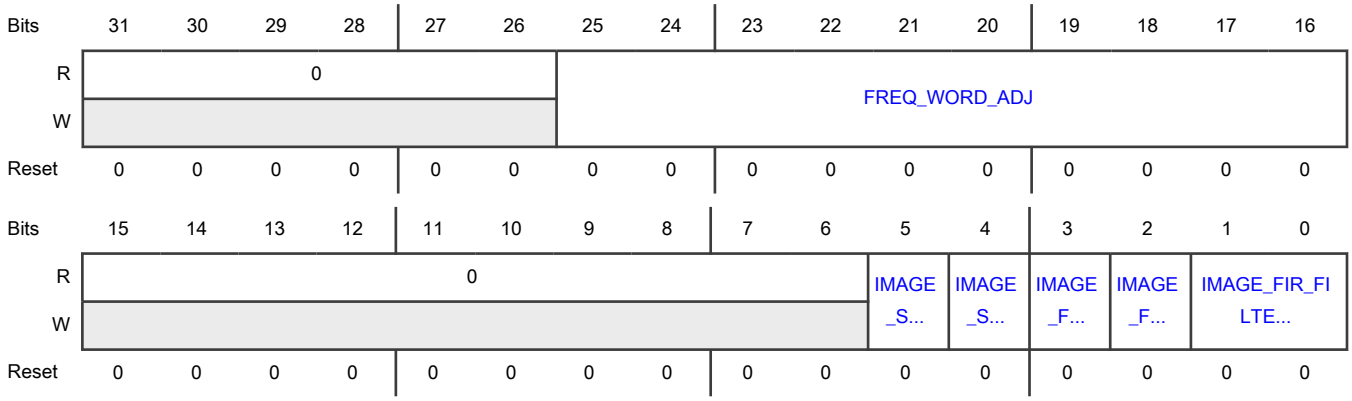
Field	Function
31-25 —	Reserved
24-16 GFSK_COEFF_7	GFSK_COEFF_7 GFSK_COEFF_7[8:0] GFSK filter coefficient 7, format u9.0
15-9 —	Reserved
8-0 GFSK_COEFF_6	GFSK_COEFF_6 GFSK_COEFF_6[8:0] GFSK filter coefficient 6, format u9.0

52.4.4.2.2.1.6.1.12 IMAGE_FILTER_CTRL (IMAGE_FILTER_CTRL)

Offset

Register	Offset
IMAGE_FILTER_CTRL	28h

Diagram



Fields

Field	Function
31-26 —	Reserved
25-16 FREQ_WORD_ADJ	FREQ_WORD_ADJ This register is a signed 10 bit number, represented in 2's complement, that is added to the GFSK modulator output. This allows the GFSK modulation to be adjusted, or skewed, by a range of -512 to +511.
15-6 —	Reserved
5 IMAGE_SYNC0_FILTER_OVRD	IMAGE_SYNC0_FILTER_OVRD Overrides the interpolator sync0 filter clock enable.
4 IMAGE_SYNC1_FILTER_OVRD	IMAGE_SYNC1_FILTER_OVRD Overrides the interpolator sync1 filter clock enable.
3 IMAGE_FIR_FILTER_OVRD	IMAGE_FIR_FILTER_OVRD If the TX_IMAGE_FILTER_OVRD_EN bit is set, then this bit turns on (=1) and off (=0) the Transmit Image Filter 0
2 IMAGE_FILTER_OVRD_EN	IMAGE_FILTER_OVRD_EN This bit enables the TX Image Filter Override Control bits.
1-0	IMAGE_FIR_FILTER_SEL Image FIR Filter Logic Select.

Table continues on the next page...

Table continued from the previous page...

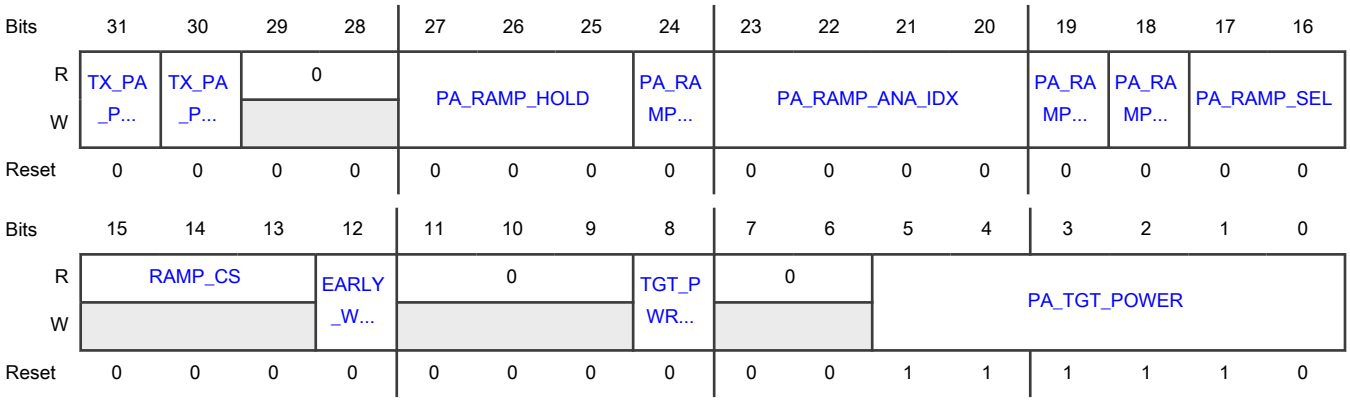
Field	Function
IMAGE_FIR_FILTER_SEL	2'b00: [11211] 2'b01: [12345654321] * (1/32 - 1/128) 2'b10: [12345677654321] * (1/64 - 1/512) 2'b11: Reserved

52.4.4.2.2.1.6.1.13 PA_CTRL (PA_CTRL)

Offset

Register	Offset
PA_CTRL	2Ch

Diagram



Fields

Field	Function
31 TX_PA_PUP_OVRD_EN	TX_PA_PUP_OVRD_EN This bit enables the TX PA_PUP Control bit.
30 TX_PA_PUP_OVRD	TX_PA_PUP_OVRD If the TX_PA_PUP_OVRD_EN bit is set, then this bit turns on (=1) and off (=0) the Transmit TX_PA_PUP bit.
29-28 —	Reserved
27-25	PA_RAMP_HOLD

Table continues on the next page...

Table continued from the previous page...

Field	Function
PA_RAMP_HOLD	Indicates the hold duration after ramp down before switching of pa_pup in us (Only in Analog ramping).
24 PA_RAMP_ANA_IDX_TYPE	PA_RAMP_ANA_IDX_TYPE When set to 1, the jump in LUT will be done at pa_ramp_idx value during ramp up and 15-pa_ramp_idx during ramp_down , to speed up power transition for analog mode ramping.
23-20 PA_RAMP_ANA_IDX	PA_RAMP_ANA_IDX Index used for analog mode set by PA_RAMP_ANA_EN. Once reached, internal ramp counter completes current phase (ramp up or ramp down) in minimum delay. . If PA_RAMP_ANA_IDX_TYPE is 0, the jump in LUT will be done at pa_ramp_idx value during ramp up and ramp down. If PA_RAMP_ANA_IDX_TYPE is set to 1, the jump in LUT will be done at PA_RAMP_ANA_IDX value during ramp up and 15-PA_RAMP_ANA_IDX during ramp down. PA_RAMP0..15 fields in PA_RAMP_TBLx registers must be set accordingly.
19 PA_RAMP_ANA_EN	PA_RAMP_ANA When set, digital ramping is shortened to handover control to analog after a given threshold. Digital ramping starts as in normal mode but as soon as internal counter selects PA_RAMPn with n=PA_RAMP_ANA_THR, next PA_RAMPp steps with p>n are skipped, and PA_TGT_POWER is applied. Ramping done starts from PA_TGT_POWER then jumps directly to PA_RAMPn then goes on decreasing as in normal mode.
18 PA_RAMP_DIG_INTERP_EN	PA_RAMP_DIG_INTERP Select interpolation mode between 2 outputs of the LUT. 0 is no interpolation, 1 is linear interpolation. When bit is set to 1 , the number of levels of power becomes : 16*v_ramp_interp. V_ramp_iterp = 2 with pa_ramp_sel = 1, 4 with pa_ramp_sel > 1. The total duration will still be the same (1/2/4 us acording to pa_ramp_sel).
17-16 PA_RAMP_SEL	PA_RAMP_SEL Indicates the ramp duration or no ramp. 2'b00: Ramp disabled. 2'b01: Ramp = 1us. 2'b10: Ramp = 2us. 2'b11: Ramp = 4us.
15-13 RAMP_CS	RAMP_CS PA Ramp Current State.
12 EARLY_WU_COMPLETE	EARLY_WU_COMPLETE When set, TXDIG 2p4 will assert pa_wu_complete after ramp-up without waiting for the settling time to expire (DATA_PADDING_CTRL_1[RAMP_UP_DLY]). If not set, the assertion of pa_wu_complete takes place normally, that is to say, after ramp-up the assertion of pa_wu_complete will happen after the number of cg1m cycles programmed in RAMP_UP_DLY have happened.
11-9	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
8 TGT_PWR_SRC	TGT_PWR_SRC Indicated the source of the target power value. 1'b0: Target power specified in PA_TGT_POWER field. 1'b1: Target power specified by the link layer. Please note that whatever is the Link Layer (BLE, Zigbee or GenericFSK), only the 6 LSB of its PA target power related register will be used to program the target power at the PA controller.
7-6 —	Reserved
5-0 PA_TGT_POWER	PA_TGT_POWER The contents of this register are used as PA target power when TGT_PWR_SRC=0.

52.4.4.2.2.1.6.1.14 PA_RAMP_TBL0 (PA_RAMP_TBL0)

Offset

Register	Offset
PA_RAMP_TBL0	30h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		PA_RAMP3						0		PA_RAMP2					
W																
Reset	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		PA_RAMP1						0		PA_RAMP0					
W																
Reset	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1

Fields

Field	Function
31-30	Reserved

Table continues on the next page...

Table continued from the previous page...

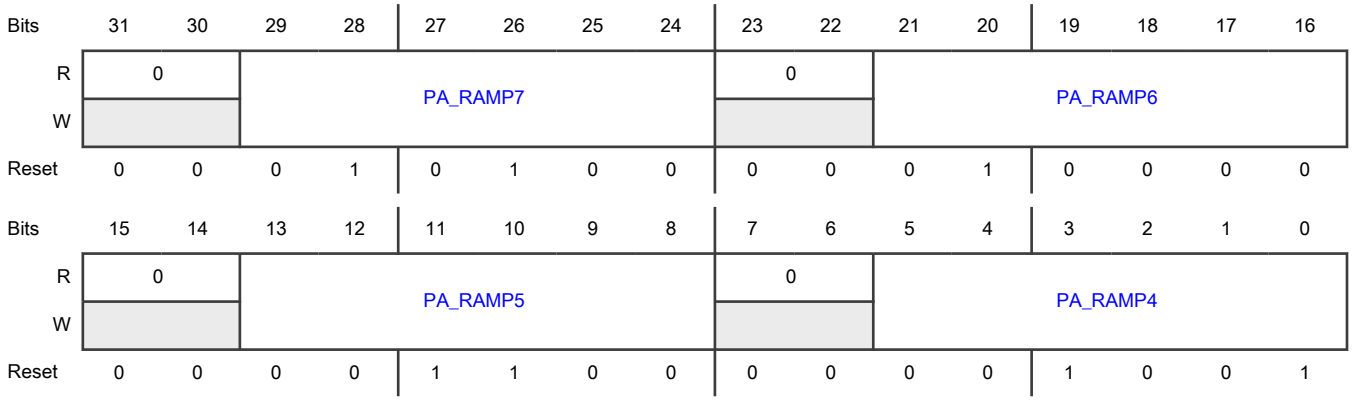
Field	Function
—	
29-24 PA_RAMP3	PA_RAMP3 PA_RAMP3 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the fourth ramp step. During PA ramp down, the contents of this register are the PA power value during the fourth-to-last ramp step. In both cases, PA_RAMP3 cannot exceed target power (enforced by PA ramping logic).
23-22 —	Reserved
21-16 PA_RAMP2	PA_RAMP2 PA_RAMP2 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the third ramp step. During PA ramp down, the contents of this register are the PA power value during the third-to-last ramp step. In both cases, PA_RAMP2 cannot exceed target power (enforced by PA ramping logic).
15-14 —	Reserved
13-8 PA_RAMP1	PA_RAMP1 PA_RAMP1 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the second ramp step. During PA ramp down, the contents of this register are the PA power value during the second-to-last ramp step. In both cases, PA_RAMP1 cannot exceed target power (enforced by PA ramping logic).
7-6 —	Reserved
5-0 PA_RAMP0	PA_RAMP0 PA_RAMP0 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, when TSM tx_pa_en transitions low to high, and then for the duration of the first ramp step. During PA ramp down, the contents of this register are the PA power value during the final ramp step. In both cases, PA_RAMP0 cannot exceed target power (enforced by PA ramping logic). When PA ramping is enabled, the contents of PA_RAMP0 are also presented to the PA during sequence idle conditions.

52.4.4.2.2.1.6.1.15 PA_RAMP_TBL1 (PA_RAMP_TBL1)

Offset

Register	Offset
PA_RAMP_TBL1	34h

Diagram



Fields

Field	Function
31-30 —	Reserved
29-24 PA_RAMP7	PA_RAMP7 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the eighth ramp step. During PA ramp down, the contents of this register are the PA power value during the eighth-to-last ramp step. In both cases, PA_RAMP7 cannot exceed target power (enforced by PA ramping logic).
23-22 —	Reserved
21-16 PA_RAMP6	PA_RAMP6 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the seventh ramp step. During PA ramp down, the contents of this register are the PA power value during the seventh-to-last ramp step. In both cases, PA_RAMP6 cannot exceed target power (enforced by PA ramping logic).
15-14 —	Reserved
13-8 PA_RAMP5	PA_RAMP5 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the sixth ramp step. During PA ramp down, the contents of this register are the PA power value during the sixth-to-last ramp step. In both cases, PA_RAMP5 cannot exceed target power (enforced by PA ramping logic).
7-6 —	Reserved
5-0	PA_RAMP4

Table continues on the next page...

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Field	Function
PA_RAMP4	If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the fifth ramp step. During PA ramp down, the contents of this register are the PA power value during the fifth-to-last ramp step. In both cases, PA_RAMP4 cannot exceed target power (enforced by PA ramping logic).

52.4.4.2.2.1.6.1.16 PA_RAMP_TBL2 (PA_RAMP_TBL2)

Offset

Register	Offset
PA_RAMP_TBL2	38h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		PA_RAMP11						0		PA_RAMP10					
W																
Reset	0	0	1	0	0	1	1	0	0	0	1	0	0	0	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		PA_RAMP9						0		PA_RAMP8					
W																
Reset	0	0	0	1	1	1	0	0	0	0	0	1	1	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 PA_RAMP11	PA_RAMP11 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the twelfth ramp step. During PA ramp down, the contents of this register are the PA power value during the twelfth-to-last ramp step. In both cases, PA_RAMP11 cannot exceed target power (enforced by PA ramping logic).
23-22 —	Reserved
21-16	PA_RAMP10

Table continues on the next page...

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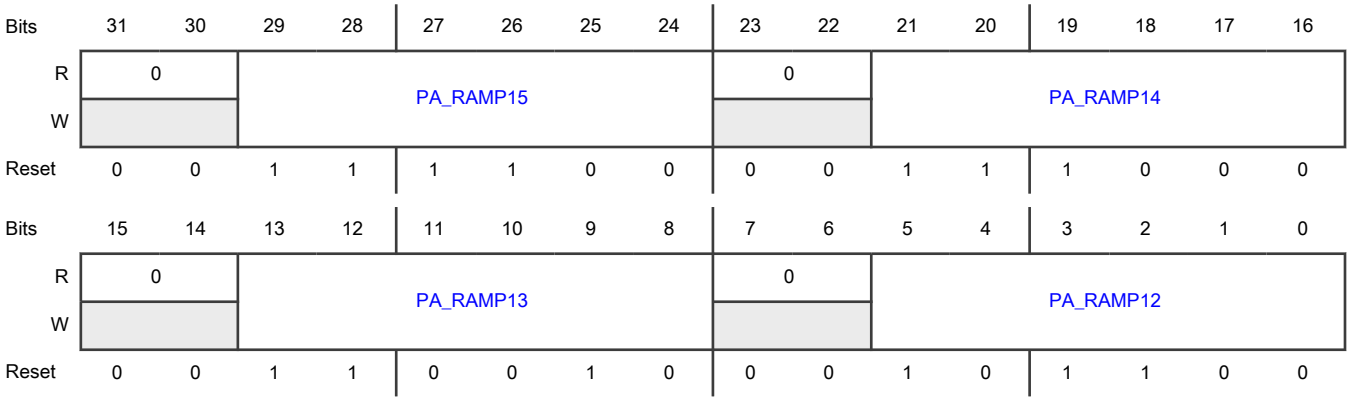
Field	Function
PA_RAMP10	If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the twelfth ramp step. During PA ramp down, the contents of this register are the PA power value during the twelfth-to-last ramp step. In both cases, PA_RAMP10 cannot exceed target power (enforced by PA ramping logic).
15-14 —	Reserved
13-8 PA_RAMP9	PA_RAMP9 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the tenth ramp step. During PA ramp down, the contents of this register are the PA power value during the tenth-to-last ramp step. In both cases, PA_RAMP9 cannot exceed target power (enforced by PA ramping logic).
7-6 —	Reserved
5-0 PA_RAMP8	PA_RAMP8 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the ninth ramp step. During PA ramp down, the contents of this register are the PA power value during the ninth-to-last ramp step. In both cases, PA_RAMP8 cannot exceed target power (enforced by PA ramping logic).

52.4.4.2.2.1.6.1.17 PA_RAMP_TBL3 (PA_RAMP_TBL3)

Offset

Register	Offset
PA_RAMP_TBL3	3Ch

Diagram



Fields

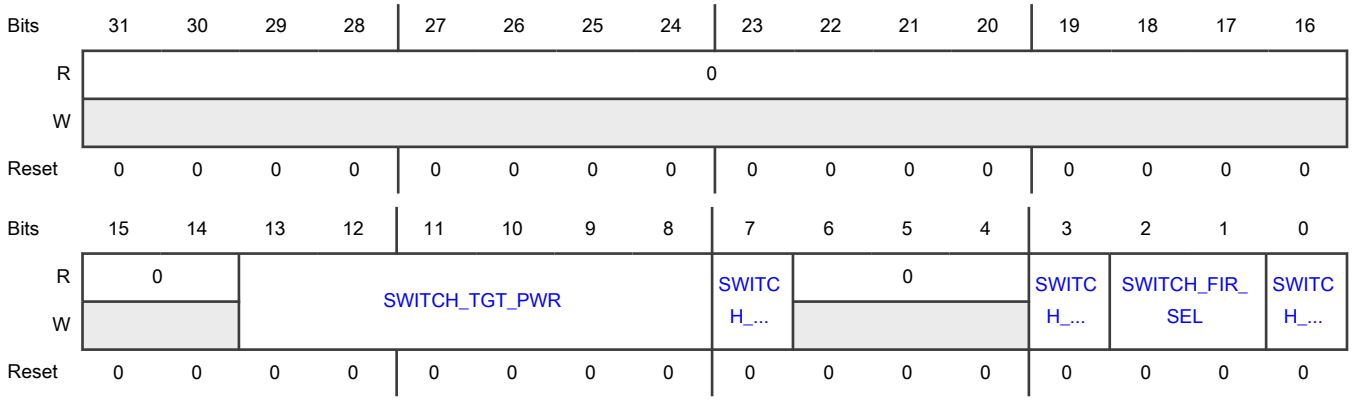
Field	Function
31-30 —	Reserved
29-24 PA_RAMP15	PA_RAMP15 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the sixteenth (final) ramp step. During PA ramp down, the contents of this register are the PA power value during the sixteenth-to-last (first) ramp step. In both cases, PA_RAMP15 cannot exceed target power (enforced by PA ramping logic).
23-22 —	Reserved
21-16 PA_RAMP14	PA_RAMP14 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the fifteenth ramp step. During PA ramp down, the contents of this register are the PA power value during the fifteenth-to-last ramp step. In both cases, PA_RAMP14 cannot exceed target power (enforced by PA ramping logic).
15-14 —	Reserved
13-8 PA_RAMP13	PA_RAMP13 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the fourteenth ramp step. During PA ramp down, the contents of this register are the PA power value during the fourteenth-to-last ramp step. In both cases, PA_RAMP13 cannot exceed target power (enforced by PA ramping logic).
7-6 —	Reserved
5-0 PA_RAMP12	PA_RAMP12 If PA ramping is enabled (TSM_CTRL[PA_RAMP_SEL] > 00), the contents of this register are presented to the PA during PA ramping, for the duration of the thirteenth ramp step. During PA ramp down, the contents of this register are the PA power value during the thirteenth-to-last ramp step. In both cases, PA_RAMP12 cannot exceed target power (enforced by PA ramping logic).

52.4.4.2.2.1.6.1.18 SWITCH_TX_CTRL (SWITCH_TX_CTRL)

Offset

Register	Offset
SWITCH_TX_CTRL	40h

Diagram



Fields

Field	Function
31-14 —	Reserved
13-8 SWITCH_TGT_PWR	SWITCH_TGT_PWR The contents of this register are used as PA target power when PLL_DIG asserts switch_tx_config.
7 SWITCH_TGT_PWR_CLAMPED	SWITCH_TGT_PWR_CLAMPED If enabled, this option set a clamp option concerning SWITCH_TGT_PWR value. 0b - SWITCH_TGT_PWR value is power target value 1b - If non-switch power target is less than SWITCH_TGT_PWR value then power target is kept the same, on the contrary power target is clamped at SWITCH_TGT_PWR value
6-4 —	Reserved
3 SWITCH_GFSK_COEFF	SWITCH_GFSK_COEFF This bits tells the GFSK modulator to whether switch to the coefficients programmed in the manual coefficient registers when the PLL_DIG asserts switch_tx_config or use the default ones in the logic.
2-1 SWITCH_FIR_SEL	SWITCH_FIR_SEL If tx_image_filter_en is set and PLL_DIG asserts switch_tx_config, the image filter output is selected as follows: 2'b00: [11211] 2'b01: [12345654321] * (1/32 - 1/128) 2'b10: [12345677654321] * (1/64 - 1/512) 2'b11: [11211]
0	SWITCH_MOD

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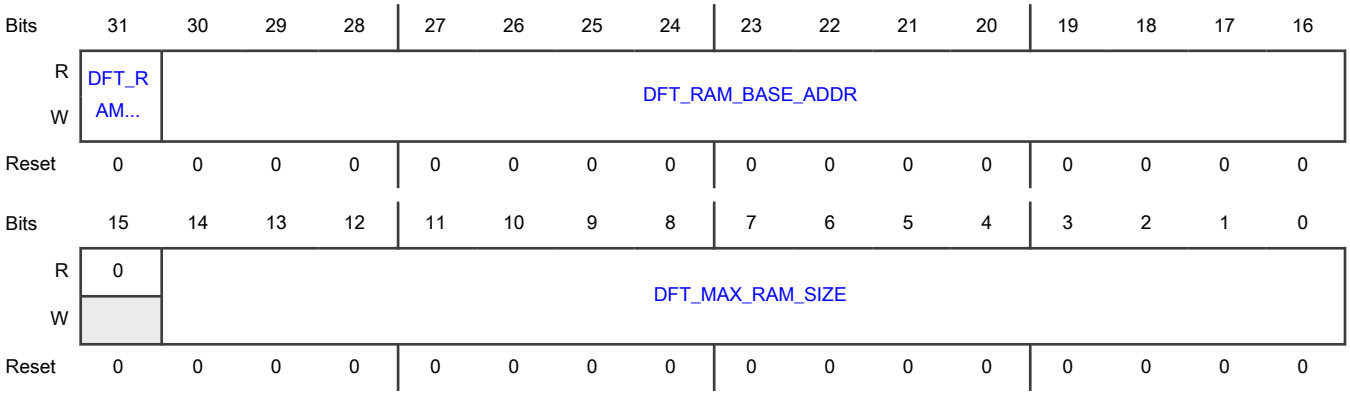
Field	Function
SWITCH_MOD	This bit tells the TX Dig 2p4 to switch between GFSK and FSK modulators when PLL_DIG asserts switch_tx_config. 1'b0: GFSK 1'b1: FSK

52.4.4.2.2.1.6.1.19 RF_DFT_TX_CTRL0 (RF_DFT_TX_CTRL0)

Offset

Register	Offset
RF_DFT_TX_CTRL0	44h

Diagram



Fields

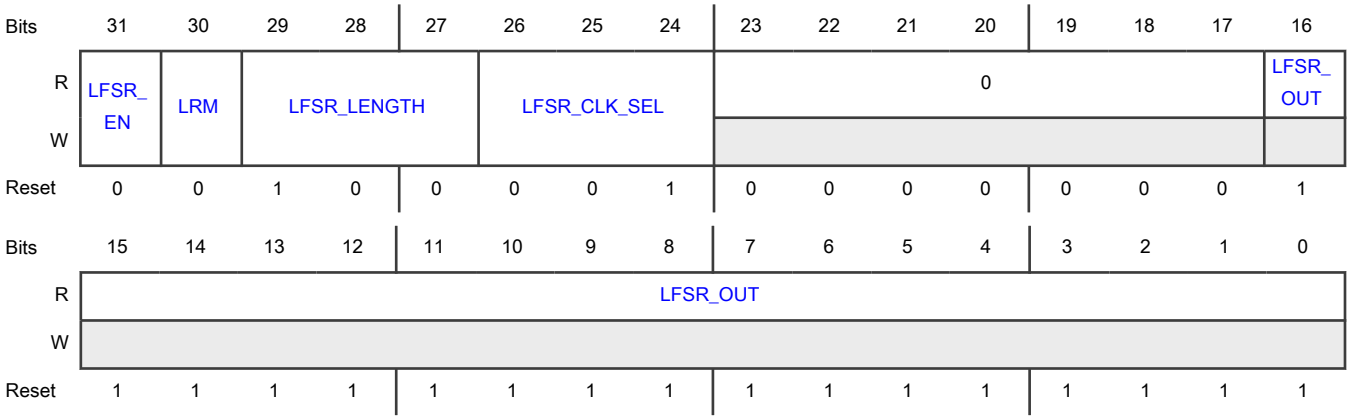
Field	Function
31 DFT_RAM_EN	DFT_RAM_EN Enables DFT RAM mode
30-16 DFT_RAM_BASE_ADDR	DFT_RAM_BASE_ADDR Base address in the RAM for DFT transmission.
15 —	Reserved
14-0 DFT_MAX_RAM_SIZE	DFT_MAX_RAM_SIZE RAM size in bytes to be used during DFT RAM transmission. Basically each word (16bit) is used as a frequency word. If negative value is stored, 2's complement should be stored in a word.

52.4.4.2.2.1.6.1.20 RF_DFT_TX_CTRL1 (RF_DFT_TX_CTRL1)

Offset

Register	Offset
RF_DFT_TX_CTRL1	48h

Diagram



Fields

Field	Function
31 LFSR_EN	LFSR_EN LFSR Enable. If the Radio is in a DFT LFSR mode, then this bit is used to turn on and off the LFSR that is used to generate the modulation. Note that the LFSR is clocked at the DFT Clock frequency.
30 LRM	LRM LFSR Reset Mask When this bit is set the DFT LFSR will not be reset when LFSR_EN is cleared and will instead continue to repeat its sequence as defined by the DFT_LFSR_LEN bits when LFSR_EN is next set. When this bit is cleared the DFT LFSR will reset every time LFSR_EN is cleared.
29-27 LFSR_LENGTH	LFSR_LENGTH LFSR Length This register selects the length of the DFT LFSR and the associated LFSR Tap Mask. The Mask is in the form of [MSB...LSB] 000b - LFSR 9, tap mask 100010000 001b - LFSR 10, tap mask 1001000000 010b - LFSR 11, tap mask 11101000000 011b - LFSR 13, tap mask 1101100000000 100b - LFSR 15, tap mask 111010000000000 101b - LFSR 17, tap mask 11110000000000000 110b - Reserved

Table continues on the next page...

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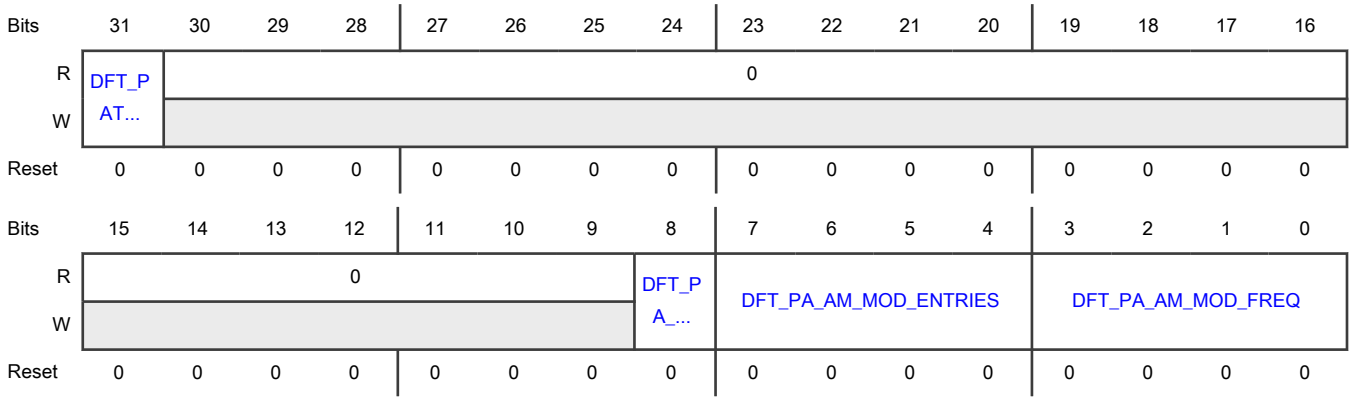
Field	Function
	111b - Reserved
26-24 LFSR_CLK_SEL	LFSR_CLK_SEL DFT Clock Selection This register selects the frequency of the DFT clock that is used to shift out the DFT Modulation Pattern inDFT Pattern Register modes, and the same frequency is also used to clock the LFSR and generate thepseudo-random modulation in DFT LFSR modes. 000b - 62.5 kHz 001b - 125 kHz 010b - 250 kHz 011b - 500 kHz 100b - 1 MHz 101b - When this option is specified, the internal symbol clock (symb_clk_en) is selected. To ensure that 2 MHz is chosen, XCVR_CTRL[DATA_RATE] needs to be programmed to 3'b000. 110b - 4 MHz 111b - RF OSC Clock
23-17 —	Reserved
16-0 LFSR_OUT	LFSR_OUT LFSR Output This register can be read to observe the current value of the DFT LFSR, only bits [14:0] are available.

52.4.4.2.2.1.6.1.21 RF_DFT_TX_CTRL2 (RF_DFT_TX_CTRL2)

Offset

Register	Offset
RF_DFT_TX_CTRL2	4Ch

Diagram



Fields

Field	Function
31 DFT_PATTERN_EN	DFT_PATTERN_EN DFT pattern enable If the Radio is in a DFT Pattern mode, then this bit is used to turn on and off the pattern that is used to generate the modulation. Note that the DFT pattern is clocked at the DFT Clock frequency.
30-9 —	Reserved
8 DFT_PA_AM_MOD_EN	DFT_PA_AM_MOD_EN RF Power Amplifier Amplitude Modulation Enable This bit enables the DFT RF Power Amplifier Amplitude Modulation. As long as this bit is set the PA will have its amplitude modulated at the frequency selected with DFT_PA_AM_MOD_FREQ using the PA_RAMP table entries selected with DFT_PA_AM_MOD_ENTRIES.
7-4 DFT_PA_AM_MOD_ENTRIES	DFT_PA_AM_MOD_ENTRIES RF Power Amplifier Amplitude Modulation Table Entries This register selects the number PA_RAMP entries to use as the PA Amplitude Modulation Table Entries. The PA will be modulated using the Modulation Table Entries in a continuous loop. 0000b - Reserved 0001b - 2 entries 0010b - 3 entries 0011b - 4 entries 0100b - 5 entries 0101b - 6 entries 0110b - 7 entries 0111b - 8 entries 1000b - 9 entries

Table continues on the next page...

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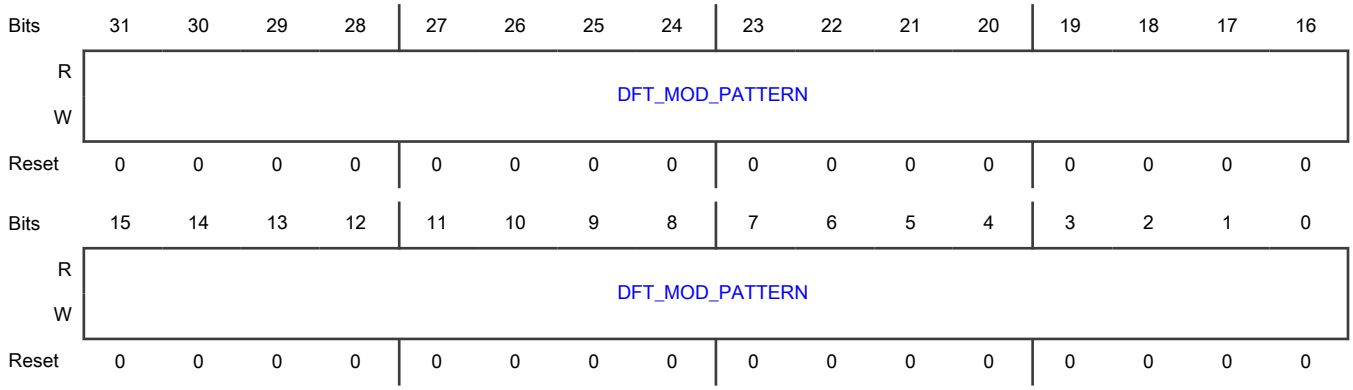
Field	Function
	1001b - 10 entries 1010b - 11 entries 1011b - 12 entries 1100b - 13 entries 1101b - 14 entries 1110b - 15 entries 1111b - 16 entries
3-0 DFT_PA_AM_MOD_FREQ	DFT_PA_AM_MOD_FREQ This register selects the Power Amplifier Amplitude Modulation Frequency. The PA will be modulated at this frequency using the Modulation Table Entries in a continuous loop. 0000b - 32 MHz 0001b - 16 MHz 0010b - 8 MHz 0011b - 4 MHz 0100b - 2 MHz 0101b - 1 MHz 0110b - 500 kHz 0111b - 250 kHz 1000b - 125 kHz 1001b - 62.5 kHz 1010b - 1111b: Reserved

52.4.4.2.2.1.6.1.22 RF_DFT_PATTERN (RF_DFT_PATTERN)

Offset

Register	Offset
RF_DFT_PATTERN	50h

Diagram



Fields

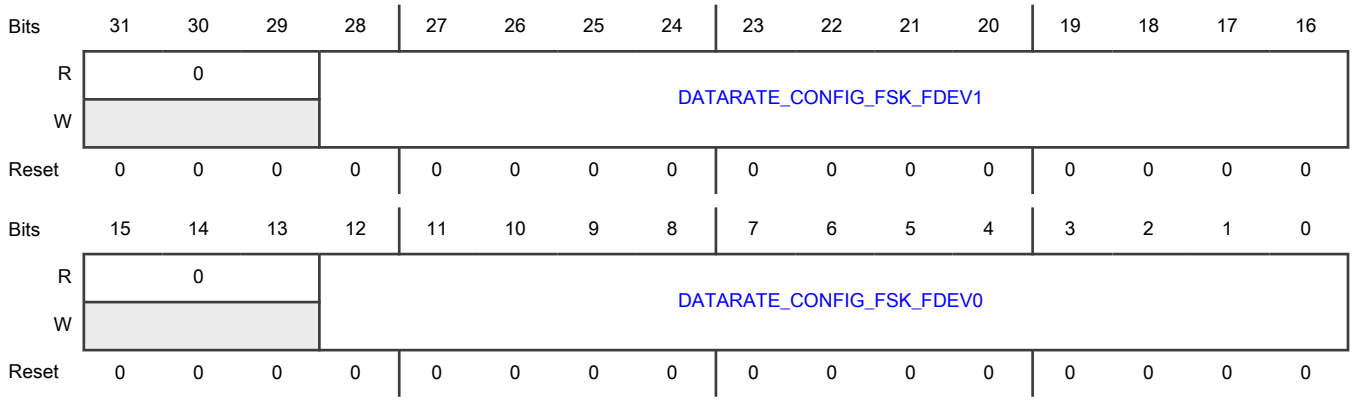
Field	Function
31-0 DFT_MOD_PATTERN	DFT_MOD_PATTERN DFT Modulation Pattern. The DFT Pattern Register can be written to any bit pattern.

52.4.4.2.2.1.6.1.23 DATARATE_CONFIG_FSK_CTRL (DATARATE_CONFIG_FSK_CTRL)

Offset

Register	Offset
DATARATE_CONFIG_FSK_CTRL	54h

Diagram



Fields

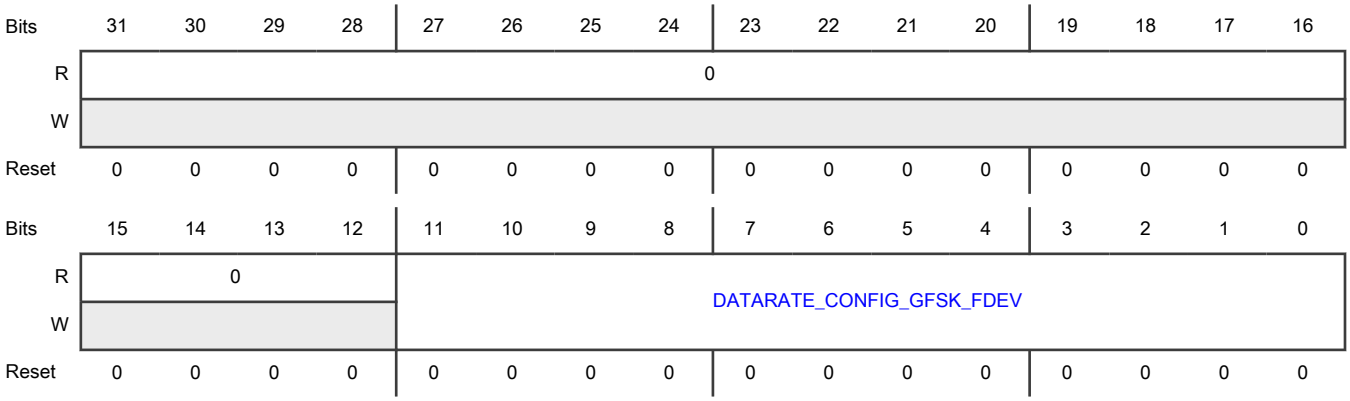
Field	Function
31-29 —	Reserved
28-16 DATARATE_CONFIG_FSK_FDEV1	DATARATE_CONFIG_DATA_PAD_PFDEV This register indicates the +1 signed frequency word, represented in two's complement, to be used when datarate_config_sel is asserted.
15-13 —	Reserved
12-0 DATARATE_CONFIG_FSK_FDEV0	DATARATE_CONFIG_DATA_PAD_MFDEV This register indicates the -1 signed frequency word, represented in two's complement, to be used when datarate_congig_sel is asserted.

52.4.4.2.2.1.6.1.24 DATARATE_CONFIG_GFSK_CTRL (DATARATE_CONFIG_GFSK_CTRL)

Offset

Register	Offset
DATARATE_CONFIG_GFSK_CTRL	58h

Diagram



Fields

Field	Function
31-16	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
15-12 —	Reserved
11-0 DATARATE_CONFIG_GFSK_FDEV	DATARATE_CONFIG_GFSK_FDEV This register indicates the signed frequency deviation word, represented in two's complement, to be used when datarate_config_sel is asserted.

52.4.4.2.2.1.6.1.25 DATARATE_CONFIG_FILTER_CTRL (DATARATE_CONFIG_FILTER_CTRL)

Offset

Register	Offset
DATARATE_CONFIG_FILTER_CTRL	5Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0			DATARAT...	0	DATARATE_CONFIG_SYNC1_C...			0	DATARATE_CONFIG_SYNC0_C...			0	DATARATE_CONFIG_GFSK_FI...		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												DATARAT...	DATARAT...	DATARAT...	DATARAT...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-29 —	Reserved
28 DATARATE_CONFIG_IMAGE_FIR_CLK_SEL	DATARATE_CONFIG_IMAGE_FIR_CLK_SEL DATARATE_CONFIG_IMAGE_FIR_CLK_SEL If datarata_config_sel = 1'b1:

Table continues on the next page...

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Field	Function
	1'b0: ref_clk 1'b1: ref_clk div_by_2
27 —	Reserved
26-24 DATARATE_CONFIG_SYNC1_CLK_SEL	DATARATE_CONFIG_IMAGE_SYNC1_CLK_SEL DATARATE_CONFIG_IMAGE_SYNC1_CLK_SEL If ref_clk = 32MHz: 3'b000: ref_clk 3'b001: ref_clk div_by_2 3'b010: ref_clk div_by_4 3'b011: ref_clk div_by_8 3'b100: ref_clk div_by_16 3'b101: ref_clk div_by_32 3'b110: ref_clk div_by_64 3'b111: ref_clk div_by_128 If ref_clk = 26MHz: 3'b000: ref_clk 3'b001: ref_clk div_by_2 3'b010: ref_clk div_by_4 3'b011: ref_clk div_by_13 3'b100: ref_clk div_by_26 3'b101: ref_clk div_by_52 3'b110: ref_clk div_by_104 3'b111: reserved
23 —	Reserved
22-20 DATARATE_CONFIG_SYNC0_CLK_SEL	DATARATE_CONFIG_IMAGE_SYNC0_CLK_SEL DATARATE_CONFIG_IMAGE_SYNC0_CLK_SEL If ref_clk = 32MHz: 3'b000: ref_clk 3'b001: ref_clk div_by_2 3'b010: ref_clk div_by_4 3'b011: ref_clk div_by_8 3'b100: ref_clk div_by_16

Table continues on the next page...

Table continued from the previous page...

Field	Function
	3'b101: ref_clk div_by_32 3'b110: ref_clk div_by_64 3'b111: ref_clk div_by_128 If ref_clk = 26MHz: 3'b000: ref_clk 3'b001: ref_clk div_by_2 3'b010: ref_clk div_by_4 3'b011: ref_clk div_by_13 3'b100: ref_clk div_by_26 3'b101: ref_clk div_by_52 3'b110: ref_clk div_by_104 3'b111: reserved
19 —	Reserved
18-16 DATARATE_CONFIG_GFSK_FILT_CLK_SEL	DATARATE_CONFIG_GFSK_FILT_CLK_SEL DATARATE_CONFIG_GFSK_FILT_CLK_SEL If datarata_config_sel = 1'b1: 3'b000: ref_clk 3'b001: ref_clk div_by_2 3'b010: ref_clk div_by_4 3'b011: ref_clk div_by_8 3'b100: ref_clk div_by_16 3'b101: ref_clk div_by_32 3'b110: ref_clk div_by_64 3'b111: ref_clk div_by_128
15-4 —	Reserved
3 DATARATE_CONFIG_SYNC1_FILTER_OVRD	DATARATE_CONFIG_SYNC1_FILTER_OVRD Overrides the interpolator sync0 filter clock enable, when datarate_confgig_sel is asserted
2	DATARATE_CONFIG_SYNC0_FILTER_OVRD Overrides the interpolator sync0 filter clock enable, when datarate_confgig_sel is asserted

Table continues on the next page...

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Field	Function
DATARATE_CONFIG_SYNC0_FILTER_OVRD	
1 DATARATE_CONFIG_FIR_FILTER_OVRD	DATARATE_CONFIG_FIR_FILTER_OVRD If the DATARATE_CONFIG_IMAGE_FILTER_OVRD_EN bit is set, this bit turns on and off the Transmit Image Filter, when datarate_config_sel is asserted
0 DATARATE_CONFIG_IMAGE_FILTER_OVRD_EN	DATARATE_CONFIG_IMAGE_FILTER_OVRD_EN Enables the TX Image filter override control bits, when datarate_config_sel is asserted

52.4.4.2.2.2 Receiver Digital Module (RX_DIG)

52.4.4.2.2.2.1 Overview

The 2.4GHz Receive Digital Module(RX_DIG) implements the receive digital signal processing functions common to Bluetooth LE, 802.15.4, and Generic Link Layer modes. Generally this includes conditioning the input samples from the ADC and produces a data output for the PHY and an RSSI/LQI for the Link Layers.

52.4.4.2.2.2.1.1 Block Diagram

52.4.4.2.2.2.1.1.1 Data Path

RX_DIG data path is shown below.

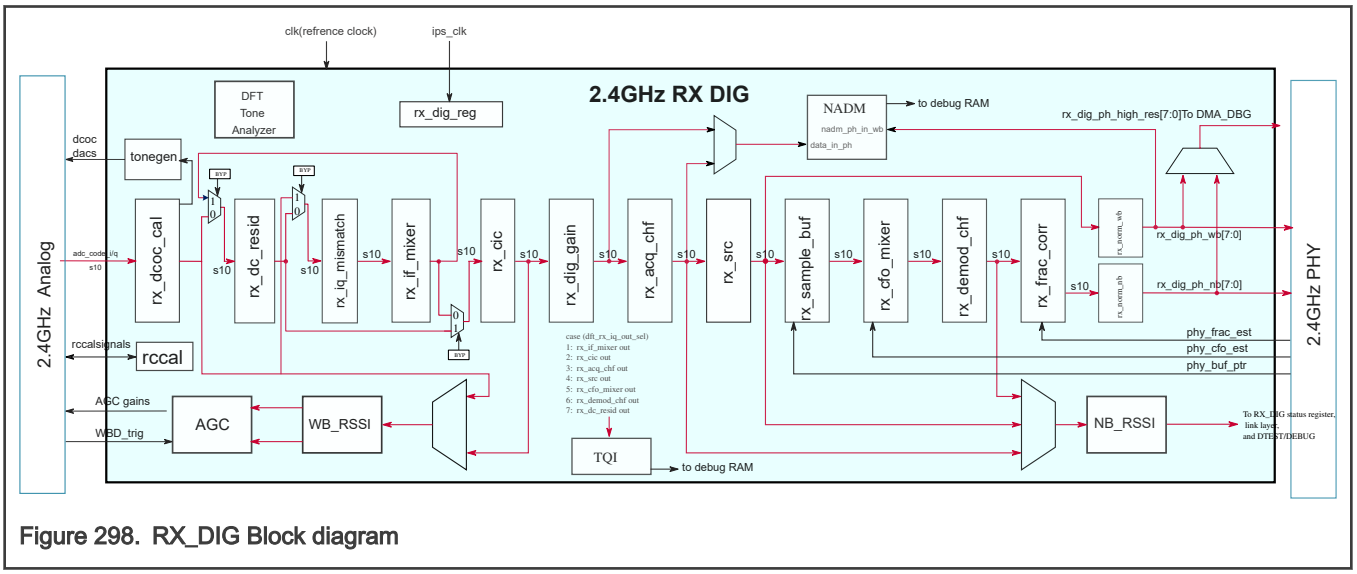


Figure 298. RX_DIG Block diagram

52.4.4.2.2.2.1.1.2 Auxiliary Output

RX_DIG has different kinds of auxiliary output for localization applications, test, or debug purposes. The following figure illustrates the structure of RX_DIG auxiliary outputs. The IQ, phase, and magnitude output support window average function, which

controlled by the DFT_RX_IQ_OUT_SEL field, and the average window size can be chosen from 1(disabled), 4, 8, 16, 32, 64, 128, and 256. An additional smaller complementary average window can be selected from 1(disabled), 4, 8, and 16 for IQ to supply an unique PCT (Phase Correction Term) value to packet RAM via tone_pct. The rx_iq_8b_out is sent to NBU, while other signals mapped to DTEST and/or DMA_DEBUG pages.

NOTE

Check RSSI Estimator section to get the detail information of RSSI and magnitude signals

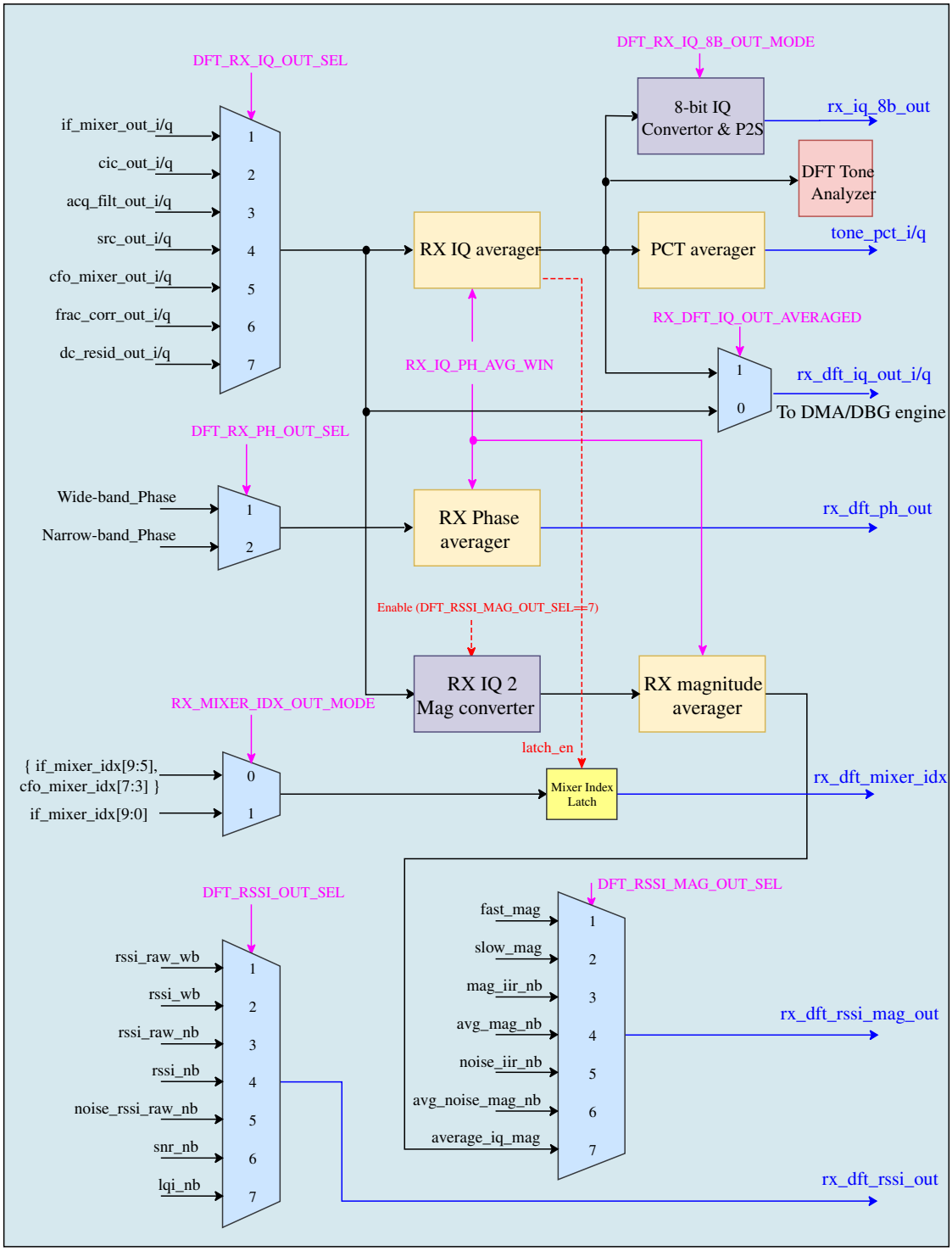


Figure 299. RX_DIG outputs selection diagram

52.4.4.2.2.2.1.2 Features

The 2.4GHz RX_DIG module includes the following features:

- Automatic Gain Control (AGC)
- CIC Decimation Filtering
- Digital IF mixer
- CFO correction
- IQ Mismatch Correction
- Fractional Correction
- Acquisition Channel Filter(16, 24-tap configurable)
- Demod Channel Filter
- Sample Rate Converter
- DC Offset Calibration and Correction
- DC Residual Correction
- Wide-Band and Narrow-Band RSSI estimator module
- Two instances of Normalizer(Wide-Band, Narrow-Band)
- RC Calibration
- Tone Quality Indicator (TQI)
- Normalised Attack Detection Metric (NADM)
- Tone Analyzer
- Multiple Auxiliary Output

52.4.4.2.2.2.1.3 Data Format

The 2.4GHz Radio contains fixed-point data path. In this document, there're two kinds of format to represent the fixed-point data, one is Simulink format [u/s]fix[Nb]_En[Nx], e.g. sfix8_En5, ufix8. And another is the customary format [u/s][N].[M], e.g. s2.5, u8(or u8.0). The below tables show how to parse the fixed point values to real.

Simulink format	
ufix or sfix	Denotes the number is unsigned or singed
Nb	Denotes the total number of bits, including the sign bit if signed
Nx	Denotes the number of bits for fractional

Customary format	
u or s	Denotes the number is unsigned or singed
N	Denotes the number of bits for integer
M	Denotes the number of bits for fractional

Examples	Note: signed values stored as 2's complement.			
Bin	Simulink	Customary	Total bits	Real value
00001111	ufix8	u8 or u8.0	8	15
10000011	ufix8	u8 or u8.0	8	131
0_0011001	sfix8	s7 or s7.0	8	25
1_1111110	sfix8	s7 or s7.0	8	-2
01_011000	ufix8_En6	u2.6	8	1.375
11_000001	ufix8_En6	u2.6	8	3.015625
0_10_11000	sfix8_En5	s2.5	8	2.75
1_11_11100	sfix8_En5	s2.5	8	-0.125

52.4.4.2.2.2.2 Functional Description

52.4.4.2.2.2.2.1 Datarate Selection

The Gen4 Radio has a hardware feature, called datarate selection, to change TX and RX datarate automatically. When RX_DIG.datarate_config_sel = 0, RX_DIG will use primary configuration values. When RX_DIG.datarate_config_sel = 1, RX_DIG will switch to use another set of configuration values for the secondary datarate. All config registers or register fields with "_DRS" postfix indicate registers which will be used for the secondary datarate.

52.4.4.2.2.2.2.2 DC Offset Calibration and Correction

The DCOC block supports the DC offset calibration during RX warmup, and DC correction after RX warmup.

52.4.4.2.2.2.2.2.1 DC Calibration

DC calibration is expected to be performed during each RX warmup. A figure illustrating DCOC during DC calibration is shown below.

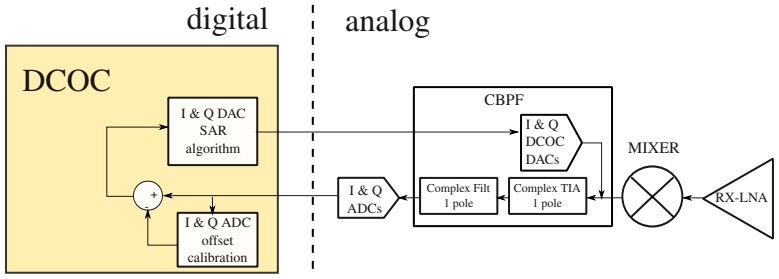


Figure 300. DC Calibration

During DC calibration the following steps are performed

1. The ADC is isolated by putting the CBPF output in a HiZ state, and the ADC inputs are shorted
2. The I and Q ADC outputs are averaged over 4 samples to estimate the DC offset related to the ADCs. These DC offsets are then subtracted from the ADC outputs which are used in steps #4-X below
3. The LNA output is put in HiZ, and the CBPF is put in high gain configuration
4. A SAR algorithm is used to determine the best values for the I DAC. If DCOC_CTRL[DCOC_DAC_ORDER]=1, the Q DAC is used instead in this step.

5. A SAR algorithm is used to determine the best value for the Q DAC. If DCOC_CTRL[DCOC_DAC_ORDER]=1, the I DAC is used instead in this step.
6. Measure the digital correction value on I and Q channel and send the result to the RO register DCOC_DIG_CORR_RESULT. If DCOC_CTRL0.DCOC_DIG_CORR_EN=1(default value), during RX_DIG enabled, the DCOC will compensate the digital correction values on both I and Q channel.

During the SAR for the I DAC, the SAR algorithm evaluates a 4-sample average of the following expression:

SAR_IN = SFIQ * QADC2 + (SFIIP)*(SFII/16) *IADC2

where SFIQ is programmable to be either 0 or 1, SFIIP is programmable to be +1 or -1, SFII is programmable from 0 to 15, IADC2 and QADC2 are the ADC samples corrected by the offsets found in step #2 above.

During the SAR for the I DAC, the SAR algorithm evaluates a 4-sample average of the following expression:

SAR_IN = SFQI * IADC2 + (SFQQP)*(SFQQ/16) *QADC2

where SFQI is programmable to be either 0 or 1, SFQQP is programmable to be +1 or -1, SFQQ is programmable from 0 to 15, and IADC2 and QADC2 are the ADC samples corrected by the offsets found in step #2 above.

After calibration, the ADC offsets and DAC codes determined during calibration can be read in the DCOC_STAT register.

The DCOC has the following additional programmable settings which affect the calibration:

- DCOC_I_CAL_POL. Polarity of the DCOC I DAC
- DCOC_Q_CAL_POL. Polarity of the DCOC Q DAC
- DCOC_CBPF_STL_TIME[3:0]. Settle time in microseconds after estimating the ADC offsets but prior to running the SAR algorithm. This is for the CBPF to be switched from HiZ to high gain.
- DCOC_SAR_STL_TIME[3:0]. Settle time in microseconds during the SAR algorithm, after changing the DAC value
- PULSE_CAPCODE. If this bit is set, then as part of the DCOC calibration sequence, the DCOC calibration logic will direct the RC calibration logic to set its seq_cbpf_ccode output to the maximum value for 3us in order to precharge cap array HiZ nodes.

The programmable values described above are determined through device characterization for the four different CBPF use cases. Preliminary guidance on settings is shown in the table below.

Table 471. DCOC Calibration Settings for 2.4GHz

Programmable Variable	
SFIQ	1
SFQI	1
SFIIP	1
SFQQP	0
SFII	13
SFQQ	9
I_CAL_POL	0
Q_CAL_POL	1
DAC_ORDER	0
CBPF_STL_TIME	3
SAR_STL_TIME	3
PULSE_CAPCODE	0

The total DC calibration duration is a function of the ref clock frequency and some DCOC configs. The reference clock cycle count during DCOC calibration can be calculated as follows:

dcoc_cycle_count = 34 + (CBPF_STL_TIME + SAR_STL_TIME * 12) * count_in_1us + 14 * AVG_WIN_SIZE

Where, count_in_1us = 32 for 32MHz ref clock, and 26 for 26MHz ref clk. CBPF_STL_TIME and SAR_STL_TIME comes from DCOC_CTRL0. AVG_WIN_SIZE = DCOC_CTRL0.DCOC_AVG_WIN ? 8 : 4.

By default config(CBPF_STL_TIME=SAR_STL_TIME=3, AVG_WIN_SIZE=4), dcoc_cycle_count = (ref clock == 32MHz) ? 1338 : 1104. Thus the DC calibration duration is about 42us for 32MHz ref clock and 43us for 26MHz ref clock.

NOTE: DCOC TSM related timing should be updated if the DCOC calibration configs use non-default value.

For a fast RX warmup, the DC calibration is either mostly or entirely skipped, depending on PULSE_CAPCODE. If PULSE_CAPCODE bit is clear, then the TSM fast RX warmup can be programmed such that the TSM enable for the DCOC calibration remains de-asserted during the RX warmup. If PULSE_CAPCODE bit is set, then the TSM fast RX warmup can be programmed such that the TSM enable for the DCOC calibration should assert for only 3us (precharge time)+ CBPF_STL_TIME (settle time). In either case, for a fast RX warmup none of the DCOC offsets will be updated from those calculated in the previous DCOC calibration.

52.4.4.2.2.2.2.2.2 DC Correction

After the RX warmup is complete, the DCOC block handles DC correction. A figure illustrating DCOC operation after RX warmup is shown below.

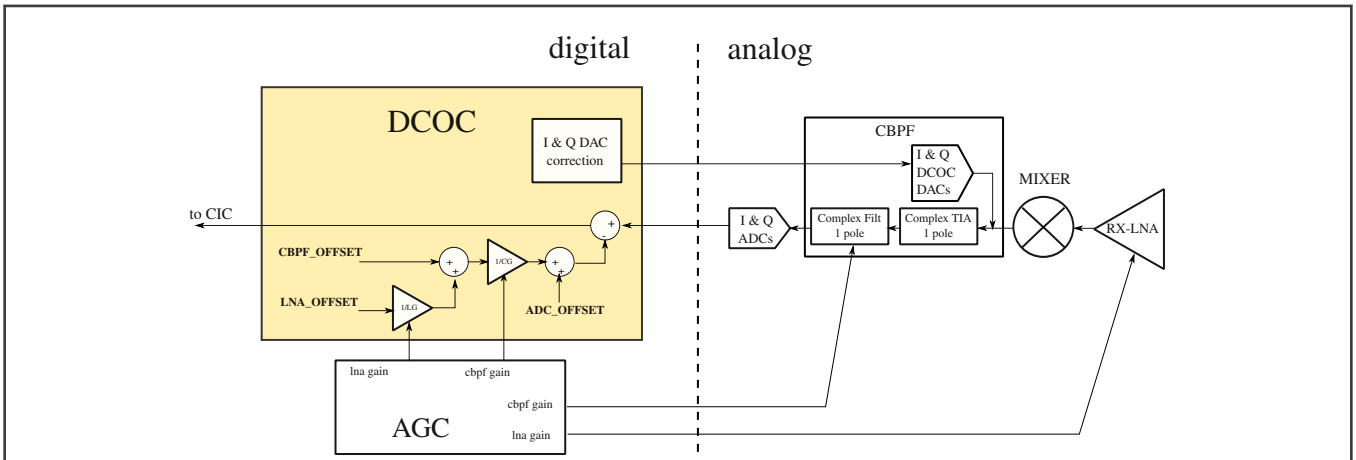


Figure 301. DC Correction

The DAC values and ADC_OFFSETs found during calibration are applied to correct the DC in the receiver. Alternately, the user can override the DAC values by programming DCOC_CTRL2[DCOC_DAC_OVRD_I] and DCOC_CTRL2[DCOC_DAC_OVRD_Q] and setting the DCOC_CTRL0[DCOC_DAC_OVRD_EN] bit. The user can also override the ADC offsets by programming the DCOC_CTRL2[DCOC_ADC_OFFSET_OVRD_I] and DCOC_CTRL2[DCOC_ADC_OFFSET_OVRD_Q] and setting the DCOC_CTRL0[DCOC_ADC_OFFSET_OVRD_EN] bit.

Additionally, the DCOC is capable of correcting for DC offsets which are dependent on the LNA and CBPF gains. These offsets are not determined during the RX warmup calibration. They have to be programmed by the user in the DCOC_CTRL1 register bitfields DCOC_ILNA_OFFSET, DCOC_QLNA_OFFSET, DCOC_ICBPF_OFFSET, and DCOC_QCBPF_OFFSET. These offsets are then scaled based on the AGC gains. In the case of the AGC's LNA gain, the scale factor 1/LG is as follows:

- highest lna gain: 1/LG = 1
- next highest lna gain: 1/LG = 1/4
- next highest lna gain: 1/LG = 1/16
- all other lna gains: 1/LG = 0

In the case of the AGC's CBPF gain, the scale factor 1/CG is as follows:

- high cbpf gain: 1/CG = 1
- low cpbf gain: 1/CG = 1/2

Note that the I & Q DAC correction value is not dependent on the CBPF gain.

52.4.4.2.2.2.2.3 DC Residual Correction

This block is used to compensate for the DC offset which is still present after AGC and DCOC calibration/tracking has completed. It estimates the DC offset by measuring the minimum and maximum value and then applies an additive correction factor to the I and Q channels. This block does not change the value of the DCOC DACs.

The DC Residual Correction block position in the RX chain is controlled by the DC_RES_AFTER_IF_MIXER bitfield of RXDIG_CTRL1 register.

If DC_RES_AFTER_IF_MIXER = 0, the DC REsidual correction is applied just after the DCOC block. If DC_RES_AFTER_IF_MIXER =1 the DC residual correction is done after the IF MIXER block and just before the CIC.

The DC offset is compensated independently on I and Q channels. The correction loop determines the minimum and maximum values over a specified window of samples (*Nwin*) which are then averaged and used (with an update parameter *Alpha*) to create the DC estimate. This DC estimate is then subtracted from the input samples. The applied DC estimate continues to be updated every *NWIN* samples until *IT_FREEZE* of these windows have elapsed, at which time the DC estimate is frozen.

Some addition capabilities are not reflected in figure above:

- the 2^{-Alpha} term can assume values of 1, 1/2, 1/4+1/8, 1/4, 1/8+1/16, 1/8, 1/16+1/32, and 1/16
- the 2^{-Alpha} term can be gearshifted using the DC_RESID_GS_EN and DC_RESID_GEARSHIFT bits.
- Further capabilities related to Long Range support. These are described at the end of this DC Residual Correction section.

Multiple modes of operations can be identified for residual DC offset compensation block. They are presented in table below.

Table 472. Residual DC offset compensation operational modes

Mode	Description	DC_RESID_EN	EXT_DC_EN	IT_FREEZE	DLY	NWIN, ALPHA
Bypass	The DC residual is disabled. The input I and Q samples to the DC Residual block are passed directly to the DC Redisdual output without any modifications. .	0	-	-	-	-
Mode 1	In this mode, DC residual has the role of calculating and applying a DC offset without use of an initial estimate from the DCOC. The DC residual processing is restarted at every AGC gain change This mode is suitable for use when an AGC gain change occurs which is not followed by DCOC tracking.	1	0	>1	>0	program as needed

Table continues on the next page...

Table 472. Residual DC offset compensation operational modes (continued)

Mode 2	In this mode, DC residual has the role of refining the DC offset estimate provided by the DCOC at the end of the DCOC tracking after the last DCOC DAC update. The DC residual processing is restarted whenever DCOC's tracking hold timer expires. This mode is suitable after AGC gain change followed by DCOC tracking.	1	1	>1	-	program as needed
Mode 3	In this mode, DC residual has the role of applying a correction based on the DC offset estimate provided by the DCOC at the end of the DCOC tracking after the last DCOC DAC update. The DC residual processing is restarted whenever DCOC's tracking hold timer expires. This mode is suitable after AGC gain change and DCOC tracking when no further refining is desired.	1	1	1	-	-

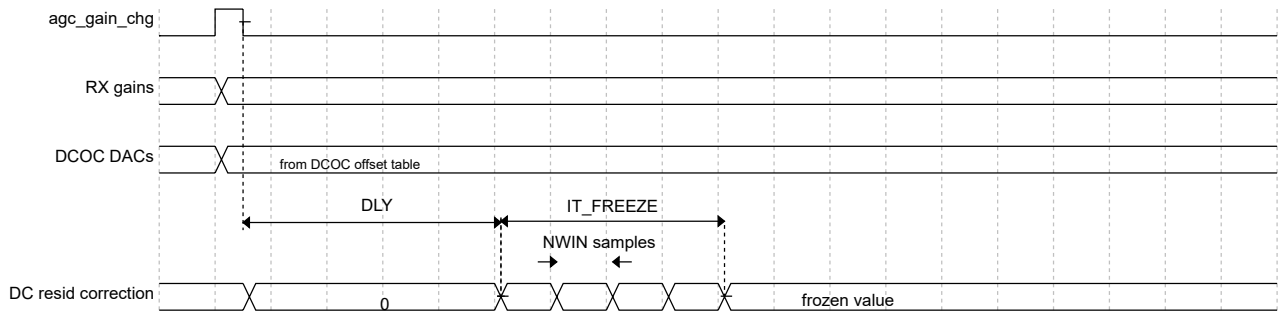


Figure 302. DC residual mode 1 timing

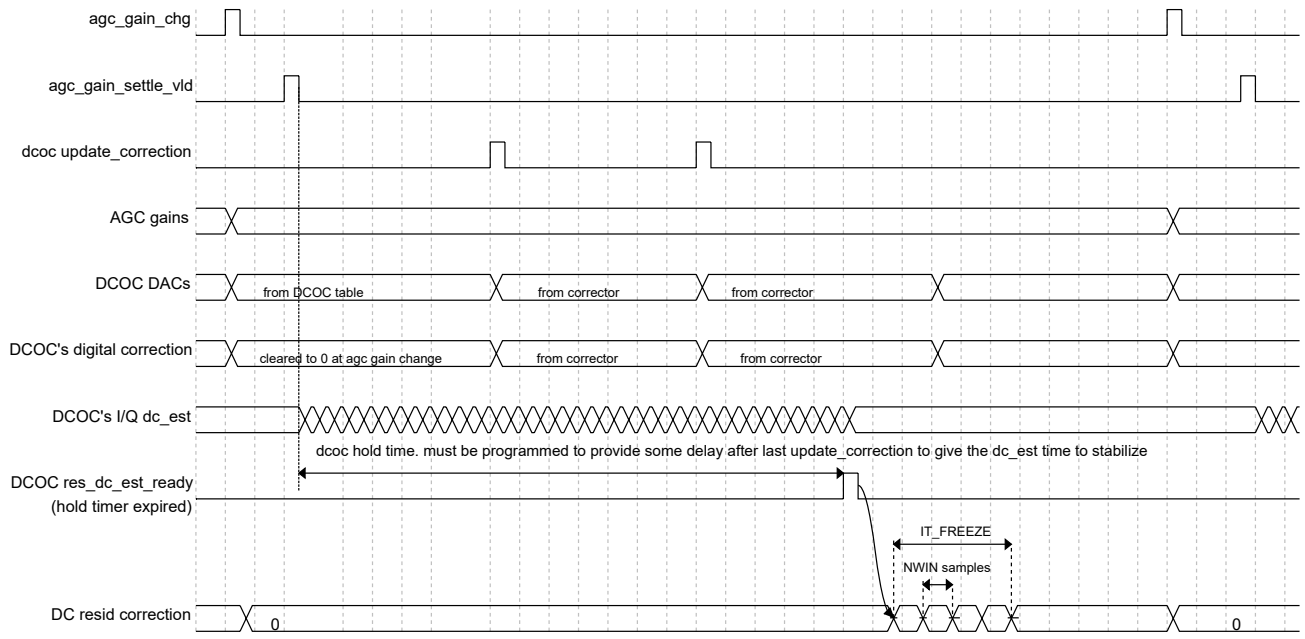


Figure 303. DC residual mode 2 timing

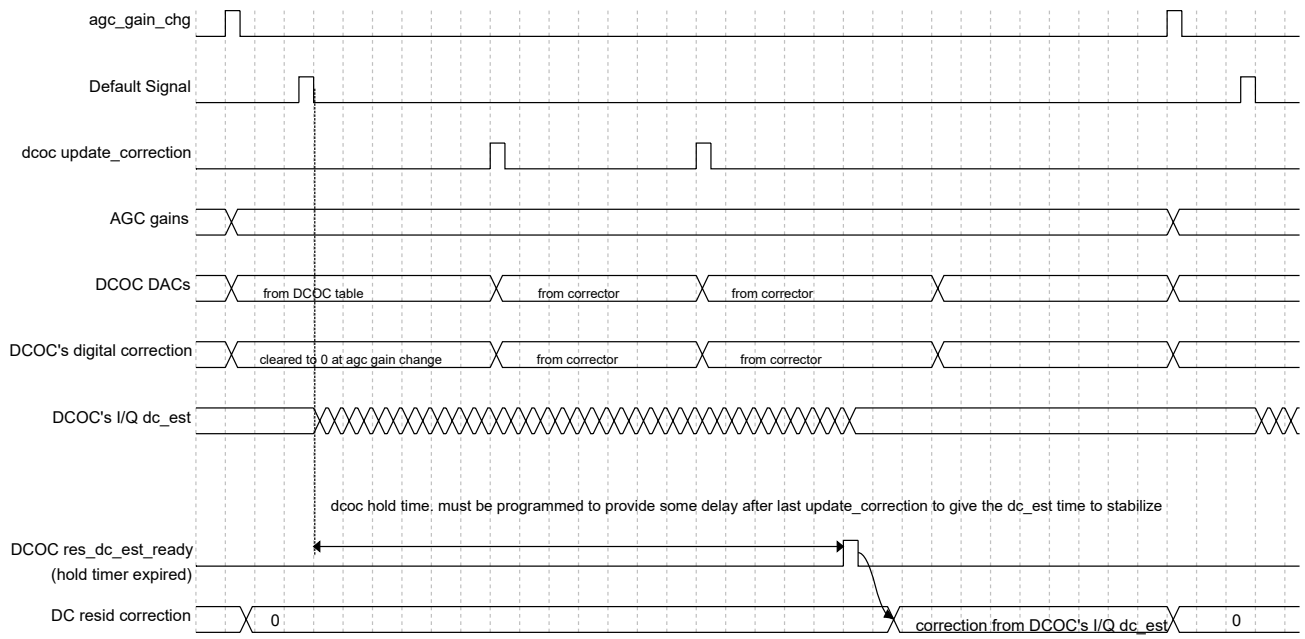


Figure 304. DC residual mode 3 timing

The behavior of the Residual DC block is also dependent on the AGC index and the values programmed for DC_RESID's MIN_AGC_IDX and the DCOC's DCOC_CTRL_1[DCOC_TRK_MIN_AGC_IDX]. This behavior is defined in the table below, which assumes DC_RESID_EN=1.

Table 473. Residual DC offset compensation operation dependency on AGC table index

EXT_DC_EN	MIN_AGC_IDX	DCOC_TRK_MIN_AGC_IDX	Behavior
-	AGC_IDX < MIN_AGC_IDX	-	DC residual is disabled
0	AGC_IDX >= MIN_AGC_IDX	-	DC residual operates in Mode 1 (it does not use an initial estimate from the DCOC)
1		AGC_IDX >= DCOC_TRK_MIN_AGC_IDX	DC residual operates in Mode 2 or 3 (It uses the estimate from the DCOC)
		AGC_IDX < DCOC_TRK_MIN_AGC_IDX	DC residual operates in Mode 1. it does not use the estimate from the DCOC, since the DCOC's tracker is disabled for this AGC gain index

For Long Range, the normal operation of the Residual DC block (as described above) may not reduce the DC level enough to support operation at very low signal levels. The Residual DC block includes an additional feature to handled such cases. If DC_RESID_SECOND_RUN_EN bit is set, then when the AGC index is greater than or equal to DC_RESID_MIN_AGC_IDX2 and the Residual DC block's normal operation has completed, additional DC compensation within the Residual DC block will activate. This "Second Run" DC compensation, when engaged, uses its own set of configuration parameters: DC_RESID_NWIN2, DC_RESID_ALPHA2, DC_RESID_ITER_FREEZE2, DC_RESID_GS2_EN, DC_RESID_GEARSHIFT2. The operation is otherwise similar to the "Mode 2" described above except that the initial DC estimate is the DC offset found at end of Residual DC block's normal operation instead of the estimate from the DCOC module. The following additional features are also supported for "Second Run"

- Slew Rate Control to limit the DC corrections. refer to DC_RESID_SR2_EN and DC_RESID_SLEWRATE2 register descriptions
- Continuous Correction. If DC_RESID_CC_EN bit is set, the DC_RESID_ITER_FREEZ2 is ignored and corrections are applied continuously until the next gain change pulse or initialization
- Operation can be stopped by the PHY. If DC_RESID_PHY_STOP_EN=1, then when the PHY signals that AA found for uncoded has been found, the "Second Run" DC compensation operation is halted (regardless of DC_RESID_ITER_FREEZE2 or DC_RESID_CC_EN bit settings) until the next gain change pulse or initialization.

52.4.4.2.2.2.2.4 I/Q Mismatch Correction

The I/Q mismatch block corrects for I/Q gain and phase mismatch. It can correct up to +/- 9 degrees of phase mismatch and +/- 4 dB of gain mismatch. After correction, phase mismatch is reduced to less than 0.5 degree and gain mismatch less than 0.3 dB.

During end product device calibration, the I/Q phase adjustment coefficient (iqmc_phase_adj) and the I/Q gain adjustment coefficient (iqmc_gain_adj) are determined. Calibration is enabled by setting the CTRL0[RX_IQMC_EN] and IQMC_CTRL0[IQMC_CAL_EN] bit. The following value should be used for calibration: IQMC_CTRL0[IQMC_NUM_ITER]=0x80. The IQMC_CTRL1 register, which also stores the calibration result, should be set to its default value 0x0000_0400. A CW input with a 250 kHz (+/-75 kHz) offset and -2 dBm (+/- 6 dBm) level at the ADC I channel input is required for calibration, though the calibration should also work with lower signal levels down to -18 dBm.

When datarate_config_sel =1, the RX_DIG will use the values stored in the IQMC_CTRL1_DRS register.

NOTE

DCOC calibration should be done before doing I/Q mismatch calibration. Also, during the calibration, the AGC should be disabled.

The IQMC_CTRL0[IQMC_CAL_FREQ_SEL] controls the sample clock frequency of the IQMC module. By default IQMC uses 1/2 reference clock(16MHz or 13MHz). Setting the IQMC_CTRL0[IQMC_CAL_FREQ_SEL] bit let IQMC use 1/4 reference clock(8MHz or 6.5MHz). With the standard number of iterations (IQMC_NUM_ITER=0x80), calibration needs 128 * 64(fixed value

for each iteration) samples. Thus takes 512 us or 1024 us, based on the IQMC_CAL_FREQ_SEL setting, when using 32MHz ref clock.

After calibration is completed the IQMC_CTRL1 register is updated and the IQMC_CAL_EN bit is cleared automatically. The gain calibration and phase calibration loops are shown in the figures below.

NOTE

For each iteration, the 64 samples(fixed value) should cover at least one full cycle of the CW. That means, suppose using 32MHz ref clock, the MINIMUM CW input freq should be 250KHz(period = 4 us) when IQMC_CAL_FREQ_SEL=0, or 125KHz(period = 8 us) when IQMC_CAL_FREQ_SEL=1.

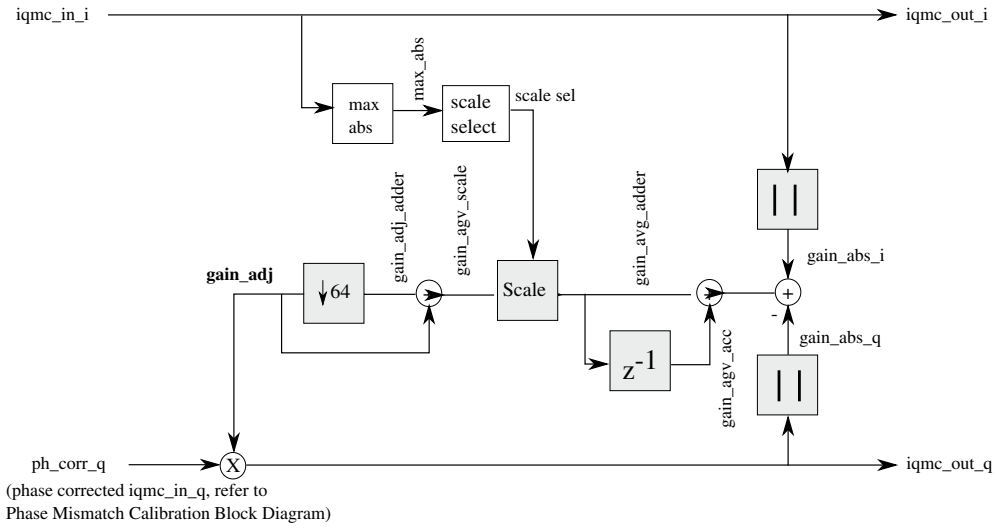


Figure 305. I/Q Gain Mismatch Calibration Block Diagram

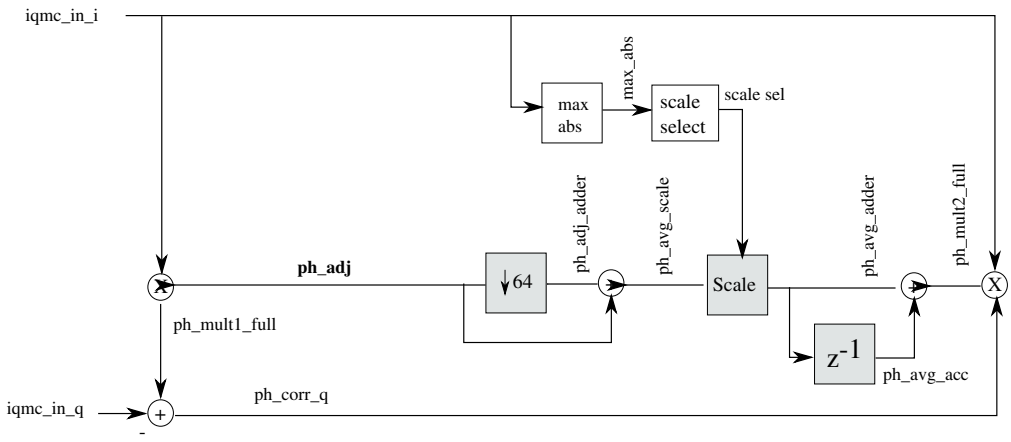


Figure 306. I/Q Phase Mismatch Calibration Block Diagram

Here is the detailed procedures to do I/Q mismatch calibration:

- Do DCOC calibration and apply the result to the input CW signal later
- Disable AGC by clear the CTRL0[AGC_EN]
- Set 0x00000400 for IQMC_CTRL1 register(Default value)

- Set proper values for IQMC_NUM_ITER and IQMC_CAL_FREQ_SEL
- Enter into RX mode and drive the CW tone to the antenna
- Set CTRL0[RX_IQMC_EN]
- Set IQMC_CTRL0[IQMC_CAL_EN]
- Poll IQMC_CTRL0[IQMC_CAL_EN] until it cleared
- Read the calibrated result from IQMC_CTRL2 register

When the receiver is enabled for packet reception, the calibration loops are disabled and the corrections are static. For gain correction, the Q channel is scaled by the gain adjustment coefficient. For phase correction, the I channel is scaled by the phase adjustment coefficient and subtracted from the Q channel. The gain and phase correction values are stored in programming model registers and may be stored in flash to eliminate the need to run I/Q mismatch calibration after each reset.

The gain and phase corrections are illustrated in the figure below.

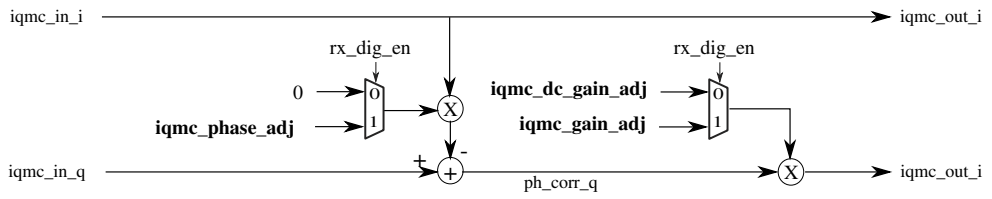


Figure 307. I/Q Mismatch Correction Block Diagram

52.4.4.2.2.2.2.5 Digital IF Mixer

The digital IF mixer performs complex mixing from low IF to DC. The mixer operates on samples at the output of the I/Q mismatch correction module. The mixer is implemented with an effective look-up table size of 1024 entries. The programmable mixer frequency is computed as follows:

DIG_MIXER_FREQ = round[1024*desired_mixer_freq/mixer_sample_frequency]

Where supported ratios of desired_mixer_freq/mixer_sample_frequency are within (-0.25, +0.25).

The table below shows the typical DIG_MIXER_FREQ configuration

Table 474. DIG_MIXER_FREQ configuration based on IF and reference clock frequency

	26MHz	32MHz
IF = 1MHz	39	32
IF = 1.5MHz	59	48

52.4.4.2.2.2.2.6 CIC Decimation Filter

RX_DIG has an Cascaded Integrator Comb (CIC) decimation filters. The CIC operates on output samples from the Digital IF Mixer at the RF reference clock rate. The order of CIC is 3 or 4 configurable and also the decimation rate can be programmed as needed by the application.

A block diagram of the CIC filter is shown below.

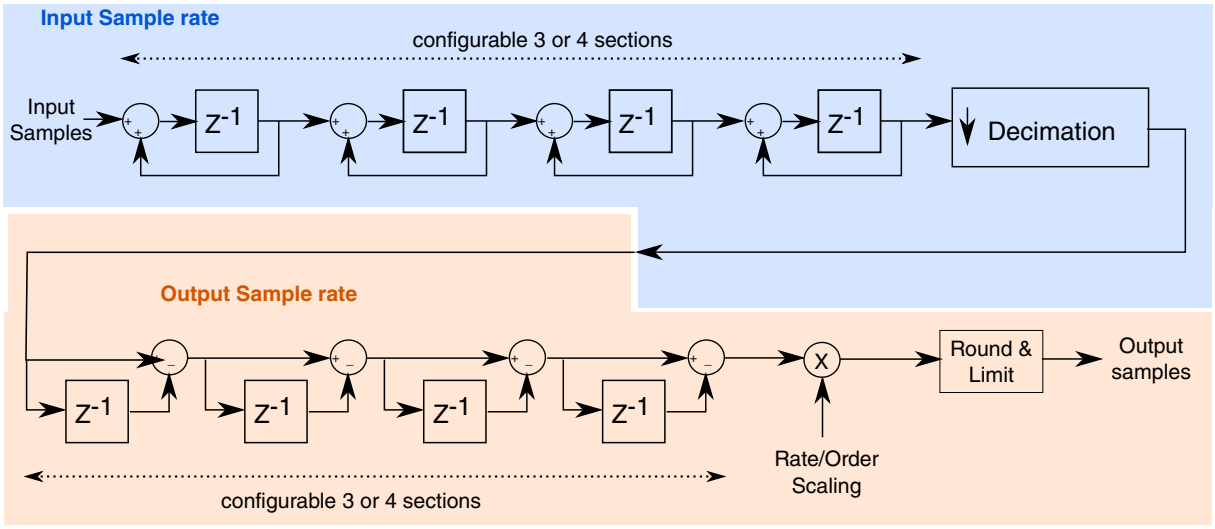


Figure 308. CIC Filter Block Diagram

The table below shows the typical CIC rate configuration.

Table 475. CIC rate configuration base on bitrate and reference clock frequency

	26MHz	32MHz
250Kbps	4	5(Only support 3-order)
500Kbps	3	4
1Mbps	2	3
2Mbps	1	2

52.4.4.2.2.2.7 Digital Gain

This block is a simple configurable multiplier applied at the output of CIC. The output of this module is computed as follows:

dig_gain_out_i/q = cic_out_i/q * (1 + RX_DIG_GAIN * 1 / 8)

Here the "RX_DIG_GAIN" can be choose from 0 ~ 7, therefore the actual gain value can be 1, 1.125,1.25, 1.375, 1.5, 1.625, 1.75, 1.875.

52.4.4.2.2.2.8 Acquisition Channel Filter

The acquisition channel filter is a 16/24-tap configurable symmetric FIR filter with real 6-bit to 10-bit coefficients. It operates at the CIC output rate on the output from Digital Gain module.

For 24-tap configuration:

$H(z) = h_0 + h_1z^{-1} + h_2z^{-2} + ... + h_{11}z^{-11} + h_{11}z^{-12} + ... + h_1z^{-22} + h_0z^{-23}$

For 16-tap configuration:

$H(z) = h_3 + h_4z^{-1} + h_5z^{-2} + ... + h_{11}z^{-7} + h_{11}z^{-8} + ... + h_4z^{-14} + h_3z^{-15}$

The filter output is scaled by 1/512, therefore the sum of the 12 or 8(depends on the CTRL0[RX_ACQ_FILT_LEN]) coefficients programmed in register ACQ_FILT_0_3 ~ ACQ_FILT_10_11 is expected to be <=256 in order to avoid saturation.

52.4.4.2.2.2.9 Sample Rate Conversion (SRC) Filter

The sample rate conversion block is used for a fractional clock rate conversion of the sampled decimated signal, when 26MHz reference clock is used. For the 2.4GHz targeted modulations, the PHY data rate is always 4x the symbol rate (of 2Mbps, 1Mbps, 500kbps or 250kbps) for (G)FSK modes and 4x the 2Mchips/sec rate for IEEE 802.15.4. These desired frequencies are not related to the ADC clock rate by an integer factor, which necessitates the need for a fractional sample rate conversion that is performed by SRC. For a complete list of the fractional conversion modes refer to . The SRC is enabled by setting RX_DIG_CTRL[RX_SRC_EN] to 1, and the conversion factor is selected by RX_DIG_CTRL[RX_SRC_RATE] as described below.

52.4.4.2.2.2.2.10 IQ Sample Buffer

This block is a 1~32 depth buffer for storing IQ values output from RX SRC. The sample buffer depth is controlled by Gen4 PHY, but can be bypassed by setting RX_SAMPLE_BUF_BYPASS in CTRL1 register.

NOTE:

1. If RX CFO MIXER bypassed, should plus 1 to the original IQ sample buffer pointer config value in PHY(PREPHY_MISC_BUFF_PTR_LR and PREPHY_MISC_BUFF_PTR_GFSK)

2. If RX Fractional Correction bypassed, should plus 1 to the original IQ sample buffer pointer config value in PHY(PREPHY_MISC_BUFF_PTR_LR and PREPHY_MISC_BUFF_PTR_GFSK)

3. If both RX CFO MIXER and RX Fractional Correction bypassed, should plus 2 to the original IQ sample buffer pointer config value in PHY(PREPHY_MISC_BUFF_PTR_LR and PREPHY_MISC_BUFF_PTR_GFSK)

52.4.4.2.2.2.2.11 CFO Mixer

The CFO mixer performs complex mixing to eliminate carrier frequency offset which operates at SRC out clock domain. The mixer is implemented with an effective look-up table size of 256 entries. Typically the CFO correction coefficient(cfo_est[9:0]) comes from PHY, but can be overridden by RX_CFO_EST_OVRD_EN and RX_CFO_EST_OVRD fields in CTRL1 register. The target CFO mixer frequency computed as follows:

cfo_frequency = round[cic_out_freq*cfo_est/2048]

The supported CFO correction range is +/-0.25 datarate. e.g. for 1Mbps, +/-250KHz CFO can be eliminated

52.4.4.2.2.2.2.12 Demodulation Channel Filter

The demodulation channel filter is a 9-tap symmetric FIR filter with real 9-bit to 10-bit coefficients. It operates at the SRC output rate on the output from CFO Mixer module.

$H(z) = h_0 + h_1z^{-1} + h_2z^{-2} + h_3z^{-3} + h_4z^{-4} + h_3z^{-5} + h_2z^{-6} + h_1z^{-7} + h_0z^{-8}$

The filter output is scaled by 1/512, therefore the 5 coefficients programmed in register DEMOD_FILT_0_1 and DEMOD_FILT_2_4 should be meet below formula:

$(h_0 + h_1 + h_2 + h_3) * 2 + h_4 <= 512$

52.4.4.2.2.2.2.13 Fractional Correction

This block is responsible with the timing error compensation. The correction factor comes from Gen4 PHY, but can be override by RX_DIG register.

The timing error compensation is realized via linear interpolation using past, current and future samples:

IQOut[k] = IQIn[k] + (IQIn[k+1]-IQIn[k])*abs(FracDly[k]), if FracDly[k]>=0

IQOut[k] = IQIn[k] + (IQIn[k-1]-IQIn[k])*abs(FracDly[k]), if FracDly[k]<0

52.4.4.2.2.2.2.14 Normalizer

The normalizer block converts the 11-bit I/Q input signal into phase output as shown in the block diagrams below. The RX_DIG has two instances of normalizer, wide-band and narrow-band, both of them have the same structure. The difference is the wide-band normalizer connects to the output of RX_SRC, while the narrow-band normalizer uses RX_FRAC_CORR output. In addition, a rounded version, PH_ZB[4:0], of PH_WB[7:0] is sent to ZB_DEMOD.

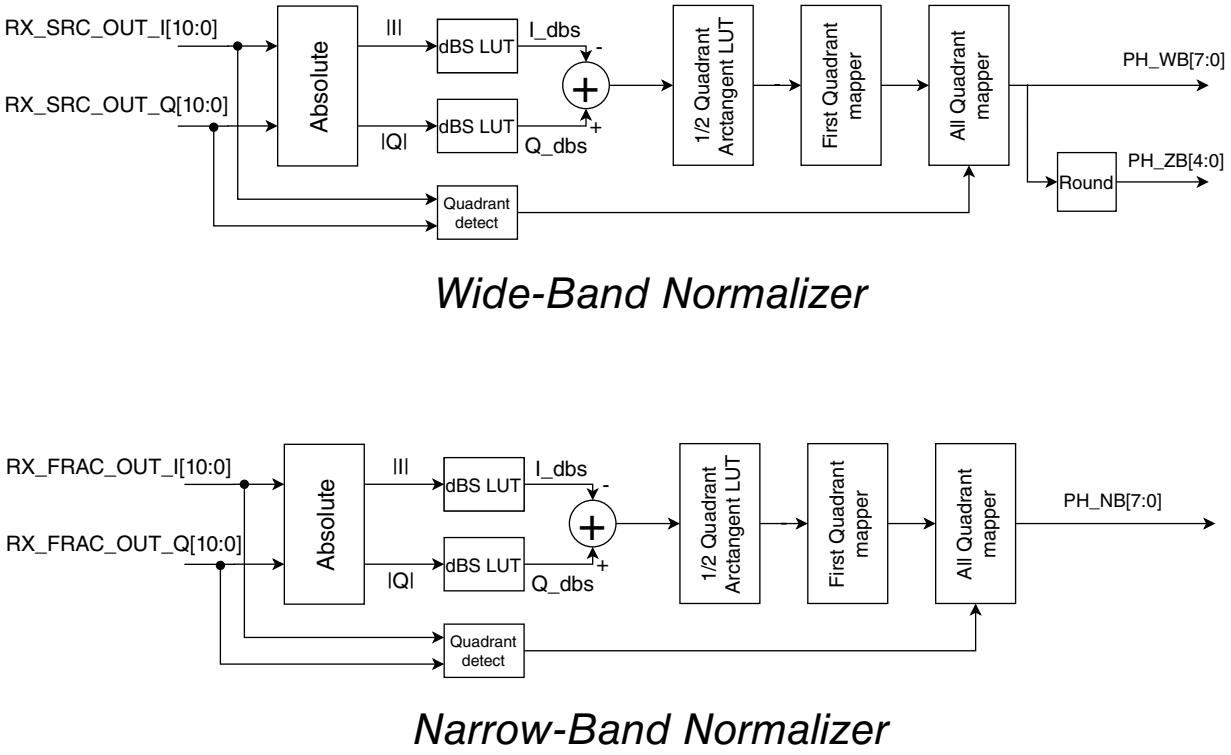


Figure 309. RX_DIG Normalizer Structure

52.4.4.2.2.2.2.15 RSSI Estimator

The role of the RSSI (Received Signal Strength Indication) estimator is to measure the energy of an incoming signal. RX_DIG has two RSSI estimator instances called Wide-Band RSSI estimator(WB_RSSI) and Narrow-Band RSSI estimator(NB_RSSI).

WB_RSSI measures the magnitude of ADC(default) or CIC output and provides the results to feed AGC. The input of NB_RSSI can be chosen from SRC(default), Acquisition Channel Filter, Demodulation Channel Filter, or Fractional Correction output and the results used by link layer controller or software.

52.4.4.2.2.2.2.15.1 Wide-band RSSI

Wide-Band RSSI(WB-RSSI) mainly for generating fast_mag and slow_mag for AGC. When AGC in magnitude mode, the AGC gain index is determined by fast_mag and slow_mag.

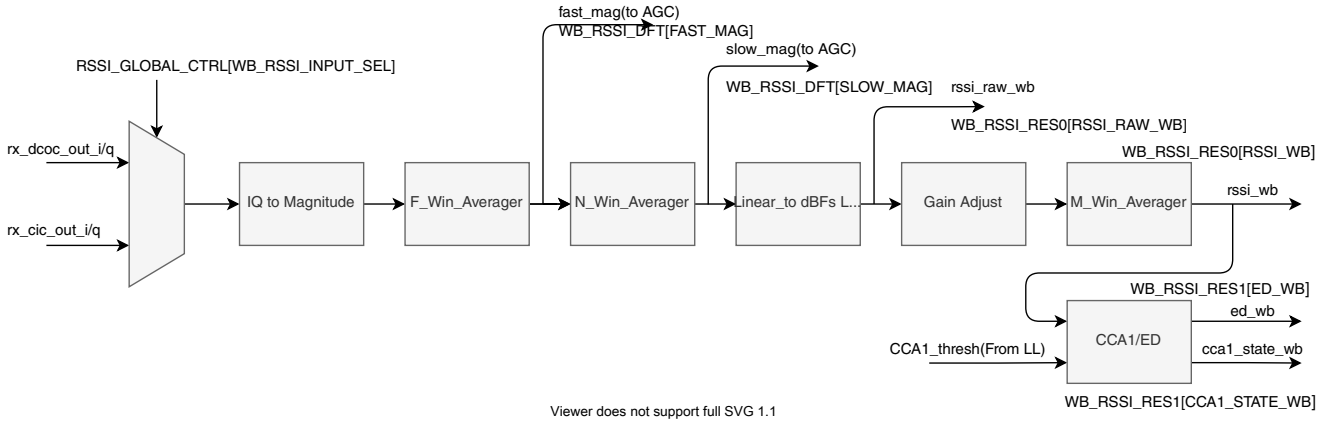


Figure 310. WB-RSSI block diagram

RSSI_WB Calculation:

rssi_wb = rssi_raw_wb - agc_log_gain + rssi_adj_wb + 13

Where:

1. rssi_raw_wb represent the dBFs result of I/Q signal magnitude. rssi_raw_wb = 20*log10((adc_i^2 + adc_q^2)^0.5/1024) ≈ max(adc_i, adc_q) + 0.375*min(adc_i, adc_q)

2. agc_log_gain indicate current analog gain values, which store in AGC_IDX*_GAIN_VAL[LOG_GAIN_*] and selected by AGC based on current AGC gain index

3. rssi_adj_wb is set by WB_RSSI_CTRL[RSSI_ADJ_WB]

52.4.4.2.2.2.2.15.1.1 WB-RSSI Freerun Mode

By default, WB-RSSI working in continuous mode(freerun), until AGC enter into FREEZE state. For debug purpose, by setting WB_CONT_MEAS_OVRD_EN=1 and WB_CONT_MEAS_OVRD=0, the WB-RSSI will stop working once the first rssi_wb calculation done. See RSSI_RDY_WB bit description to get the information about how to get WB-RSSI results continuously.

52.4.4.2.2.2.2.15.2 Narrow-Band RSSI

The role of the Narrow-Band RSSI(NB-RSSI) is to estimate and report: narrow band received signal strength, SNR and LQI result to link layer controller. It also can be chosen for CCA1/ED calculation.

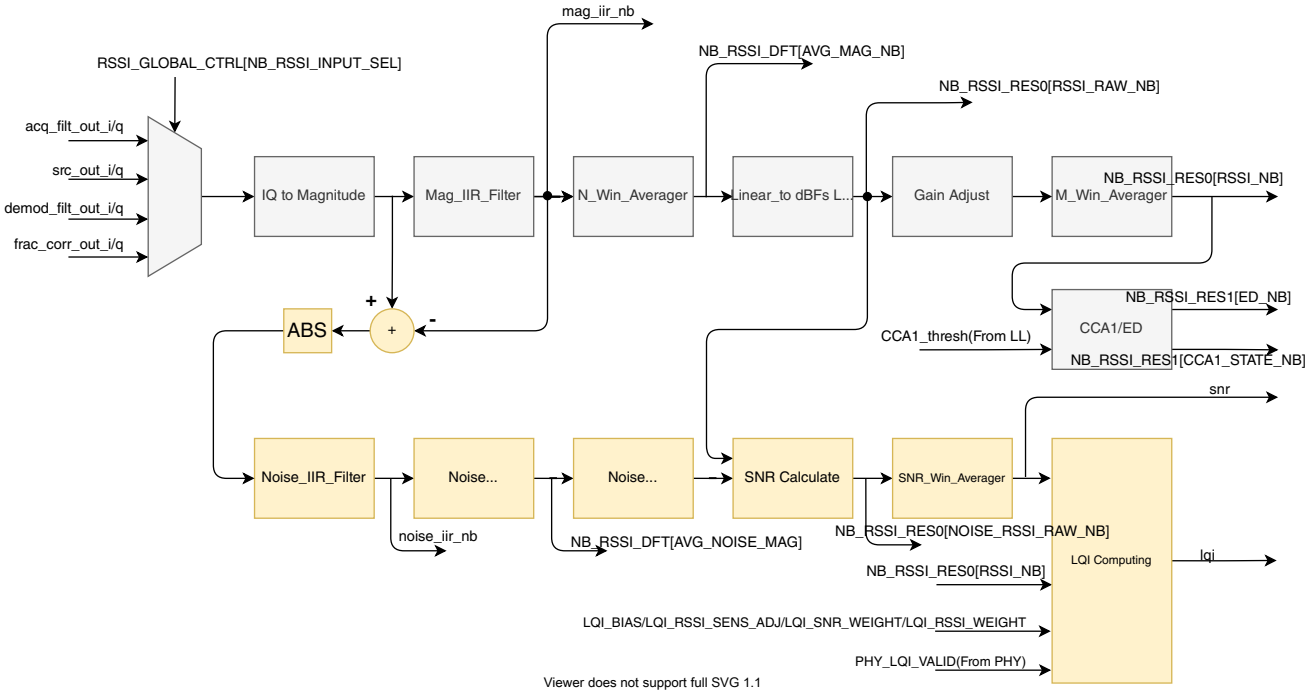


Figure 311. NB-RSSI block diagram

RSSI_NB Calculation:

rssi_nb = rssi_raw_nb - agc_log_gain + rssi_adj_nb + 13

Where:

1. rssi_raw_nb represent the dBFs result of I/Q signal magnitude. rssi_raw_nb = 20*log10((i^2 + q^2)^0.5/1024) ≈ max(i, q) + 0.375*min(i, q)

2. agc_log_gain indicate current analog gain values, which store in AGC_IDX*_GAIN_VAL[LOG_GAIN_*] and selected by AGC based on current AGC gain index

3. rssi_adj_nb is set by NB_RSSI_CTRL[RSSI_ADJ_NB]. **NOTE**: If CTRL0[RX_DIG_GAIN] set a non-zero value. Should add a negative offset value to NB_RSSI_CTRL[RSSI_ADJ_NB]

52.4.4.2.2.2.2.15.2.1 NB-RSSI Freerun Mode

By default, NB-RSSI working in one-time mode. By setting NB_CONT_MEAS_OVRD_EN=1 and NB_CONT_MEAS_OVRD=1 bit, the NB-RSSI will calculate RSSI/LQI/SNR continuously. See RSSI_RDY_NB bit description to get the information about how to get NB-RSSI results continuously.

52.4.4.2.2.2.2.15.2.2 NB-RSSI Manually Enable Mode

By default, NB-RSSI starts when PHY AA found. To manually trigger the NB-RSSI(e.g. for software CCA), follow the below steps:

- Make sure XCVR in idle mode
- Clear RSSI_GLOBAL_CTRL[NB_RSSI_AA_MATCH_OVRD]
- Set RSSI_GLOBAL_CTRL[NB_RSSI_AA_MATCH_OVRD_EN]
- Set RSSI_GLOBAL_CTRL[NB_CONT_MEAS_OVRD_EN] and RSSI_GLOBAL_CTRL[NB_CONT_MEAS_OVRD]
- Start RX sequence
- Wait RX warmup done
- Set RSSI_GLOBAL_CTRL[NB_RSSI_AA_MATCH_OVRD], when software get ready

- Poll NB_RSSI_RES0[RSSI_RDY_NB] until 1, which means the NB-RSSI results(

  RSSI_NB/SNR_NB/LQI_NB/ED_NB

) are ready. Check RSSI_RDY_NB bit description for more information
- When measurement done, clear RSSI_GLOBAL_CTRL[NB_RSSI_AA_MATCH_OVRD], GLOBAL_CTRL[NB_RSSI_AA_MATCH_OVRD_EN], RSSI_GLOBAL_CTRL[NB_CONT_MEAS_OVRD_EN], RSSI_GLOBAL_CTRL[NB_CONT_MEAS_OVRD]
- Write 1 to RSSI_RDY_NB to clear this status bit
- Exit RX mode

52.4.4.2.2.2.2.15.3 CCA1 and ED Measurement

Both WB and NB RSSI can do CCA1 and ED measurement. The following steps show how to enable the CCA1 and ED function.

- Config CCA1_ED_FROM_NB bit to select use which RSSI instance to do CCA1 and ED measurement
- Set either WB_CCA1_ED_EN or NB_CCA1_ED_EN bit based on the value of CCA1_ED_FROM_NB
- Set CCA1 threshold. Note, this config is located in GEN-LL or 15p4-LL
- Launch CCA1 sequence from GEN-LL or 15p4-LL

> **NOTE**
>
> If 15p4-LL is active, set 15p4_PHY->CCA_LQI_SRC[CCA1_FROM_RX_DIG], or the CCA1 will be measured by 15p4_PHY

52.4.4.2.2.2.2.16 Automatic Gain Control (AGC)

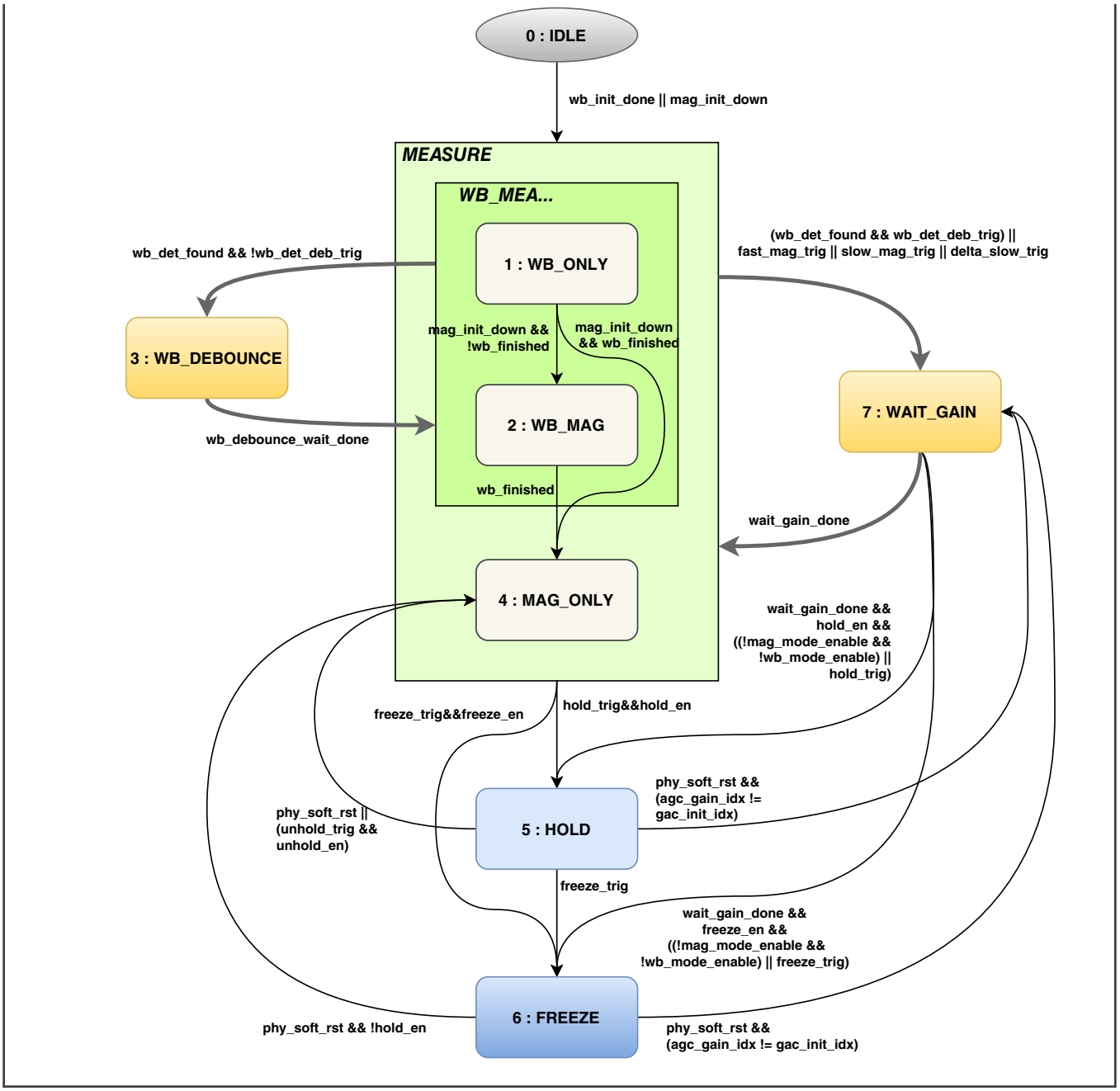
The Automatic Gain Control (AGC) system is designed to ensure that the received signal does not become distorted because of clipping in the analog receive chain, while attempting to maintain an optimal signal level for demodulation. There are two locations where gain may be adjusted: analog LNA, and analog CBPF. The AGC system manipulates these gains to maintain a targeted ADC input signal level. The targeted ADC signal level is chosen as a compromise between receiver linearity, blocker headroom requirements and the goal to maximize the digital signal SNR that is provided to the protocol-specific PHY demodulators.

The AGC system operated with a state machine that is depicted in below figure and has the following significant states:

- **IDLE(000b)**: No actions are taken. The system waits for RX_DIG enable and than AGC initial wait done
- **WB_ONLY(001b)**: AGC is working with Wide-Band detector enabled
- **WB_MAG(010b)**: AGC is working with Wide-Band detector and magnitude mode enabled
- **WB_DEBOUNCE(011b)**: AGC is in WB trigger debounce waiting state
- **MAG_ONLY(100b)**: AGC is working with magnitude mode enabled
- **HOLD(101b)**: AGC hold mode
- **FREEZE(110b)**: AGC is freeze
- **WAIT_GAIN(111b)**: Wait analog gain settle state.

52.4.4.2.2.2.2.16.1 AGC FSM

Figure 312. AGC FSM state diagram



52.4.4.2.2.2.2.16.2 AGC Gain Step Triggers

Gen4 AGC has two kinds of gain step trigger sources. One is from the analog comparator output called wideband detector(WBD) or peak detector, which can only make AGC gain step down. The other is the magnitude output from WB-RSSI, which can make AGC gain step down or up. When WBD enabled, the AGC works in WB_ONLY mode. When magnitude mode enabled, AGC works in MAG_MODE mode. In addition, if both WBD and magnitude mode enabled, AGC works in WB_MAG mode.

In one RX sequence, WBD can trigger once or twice(called WBD step1 and step2), based on the settings of AGC_CTRL[AGC_WBD_EN]. Each step has its own threshold and gain index step down config. In addition, to avoid the WBD triggered by noise or glitch on the antenna, users can enable the WBD dual clip function. When this function enabled, only continually twice trigger occurs can be considered as one WBD trigger. The cooldown(or debounce wait) time can be set by AGC_WBD_STEP1_DUAL_CLIP_WAIT and AGC_WBD_STEP2_DUAL_CLIP_WAIT.

For magnitude mode, AGC compares the FAST_MAG and/or SLOW_MAG value from WB_RSSI with the AGC_THR_FAST and/or AGC_IDX*_THR values to determine gain index step up or step down.

There's a special magnitude trigger called delta slow trigger. To enable delta slow detection, slow magnitude mode also need to be enabled. When the previous Nth(Defined by DELTA_SLOW_WAIT) slow mag value minus the latest slow mag value exceed the value set in DELTA_SLOW_THR, the AGC will issue a big gain index step up, defined by AGC_DELTA_SLOW_STEP.

52.4.4.2.2.2.2.16.3 AGC Gains

Gen4 AGC supports up to 12-gear of gain index and enables 11-gear(10~0) by default. Each gain index has its own analog gain control settings and stored in AGC_IDX*_GAIN_CFG register.

The AGC_IDX*_GAIN_VAL registers store the analog gain values for each gain index. The LOG_GAIN is referenced by WB-RSSI and NB-RSSI module to estimate the input power level of RF signal, while LINEAR_GAIN used by Gen4 PHY to determine whether there is RF signal on the antenna.

52.4.4.2.2.2.2.16.4 AGC State

52.4.4.2.2.2.2.16.4.1 IDLE

This is the default state of AGC. AGC will keep in this state until initialize done. The AGC internal counter will start counting(use reference clock) when RX_DIG enabled. When the AGC counter matches the value of AGC_WBD_INIT_WAIT or AGC_MAG_INIT_WAIT, the AGC will trans to measurement state(WB_ONLY, WB_MAG or MAG_ONLY). Typically, if both WBD and magnitude mode enabled, the programed AGC_WBD_INIT_WAIT should no less than AGC_MAG_INIT_WAIT.

52.4.4.2.2.2.2.16.4.2 WB_ONLY

After the AGC initialization done, if AGC_WBD_EN!=0 and AGC_WBD_INIT_WAIT<AGC_MAG_INIT_WAIT, AGC will trans to this mode. In WB_ONLY mode, the AGC only accepts WBD trigger.

If AGC_WBD_AUTO_DIS_CFG != 00, AGC will disable WBD automatically when condition matches. See description of AGC_WBD_AUTO_DIS_CFG for more info. After WBD disabled, AGC will trans to next mode, typically the MAG_ONLY.

If AGC_WBD_STEP*_DUAL_CLI P_EN set, two consecutive WBD triggers treat as one effective AGC gain change trigger. That means the first WBD trigger will make AGC trans to WB_DEBOUNCE mode and wait a moment. After AGC back to WB_ONLY mode, if the WBD trigged again in time, typically less than 5 reference clock cycles, AGC will step down the gain index.

AGC supports WBD gain limit function. If agc_wbd1_gain_limit_en set, after wbd_step1 trig occurs, the AGC max gain will be set as "agc_init_gain – wbd_step1”, that means even if mag value is too small, AGC will not increase gain_idx larger than “agc_max_gain – wb_step1”(NOTE: Typically, agc_max_gain = agc_init_gain). Similar function for agc_wb2_gain_limit_en.

52.4.4.2.2.2.2.16.4.3 MAG_ONLY

In this state, AGC will compare the magnitude from WB-RSSI with the threshold to determine the AGC gain index. There are two kinks of magnitude called fast_mag and slow_mag and which are using for driven the fast mag trigger(called fast mag mode) and slow mag trigger(called slow mag mode). The difference between fast mode and slow mode is response time and adjustment accuracy. Both fast and slow mag mode can be enabled individually, however, delta slow mode can only work with slow mag mode enabled.

52.4.4.2.2.2.2.16.4.4 WB_MAG

This state can be considered as a combination of WB_ONLY and MAG_ONLY. In this state, AGC accepts both WBD and magnitude triggers.

52.4.4.2.2.2.2.16.4.5 WAIT_GAIN

After AGC gain index changed, AGC will enter into WAIT_GAIN state and keep a while. At the same time, reset the WBD and WB-RSSI.

52.4.4.2.2.2.2.16.4.6 WB_DEBOUNCE

If WBD dual clip(debounce) function enabled, AGC will enter into this state when the first WBD trigger occurs without gain index change and reset the WBD at the same time. After a while(defined by AGC_WBD_DUAL_CLIP_TIMEOUT), AGC will back to WB_ONLY or WB_MAG state.

52.4.4.2.2.2.2.16.4.7 HOLD

There are two ways to enter into HOLD state, hold mode timeout(defined by AGC_HOLD_TIMEOUT) matches or hold mode trigger(selected by AGC_PHY_HOLD_TRIG_SEL) occurs.

Note, the hold mode timeout counter will start work when AGC enter into WB_ONLY, WB_MAG or MAG_ONLY and reset when AGC gain index changed.

In HOLD state, AGC will disable WBD and fast mag comparison. However, if AGC_UNHOLD_FEAT_EN[0] and AGC_SLOW_EN set, AGC will be continuing to monitor the slow magnitude values to determine whether exit HOLD and back to MAG_ONLY state.

When AGC_UNHOLD_FEAT_EN[1] set, AGC will exit HOLD mode after N(defined by AGC_UNHOLD _FEAT_TIMEOUT) micro second and back to MAG_ONLY mode.

52.4.4.2.2.2.2.16.4.8 FREEZE

In this state, AGC will disable both WBD and mag comparison. Freeze mode timeout(defined by AGC_FREEZE_TIMEOUT) matches or freeze mode trigger(selected by AGC_PHY_FREEZE_TRIG_SEL) occurs can make AGC enter into FREEZE state.

If both HOLD and FREEZE state triggered by timeout, the AGC will enter into HOLD state first, then wait for freeze timeout and finally enter into FREEZE state. However, AGC can trans to FREEZE state immediately when PHY freeze trigger occurs.

When AGC_UNFREEZE_FEAT_EN set, if RX sequence not be finished in N(defined by AGC_UNFREEZE_FEAT_TIMEOUT) micro second, AGC will exit FREEZE mode and back to MAG_ONLY mode.

52.4.4.2.2.2.2.16.5 AGC PHY Magnitude Threshold

The 2.4GHz PHY acquisition module needs 2 threshold values, mag_thr and mag_thr_hi, to determine if the current input signal is valid.

When the magnitude of the input signal exceeds the mag_thr(pt_sig_pres=01b), the 2.4GHz PHY acquisition module starts working and use GEN4_PHY->FSK_CFG0[HAMMING_AA_LOW_PWR] to find access address. In addition, if the magnitude exceeds both mag_thr and mag_thr_hi(pt_sig_pres=11b), the acquisition module will use another hamming value (GEN_LL->NTW_ADR_CTRL[NTW_ADR_THR] or GEN4_PHY->FSK_CFG0[BLE_NTW_ADR_THR], depends on which LL is active)to do access address searching.

The mag_thr and mag_thr_hi are AGC gain index dependent, which means for each AGC gain index, there's one pair of mag_thr and mag_thr_hi value. These values are configured by AGC_IDX*_GAIN_VAL[MAG_THR_*] and AGC_IDX*_GAIN_VAL[MAG_THR_HI_*] fields.

Furthermore, when datarate_config_sel = 1, a pair of **signed** offset(AGC_IDX*_GAIN_CFG[MAG_THR_*_DRS_OFS] and AGC_IDX*_GAIN_CFG[MAG_THR_HI_*_DRS_OFS]) values will be added to the AGC_IDX*_GAIN_VAL[MAG_THR_(HI_)*] to calculate the final threshold value.

The below example shows how to determine the mag_thr and mag_thr_hi value when the AGC gain index is 11.

When datarate_config_sel = 0 :

mag_thr = AGC_IDX11_GAIN_VAL[MAG_THR_11]

mag_thr_hi = AGC_IDX11_GAIN_VAL[MAG_THR_HI_11]

When datarate_config_sel = 1 :

mag_thr = AGC_IDX11_GAIN_VAL[MAG_THR_11] + AGC_IDX11_GAIN_CFG[MAG_THR_11_DRS_OFS]

mag_thr_hi = AGC_IDX11_GAIN_VAL[MAG_THR_HI_11] + AGC_IDX11_GAIN_CFG[MAG_THR_11_HI_DRS_OFS]

NOTE: for each AGC gain index, the programmed AGC_IDX*_GAIN_VAL[MAG_THR_*] , AGC_IDX*_GAIN_VAL[MAG_THR_HI*],

AGC_IDX*_GAIN_CFG[MAG_THR_*_DRS_OFS], and AGC_IDX*_GAIN_CFG[MAG_THR_HI*_DRS_OFS] values should let mag_thr and mag_thr_hi meet the following equation:

0 <= mag_thr <= mag_thr_hi <= 2047

52.4.4.2.2.2.2.17 RC Calibration

The RX RC Calibration module uses a binary search to find the best 5bit calibration code (rccal_code[4:0]) for the RC calibration circuit in the analog. It is expected that the RC calibration will be performed on each RX warmup. The entire RCCAL sequence requires no more than 8us for all XO reference frequencies supported.

The rccal_code code is then used to calculate a 7bit code for the CBPF circuit, which is dependent on a programmable bandwidth setting (bw_code)and IF setting (sc_code). Also, programmable offsets are provided to allow additional adjustments to the rccal_code or to the computed CBPF code:

cbpf_ccode = round[9 + 2*bw_code)*(2 + sc_code)*(48 + rccal_code + rccal_code_offset)/32] + cpbf_ccode_offset

The figure below illustrates the RC calibration timing. The calibration sequence is initiated by a TSM control signal (seq_rccal_pup). After the seq_rccal_pup asserts, there is a 1.0us settling time followed by a few clock cycles where rccal_code[4:0] = 5'h1_F. Then, 5 calibration stages are performed, each of which requires 1us + 10clks.

Near the end of each calibration stage, the rccal_cmpout signal from the analog is used to determine whether the appropriate bit of rccal_code[4:0] will be set or cleared. By default, the rccal_cmpout is sampled 2 clk cycles after rccal_sample de-asserts, but there are also programmable options for 1clk and 3clk cycles. Also, there is a programmable option to invert the rccal_cmpout signal if needed.

The total calibration time is 1.0us + 5 clks + 5*(1us + 10clks), which is less than 9us for 26MHz and less than 8us for all other XO reference frequencies supported.

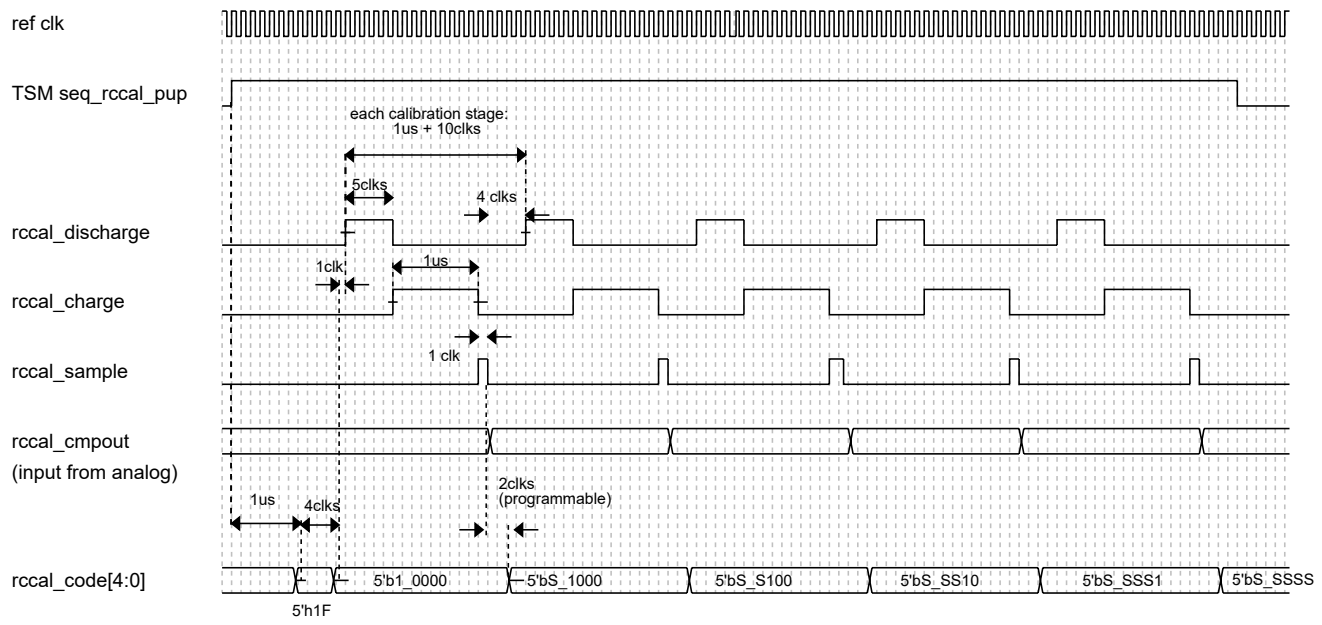


Figure 313. RCCAL timing

52.4.4.2.2.2.2.18 TQI

The Tone Quality Indicator (TQI) is a quality measurement of the received tone. Its value (good, medium or bad) is based on the comparison of the received signal quality factor(a kind of standard deviation measurement) versus programmable thresholds.

52.4.4.2.2.2.2.19 NADM

Normalized Attack Detection Metric (NADM) is aimed at detecting Early Commit Late Detect/ Early Detect Late Commit (ECLD/EDLC) attacks. It yields two results per packet:

- FM correlator measures how close the received GFSK signal is from an expected GFSK reference.
- FM symbol path provides the ability of detecting one or more bit errors in the payload.

52.4.4.2.2.2.20 Clocking

The RX_DIG uses two clocks, the 26 or 32MHz RF reference clock (clk), and the IPS gated clock (ips_clk) that has been synchronized to the reference clock. All programming model registers are clocked by the IPS clock. All other registers are clocked by the RF reference clock.

52.4.4.2.2.2.21 Reset

All RX_DIG registers that require a reset are reset by a global asynchronous reset. The rx_init signal also synchronously resets the state of various rxdig sub-modules. In addition, a software reset from 2P4Ghz XCVR can reset all RX_DIG modules except RX_DIG control register module.

52.4.4.2.2.2.22 Interrupts

All interrupts are managed at transceiver level and will be described in the corresponding section.

52.4.4.2.2.2.23 DMA

DMA engine and Packet RAM debug engine located in transceiver will have the possibility to get data from rx_digital datapath at different levels. These data will be sent to Packet RAM or System RAM at host level.

Refer to DMA section in the Transceiver chapter for more information about DMA possibility inside the RX.

52.4.4.2.2.3 Initialization

To enable the Rx digital bloc, the registers must be first programmed in the correct mode, as described in the chapter Functional description for each sub bloc. Then, the rx_dig_en should be set via TSM programming.

52.4.4.2.2.4 Application information

The sub-blocs inside rx_digital will be enabled with the procedures described in the sub_chapters and register definition.

Then, the rx_digital bloc will be enabled from TSM programming , mainly rx_dig_en and rx_init signals.

52.4.4.2.2.5 Memory Map and register definition

The 2p4GHz RX_DIG memory map and register description is included in the following section.

52.4.4.2.2.5.1 2P4GHZ_RX_DIG register descriptions

52.4.4.2.2.5.1.1 RX_DIG_REG memory map

RADIO.XCVR_RX_DIG base address: 48A0_7000h

Offset	Register	Width (In bits)	Access	Reset value
0h	RXDIG Control 0 (CTRL0)	32	RW	2000_3000h
4h	RXDIG Control 0 DRS (CTRL0_DRS)	32	RW	0000_20C0h
8h	RXDIG Control 1 (CTRL1)	32	RW	0000_0180h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
Ch	RXDIG DFT Control (DFT_CTRL)	32	RW	0000_0000h
10h	RCCAL Control 0 (RCCAL_CTRL0)	32	RW	0000_002Ah
14h	RCCAL Control 1 (RCCAL_CTRL1)	32	RW	0000_0000h
18h	RCCAL Result (RCCAL_RES)	32	R	0000_4E10h
1Ch	DCOC Control 0 (DCOC_CTRL0)	32	RW	0033_2F56h
20h	DCOC Control 0 DRS (DCOC_CTRL0_DRS)	32	RW	0000_0356h
24h	DCOC CONTROL 1 (DCOC_CTRL1)	32	RW	0000_0000h
28h	DCOC CONTROL 2 (DCOC_CTRL2)	32	RW	0000_0000h
2Ch	DCOC Status (DCOC_STAT)	32	R	0000_2020h
30h	IQ Mismatch Control 0 (IQMC_CTRL0)	32	RW	0400_8000h
34h	IQ Mismatch Control 1 (IQMC_CTRL1)	32	RW	0000_0400h
38h	Acquisition Filter Coeffs 0~3 (ACQ_FILT_0_3)	32	RW	0000_0000h
3Ch	Acquisition Filter Coeffs 4~7 (ACQ_FILT_4_7)	32	RW	0000_0000h
40h	Acquisition Filter Coeffs 8~9 (ACQ_FILT_8_9)	32	RW	0000_0000h
44h	Acquisition Filter Coeffs 10~11 (ACQ_FILT_10_11)	32	RW	0000_0000h
48h	Demod Filter Coeffs 0~1 (DEMOD_FILT_0_1)	32	RW	0000_0000h
4Ch	Demod Filter Coeffs 2~4 (DEMOD_FILT_2_4)	32	RW	0000_0000h
50h	Acquisition Filter Coeffs 0~3 DRS (ACQ_FILT_0_3_DRS)	32	RW	0000_0000h
54h	Acquisition Filter Coeffs 4~7 DRS (ACQ_FILT_4_7_DRS)	32	RW	0000_0000h
58h	Acquisition Filter Coeffs 8~9 DRS (ACQ_FILT_8_9_DRS)	32	RW	0000_0000h
5Ch	Acquisition Filter Coeffs 10~11 DRS (ACQ_FILT_10_11_DRS)	32	RW	0000_0000h
60h	Demod Filter Coeffs 0~1 DRS (DEMOD_FILT_0_1_DRS)	32	RW	0000_0000h
64h	Demod Filter Coeffs 2~4 DRS (DEMOD_FILT_2_4_DRS)	32	RW	0000_0000h
68h	RSSI Global Control (RSSI_GLOBAL_CTRL)	32	RW	0000_0310h
6Ch	Wide-Band RSSI Control (WB_RSSI_CTRL)	32	RW	0022_3222h
70h	Wide-Band RSSI Result 0 (WB_RSSI_RES0)	32	RW	0080_0100h
74h	Wide-Band RSSI Result 1 (WB_RSSI_RES1)	32	R	0000_0000h
78h	Wide-Band RSSI DFT Result (WB_RSSI_DFT)	32	R	0000_0000h
7Ch	Narrow-Band RSSI Control 0 (NB_RSSI_CTRL0)	32	RW	0040_0022h
80h	Narrow-Band RSSI Control 1 (NB_RSSI_CTRL1)	32	RW	0000_0000h
84h	Narrow-Band RSSI Result 0 (NB_RSSI_RES0)	32	RW	8080_0100h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
88h	Narrow-Band RSSI Result 1 (NB_RSSI_RES1)	32	R	0000_0000h
8Ch	Narrow-Band RSSI DFT Result (NB_RSSI_DFT)	32	R	0000_0000h
90h	AGC Control (AGC_CTRL)	32	RW	805C_CD10h
94h	AGC Control Status (AGC_CTRL_STAT)	32	RW	017E_802Ch
98h	AGC Timing Control 0 (AGC_TIMING0)	32	RW	0810_4398h
9Ch	AGC Timing Control 1 (AGC_TIMING1)	32	RW	1902_440Ah
A0h	AGC Timing Control 2 (AGC_TIMING2)	32	RW	C000_0000h
A4h	AGC Timing Control 0 DRS (AGC_TIMING0_DRS)	32	RW	0000_4000h
A8h	AGC Timing Control 1 DRS (AGC_TIMING1_DRS)	32	RW	0000_040Ah
ACh	AGC Timing Control 2 DRS (AGC_TIMING2_DRS)	32	RW	0000_0000h
B0h	AGC IDX11 Gain Config (AGC_IDX11_GAIN_CFG)	32	RW	0000_7E07h
B4h	AGC IDX10 Gain Config (AGC_IDX10_GAIN_CFG)	32	RW	0000_2E07h
B8h	AGC IDX9 Gain Config (AGC_IDX9_GAIN_CFG)	32	RW	0000_1207h
BCh	AGC IDX8 Gain Config (AGC_IDX8_GAIN_CFG)	32	RW	0000_0607h
C0h	AGC IDX7 Gain Config (AGC_IDX7_GAIN_CFG)	32	RW	0000_0207h
C4h	AGC IDX6 Gain Config (AGC_IDX6_GAIN_CFG)	32	RW	0000_0187h
C8h	AGC IDX5 Gain Config (AGC_IDX5_GAIN_CFG)	32	RW	0000_0107h
CCh	AGC IDX4 Gain Config (AGC_IDX4_GAIN_CFG)	32	RW	0000_01A7h
D0h	AGC IDX3 Gain Config (AGC_IDX3_GAIN_CFG)	32	RW	0000_0127h
D4h	AGC IDX2 Gain Config (AGC_IDX2_GAIN_CFG)	32	RW	0000_00B7h
D8h	AGC IDX1 Gain Config (AGC_IDX1_GAIN_CFG)	32	RW	0000_00B6h
DCh	AGC IDX0 Gain Config (AGC_IDX0_GAIN_CFG)	32	RW	0000_80F6h
E0h	AGC Miscellaneous Gain Config (AGC_MIS_GAIN_CFG)	32	RW	0000_0043h
E4h	AGC IDX11 Gain Value (AGC_IDX11_GAIN_VAL)	32	RW	0000_010Bh
E8h	AGC_IDX10_GAIN_VAL (AGC_IDX10_GAIN_VAL)	32	RW	0000_00EBh
ECh	AGC_IDX9_GAIN_VAL (AGC_IDX9_GAIN_VAL)	32	RW	0000_00CDh
F0h	AGC_IDX8_GAIN_VAL (AGC_IDX8_GAIN_VAL)	32	RW	0000_00AEh
F4h	AGC_IDX7_GAIN_VAL (AGC_IDX7_GAIN_VAL)	32	RW	0000_0096h
F8h	AGC_IDX6_GAIN_VAL (AGC_IDX6_GAIN_VAL)	32	RW	0000_0077h
FCh	AGC_IDX5_GAIN_VAL (AGC_IDX5_GAIN_VAL)	32	RW	0000_005Fh
100h	AGC_IDX4_GAIN_VAL (AGC_IDX4_GAIN_VAL)	32	RW	0000_0049h

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Offset	Register	Width (In bits)	Access	Reset value
104h	AGC_IDX3_GAIN_VAL (AGC_IDX3_GAIN_VAL)	32	RW	0000_0031h
108h	AGC_IDX2_GAIN_VAL (AGC_IDX2_GAIN_VAL)	32	RW	0000_001Ah
10Ch	AGC_IDX1_GAIN_VAL (AGC_IDX1_GAIN_VAL)	32	RW	0000_0002h
110h	AGC_IDX0_GAIN_VAL (AGC_IDX0_GAIN_VAL)	32	RW	0000_03E4h
114h	AGC Fast Mode Threshold (AGC_THR_FAST)	32	RW	01C2_001Eh
118h	AGC Fast Mode Threshold DRS (AGC_THR_FAST_DRS)	32	RW	01C2_001Eh
11Ch	AGC IDX11 Slow Mode Threshold (AGC_IDX11_THR)	32	RW	0190_0000h
120h	AGC IDX10 Slow Mode Threshold (AGC_IDX10_THR)	32	RW	0190_0032h
124h	AGC IDX9 Slow Mode Threshold (AGC_IDX9_THR)	32	RW	0190_0032h
128h	AGC IDX8 Slow Mode Threshold (AGC_IDX8_THR)	32	RW	0190_0032h
12Ch	AGC IDX7 Slow Mode Threshold (AGC_IDX7_THR)	32	RW	0190_0032h
130h	AGC IDX6 Slow Mode Threshold (AGC_IDX6_THR)	32	RW	0190_0032h
134h	AGC IDX5 Slow Mode Threshold (AGC_IDX5_THR)	32	RW	0190_0032h
138h	AGC IDX4 Slow Mode Threshold (AGC_IDX4_THR)	32	RW	0190_0032h
13Ch	AGC IDX3 Slow Mode Threshold (AGC_IDX3_THR)	32	RW	0190_0032h
140h	AGC IDX2 Slow Mode Threshold (AGC_IDX2_THR)	32	RW	0190_0032h
144h	AGC IDX1 Slow Mode Threshold (AGC_IDX1_THR)	32	RW	0190_0032h
148h	AGC IDX0 Slow Mode Threshold (AGC_IDX0_THR)	32	RW	0000_0032h
14Ch	AGC Miscellaneous Thresholds (AGC_THR_MIS)	32	RW	0014_0028h
150h	AGC Override Control (AGC_OVRD)	32	RW	0000_0000h
154h	DC Residual Control (DC_RESID_CTRL)	32	RW	0000_0000h
158h	DC Residual Control2 (DC_RESID_CTRL2)	32	RW	0000_0000h
15Ch	DC Residual Control DataRate1 (DC_RESID_CTRL_DRS)	32	RW	0000_0000h
160h	DC Residual Estimate (DC_RESID_EST)	32	R	0000_0000h
164h	DfT tone analyzer (DFT_TONE_ANALYZER0)	32	RW	0000_A000h
168h	DfT tone analyzer (DFT_TONE_ANALYZER1)	32	RW	0000_0000h
16Ch	DfT tone analyzer (DFT_TONE_ANALYZER2)	32	R	0000_0000h
170h	DfT tone analyzer (DFT_TONE_ANALYZER3)	32	RW	0000_0000h
174h	DCOC Digital Correction Result (DCOC_DIG_CORR_RESULT)	32	R	0000_0000h
178h	IQ Mismatch Control 1 DRS (IQMC_CTRL1_DRS)	32	RW	0000_0400h
17Ch	TQI control fields (TQI_CTRL)	32	RW	0001_0403h

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Offset	Register	Width (In bits)	Access	Reset value
180h	TQI thresholds (TQI_THR)	32	RW	4009_0009h
184h	RXDIG Control 2 (CTRL2)	32	RW	0000_000Bh
188h	Controls for the NADM module (NADM_CTRL)	32	RW	001E_9413h
18Ch	NADM latest packet results. (NADM_RES)	32	R	0000_0000h
190h	Fine CFO module controls. (FCFO_CTRL)	32	RW	0000_0001h
194h	Tone parameters. (FCFO_TN)	32	RW	0004_0003h
198h	F2 carrier iq phases (FCFO_TN_PH)	32	RW	0050_00A0h
19Ch	Fine CFO results. (FCFO_RES)	32	R	0000_0000h

52.4.4.2.2.2.5.1.2 RXDIG Control 0 (CTRL0)

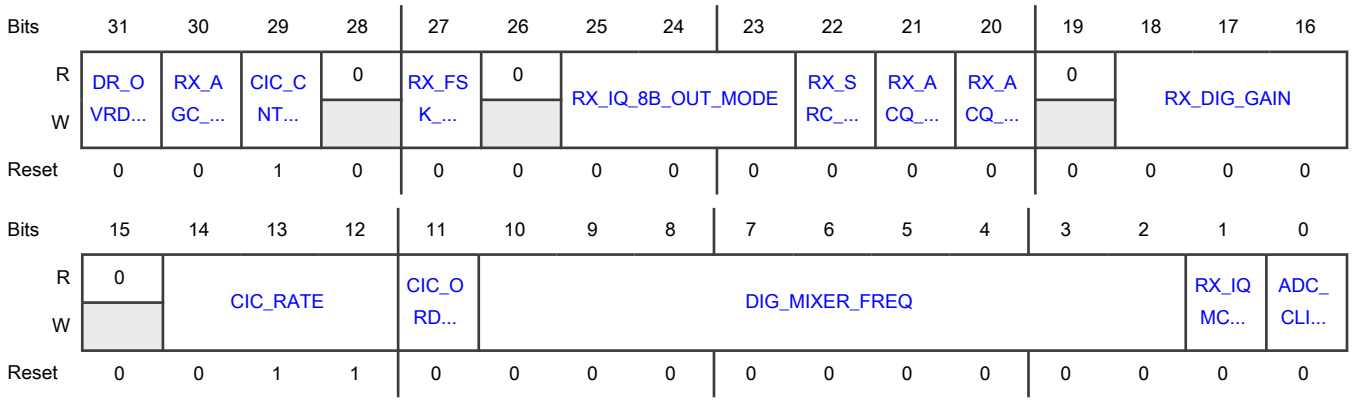
Offset

Register	Offset
CTRL0	0h

Function

RXDIG control register 0

Diagram



Fields

Field	Function
31	DATARATE_CONFIG_SEL Override In CTE

Table continues on the next page...

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Field	Function
DR_OVRD_IN_CTE	For debugging purpose. Keep 0 for the normal case.
30 RX_AGC_EN	AGC Enable 0b - AGC is disabled 1b - AGC is enabled
29 CIC_CNTR_FREE_RUN_EN	CIC Dec Counter Free Run Enable This bit is for RSM use case. If this bit set, during rsm_active=1, the CIC decimation counter will keep running even rx_dig_en=0. In addition, the rx_init will not reset the CIC decimation counter.
28 —	Reserved
27 RX_FSK_ZB_SEL	PHY/Demodulator selection 0b - 2.4GHz PHY is selected 1b - 15.4 PHY is selected
26 —	Reserved
25-23 RX_IQ_8B_OUT_MODE	RX 8-bit IQ Output Mode The 8-bit I/Q source is selected by DFT_CTRL[DFT_RX_IQ_OUT_SEL] 000b - Disable 8-bit IQ output 001b - {I[10],I[9:3]}, {Q[10],Q[9:3]} 010b - {I[10],I[8:2]}, {Q[10],Q[8:2]} 011b - {I[10],I[7:1]}, {Q[10],Q[7:1]} 100b - Dynamic scaling
22 RX_SRC_EN	RX Sample Rate Converter Enable When use 26MHz reference clock, SRC should be enabled. 0b - SRC is disabled. 1b - SRC is enabled.
21 RX_ACQ_FILT_BYPASS	Acquisition Filter Bypass This bit is for test purpose and should not be set in normal mode. 0b - Acquisition filter is enabled 1b - Acquisition filter is bypassed
20	Acquisition Filter Length When set 1, only ACQ_FILT_H4 - ACQ_FILT_H11 are used.

Table continues on the next page...

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Field	Function
RX_ACQ_FILT_LEN	0b - Acquisition filter length is 24. 1b - Acquisition filter length is 16.
19 —	Reserved
18-16 RX_DIG_GAIN	RX Digital Gain Value The values listed here below are intended as multipliers 000b - Digital gain value is 1.000. 001b - Digital gain value is 1.125. 010b - Digital gain value is 1.250. 011b - Digital gain value is 1.375. 100b - Digital gain value is 1.500. 101b - Digital gain value is 1.625. 110b - Digital gain value is 1.750. 111b - Digital gain value is 1.875.
15 —	Reserved
14-12 CIC_RATE	CIC Decimation Rate The actual CIC decimation Rate is 2^CIC_RATE. Note: check CIC_ORDER description for more information. 000b - Decimation Rate is 1. 001b - Decimation Rate is 2. 010b - Decimation Rate is 4. 011b - Decimation Rate is 8. 100b - Decimation Rate is 16. 101b - Decimation Rate is 32. 110b - Reserved 111b - Reserved
11 CIC_ORDER	CIC Order(Stage) Selection The programmed value of CIC_ORDER and the CIC decimation rate(dec_rate) should conform to the formula: (4-CIC_ORDER)*log2(dec_rate) <= 16 0b - 4-stage CIC 1b - 3-stage CIC

Table continues on the next page...

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Field	Function
10-2 DIG_MIXER_FREQ	Digital Mixer Frequency Represents the ratio of the digital mixer frequency to the sample rate frequency at the digital mixer (which is at the CIC output rate). Supported ratios are in the range (-0.25, 0.25). Computed as nearest integer to 1024*desired_mixer_freq/mixer_sample_rate_frequency. Check Digital IF Mixer section for more information.
1 RX_IQMC_EN	IQ Mismatch Compensation Enable NOTE: When IQMC_CTRL0[IQMC_CAL_EN]=1, RX_IQMC_EN should also be set. 0b - IQ mismatch compensation is disabled. 1b - IQ mismatch compensation is enabled.
0 ADC_CLIP_EN	ADC Output Clip Enable When enabled, RXDIG input adc_i and adc_q value will be saturated to +-512. 0b - ADC clip is disabled. 1b - ADC clip is enabled.

52.4.4.2.2.2.5.1.3 RXDIG Control 0 DRS (CTRL0_DRS)

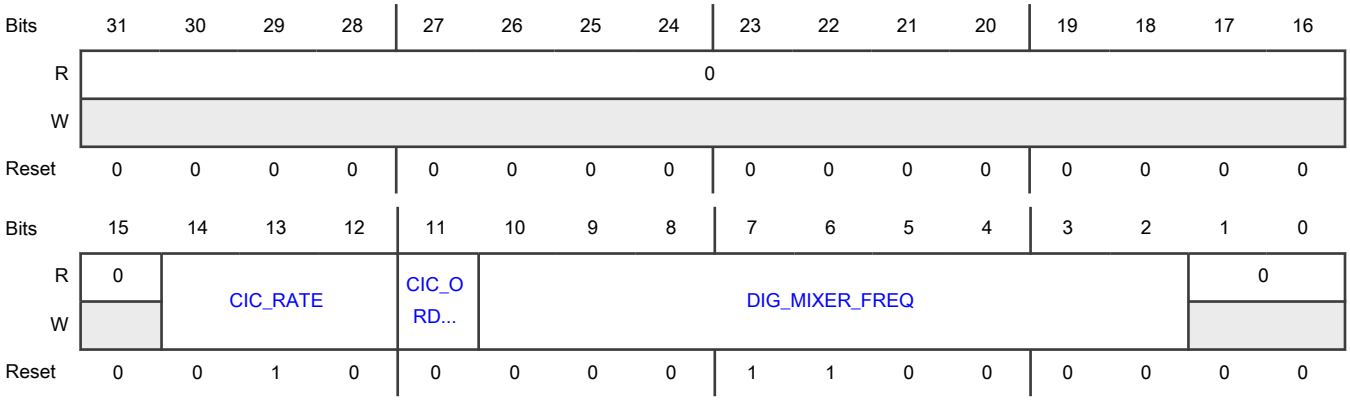
Offset

Register	Offset
CTRL0_DRS	4h

Function

When datarate_config_sel=1, the RX_DIG will use these config values instead of CTRL0.

Diagram



Fields

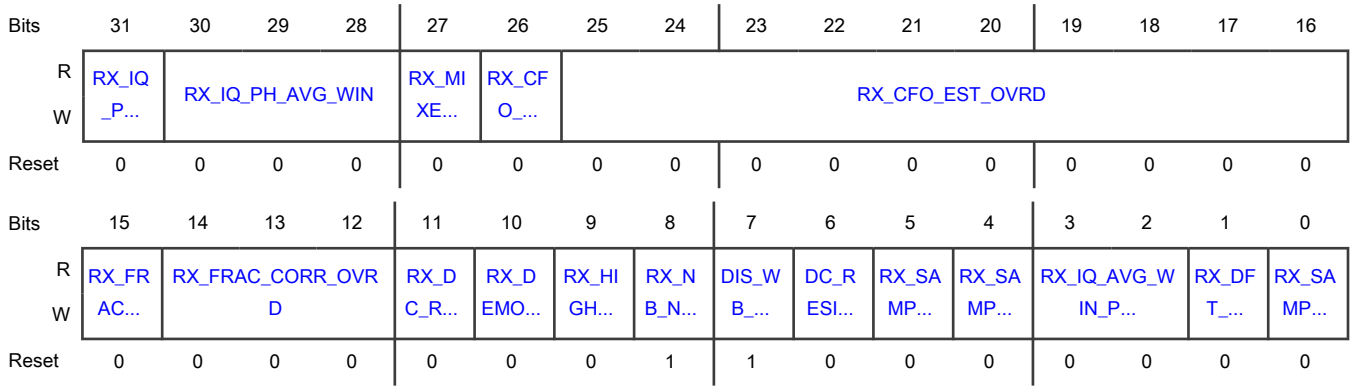
Field	Function
31-15 —	Reserved
14-12 CIC_RATE	CIC Decimation Rate The actual CIC decimation Rate is 2^CIC_RATE. Note: check CIC_ORDER description to get more information. 000b - Decimation Rate is 1. 001b - Decimation Rate is 2. 010b - Decimation Rate is 4. 011b - Decimation Rate is 8. 100b - Decimation Rate is 16. 101b - Decimation Rate is 32. 110b - Reserved 111b - Reserved
11 CIC_ORDER	CIC Order(Stage) Selection The programmed value of CIC_ORDER and the CIC decimation rate(dec_rate) should conform to the following formula: (4-CIC_ORDER)*log2(dec_rate) <= 16 0b - 4-stage CIC 1b - 3-stage CIC
10-2 DIG_MIXER_FREQ	Digital Mixer Frequency Represents the ratio of the digital mixer frequency to the sample rate frequency at the digital mixer (which is at the CIC output rate). Supported rations are in the range (-0.25, 0.25). Computed as nearest integer to 1024*desired_mixer_freq/mixer_sample_rate_frequency. Check Digital IF Mixer section for more information.
1-0 —	Reserved

52.4.4.2.2.2.5.1.4 RXDIG Control 1 (CTRL1)

Offset

Register	Offset
CTRL1	8h

Diagram



Fields

Field	Function
31 RX_IQ_PH_OUTPUT_COND	RX IQ or Phase Output Conditioning This field only has effect when DFT_CTRL[DFT_RX_IQ_OUT_SEL], DFT_CTRL[DFT_RX_PH_OUT_SEL] set a non-zero value or DFT_CTRL[DFT_RSSI_MAG_OUT_SEL]=7. When this bit cleared, the RX_DIG will output the selected IQ and/or Phase, Mag signal to DTEST and/or DMA_DEBUG as soon as RX_DIG starts work. For localization application, set this bit can let RX_DIG send the IQ and/or Phase signal to DTEST and/or DMA_DEBUG only during localization(AoA/AoD/HADM/PDE) sample slot. It will reduce the packet buffer usage and software loading. NOTE: this bit has to be set to 1 in order to generate correct PCT data. 0b - Output IQ and/or Phase all-time 1b - Only output IQ and/or Phase during localization sample slot
30-28 RX_IQ_PH_AVG_WIN	RX IQ Phase Output Average Window Config Programing a non-zero value to this field will apply a window averager on RX_DIG output IQ, Phase signal, or Mag. The actual average window size is 2^(RX_IQ_PH_AVG_WIN+1). NOTE: Programing a non-zero value to this field will reduce the RX IQ and/or Phase output rate to 1/2^(RX_IQ_PH_AVG_WIN+1). 000b - Disable RX IQ and/or Phase output average function 001b - Average window size = 4 010b - Average window size = 8 011b - Average window size = 16 100b - Average window size = 32 101b - Average window size = 64 110b - Average window size = 128 111b - Average window size = 256
27 RX_MIXER_IDX_OUT_MODE	RX_DIG Mixer Index Output Mode

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Field	Function
	RX_DIG has 10-bit mixer(s) index output to DMA_DEBUG. By default, the 10-bit output is composed by rx_if_mixer_idx[9:5] and rx_cfo_mixer[7:3]. By setting RX_MIXER_IDX_OUT_MODE, the RX_DIG will send rx_if_mixer_idx[9:0] to DMA_DEBUG.
26 RX_CFO_EST_OVRD_EN	CFO Estimation Override Enable When this bit set, the CFO mixer will use RX_CFO_EST_OVRD value to do CFO compensation. 0b - CFO override is enabled 1b - CFO override is disabled
25-16 RX_CFO_EST_OVRD	CFO Estimation Override Value This field only valid when RX_CFO_EST_OVRD_EN=1
15 RX_FRAC_CORR_OVRD_EN	Fractional Correction Coefficient Override Enable When this bit set, the Fractional correction module will use RX_FRAC_CORR_OVRD value to do correction.
14-12 RX_FRAC_CORR_OVRD	Fractional Correction Coefficient Override Value This field only valid when RX_FRAC_CORR_OVRD_EN=1
11 RX_DC_RES_AFTER_IF_MIX	When programmed to 1, it moves the DC RESIDUAL block after the IF MIXER When 0, the DC RESIDUAL is between the DCOC and IQMC blocks
10 RX_DEMOD_FILT_BYPASS	Demod Channel Filter Bypass This bit is for test purpose and should not be set in normal mode. 0b - Demod channel filter is enabled. 1b - Demod channel filter is bypassed.
9 RX_HIGH_RES_NORM_SEL	High Resolution Phase Source Select 0b - From RX_NORM_NB 1b - From RX_NORM_WB
8 RX_NB_NORM_EN	Narrow-Band Normalizer Enable 0b - Narrow-Band normalizer is disabled. 1b - Narrow-Band normalizer is enabled.
7 DIS_WB_NORM_AA_FOUND	Disable WB-NORM when AA found When this bit set, RX_DIG will disable the WB-NORM as soon as AA(access address) found by 2.4GHz PHY to save power. NOTE: when using 15p4 PHY, this bit should be cleared.
6	DC_RESID Enable

Table continues on the next page...

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Field	Function
DC_RESID_EN	When set to 1, this field enables the DC Residual block. This bloc is doing DC tracking over the time to compensate it with windows mechanism. When this bit is 0, the DC Residual block is bypassed
5 RX_SAMPLE_BUF_AUTO_GATE	Sample Buffer Automatically Gate Off When enabled, after PHY_AA_MATCH asserted, unused taps of sample buffer will be gated off to save power. Here, unused taps is controlled by 2.4GHz PHY.
4 RX_SAMPLE_BUF_BYPASS_IN_CTE	Bypass Sample Buffer During CTE If enabled, during CTE field receiving, sample buffer will be bypassed to save power and reduce latency.
3-2 RX_IQ_AVG_WIN_PCT	RX IQ Output Average Window Config to generate PCT Programing a non-zero value to this field will apply a window averager on IQ data from first averager to generate PCT data. The actual average window size is 2^(RX_IQ_PH_AVG_WIN_PCT+1). NOTE: Programing a non-zero value to this field will reduce the RX IQ output rate to 1/2^(RX_IQ_AVG_WIN_PCT+1). 00b - Disable RX IQ output average function 01b - Average window size = 4 10b - Average window size = 8 11b - Average window size = 16
1 RX_DFT_IQ_OUT_AVERAGED	I/Q output as raw or averaged data If set to 1, RX_DIG outputs I/Q averaging else it outputs raw data. 0b - Raw data at rx_dft_iq_out 1b - Averaged data at rx_dft_iq_out
0 RX_SAMPLE_BUF_BYPASS	Bypass Sample Buffer This bit is for test or debug purpose, should not be set in normal mode.

52.4.4.2.2.2.5.1.5 RXDIG DFT Control (DFT_CTRL)

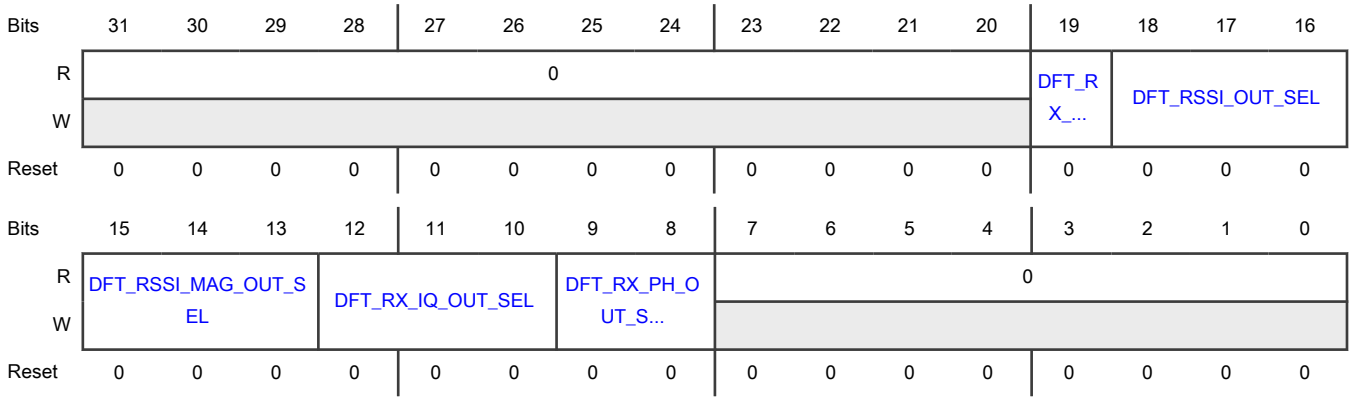
Offset

Register	Offset
DFT_CTRL	Ch

Function

RXDIG test control register.

Diagram



Fields

Field	Function
31-20 —	Reserved
19 DFT_RX_IQ_OUT_SAMPLE_BUF_OUT2	Enable sample_buf output after delay line instead of src output for DFT RX_IQ_OUT If set to 1, sample buffer output with delay line will be send to DFT_RX_IQ_OUT_SEL 4 (SRC output). 0b - SRC output 1b - SAMPLE BUF 2 output
18-16 DFT_RSSI_OUT_SEL	DFT RSSI Result Output Selection WB-RSSI and NB-RSSI results output to DTEST/DMA_DEBUG selection. 000b - Disable RSSI output 001b - Wide-band RSSI_RAW output 010b - Wide-band RSSI output 011b - Narrow-band RSSI_RAW output 100b - Narrow-band RSSI output 101b - Narrow-band NOISE_RAW output 110b - Narrow-band SNR output 111b - Narrow-band LQI output
15-13 DFT_RSSI_MAG_OUT_SEL	DFT RSSI Magnitude Output Selection WB-RSSI and NB-RSSI magnitude output to DTEST/DMA_DEBUG selection. NOTE: When DFT_RSSI_MAG_OUT_SEL=7, the Mag is calculated based on the IQ signal selected by DFT_RX_IQ_OUT_SEL and send to Mag averager. The typical use case is select SRC out IQ with WB-Phase or Frac out IQ with NB-Phase to make sure the mag and phase is aligned in the MAG-PHASE page of DMA_DEBUG. 000b - Disabled

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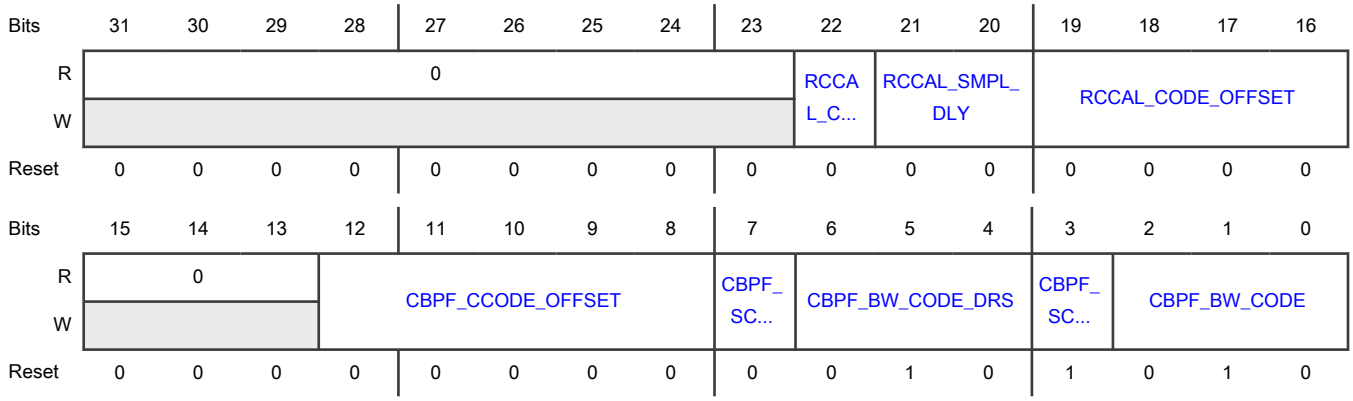
Field	Function
	001b - WB-RSSI fast magnitude 010b - WB-RSSI slow magnitude 011b - NB-RSSI mag IIR 100b - NB-RSSI mag avg 101b - NB-RSSI noise mag IIR 110b - NB-RSSI noise mag avg 111b - DFT_RX_IQ_OUT mag
12-10 DFT_RX_IQ_OUT_SEL	DFT I/Q Output Selection RXDIG sub-module's I/Q output to DTEST/DMA_DEBUG selection. NOTE: The selected DFT_RX_IQ signal is also used as the input of DFT_TONE_ANALYZER 000b - Disabled 001b - Select IF_MIXER 010b - Select CIC 011b - Select ACQ channel filter 100b - Select SRC 101b - Select CFO_MIXER 110b - Select FRAC_CORR 111b - Select DC_RESID
9-8 DFT_RX_PH_OUT_SEL	DFT RXDIG Phase Output Selection RXDIG normalizers output to DTEST/DMA_DEBUG selection 00b - Disable DFT phase output 01b - Select wide-band phase output 10b - Select narrow-band phase output 11b - Disable DFT phase output
7-0 —	Reserved

52.4.4.2.2.2.5.1.6 RCCAL Control 0 (RCCAL_CTRL0)

Offset

Register	Offset
RCCAL_CTRL0	10h

Diagram



Fields

Field	Function
31-23 —	Reserved
22 RCCAL_CMPOUT_INV	RCCAL Comparator Output Invert If set, the RCCAL comparator output from analog is inverted before it is used to determine the RCCAL code value
21-20 RCCAL_SMPL_DLY	RCCAL Sample Delay Indicates the number of clk cycles after sample vld is deasserted when the rccal comparator output is captured 00b - 2 cycles (default) 01b - 1 cycle 10b - 2 cycles 11b - 3 cycles
19-16 RCCAL_CODE_OFFSET	RCCAL_CODE Offset This signed value is used as an offset from the calculated RCCAL_CODE value in the computation of the CBPF_CCODE value
15-13 —	Reserved
12-8 CBPF_CCODE_OFFSET	CBPF_CCODE Offset This signed value is used as an offset to CBPF_CCODE from the calculated RCCAL_CODE value
7 CBPF_SC_CODE_DRS	When datarate_config_sel=1, will choose this value instead of CBPF_SC_CODE

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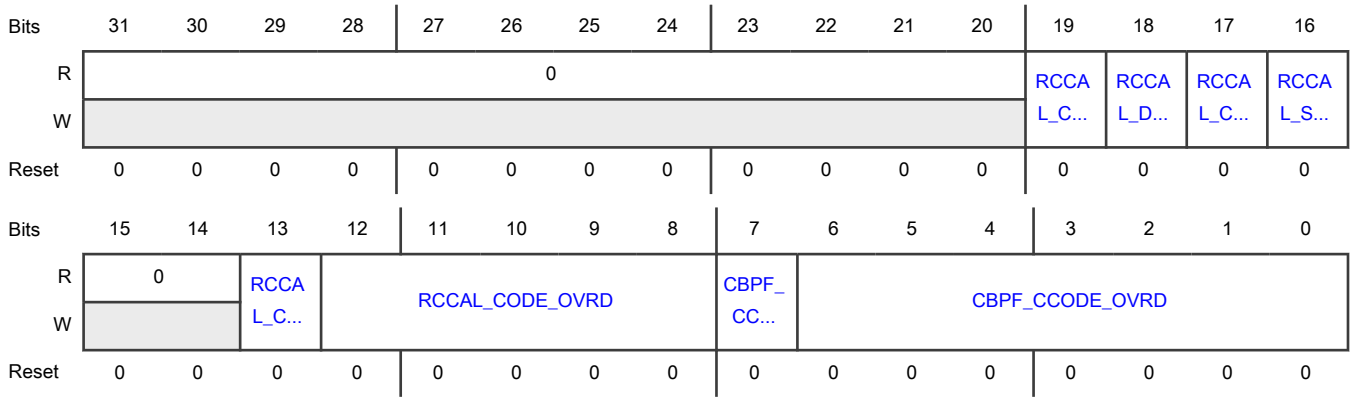
Field	Function
6-4 CBPF_BW_CODE_DRS	When datarate_config_sel=1, will choose this value instead of CBPF_BW_CODE
3 CBPF_SC_CODE	See detail in CBPF_BW_CODE description
2-0 CBPF_BW_CODE	CBPF BW_CODE BW_CODE and SC_CODE used in calculation of the CBPF_CCODE and determine the bandwidth of CBPF. When CBPF_SC_CODE=1 --> 0 (1007.2kHz), 1 (824kHz), 2 (697.6kHz), 3 (604.8kHz),4 (533.6kHz). When CBPF_SC_CODE=0 --> 0 (1511.2kHz), 1 (1236kHz), 2 (1046.4kHz),3 (906.4kHz),4 (800kHz).

52.4.4.2.2.2.5.1.7 RCCAL Control 1 (RCCAL_CTRL1)

Offset

Register	Offset
RCCAL_CTRL1	14h

Diagram



Fields

Field	Function
31-20 —	Reserved

Table continues on the next page...

Table continued from the previous page...

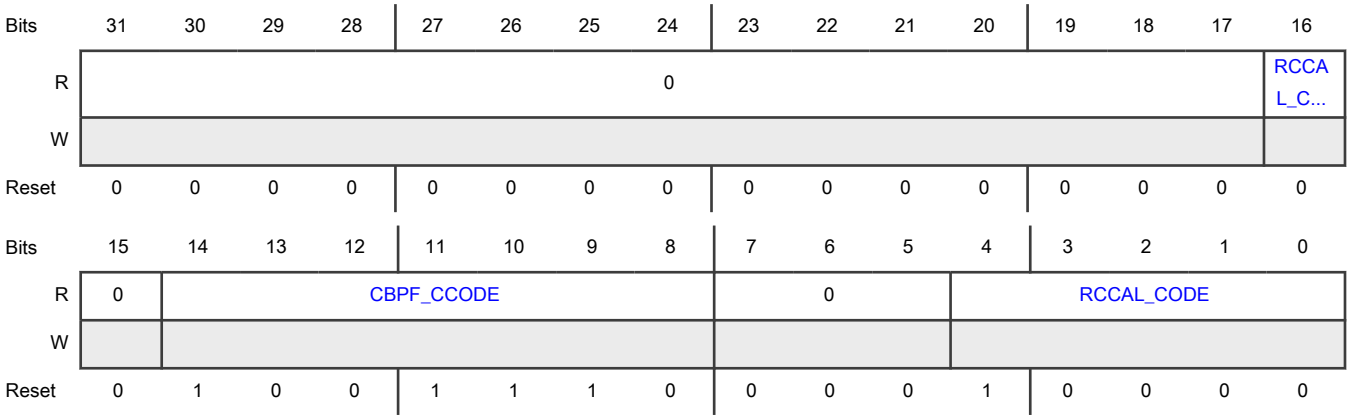
Field	Function
19 RCCAL_CTRL_OVRD_EN	RCCAL Control Signals Override Enable If set, the RCCAL_CHARGE_OVRD, RCCAL_DISCHARGE_OVRD, and RCCAL_SAMPLE_OVRD are used instead of being controlled by RCCAL logic
18 RCCAL_DISCHARGE_OVRD	RCCAL_DISCHARGE Override Value If RCCAL_CTRL_OVR_EN=1, this value is used for RCCAL_DISCHARGE signal instead of being controlled by the RCCAL logic
17 RCCAL_CHARGE_OVRD	RCCAL_CHARGE Override Value If RCCAL_CTRL_OVR_EN=1, this value is used for RCCAL_CHARGE signal instead of being controlled by the RCCAL logic
16 RCCAL_SAMPLE_OVRD	RCCAL_SAMPLE Override Value If RCCAL_CTRL_OVR_EN=1, this value is used for RCCAL_SAMPLE signal instead of being controlled by the RCCAL logic
15-14 —	Reserved
13 RCCAL_CODE_OVRD_EN	RCCAL_CODE Override Enable If set, the RCCAL_CODE_OVRD value is used for RCCAL_CODE signal instead of the value calculated by RCCAL logic
12-8 RCCAL_CODE_OVRD	RCCAL_CODE Override Value If RCCAL_CODE_OVR_EN=1, this value is used for RCCAL_CODE instead of the value calculated by RCCAL logic
7 CBPF_CCODE_OVRD_EN	CBPF_CCODE Override Enable If set, the CBPF_CCODE_OVRD value is used for CBPF_CCODE instead of the value calculated by RCCAL logic
6-0 CBPF_CCODE_OVRD	CBPF_CCODE Override Value If CBPF_CCODE_OVR_EN=1, this value is used for CBPF_CCODE instead of the value calculated by RCCAL logic

52.4.4.2.2.2.5.1.8 RCCAL Result (RCCAL_RES)

Offset

Register	Offset
RCCAL_RES	18h

Diagram



Fields

Field	Function
31-17 —	Reserved
16 RCCAL_CMPOUT	RCCAL CMPOUT Instantaneous value of the RCCAL_CMPOUT signal
15 —	Reserved
14-8 CBPF_CCODE	CBPF_CCODE The CBPF_CCODE value determined by the RCCAL logic. (When CBPF_CCODE_OVRD_EN=1, this value reflects CBPF_CCODE_OVRD.). This result will be kept until the next RX sequence started.
7-5 —	Reserved
4-0 RCCAL_CODE	RCCAL_CODE The RCCAL_CODE determined by the RCCAL logic. This result will be kept until the next RX sequence started.

52.4.4.2.2.2.5.1.9 DCOC Control 0 (DCOC_CTRL0)

Offset

Register	Offset
DCOC_CTRL0	1Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	DCOC_CB...	DCOC_CB...	DCOC_CB...	DCOC_AD...	DCOC_DA...	DCOC_DI...	DCOC_AV...	DCOC_CA...	DCOC_SAR_STL_TIME				DCOC_CBPF_STL_TIME			
Reset	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	DCOC_PU...	DCOC_DA...	DCOC_Q_...	DCOC_I_...	DCOC_SF...	DCOC_SF...	DCOC_SF...	DCOC_SF...	DCOC_SFQQ				DCOC_SFII			
Reset	0	0	1	0	1	1	1	1	0	1	0	1	0	1	1	0

Fields

Field	Function
31 DCOC_CBPF_HIZ_SHORT_OVRD_EN	DCOC CBPF HIZ SHORT Override Enable If this bit is set, then the CBPF_HIZ and CBPF_SHORT signals are controlled by the DCOC_CBPF_HIZ_OVRD and DCOC_CBPF_SHORT_OVRD bits, respectively. Otherwise, the DCOC controls these signals which are used during DCOC calibration.
30 DCOC_CBPF_HIZ_OVRD	DCOC CBPF_HIZ Override Value If DCOC_CBPF_HIZ_SHORT_OVRD_EN is set to 1, DCOC_CBPF_HIZ_OVRD overrides the DCOC-controlled value of the CBPF_HIZ output
29 DCOC_CBPF_SHORT_OVRD	DCOC CBPF_SHORT Override Value If DCOC_CBPF_HIZ_SHORT_OVRD_EN is set to 1, DCOC_CBPF_SHORT_OVRD overrides the DCOC-controlled value of the CBPF_SHORT output
28 DCOC_ADC_OFFSET_OVRD_EN	DCOC_ADC_OFFSET_OVRD_EN If set, the DCOC_ADC_OFFSET_OVRD_I and DCOC_ADC_OFFSET_OVRD_Q values in the DCOC_CTRL2 register are used instead of the values found during DCOC calibration
27 DCOC_DAC_OVRD_EN	DCOC_DAC_OVRD_EN If set, the DCOC_DAC_OVRD_I and DCOC_DAC_OVRD_Q values in the DCOC_CTRL2 register are used instead of the values found during DCOC calibration
26 DCOC_DIG_CORR_EN	DCOC Digital Correction Enable Compensate the residual DC after CBPF DAC calibration done. NOTE: 1. The measurement of digital correction value is always enabled and the result can be read from DCOC_DIG_CORR_RESULT register. 2. When fast RX warmup enabled, the digital measurement stage will be skipped.
25 DCOC_AVG_WIN	DCOC Average Window Select Sample average window size for ADC, DAC calibration, and digital residual DC measurement. NOTE: If set this bit, the TSM timing of RX warmup and DCOC cal duration need to extend by 2us(32MHz ref clock) or 3us(26MHz ref clock)

Table continues on the next page...

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Field	Function
	0b - 4-sample 1b - 8-sample
24 DCOC_CAL_USE_OFFSET	Apply dcoc_i/qcbpf_offset during DCOC calibration. 0b - Do not apply dcoc_i/qcbpf_offset during DCOC calibration 1b - Apply dcoc_i/qcbpf_offset during DCOC calibration
23-20 DCOC_SAR_STL_TIME	DCOC CBPF Settle Time DCOC SAR Settle time in us
19-16 DCOC_CBPF_STL_TIME	DCOC CBPF Settle Time DCOC CBPF Settle time in us
15 DCOC_PULSE_CAPCODE	DCOC pulse capcode When set to 1, enables the DCOC block to generate the capcode pulse to the RCCAL block, forcing the cbpf_ccode to its max value.
14 DCOC_DAC_ORDER	DCOC_DAC_ORDER 0b - DCOC I DAC is calibrated first 1b - DCOC Q DAC is calibrated first
13 DCOC_Q_CAL_POL	DCOC_Q_CAL_POL Polarity of the DCOC Q DAC
12 DCOC_I_CAL_POL	DCOC_I_CAL_POL Polarity of the DCOC I DAC
11 DCOC_SFQI	DCOC_SFQI The SFQI parameter used in DCOC calibration ,used for correction of coupling from Q to I
10 DCOC_SFIQ	DCOC_SFIQ The SFIQ parameter used in DCOC calibration, ,used for correction of coupling from I to Q
9 DCOC_SFQQP	DCOC_SFQQP If set, the SFQQ is negated
8 DCOC_SFIIP	DCOC_SFIIP If set, the SFII is negated

Table continues on the next page...

Table continued from the previous page...

Field	Function
7-4 DCOC_SFQQ	DCOC_SFQQ The SFQQ parameter used in DCOC calibration. Unsigned
3-0 DCOC_SFII	DCOC_SFII The SFII parameter used in DCOC calibration. Unsigned

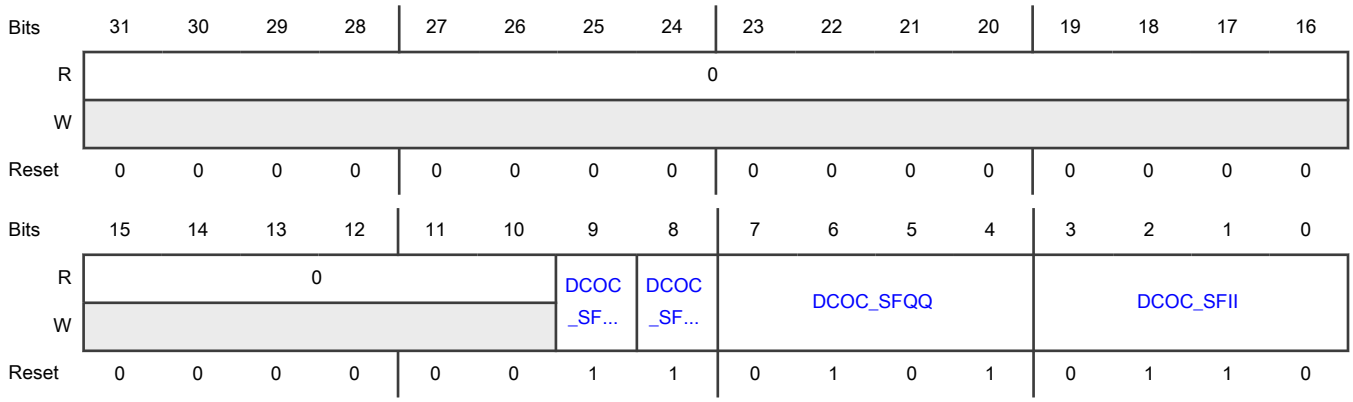
52.4.4.2.2.2.5.1.10 DCOC Control 0 DRS (DCOC_CTRL0_DRS)

Offset

Register	Offset
DCOC_CTRL0_DRS	20h

Function
When datarate_config_sel=1, will use this register instead of DCOC_CTRL0

Diagram



Fields

Field	Function
31-10 —	Reserved
9 DCOC_SFQQP	DCOC_SFQQP If set, the SFQQ is negated
8 DCOC_SFIIP	DCOC_SFIIP If set, the SFII is negated

Table continues on the next page...

Table continued from the previous page...

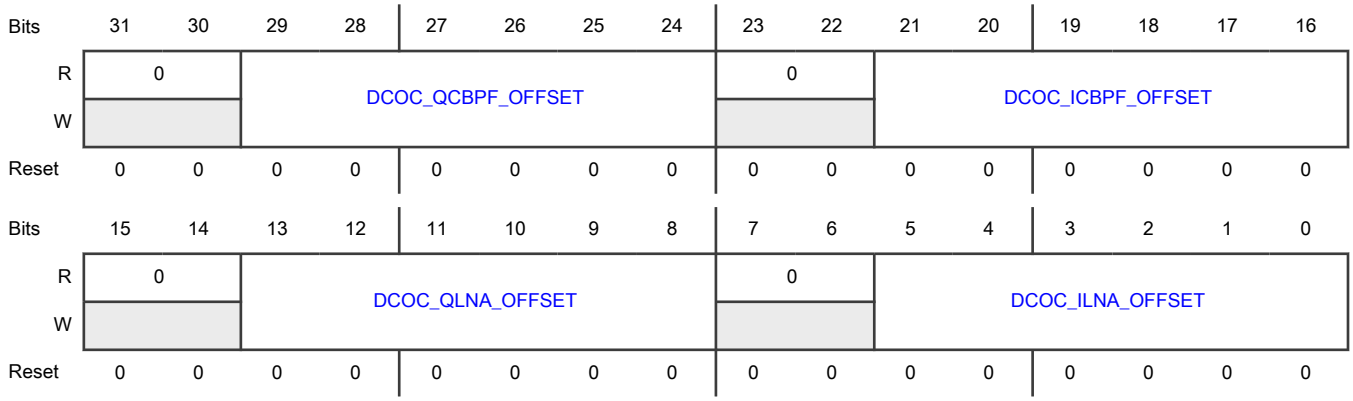
Field	Function
7-4 DCOC_SFQQ	DCOC_SFQQ The SFQQ parameter used in DCOC calibration. Unsigned
3-0 DCOC_SFII	DCOC_SFII The SFII parameter used in DCOC calibration. Unsigned

52.4.4.2.2.2.5.1.11 DCOC CONTROL 1 (DCOC_CTRL1)

Offset

Register	Offset
DCOC_CTRL1	24h

Diagram



Fields

Field	Function
31-30 —	Reserved
29-24 DCOC_QCBPF_OFFSET	DCOC_QCBPF_OFFSET This 2's complement signed value is scaled by the BPF gain and used as part of the ADC Q channel offset
23-22 —	Reserved
21-16	DCOC_ICBPF_OFFSET

Table continues on the next page...

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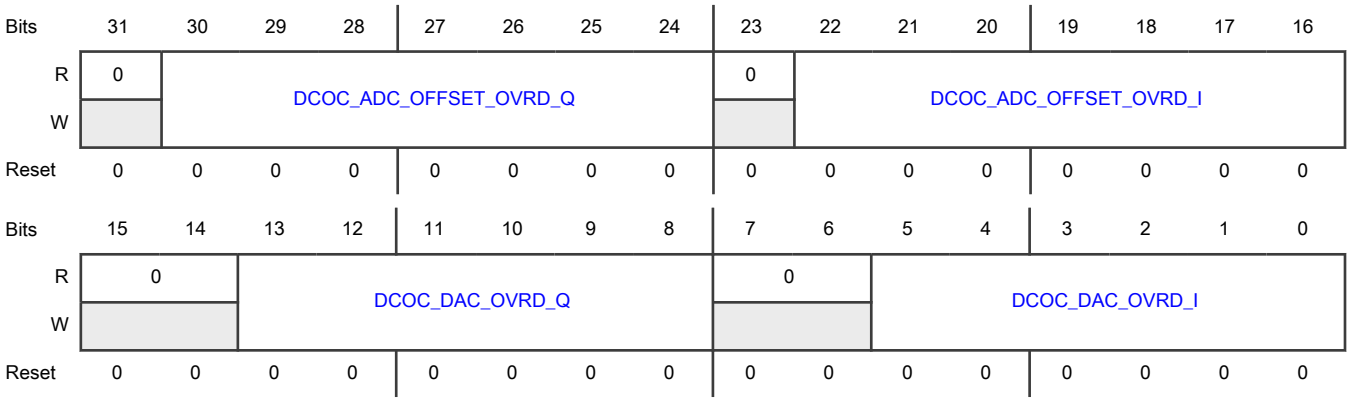
Field	Function
DCOC_ICBPF_OFFSET	This 2's complement signed value is scaled by the BPF gain and used as part of the ADC I channel offset
15-14 —	Reserved
13-8 DCOC_QLNA_OFFSET	DCOC_QLNA_OFFSET This 2's complement signed value is scaled by the LNA gain and used as part of the ADC Q channel offset
7-6 —	Reserved
5-0 DCOC_ILNA_OFFSET	DCOC_ILNA_OFFSET This 2's complement signed value is scaled by the LNA gain and used as part of the ADC I channel offset

52.4.4.2.2.2.5.1.12 DCOC CONTROL 2 (DCOC_CTRL2)

Offset

Register	Offset
DCOC_CTRL2	28h

Diagram



Fields

Field	Function
31	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
30-24 DCOC_ADC_OFFSET_OVRD_Q	DCOC_ADC_OFFSET_OVRD_Q If DCOC_ADC_OFFSET_OVRD_EN is set (see DCOC_CTRL0 register), this value is used for the ADC Q channel offset instead of the value found during calibration
23 —	Reserved
22-16 DCOC_ADC_OFFSET_OVRD_I	DCOC_ADC_OFFSET_OVRD_I If DCOC_ADC_OFFSET_OVRD_EN is set (see DCOC_CTRL0 register), this value is used for the ADC I channel offset instead of the value found during calibration
15-14 —	Reserved
13-8 DCOC_DAC_OVRD_Q	DCOC_DAC_OVRD_Q If DCOC_DAC_OVRD_EN is set (see DCOC_CTRL0 register), this value is used for the DCOC Q channel DAC instead of the value found during calibration
7-6 —	Reserved
5-0 DCOC_DAC_OVRD_I	DCOC_DAC_OVRD_I If DCOC_DAC_OVRD_EN is set (see DCOC_CTRL0 register), this value is used for the DCOC I channel DAC instead of the value found during calibration

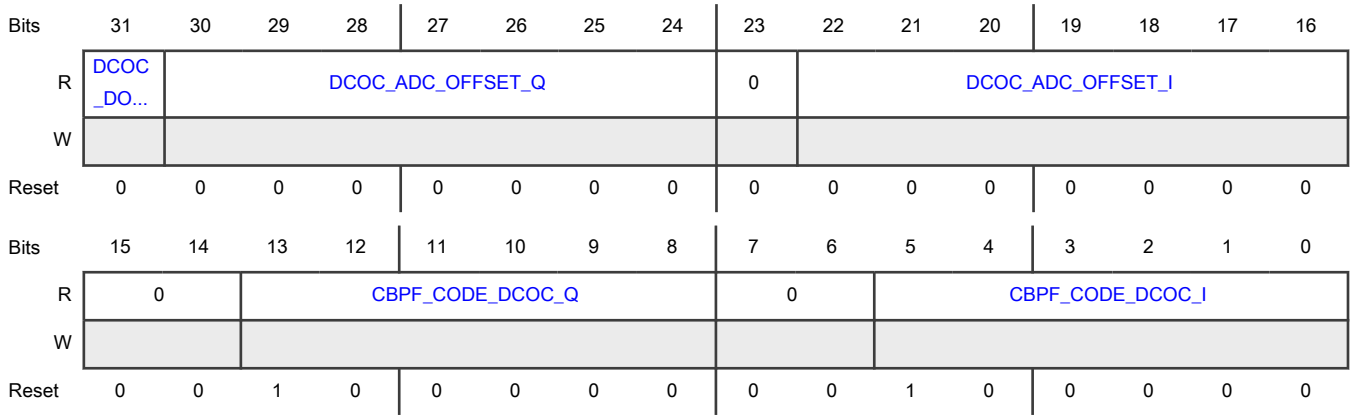
52.4.4.2.2.2.5.1.13 DCOC Status (DCOC_STAT)

Offset

Register	Offset
DCOC_STAT	2Ch

Function
DCOC_STAT

Diagram



Fields

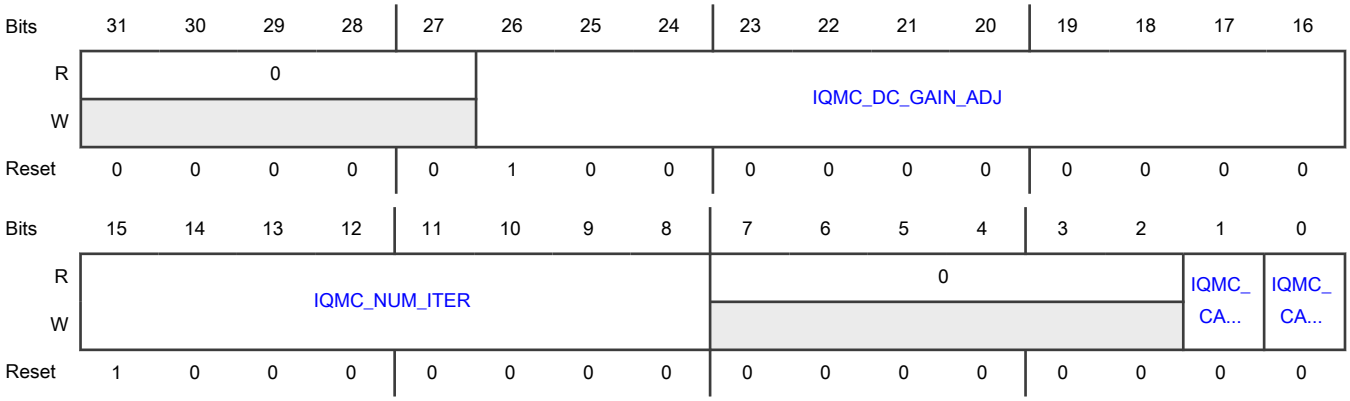
Field	Function
31 DCOC_DONE	This bit indicates that the dcoc run is completed. It is raised high at the end of the measurement and stays high until a new DCOC run request is detected
30-24 DCOC_ADC_OFFSET_Q	DCOC_ADC_OFFSET_Q The value of the ADC Q channel offset found during DCOC calibration. This result will be kept until the next DCOC calibration.
23 —	Reserved
22-16 DCOC_ADC_OFFSET_I	DCOC_ADC_OFFSET_I The value of the ADC I channel offset found during DCOC calibration. This result will be kept until the next DCOC calibration.
15-14 —	Reserved
13-8 CBPF_CODE_DCOC_Q	CBPF_CODE_DCOC_Q The current value of the DCOC Q channel DAC. If DCOC_DAC_OVRD_EN=0, this is the value found during DCOC calibration, and this result will be kept until the next DCOC calibration. If DCOC_DAC_OVRD_EN=1, this reflects the DCOC_DAC_OVRD_Q override values.
7-6 —	Reserved
5-0 CBPF_CODE_DCOC_I	CBPF_CODE_DCOC_I The current value of the DCOC I channel DAC. If DCOC_DAC_OVRD_EN=0, this is the value found during DCOC calibration, and this result will be kept until the next DCOC calibration. If DCOC_DAC_OVRD_EN=1, this reflects the DCOC_DAC_OVRD_I override values.

52.4.4.2.2.2.5.1.14 IQ Mismatch Control 0 (IQMC_CTRL0)

Offset

Register	Offset
IQMC_CTRL0	30h

Diagram



Fields

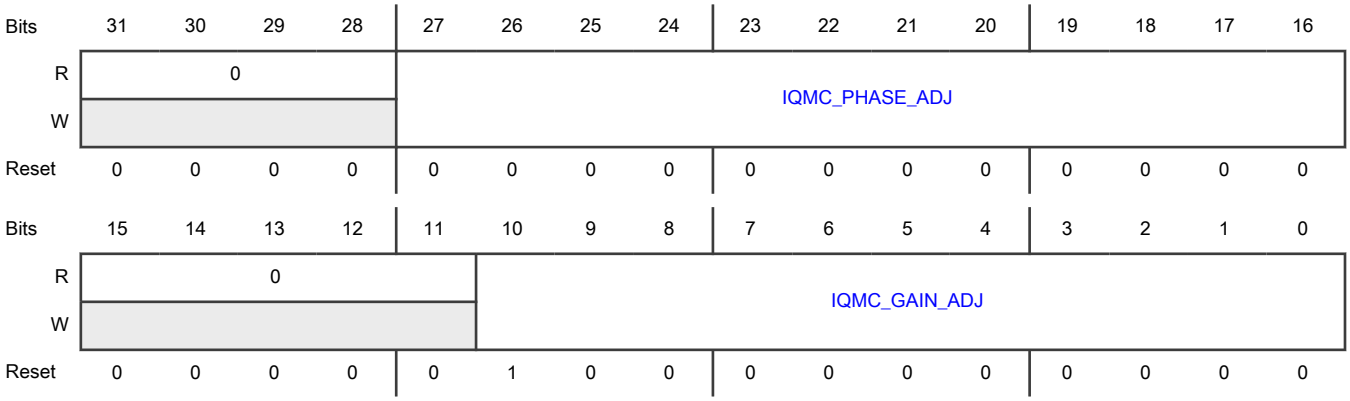
Field	Function
31-27 —	Reserved
26-16 IQMC_DC_GAIN_ADJ	IQ Mismatch gain adjust Gain adjustment coefficient to use during DCOC calibration
15-8 IQMC_NUM_ITER	IQ Mismatch Cal Num Iter Number of iteration done during the algorithm to get final result.
7-2 —	Reserved
1 IQMC_CAL_FREQ_SEL	IQMC_CAL_FREQ_SEL Clock frequency selection for IQ mismatch calibration. Note, the IQMC module will work at reference clock during correction. 0b - Reference clk divided by 2 1b - Reference clk divided by 4
0 IQMC_CAL_EN	IQ Mismatch Cal Enable Enables IQ mismatch calibration. This bit is self-clearing; it will clear automatically at the end of the calibration sequence. NOTE: To start IQ mismatch calibration, should set IQMC_CAL_EN and CTRL0[RX_IQMC_EN] together.

52.4.4.2.2.2.5.1.15 IQ Mismatch Control 1 (IQMC_CTRL1)

Offset

Register	Offset
IQMC_CTRL1	34h

Diagram



Fields

Field	Function
31-28 —	Reserved
27-16 IQMC_PHASE_ADJ	IQ Mismatch Correction Phase Coeff I/Q mismatch correction phase coefficient. This value is updated automatically at the end of the IQMC calibration sequence. It can also be written by software. The value persists until a new IQMC calibration or a new SW write. It is also reset to 0 at each HW/SW reset. The format is signed, with the maximum positive value 0x7ff corresponding to a phase coefficient of 0.25, and the maximum negative value 0x800 corresponding to -0.25. The reset value of 0x000 corresponds to a phase coefficient of 0.
15-11 —	Reserved
10-0 IQMC_GAIN_ADJ	IQ Mismatch Correction Gain Coeff I/Q mismatch correction gain coefficient. This value is updated automatically at the end of the IQMC calibration sequence. It can also be written by software. The format is u1.10. The reset value of 0x400 corresponds to a gain coefficient of 1.0.

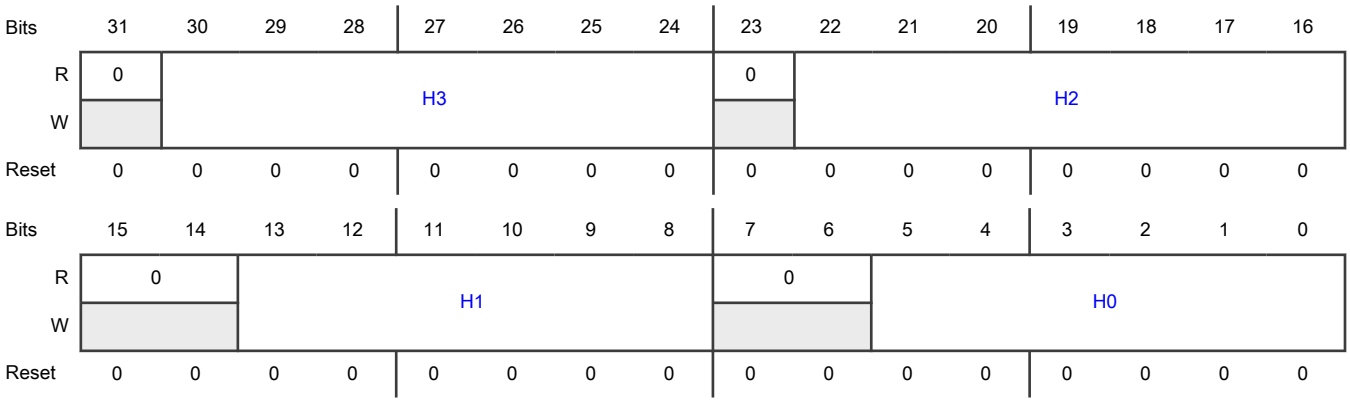
52.4.4.2.2.2.5.1.16 Acquisition Filter Coeffs 0~3 (ACQ_FILT_0_3)

Offset

Register	Offset
ACQ_FILT_0_3	38h

Function
Acquisition filter coefficient 0~3

Diagram



Fields

Field	Function
31 —	Reserved
30-24 H3	Acquisition Filter Coefficient 3 Acquisition filter coefficient 3, 7-bit signed fractional
23 —	Reserved
22-16 H2	Acquisition Filter Coefficient 2 Acquisition filter coefficient 2, 7-bit signed fractional
15-14 —	Reserved
13-8 H1	Acquisition Filter Coefficient 1 Acquisition filter coefficient 1, 6-bit signed fractional
7-6 —	Reserved

Table continues on the next page...

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Field	Function
5-0 H0	Acquisition Filter Coefficient 0 Acquisition filter coefficient 0, 6-bit signed fractional

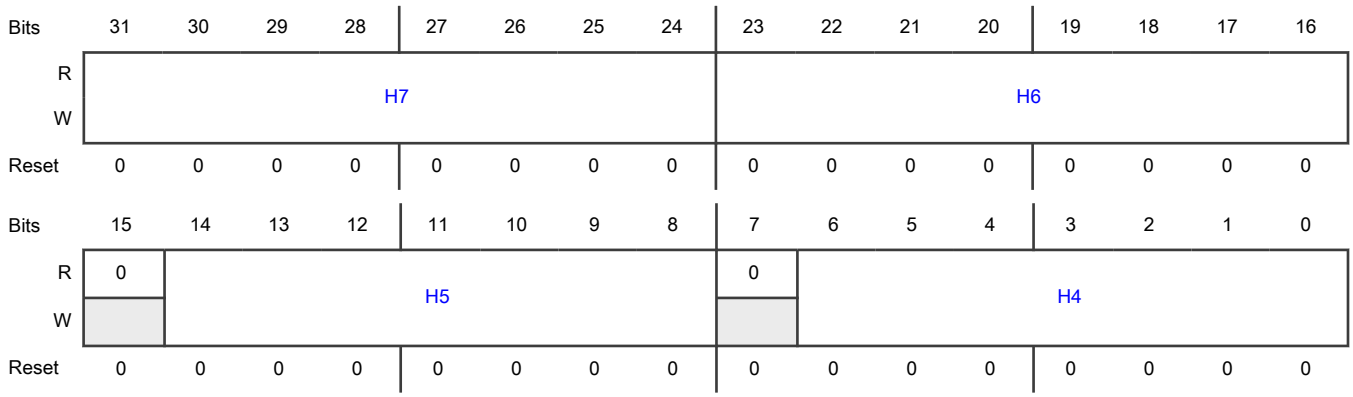
52.4.4.2.2.2.5.1.17 Acquisition Filter Coeffs 4~7 (ACQ_FILT_4_7)

Offset

Register	Offset
ACQ_FILT_4_7	3Ch

Function
Acquisition filter coefficient 4~7

Diagram



Fields

Field	Function
31-24 H7	Acquisition Filter Coefficient 7 Acquisition filter coefficient 7, 8-bit signed fractional
23-16 H6	Acquisition Filter Coefficient 6 Acquisition filter coefficient 6, 8-bit signed fractional
15 —	Reserved
14-8 H5	Acquisition Filter Coefficient 5 Acquisition filter coefficient 5, 7-bit signed fractional

Table continues on the next page...

Table continued from the previous page...

Field	Function
7 —	Reserved
6-0 H4	Acquisition Filter Coefficient 4 Acquisition filter coefficient 4, 7-bit signed fractional

52.4.4.2.2.2.5.1.18 Acquisition Filter Coeffs 8~9 (ACQ_FILT_8_9)

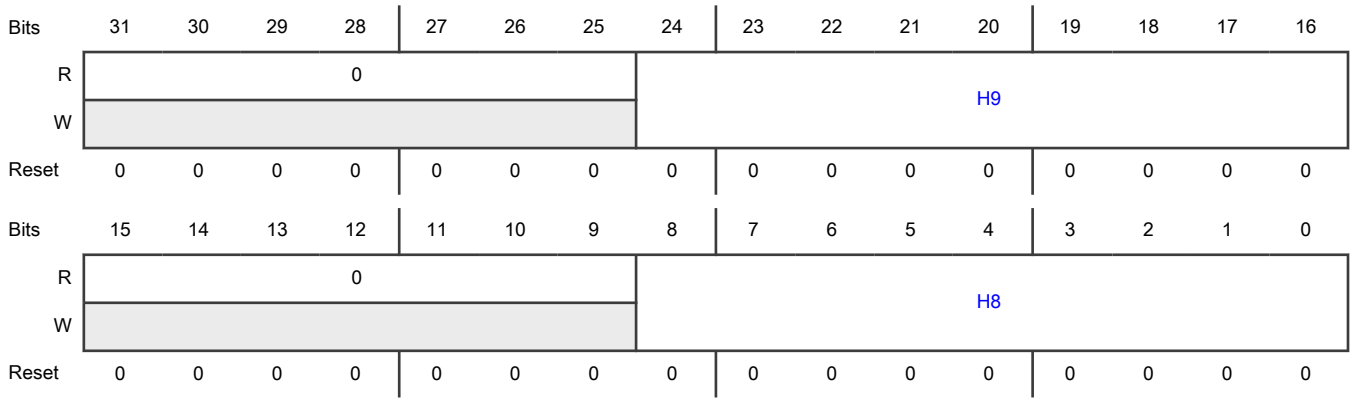
Offset

Register	Offset
ACQ_FILT_8_9	40h

Function

Acquisition filter coefficient 8~9

Diagram



Fields

Field	Function
31-25 —	Reserved
24-16 H9	Acquisition Filter Coefficient 9 Acquisition filter coefficient 9, 9-bit signed fractional
15-9 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
8-0 H8	Acquisition Filter Coefficient 8 Acquisition filter coefficient 8, 9-bit signed fractional

52.4.4.2.2.2.5.1.19 Acquisition Filter Coeffs 10~11 (ACQ_FILT_10_11)

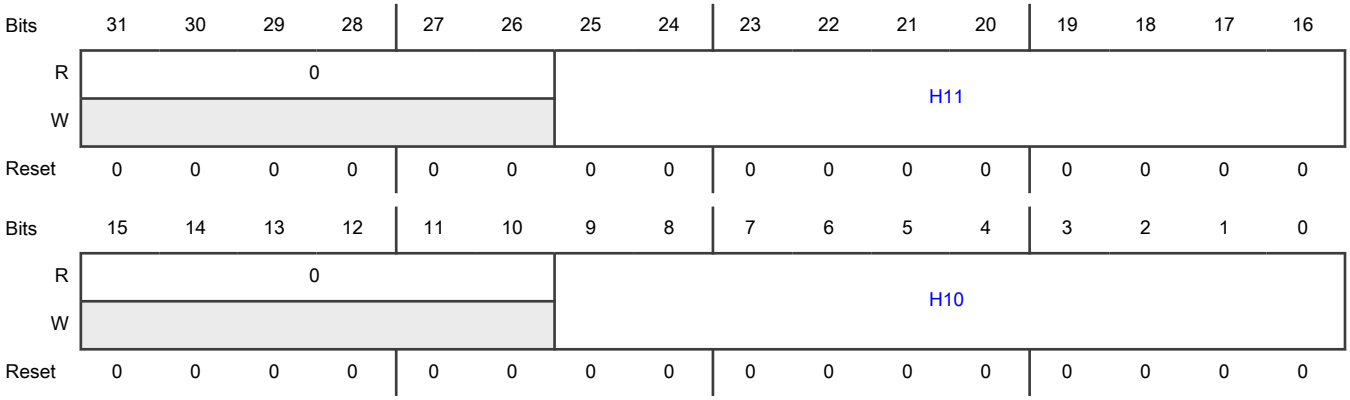
Offset

Register	Offset
ACQ_FILT_10_11	44h

Function

Acquisition filter coefficient 10~11

Diagram



Fields

Field	Function
31-26 —	Reserved
25-16 H11	Acquisition Filter Coefficient 11 Acquisition filter coefficient 11, 10-bit signed fractional
15-10 —	Reserved
9-0 H10	Acquisition Filter Coefficient 10 Acquisition filter coefficient 10, 10-bit signed fractional

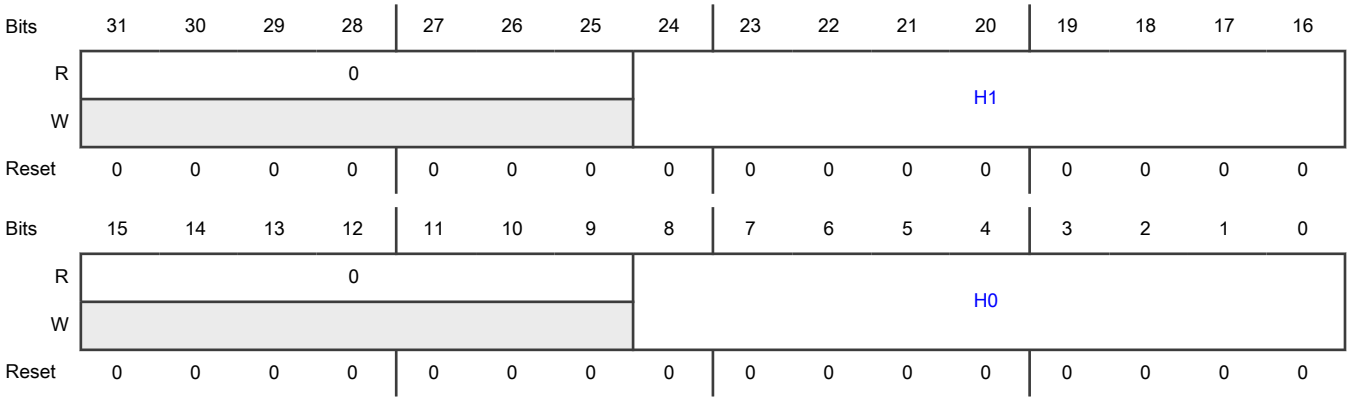
52.4.4.2.2.2.5.1.20 Demod Filter Coeffs 0~1 (DEMOD_FILT_0_1)

Offset

Register	Offset
DEMOD_FILT_0_1	48h

Function
Demod channel filter coefficient 0~1

Diagram



Fields

Field	Function
31-25 —	Reserved
24-16 H1	Demod Channel Filter Coefficient 1 Demod channel filter coefficient 1, 9-bit signed fractional
15-9 —	Reserved
8-0 H0	Demod Channel Filter Coefficient 0 Demod channel filter coefficient 0, 9-bit signed fractional

52.4.4.2.2.2.5.1.21 Demod Filter Coeffs 2~4 (DEMOD_FILT_2_4)

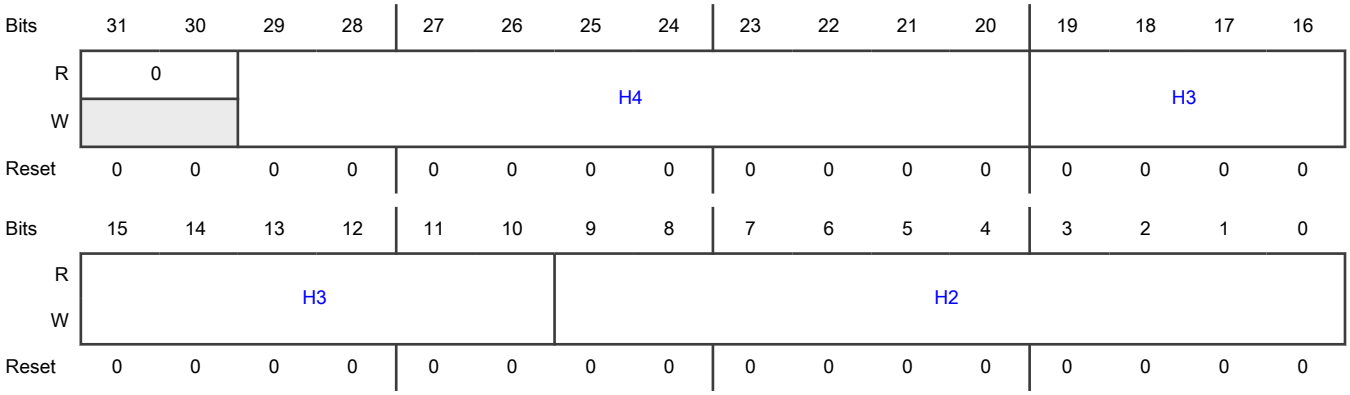
Offset

Register	Offset
DEMOD_FILT_2_4	4Ch

Function

Demod channel filter coefficient 2~4

Diagram



Fields

Field	Function
31-30 —	Reserved
29-20 H4	Demod Channel Filter Coefficient 4 Demod channel filter coefficient 4, 10-bit signed fractional
19-10 H3	Demod Channel Filter Coefficient 3 Demod channel filter coefficient 3, 10-bit signed fractional
9-0 H2	Demod Channel Filter Coefficient 2 Demod channel filter coefficient 2, 10-bit signed fractional

52.4.4.2.2.2.5.1.22 Acquisition Filter Coeffs 0~3 DRS (ACQ_FILT_0_3_DRS)

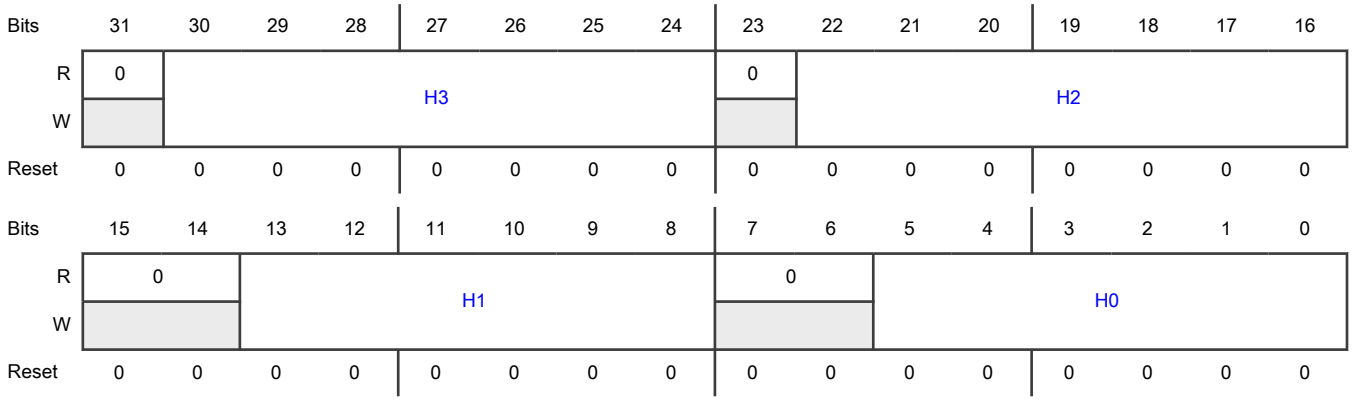
Offset

Register	Offset
ACQ_FILT_0_3_DRS	50h

Function

Acquisition filter coefficient 0~3 for datarate_config_sel=1

Diagram



Fields

Field	Function
31 —	Reserved
30-24 H3	Acquisition Filter Coefficient 3 Acquisition filter coefficient 3, 7-bit signed fractional
23 —	Reserved
22-16 H2	Acquisition Filter Coefficient 2 Acquisition filter coefficient 2, 7-bit signed fractional
15-14 —	Reserved
13-8 H1	Acquisition Filter Coefficient 1 Acquisition filter coefficient 1, 6-bit signed fractional
7-6 —	Reserved
5-0 H0	Acquisition Filter Coefficient 0 Acquisition filter coefficient 0, 6-bit signed fractional

52.4.4.2.2.2.5.1.23 Acquisition Filter Coeffs 4~7 DRS (ACQ_FILT_4_7_DRS)

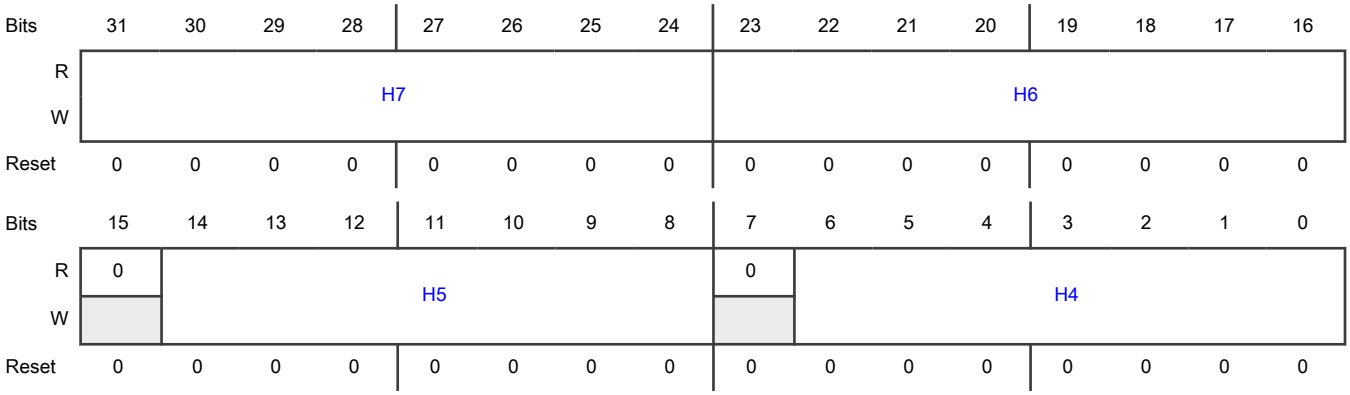
Offset

Register	Offset
ACQ_FILT_4_7_DRS	54h

Function

Acquisition filter coefficient 4~7 for datarate_config_sel=1

Diagram



Fields

Field	Function
31-24 H7	Acquisition Filter Coefficient 7 Acquisition filter coefficient 7, 8-bit signed fractional
23-16 H6	Acquisition Filter Coefficient 6 Acquisition filter coefficient 6, 8-bit signed fractional
15 —	Reserved
14-8 H5	Acquisition Filter Coefficient 5 Acquisition filter coefficient 5, 7-bit signed fractional
7 —	Reserved
6-0 H4	Acquisition Filter Coefficient 4 Acquisition filter coefficient 4, 7-bit signed fractional

52.4.4.2.2.2.5.1.24 Acquisition Filter Coeffs 8~9 DRS (ACQ_FILT_8_9_DRS)

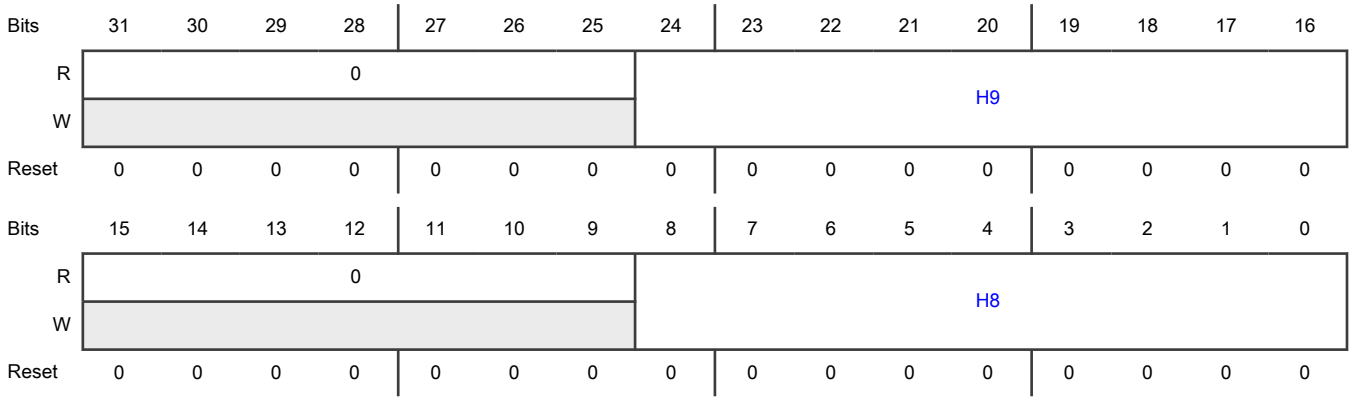
Offset

Register	Offset
ACQ_FILT_8_9_DRS	58h

Function

Acquisition filter coefficient 8~9 for datarate_config_sel=1

Diagram



Fields

Field	Function
31-25 —	Reserved
24-16 H9	Acquisition Filter Coefficient 9 Acquisition filter coefficient 9, 9-bit signed fractional
15-9 —	Reserved
8-0 H8	Acquisition Filter Coefficient 8 Acquisition filter coefficient 8, 9-bit signed fractional

52.4.4.2.2.2.5.1.25 Acquisition Filter Coeffs 10~11 DRS (ACQ_FILT_10_11_DRS)

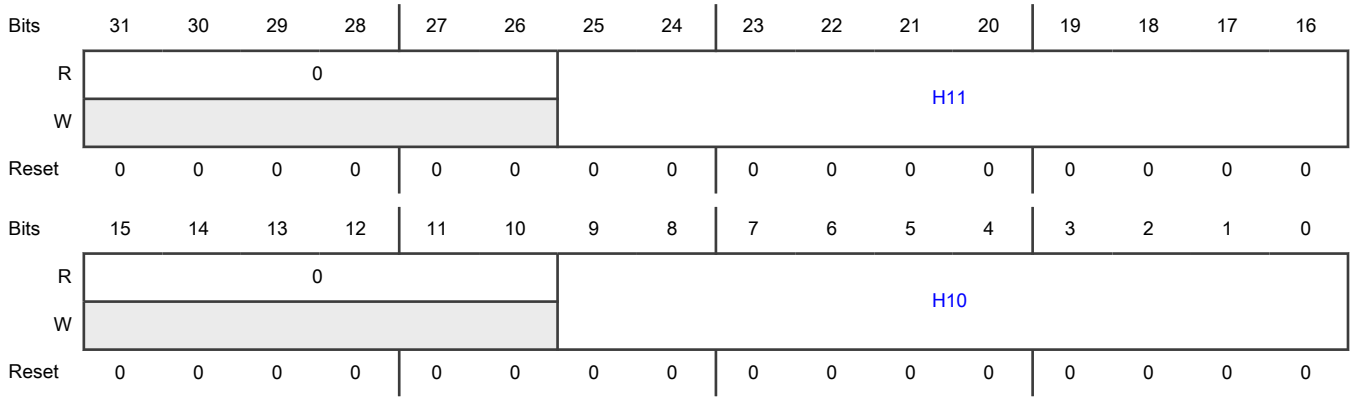
Offset

Register	Offset
ACQ_FILT_10_11_DRS	5Ch

Function

Acquisition filter coefficient 10~11 for datarate_config_sel=1

Diagram



Fields

Field	Function
31-26 —	Reserved
25-16 H11	Acquisition Filter Coefficient 11 Acquisition filter coefficient 11, 10-bit signed fractional
15-10 —	Reserved
9-0 H10	Acquisition Filter Coefficient 10 Acquisition filter coefficient 10, 10-bit signed fractional

52.4.4.2.2.2.5.1.26 Demod Filter Coeffs 0~1 DRS (DEMOD_FILT_0_1_DRS)

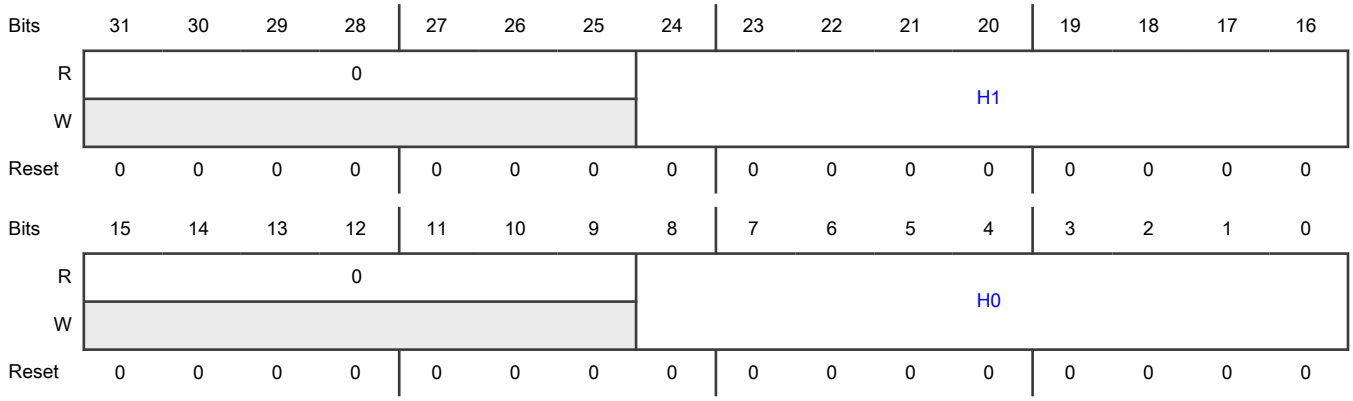
Offset

Register	Offset
DEMOD_FILT_0_1_DRS	60h

Function

Demod channel filter coefficient 0~1 for datarate_config_sel=1

Diagram



Fields

Field	Function
31-25 —	Reserved
24-16 H1	Demod Channel Filter Coefficient 1 Demod channel filter coefficient 1, 9-bit signed fractional
15-9 —	Reserved
8-0 H0	Demod Channel Filter Coefficient 0 Demod channel filter coefficient 0, 9-bit signed fractional

52.4.4.2.2.2.5.1.27 Demod Filter Coeffs 2~4 DRS (DEMOD_FILT_2_4_DRS)

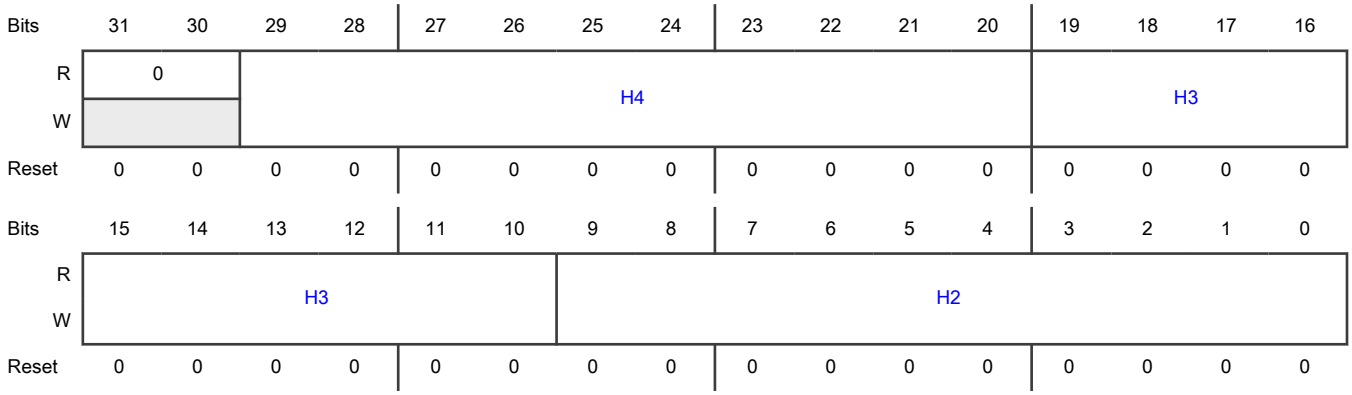
Offset

Register	Offset
DEMOD_FILT_2_4_DRS	64h

Function

Demod channel filter coefficient 2~4 for datarate_config_sel=1

Diagram



Fields

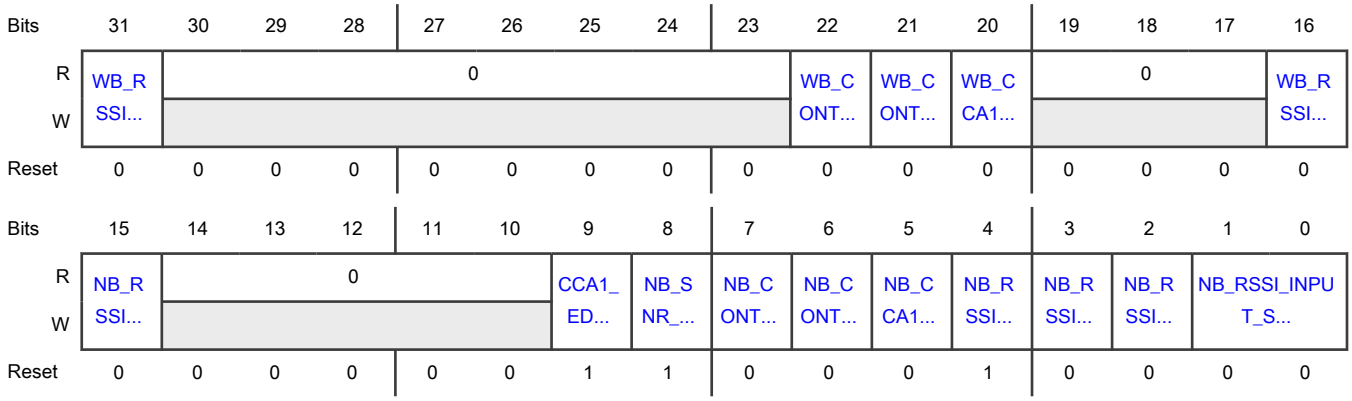
Field	Function
31-30 —	Reserved
29-20 H4	Demod Channel Filter Coefficient 4 Demod channel filter coefficient 4, 10-bit signed fractional
19-10 H3	Demod Channel Filter Coefficient 3 Demod channel filter coefficient 3, 10-bit signed fractional
9-0 H2	Demod Channel Filter Coefficient 2 Demod channel filter coefficient 2, 10-bit signed fractional

52.4.4.2.2.2.5.1.28 RSSI Global Control (RSSI_GLOBAL_CTRL)

Offset

Register	Offset
RSSI_GLOBAL_CTRL	68h

Diagram



Fields

Field	Function
31 WB_RSSI_EN	WB RSSI Enable 0b - WB-RSSI is disabled 1b - WB-RSSI is enabled
30-23 —	Reserved
22 WB_CONT_MEAS_OVRD_EN	WB RSSI Continuous Measurement Override Enable By default, WB-RSSI working in continuous mode. By setting WB_CONT_MEAS_OVRD_EN=1 and WB_CONT_MEAS_OVRD=0, the WB-RSSI will stop working once the first rssi_wb calculation done.
21 WB_CONT_MEAS_OVRD	WB RSSI Continuous Measurment Override Value
20 WB_CCA1_ED_EN	WB RSSI CCA1 ED Enable 0b - WB-RSSI CCA1/ED disabled 1b - WB-RSSI CCA1/ED enabled
19-17 —	Reserved
16 WB_RSSI_INPUT_SEL	WB RSSI Input Select 0b - DCOC output I/Q 1b - CIC output I/Q
15 NB_RSSI_EN	NB RSSI Enable 0b - NB-RSSI is disabled 1b - NB-RSSI is enabled

Table continues on the next page...

Table continued from the previous page...

Field	Function
14-10 —	Reserved
9 CCA1_ED_FROM_NB	CCA1/ED Result Selection 0b - WB-RSSI's CCA1/ED result is selected 1b - NB-RSSI's CCA1/ED result is selected
8 NB_SNR_LQI_ENABLE	NB RSSI SNR LQI Enable 0b - NB-RSSI SNR/LQI calculation is disabled 1b - NB-RSSI SNR/LQI calculation is enabled
7 NB_CONT_MEAS_OVRD_EN	NB RSSI One-time Measure Override Enable By default, NB-RSSI working in one-time mode. By setting NB_CONT_MEAS_OVRD_EN=1 and NB_CONT_MEAS_OVRD=1 bit, the NB-RSSI will calculate RSSI/LQI/SNR continuously.
6 NB_CONT_MEAS_OVRD	NB RSSI Onetime Measure Override
5 NB_CCA1_ED_EN	NB RSSI CCA1 ED Enable 0b - NB-RSSI CCA1/ED is disabled 1b - NB-RSSI CCA1/ED is enabled
4 NB_RSSI_PA_AA_MATCH_SEL	NB RSSI PHY Trigger Select 0b - NB-RSSI starts work when PHY_PD_FOUND asserted 1b - NB-RSSI starts work when PHY_AA_MATCH asserted
3 NB_RSSI_AA_MATCH_OVRD_EN	NB RSSI PHY Trigger Override Enable By setting the NB_RSSI_AA_MATCH_OVRD_EN=1, the software can determine when will NB-RSSI start working.
2 NB_RSSI_AA_MATCH_OVRD	NB RSSI PHY Trigger Override
1-0 NB_RSSI_INPUT_SEL	NB RSSI Input Select 00b - ACQ_CHF output I/Q 01b - SRC output I/Q 10b - DEMOD_CHF output I/Q 11b - Reserved

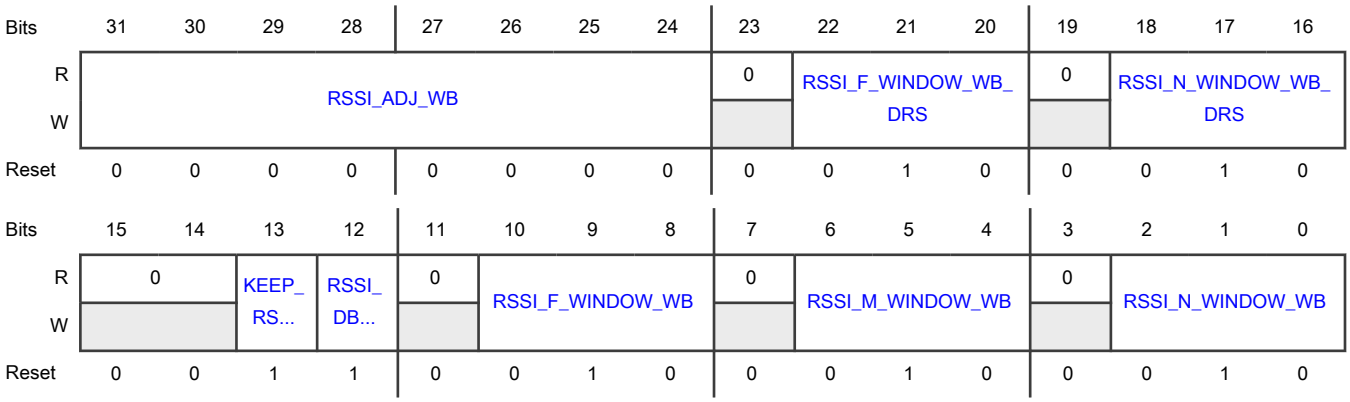
52.4.4.2.2.2.5.1.29 Wide-Band RSSI Control (WB_RSSI_CTRL)

Offset

Register	Offset
WB_RSSI_CTRL	6Ch

Function
Wide-Band RSSI control

Diagram



Fields

Field	Function
31-24 RSSI_ADJ_WB	WB RSSI Adjust Value WB_RSSI adjust value. Store in s5.2 format.
23 —	Reserved
22-20 RSSI_F_WINDOW_WB_DRS	DRS WB RSSI F Window Averager Factor Actual F window averager width is 2^(RSSI_F_WINDOW_WB_DRS). Max value for this field is 6. It's the DRS version of RSSI_F_WINDOW_WB
19 —	Reserved
18-16 RSSI_N_WINDOW_WB_DRS	DRS WB RSSI N Window Averager Factor Actual N window averager width is 2^(RSSI_N_WINDOW_WB_DRS). Max value for this field is 7. It's the DRS version of RSSI_N_WINDOW_WB
15-14 —	Reserved
13	Keep WB RSSI Result

Table continues on the next page...

Table continued from the previous page...

Field	Function
KEEP_RSSI_RESULT_WB	1: the WB-RSSI results will be kept until next update/refresh 1: the WB-RSSI results will be cleared when rssi_init asserts
12 RSSI_DB_EN_WB	WB RSSI dB Calculate Enable If only need to use WB-RSSI to calculate fast_mag and slow_mag to feed AGC, this bit can be cleared to disable WB-RSSI's window-m-averager to save power. However, if need RSSI/CCA1/ED results from WB-RSSI, this bit should be set.
11 —	Reserved
10-8 RSSI_F_WINDOW_WB	WB RSSI F Window Averager Factor Actual F window averager width is 2^(RSSI_F_WINDOW_WB). Max value for this field is 6.
7 —	Reserved
6-4 RSSI_M_WINDOW_WB	WB RSSI M Window Averager Factor Actual M window averager width is 2^(RSSI_M_WINDOW_WB). Max value for this field is 4.
3 —	Reserved
2-0 RSSI_N_WINDOW_WB	WB RSSI N Window Averager Factor Actual N window averager width is 2^(RSSI_N_WINDOW_WB). Max value for this field is 7.

52.4.4.2.2.2.5.1.30 Wide-Band RSSI Result 0 (WB_RSSI_RES0)

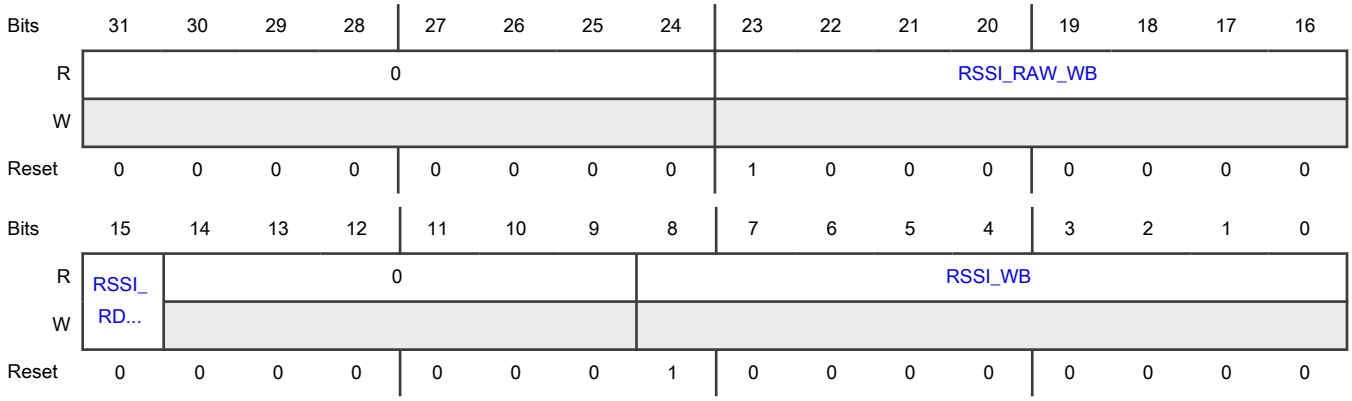
Offset

Register	Offset
WB_RSSI_RES0	70h

Function

Check WB-RSSI block diagram in "RSSI Estimator" section to find where these results come from.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 RSSI_RAW_WB	WB Raw RSSI Result Store in s7.0 format. This field is for debug purpose and the refresh rate depends on ref CLK frequency, WB_RSSI_INPUT_SEL, RSSI_F_WINDOW_WB and RSSI_N_WINDOW_WB. In some cases, the software may not capture all values.
15 RSSI_RDY_WB	This bit is set when RSSI_WB value ready to read(or updated) and is cleared by rx_init or write "1" to this field(W1C). In RX mode, the software can poll this field until 1, then read the RSSI_WB value and finally write 1 to clear it. Do this loop to get RSSI_WB values continuously.
14-9 —	Reserved
8-0 RSSI_WB	WB RSSI Result Store in s8.0 format. After this field updated, the result will keep until: KEEP_RSSI_RESULT_WB=0 : Next result update(In same RX sequence) or RX initial(Next RX sequence started) KEEP_RSSI_RESULT_WB=1 : Next result update, no matter in same or different RX sequence

52.4.4.2.2.2.5.1.31 Wide-Band RSSI Result 1 (WB_RSSI_RES1)

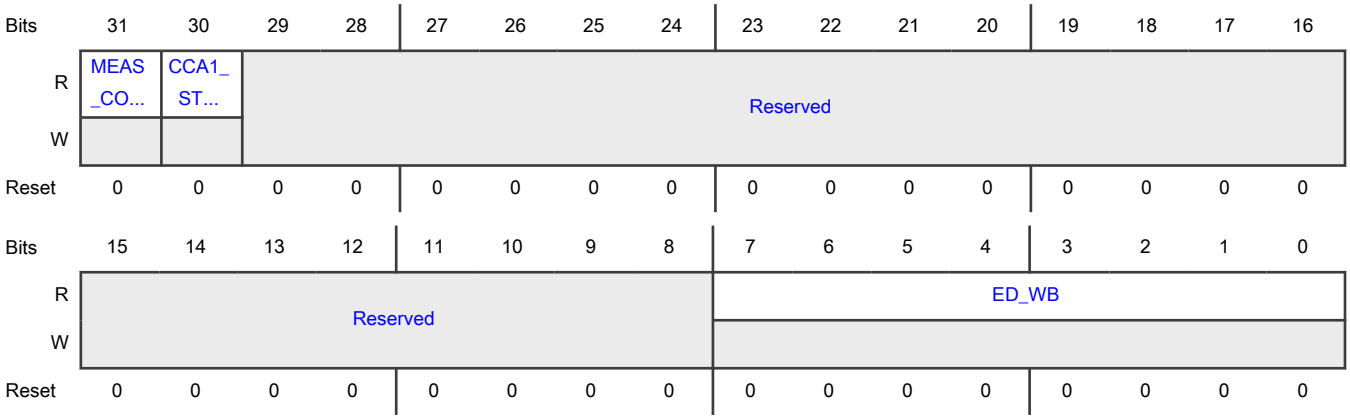
Offset

Register	Offset
WB_RSSI_RES1	74h

Function

Check WB-RSSI block diagram in "RSSI Estimator" section to find where these results come from.

Diagram



Fields

Field	Function
31 MEAS_COMPLETE_WB	WB RSSI Measure Complete Measure complete status bit. Indicate that RSSI_WB, ED_WB, CCA1_STATE_WB updated. However, in continuous measurement mode(check WB_CONT_MEAS_OVRD_EN for more info), this bit is an instant pulse, the software may not capture it. While in non-continuous mode, this bit will keep high until next RX initial or AGC gain change.
30 CCA1_STATE_WB	WB RSSI CCA1 State CCA1/ED status bit. After this field updated, the result will keep until next result update(If continues mode enabled) or RX initial(Next RX sequence started).
29-8 —	Reserved
7-0 ED_WB	WB RSSI ED Result Store in s7.0 format. After this field updated, the result will keep until next result update(If continues mode enabled) or RX initial(Next RX sequence started)

52.4.4.2.2.2.5.1.32 Wide-Band RSSI DFT Result (WB_RSSI_DFT)

Offset

Register	Offset
WB_RSSI_DFT	78h

Function

WB_RSSI_DFT

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0												FAST_MAG			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	FAST_MAG						SLOW_MAG									
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-20 —	Reserved
19-10 FAST_MAG	WB RSSI Fast Magnitude Value Due to this field is updated at high frequency, software may not read every value. Should use DTEST or DMA_DEBUG to capture all fast_mag result.
9-0 SLOW_MAG	WB RSSI Slow Magnitude Value Due to this field is updated at high frequency, software may not read every value. Should use DTEST or DMA_DEBUG to capture all slow_mag result.

52.4.4.2.2.2.5.1.33 Narrow-Band RSSI Control 0 (NB_RSSI_CTRL0)

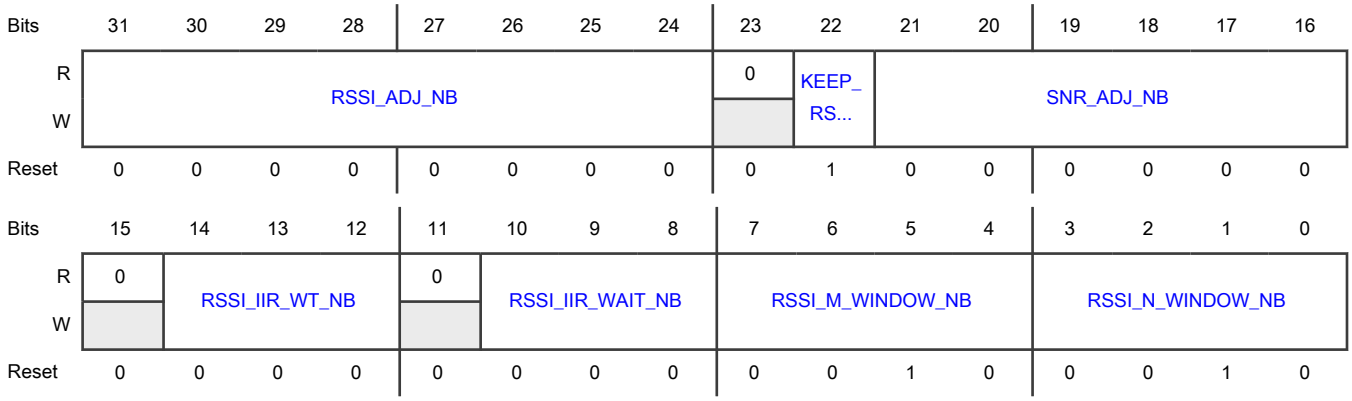
Offset

Register	Offset
NB_RSSI_CTRL0	7Ch

Function

NB_RSSI_CTRL0

Diagram



Fields

Field	Function
31-24 RSSI_ADJ_NB	NB RSSI Adjust Value NB_RSSI adjust value. Store in s5.2 format.
23 —	Reserved
22 KEEP_RSSI_RESULT_NB	When enabled, the NB-RSSI results will keep until next update/refresh, or the NB-RSSI results will be cleared when rx_init or rssi_init asserts.
21-16 SNR_ADJ_NB	NB RSSI SNR Adjust Value Store in s5.0 format.
15 —	Reserved
14-12 RSSI_IIR_WT_NB	NB RSSI IIR Filter Factor Factor for NB-RSSI mag and noise IIR filter. The actual factor is 1/(2^RSSI_IIR_WT_NB). The max valid value for this field is 5.
11 —	Reserved
10-8 RSSI_IIR_WAIT_NB	NB RSSI IIR Filter Initial Wait Time NB-RSSI IIR filter warmup time, count by input I/Q signal frequency. The actual warmup cycle number is 2^RSSI_IIR_WAIT_NB.
7-4 RSSI_M_WINDOW_NB	NB RSSI M Window Averager Factor Actual M window averager width is 2^(RSSI_M_WINDOW_NB). Max value for this field is 10.

Table continues on the next page...

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Field	Function
3-0 RSSI_N_WINDOW_NB	NB RSSI N Window Averager Factor Actual N window averager width is 2^(RSSI_N_WINDOW_NB). Max value for this field is 8.

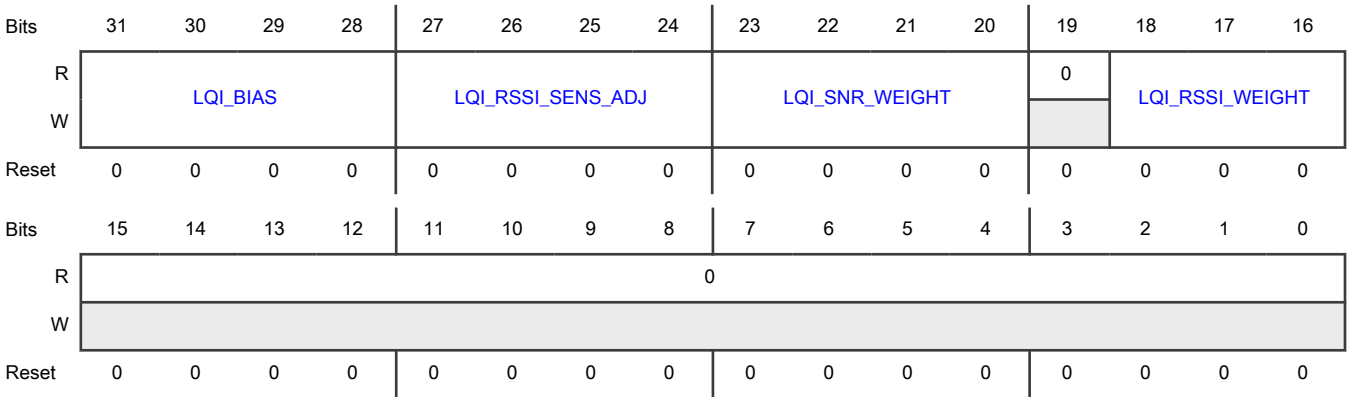
52.4.4.2.2.2.5.1.34 Narrow-Band RSSI Control 1 (NB_RSSI_CTRL1)

Offset

Register	Offset
NB_RSSI_CTRL1	80h

Function
NB_RSSI_CTRL1

Diagram



Fields

Field	Function
31-28 LQI_BIAS	LQI Bias Value Actual LQI bias value = -36 + 2*LQI_BIAS
27-24 LQI_RSSI_SENS_ADJ	LQI Sensitivity Adjust Value Actual LQI sensitivity value is: -103 + LQI_RSSI_SENS_ADJ
23-20 LQI_SNR_WEIGHT	SNR Weight For LQI Calculation SNR result weight in LQI calculation. LQI_SNR_WEIGHT!=0: the actual weight value is 1 + 0.125 * LQI_SNR_WEIGHT

Table continues on the next page...

Table continued from the previous page...

Field	Function
	LQI_SNR_WEIGHT=0: the actual weight value is 0
19 —	Reserved
18-16 LQI_RSSI_WEIGHT	RSSI Weight For LQI Calulation RSSI result weight in LQI calculation. Actual weight is: 2 + 0.125 * LQI_RSSI_WEIGHT
15-0 —	Reserved

52.4.4.2.2.2.5.1.35 Narrow-Band RSSI Result 0 (NB_RSSI_RES0)

Offset

Register	Offset
NB_RSSI_RES0	84h

Function

Check NB-RSSI block diagram in "RSSI Estimator" section to find where these results come from.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	NOISE_RSSI_RAW_NB								RSSI_RAW_NB							
W																
Reset	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	RSSI_RD...	0							RSSI_NB							
W																
Reset	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24	Raw Noise Result Store in s7.0 format

Table continues on the next page...

Table continued from the previous page...

Field	Function
NOISE_RSSI_RAW_NB	This field is for debug purpose and the refresh rate depends on ref CLK frequency, NB_RSSI_INPUT_SEL, RSSI_N_WINDOW_NB. In some cases, the software may not capture all values.
23-16 RSSI_RAW_NB	Raw NB RSSI Result Store in s7.0 format This field is for debug purpose and the refresh rate depends on ref CLK frequency, NB_RSSI_INPUT_SEL, RSSI_N_WINDOW_NB. In some cases, the software may not capture all values.
15 RSSI_RDY_NB	This bit set when RSSI_NB/SNR_NB/LQI_NB/ED_NB value ready to read(or updated) and cleared by rx_init or write "1" to this field(W1C). In RX mode, the software can poll this filed until 1, then read the RSSI_NB/SNR_NB/LQI_NB/ED_NB value and finally write 1 to clear it. Do this loop to get values continuously if NB_RSSI is working in continuous mode.
14-9 —	Reserved
8-0 RSSI_NB	NB RSSI Result Store in s8.0 format. After this field updated, the result will keep until: KEEP_RSSI_RESULT_NB=0 : Next result update(In same RX sequence) or RX initial(Next RX sequence started) KEEP_RSSI_RESULT_NB=1 : Next result update, no matter in same or different RX sequence

52.4.4.2.2.2.5.1.36 Narrow-Band RSSI Result 1 (NB_RSSI_RES1)

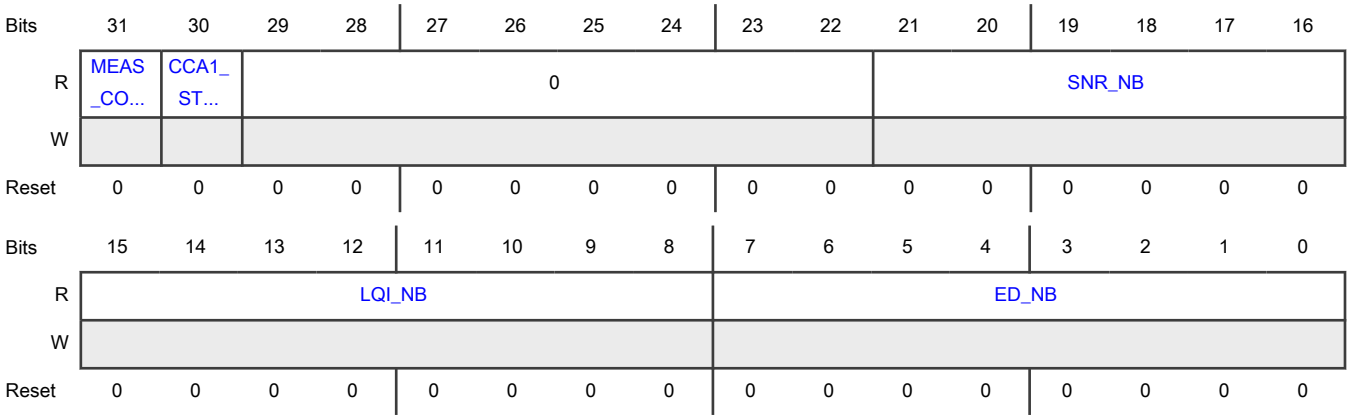
Offset

Register	Offset
NB_RSSI_RES1	88h

Function

Check NB-RSSI block diagram in "RSSI Estimator" section to find where these results come from.

Diagram



Fields

Field	Function
31 MEAS_COMPLETE_NB	NB RSSI Measure Complete Measure complete status bit. Indicate that RSSI_NB, ED_NB, CCA1_STATE_NB, SNR_NB, LQI_NB updated. However, in continuous measurement mode(check NB_CONT_MEAS_OVRD_EN for more info), this bit is an instant pulse, the software may not capture it. While in non-continuous mode, this bit will keep high until next RX initial or AGC gain change.
30 CCA1_STATE_NB	NB RSSI CCA1 State CCA1/ED status bit. After this field updated, the result will keep until next result update(If continues mode enabled) or RX initial(Next RX sequence started)
29-22 —	Reserved
21-16 SNR_NB	NB RSSI SNR Result After this field updated, the result will keep until: KEEP_RSSI_RESULT_NB=0 : Next result update(In same RX sequence) or RX initial(Next RX sequence started) KEEP_RSSI_RESULT_NB=1 : Next result update, no matter in same or different RX sequence
15-8 LQI_NB	NB RSSI LQI Result After this field updated, the result will keep until: KEEP_RSSI_RESULT_NB=0 : Next result update(In same RX sequence) or RX initial(Next RX sequence started) KEEP_RSSI_RESULT_NB=1 : Next result update, no matter in same or different RX sequence
7-0 ED_NB	NB RSSI ED Result Store in s7.0 format. After this field updated, the result will keep until next result update(If continues mode enabled) or RX initial(Next RX sequence started)

52.4.4.2.2.2.5.1.37 Narrow-Band RSSI DFT Result (NB_RSSI_DFT)

Offset

Register	Offset
NB_RSSI_DFT	8Ch

Function

Check NB-RSSI block diagram in "RSSI Estimator" section to find where these results come from.

NOTE: The result values in this register only refresh and valid during NB_RSSI is working.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				AVG_MAG_NB											
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				AVG_NOISE_MAG_NB											
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 —	Reserved
27-16 AVG_MAG_NB	NB RSSI Averaged Magnitude Value Due to this field is updated at high frequency, software may not read every value.
15-12 —	Reserved
11-0 AVG_NOISE_MAG_NB	NB RSSI Averaged Noise Magnitude Value Due to this field is updated at high frequency, software may not read every value.

52.4.4.2.2.2.5.1.38 AGC Control (AGC_CTRL)

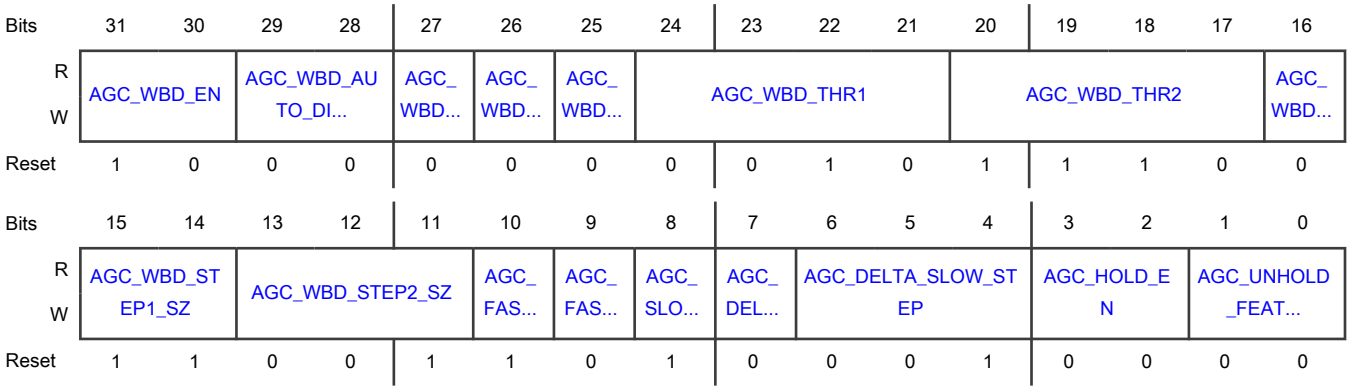
Offset

Register	Offset
AGC_CTRL	90h

Function

AGC control register

Diagram



Fields

Field	Function
31-30 AGC_WBD_EN	AGC WBD Enable AGC WBD enable 00b - AGC WBD is disabled 01b - AGC WBD step1 is enabled 10b - AGC WBD step1 and step2 is enabled 11b - Reserved
29-28 AGC_WBD_AUTO_DIS_CFG	AGC WBD Auto Disable If AGC_WBD_AUTO_DIS[0] set and fast or slow magnitude triggers occurs with no WB triggered, WB detect function will be disabled automatically. If AGC_WBD_AUTO_DIS[1] set and WB trigger not occurs in period, specified by AGC_WBD_TIMEOUT, WB detect function will be disabled automatically. NOTE: AGC_WBD_AUTO_DIS = 2'b11 is valid.
27 AGC_WBD_GAIN_LIMIT_EN	AGC WBD Gain Limit When this bit set: -- If WBD takes the first step, then the AGC_max_index is set equal to the gain index after the AGC_WBD_det_step -- If WBD takes the 2nd step, then the AGC_max_index is set equal to the gain index after the AGC_WBD_det_step2
26 AGC_WBD_STEP1_DUAL_CLIP_EN	AGC WBD Step1 Dual Clip Enable When this bit set. AGC need two consecutive WB trigger occurs then issue WB step 1 gain step down. The cool-down duration is specified by AGC_WBD_STEP1_DUAL_CLIP_WAIT

Table continues on the next page...

Table continued from the previous page...

Field	Function
25 AGC_WBD_STEP2_DUAL_CLIP_EN	AGC WBD Step2 Dual Clip Enable When this bit set. AGC need two consecutive WB trigger occurs then issue WB step 2 gain step down. The cool-down duration is specified by AGC_WBD_STEP2_DUAL_CLIP_WAIT
24-21 AGC_WBD_THR1	AGC WBD Step1 threshold Threshold value(unit: mV) for AGC WBD step1. 0000b - 49.31 0001b - 67.56 0010b - 90.98 0011b - 117.42 0100b - 150.66 0101b - 180.98 0110b - 211.87 0111b - 245.2 1000b - 288.31 1001b - 336.02 1010b - 394.34 1011b - 462.71 1100b - 548.04 1101b - 650.13 1110b - 771.65 1111b - 918.12
20-17 AGC_WBD_THR2	AGC WBD Step2 threshold Threshold value(unit: mV) for AGC WBD step2. The actual threshold voltage is as same as the description in AGC_WBD_THR1.
16-14 AGC_WBD_STEP1_SZ	AGC WBD Step1 Gain Decrease Value Specify the gain index decrease value when AGC WBD step1 triggered. Actual gain step is: AGC_WBD_STEP1_SZ + 1
13-11 AGC_WBD_STEP2_SZ	AGC WBD Step2 Gain Decrease Value Specify the gain index decrease value when AGC WBD step2 triggered. Actual gain step is: AGC_WBD_STEP2_SZ + 1
10 AGC_FAST_EN	AGC Fast Magnitude Mode Enable 0b - Disable fast magnitude mode 1b - Enable fast magnitude mode

Table continues on the next page...

Table continued from the previous page...

Field	Function
9 AGC_FAST_STEP_UP_EN	AGC Fast Magnitude Mode Step Up Enable AGC step up enable in fast magnitude mode. This bit only take effect with AGC_FAST_EN=1. If this bit cleared, the fast magnitude mode can only make AGC gain index step down. 0b - Fast magnitude mode can only make AGC gain index step down 1b - Fast magnitude mode can make AGC gain index step down or step up
8 AGC_SLOW_EN	AGC Slow Magnitude Mode Enable 0b - Disable AGC slow magnitude mode 1b - Enable AGC slow magnitude mode
7 AGC_DELTA_SLOW_EN	AGC Delta Slow Magnitude Mode Enable AGC delta slow magnitude mode enable. Note: The AGC delta slow magnitude mode can only work with AGC slow magnitude mode enabled(AGC_SLOW_EN=1). 0b - Disable AGC delta slow magnitude mode 1b - Enable AGC delta slow magnitude mode
6-4 AGC_DELTA_SLOW_STEP	AGC Delta Slow Mode Gain Step Up Value Gain index change for a big step up when delta slow mode triggered
3-2 AGC_HOLD_EN	AGC Hold Mode Enable AGC hold mode enable and control 00b - Disable AGC hold mode 01b - AGC hold when preamble found 10b - AGC hold when AGC hold timeout matched 11b - AGC hold when preamble found or hold timeout matched
1-0 AGC_UNHOLD_FEAT_EN	AGC Unhold Enable AGC unhold feature enable and config. AGC_UNHOLD_FEAT_EN[0]: When AGC in HOLD mode and the selected mag values exceed the range of "agc_hold_mag +/- ipr_hold_mag_margin", AGC will exit from HOLD mode. NOTE: See AGC_TIMING2[AGC_UNHOLD_MAG_SRC_SEL] and AGC_TIMING2[AGC_UNHOLD_MAG_CNT_SEL] for more info AGC_UNHOLD_FEAT_EN[1]: If AGC does not enter into FREEZE mode or receive done in time, AGC will exit HOLD mode. The unhold timeout value is set by AGC_UNHOLD_TMEOUT NOTE: AGC_UNHOLD_FEAT_EN=3 is a valid configuration

52.4.4.2.2.2.5.1.39 AGC Control Status (AGC_CTRL_STAT)

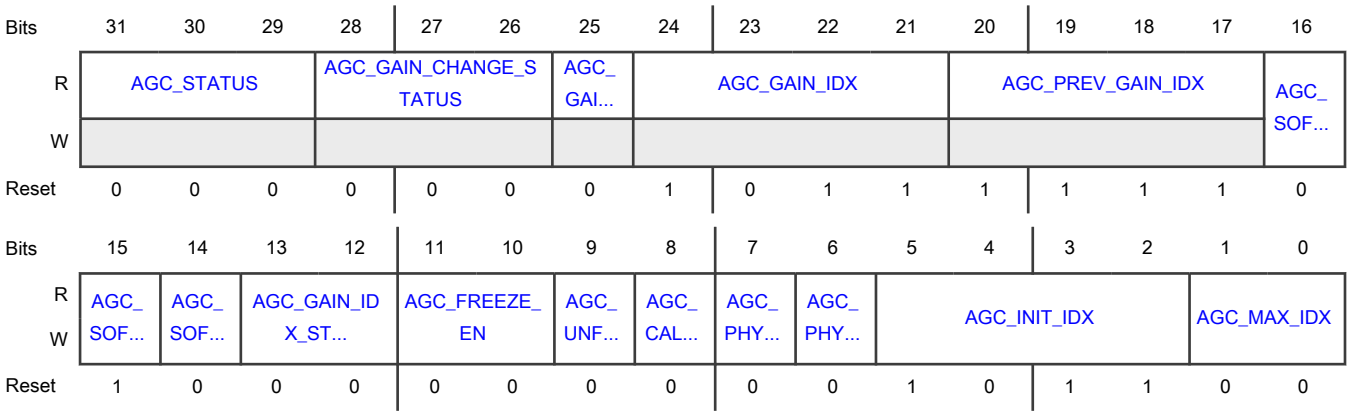
Offset

Register	Offset
AGC_CTRL_STAT	94h

Function

AGC control and status register

Diagram



Fields

Field	Function
31-29 AGC_STATUS	AGC FSM Status Indicate the current state of AGC state machine. This field will be 0 when RX_DIG or AGC are not enabled. 000b - AGC_IDLE 001b - AGC_WB_ONLY 010b - AGC_WB_MAG 011b - AGC_WB_DEBOUNCE 100b - AGC_MAG_ONLY 101b - AGC_HOLD 110b - AGC_FREEZE 111b - AGC_WAIT_GAIN_SETTLE
28-26 AGC_GAIN_CHANGE_STATUS	AGC Gain Change Status Indicate the latest AGC gain index change reason. This field will be 0 when RX_DIG or AGC not be enabled. 000b - No gain change 001b - Gain decreased by WBD step1

Table continues on the next page...

Table continued from the previous page...

Field	Function
	010b - Gain decreased by WBD step2 011b - Gain decreased by fast mode 100b - Gain increased by fast mode 101b - Gain decreased by slow mode 110b - Gain increased by slow mode 111b - Gain increased by delta slow mode
25 AGC_GAIN_CHANGE	AGC Gain Change Indicate the AGC gain is changing. NOTE: This is a pulse signal, software may not read it correctly.
24-21 AGC_GAIN_IDX	AGC Gain Index Indicate current AGC gain index. This field will be reset to AGC_INIT_IDX when AGC or RX_DIG disabled(rx_dig_en deassert) . To get the AGC gain index value using for previous packet receiving, enable the AGC gain index store function(set a non-zero value for AGC_GAIN_STORE field) and read the AGC_PREV_GAIN_IDX field.
20-17 AGC_PREV_GAIN_IDX	AGC Previous Gain Index Indicate previous AGC stable gain index. To use this status field, user should set a non-zero value for AGC_GAIN_IDX_STORE. The value of this field will be kept until next AGC gain store trigger occurs. That means RX_DIG disable or RX_DIG initial will not reset this field. See AGC_GAIN_IDX and AGC_GAIN_IDX_STOR for more info.
16-15 AGC_SOFT_RST_SRC_SEL	PHY AGC Soft Reset Sel 00b - Disable PHY AGC soft reset function 01b - Use posedge phy_soft_rst to reset AGC 10b - Use negedge phy_soft_rst to reset AGC 11b - Use negedge phy_agc_freeze_trig to reset AGC
14 AGC_SOFT_RST_GAIN_SEL	PHY AGC Soft Reset Gain Sel 0b - AGC keep current gain index when PHY AGC soft reset trigged, 1b - AGC return to AGC_INIT_IDX when PHY AGC soft reset trigged,
13-12 AGC_GAIN_IDX_STORE	Enable and config AGC gain index store function. The stored AGC gain index can be read from AGC_PREV_GAIN_IDX field 00b - AGC gain index store function is disabled 01b - Store AGC gain index when AGC enter into HOLD mode 10b - Store AGC gain index when AGC enter into FREEZE mode 11b - Store AGC gain index when AA matched
11-10	AGC Freeze Mode Enable

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Field	Function
AGC_FREEZE_EN	AGC Freeze mode enable and configure 00b - Disable AGC freeze mode 01b - AGC freeze when AA/SFD matched 10b - AGC freeze when AGC freeze timeout matched 11b - AGC freeze when AA/SFD matched or freeze timeout matched
9 AGC_UNFREEZE_FEAT_EN	AGC Unfreeze Feature Enable 0b - AGC unfreeze function is disabled 1b - AGC will exit FREEZE mode when AGC_UNFREEZE_TMEOUT matched and aa_found not be asserted
8 AGC_CALC_MAG_IN_FRZ	AGC Calculate Magnitude In Freeze Mode RXDIG continues to calculate the magnitude value after AGC freezed. NOTE: If NB_RSSI module is expected to start measurement by the assertion of aa_match, pd_found, or sdf_detect, and one of those signal set as AGC Freeze mode trigger, setting this bit is required or the NB-RSSI module cannot work when AGC freezed.
7 AGC_PHY_FREEZE_TRIG_SEL	AGC PHY Freeze Trigger Select 0b - PHY_AGC_FREEZE_TRIG is select as AGC freeze trig. 1b - PHY_AGC_HOLD_TRIG is select as AGC freeze trig.
6 AGC_PHY_HOLD_TRIG_SEL	AGC PHY Hold Trigger Select 0b - PHY_AGC_HOLD_TRIG is select as AGC hold trig. 1b - PHY_AGC_FREEZE_TRIG is select as AGC hold trig.
5-2 AGC_INIT_IDX	AGC Initial Gain Index Initial AGC gain index value. Note: the AGC_INIT_IDX should not greater than 11. Also see AGC_MAX_IDX for more information.
1-0 AGC_MAX_IDX	AGC Max Gain Index Actual AGC max gain index is: 12 - AGC_MAX_IDX. When reaches the max gain index AGC will not perform gain index step up. Value 0 for AGC_MAX_IDX is forbidden.

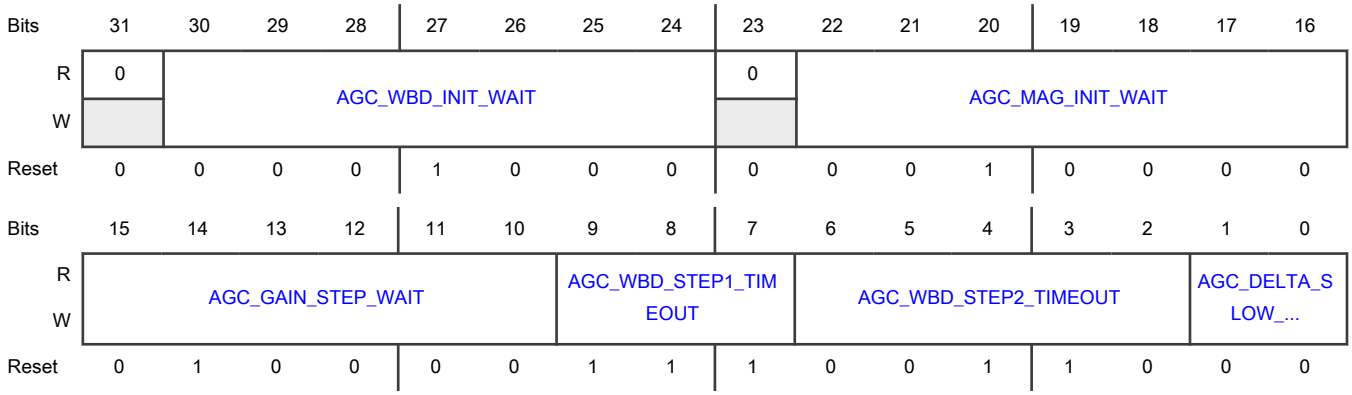
52.4.4.2.2.2.5.1.40 AGC Timing Control 0 (AGC_TIMING0)

Offset

Register	Offset
AGC_TIMING0	98h

Function
AGC timing control 0

Diagram



Fields

Field	Function
31 —	Reserved
30-24 AGC_WBD_INIT_WAIT	AGC WBD Mode Initial Wait Time When RXDIG enabled, the AGC will wait AGC_WBD_INIT_WAIT reference clock cycles than enable WB detect function. NOTE: The programmed value should not be less than 2 and not larger than AGC_MAG_INIT_WAIT
23 —	Reserved
22-16 AGC_MAG_INIT_WAIT	AGC Magnitude Mode Initial Wait Time When RXDIG enabled, the AGC will wait AGC_MAG_INIT_WAIT reference clock cycles than enable FAST and/or SLOW mode. NOTE: The programmed value should not less than 2 and not largen than AGC_WBD_INIT_WAIT
15-10 AGC_GAIN_STEP_WAIT	AGC Gain Change Wait Time Determine the duration of AGC WAIT_GAIN_STEL state. That means the number of reference clock cycles to wait for analog stable after AGC gain index changed.
9-7 AGC_WBD_STEP1_TIMEOUT	AGC WBD Timeout WBD step1 timeout value. This timeout counter will start work at the point of AGC WBD initialization done. If AGC_WBD_AUTO_DIS[1]=1 and no WB trigger occurs, AGC will disable WB detect function. The actual timeout duration(Unit is microsecond) is: AGC_WBD_STEP1_TIMEOUT + 1
6-2 AGC_WBD_STEP2_TIMEOUT	AGC WBD Step2 Timeout Indicating the WBD step2 enable duration, counted by reference clock cycles. If no WBD step2 trigger occurs, the AGC will disable WBD function. NOTE: The programmed value should be no less than 2.

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Field	Function
1-0 AGC_DELTA_SLOW_WAIT	AGC Delta Slow Mode Timing In delta slow mode, AGC will compare current slow_mag(slow_mag[N]) to the previous Kth(Here K = AGC_DELTA_SLOW_WAIT+1)slow mag(slow_mag[N-k]) and check whether the delta slow mag(slow_mag[N-K] - slow_mag[N]) exceed DELTA_SLOW_THR. If yes, the AGC will issue a delta slow trig and increase the gain index by AGC_DELATA_SLOW_STEP.

52.4.4.2.2.2.5.1.41 AGC Timing Control 1 (AGC_TIMING1)

Offset

Register	Offset
AGC_TIMING1	9Ch

Function
AGC timing control 1

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		AGC_WBD_DUAL_CLIP_TIMEOUT				AGC_WBD_STEP2_WAIT						AGC_WBD_STEP1_DUAL_CLIP...			AGC_WBD...
W																
Reset	0	0	0	1	1	0	0	1	0	0	0	0	0	0	1	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	AGC_WBD_STEP2_D...		AGC_HOLD_TIMEOUT						AGC_FREEZE_TIMEOUT							
W																
Reset	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0

Fields

Field	Function
31-30 —	Reserved
29-26 AGC_WBD_DUAL_CLIP_TIMEOUT	Indicate the max duration, count by reference clk, for WBD debounce. If WBD not be triggered again in this time, debounce failed. If AGC_WBD_EN=2, the programmed AGC_WBD_DUAL_CLIP_TIMEOUT value should be no large than AGC_WBD_STEP2_TIMEOUT. This field has no effect when AGC_WBD_STEP1_DUAL_CLIP_EN || AGC_WBD_STEP2_DUAL_CLIP_EN=0.

Table continues on the next page...

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Field	Function
25-20 AGC_WBD_STEP2_WAIT	AGC Gain Change Wait For WBD step2 Gain stable wait duration, count by reference clock, for AGC WBD step2.
19-17 AGC_WBD_STEP1_DUAL_CLIP_WAIT	AGC WBD step1 Debounce Wait Time Cooldown duration, count by reference clock, for WBD step1.
16-14 AGC_WBD_STEP2_DUAL_CLIP_WAIT	AGC WBD step2 Debounce Wait Time Cooldown duration, count by reference clock, for WBD step2.
13-7 AGC_HOLD_TIMEOUT	AGC HOLD Mode Wait Time If AGC_HOLD_EN[1] = 1, AGC will trans to hold state when hold timeout matched. The actual hold timeout duration can be calculated as: hold_timeout_duration(microsecond) = AGC_HOLD_TIMEOUT + 1 The hold_timeout counter will start work at the point of AGC initialization done, and which will be reset when every gain index changed.
6-0 AGC_FREEZE_TIMEOUT	AGC FREEZE Mode Wait Time If AGC_FREEZE_EN[1] = 1, AGC will trans to FREEZE state when freeze timeout matched. The actual freeze timeout duration can be calculated as: freeze_timeout_duration(microsecond) = AGC_FREEZE_TIMEOUT + 1 If HOLD function enabled, the freeze_timeout counter will start work when AGC entered into HOLD mode,or it will start counting at the point of AGC initialization done. Similar to the hold_timeout counter, the freeze_timeout counter will be reset when every gain index changes.

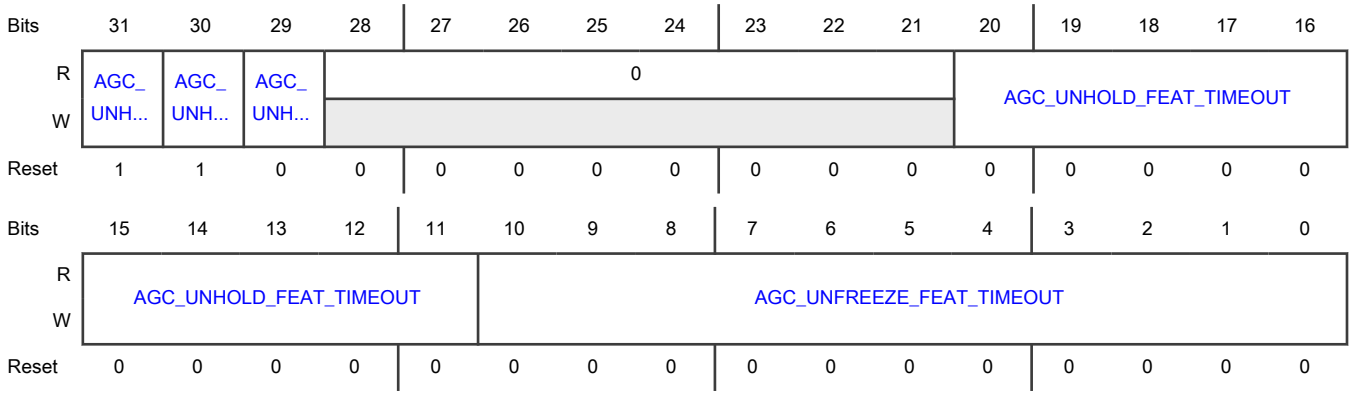
52.4.4.2.2.2.5.1.42 AGC Timing Control 2 (AGC_TIMING2)

Offset

Register	Offset
AGC_TIMING2	A0h

Function
AGC timing control 2

Diagram



Fields

Field	Function
31 AGC_UNHOLD_MAG_SRC	AGC Magnitude Unhold Feature Source Selection Choose fast_mag or slow_mag for AGC magnitude unhold feature source. NOTE: This bit only takes effect when AGC_CTRL[AGC_UNHOLD_FEAT_EN][0]=1 0b - fast_mag 1b - slow_mag
30 AGC_UNHOLD_MAG_CNT	AGC Unhold Magnitude Count Selection This bit controls how many times the selected magnitude value exceeds unhold margin will unhold the AGC. NOTE: This bit only takes effect when AGC_CTRL[AGC_UNHOLD_FEAT_EN][0]=1 0b - Once the selected magnitude exceeds unhold margin, the AGC will exit HOLD mode 1b - Need two consecutive selected magnitude values exceeds unhold margin to let AGC exit HOLD mode
29 AGC_UNHOLD_GAIN_CHG	AGC Gain Index Change When UNHOLD If enabled, AGC will do gain index change immediately when AGC unhold by magnitude value exceed the hold margin. If the "mag > hold_mag + AGC_THR_MIS[HOLD_MARGIN_THR]", AGC will decrease the gain index by 1, while if "mag < hold_mag - AGC_THR_MIS[HOLD_MARGIN_THR]", AGC will increase the gain index by 1.
28-21 —	Reserved
20-11 AGC_UNHOLD_FEAT_TIMEOUT	AGC Unhold Feature Timeout When AGC_UNHOLD_EN[1]=1, AGC will exit HOLD mode and enter into MAG_ONLY mode if AA not be found in N microseconds. Where N equal to "AGC_UNHOLD_TIMEOUT + 1". If AGC_SOFT_RST_GAIN_SEL=1 and AGC currently at the non-initial gain index, AGC will exit HOLD mode with changing the gain index to AGC_INIT_IDX, thus the next state will be WAIT_GAIN_CHANGE followed by MAG_ONLY

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Field	Function
10-0 AGC_UNFREEZE_FEAT_TIMEOUT	AGC Unfreeze Feature Timeout When AGC_UNFREEZE_EN, AGC will exit FREEZE mode and enter into MAG_ONLY mode if AA not be found in N microseconds. Where N equal to "AGC_UNFREEZE_FEAT_TIMEOUT + 1". If AGC_SOFT_RST_GAIN_SEL=1 and AGC currently at the non-initial gain index, AGC will exit FREEZE mode with changing the gain index to AGC_INIT_IDX, thus the next state will be WAIT_GAIN_CHANGE followed by MAG_ONLY

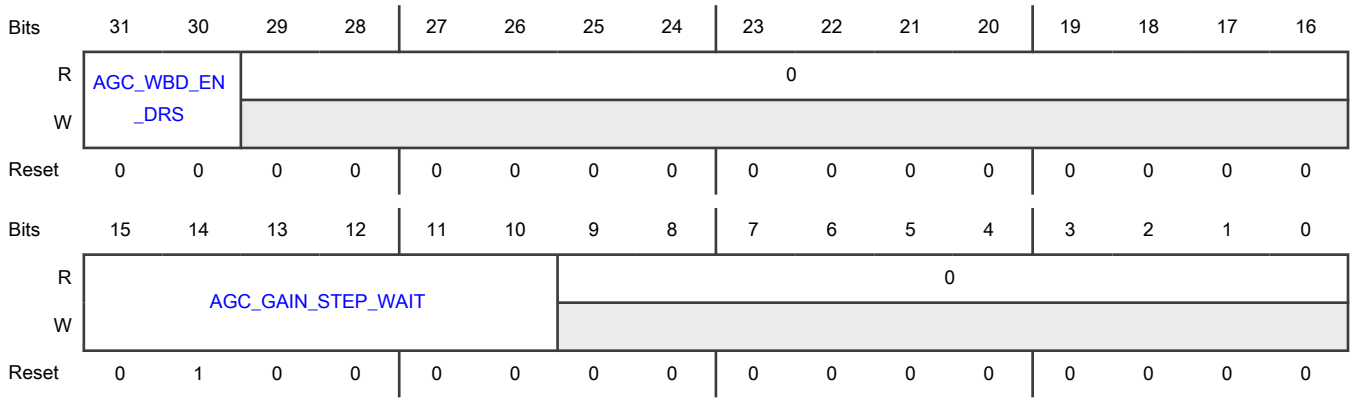
52.4.4.2.2.2.5.1.43 AGC Timing Control 0 DRS (AGC_TIMING0_DRS)

Offset

Register	Offset
AGC_TIMING0_DRS	A4h

Function
AGC timing control 0 for datarate_config_sel=1

Diagram



Fields

Field	Function
31-30 AGC_WBD_EN_DRS	DRS version of AGC_CTRL[AGC_WBD_EN]
29-16 —	Reserved

Table continues on the next page...

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Field	Function
15-10 AGC_GAIN_STEP_WAIT	AGC Gain Change Wait Time AGC_GAIN_STEP_WAIT for datarate_config_sel=1
9-0 —	Reserved

52.4.4.2.2.2.5.1.44 AGC Timing Control 1 DRS (AGC_TIMING1_DRS)

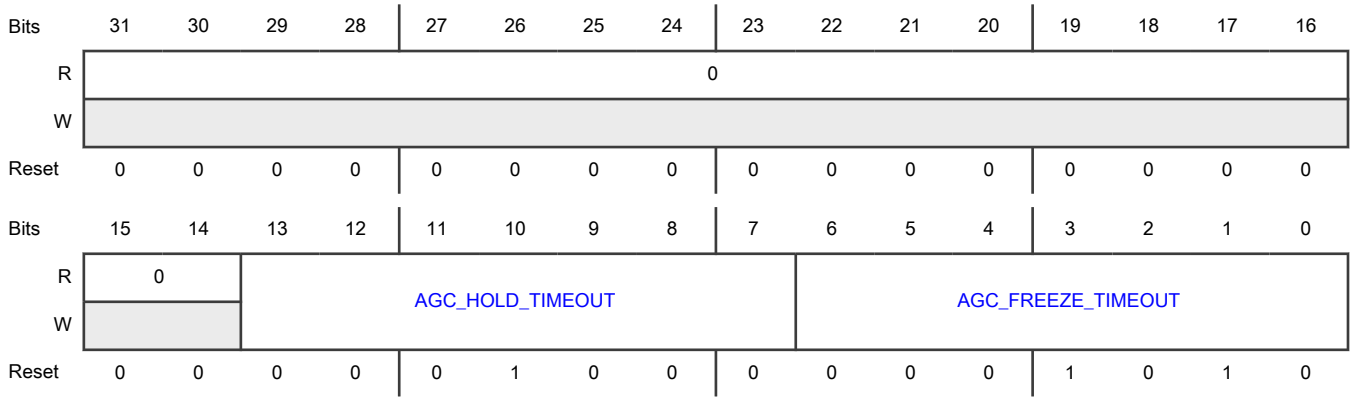
Offset

Register	Offset
AGC_TIMING1_DRS	A8h

Function

AGC timing control 1 for datarate_config_sel=1

Diagram



Fields

Field	Function
31-14 —	Reserved
13-7 AGC_HOLD_TIMEOUT	AGC HOLD Mode Wait Time AGC_HOLD_TIMEOUT for datarate_config_sel=1

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Field	Function
6-0 AGC_FREEZE_TIMEOUT	AGC FREEZE Mode Wait Time AGC_FREEZE_TIMEOUT for datarate_config_sel=1

52.4.4.2.2.2.5.1.45 AGC Timing Control 2 DRS (AGC_TIMING2_DRS)

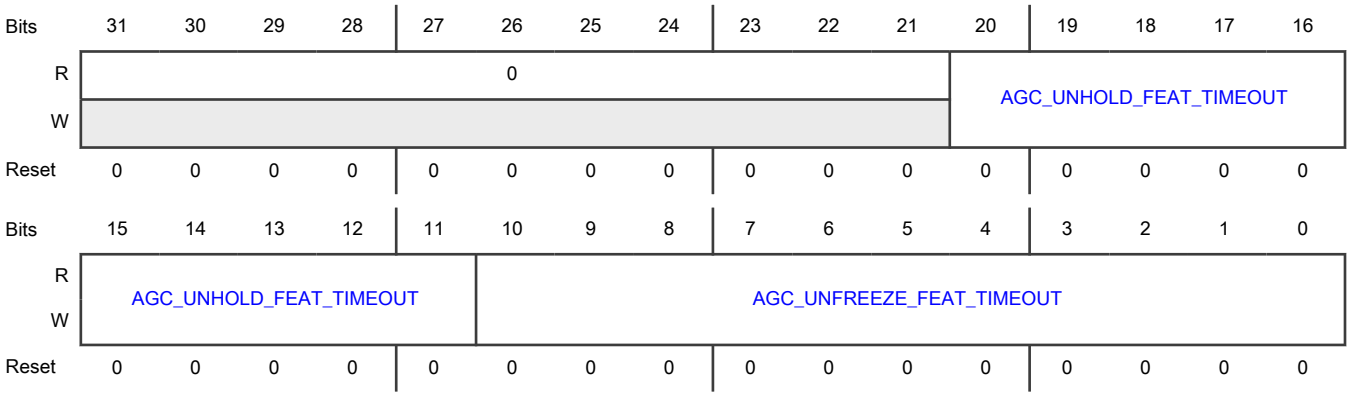
Offset

Register	Offset
AGC_TIMING2_DRS	ACh

Function

AGC timing control 2 for datarate_config_sel=1

Diagram



Fields

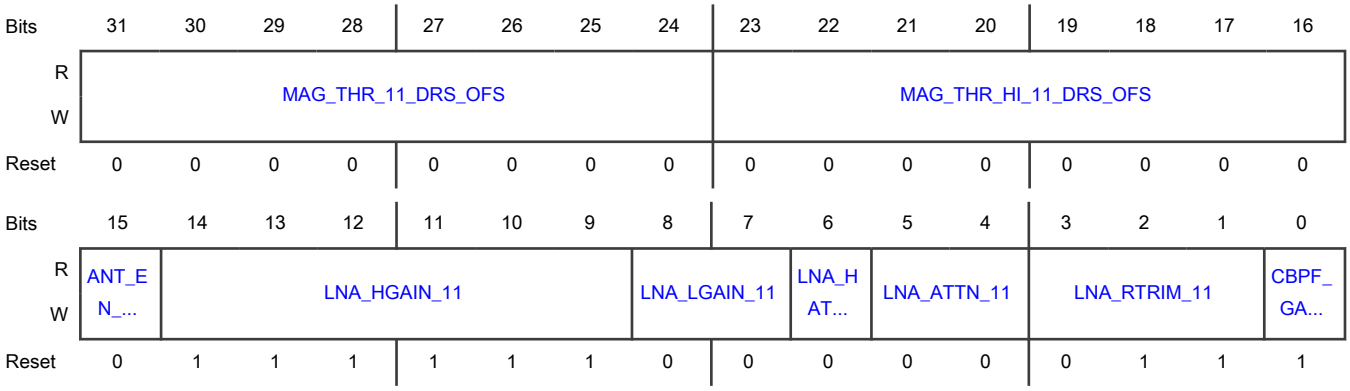
Field	Function
31-21 —	Reserved
20-11 AGC_UNHOLD_FEAT_TIMEOUT	AGC Unhold Feature Timeout AGC_UNHOLD_FEAT_TIMEOUT for datarate_config_sel=1
10-0 AGC_UNFREEZE_FEAT_TIMEOUT	AGC Unfreeze Feature Timeout AGC_UNFREEZE_FEAT_TIMEOUT for datarate_config_sel=1

52.4.4.2.2.2.5.1.46 AGC IDX11 Gain Config (AGC_IDX11_GAIN_CFG)

Offset

Register	Offset
AGC_IDX11_GAIN_CFG	B0h

Diagram



Fields

Field	Function
31-24 MAG_THR_11_DRS_OFS	Mag Thresh High DRS for AGC Gain Index 11 Magnitude threshold offset for AGC gain index 11 when datarate_config_sel = 1. Check the "AGC PHY Magnitude Threshold" chapter for more information.
23-16 MAG_THR_HI_11_DRS_OFS	Mag Thresh DRS for AGC Gain Index 11 Magnitude threshold high offset for AGC gain index 11 when datarate_config_sel = 1. Check the "AGC PHY Magnitude Threshold" chapter for more information.
15 ANT_EN_RLOAD_11	ANT_EN_RLOAD_11 ldo_ant_en_rload during gain index=11
14-9 LNA_HGAIN_11	LNA_HGAIN_11 LNA high gain slices during gain index=11
8-7 LNA_LGAIN_11	LNA_LGAIN_11 LNA low gain slices during gain index=11
6 LNA_HATTN_11	LNA_HATTN_11 LNA high gain capacitor attenuation during gain index=11
5-4	LNA_ATTN_11

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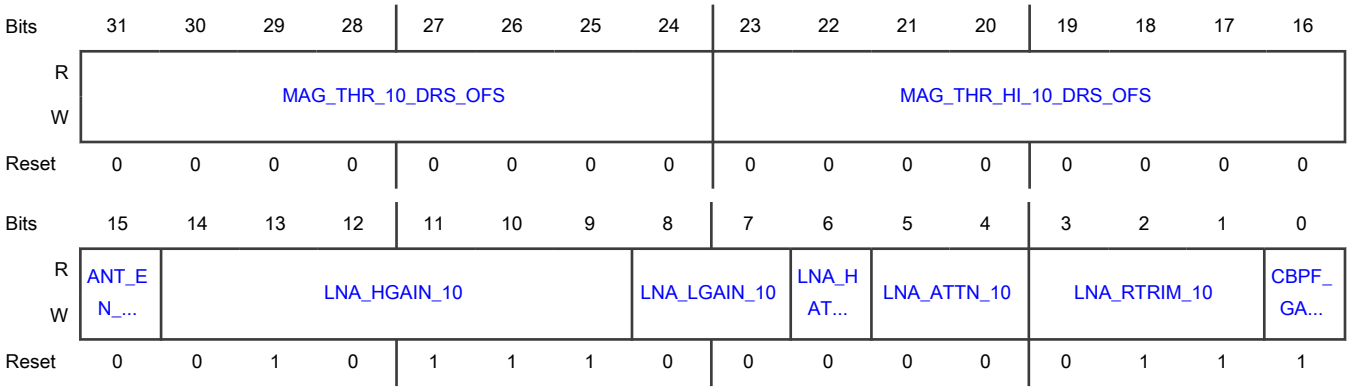
Field	Function
LNA_ATTN_11	LNA low gain capacitor attenuation during gain index=11
3-1 LNA_RTRIM_11	LNA_RTRIM_11 LNA RTFE matching resistor adjustment value during gain index=11
0 CBPF_GAIN_11	CBPF_GAIN_11 CBPF gain select during gain index=11 0b - -6 dB 1b - 0 dB

52.4.4.2.2.2.5.1.47 AGC IDX10 Gain Config (AGC_IDX10_GAIN_CFG)

Offset

Register	Offset
AGC_IDX10_GAIN_CFG	B4h

Diagram



Fields

Field	Function
31-24 MAG_THR_10_DRS_OFS	Magnitude threshold offset for AGC gain index 10 when datarate_config_sel = 1
23-16 MAG_THR_HI_10_DRS_OFS	Magnitude threshold high offset for AGC gain index 10 when datarate_config_sel = 1

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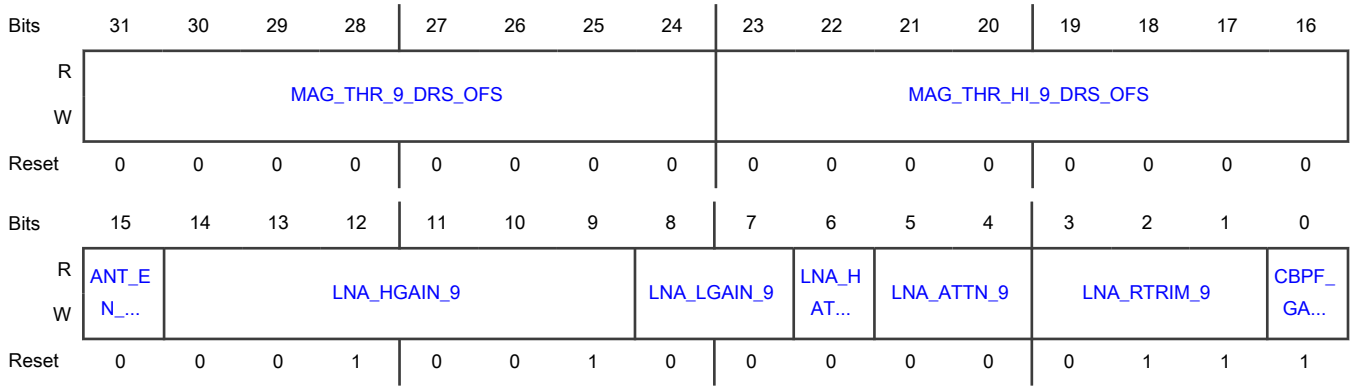
Field	Function
15 ANT_EN_RLOAD_10	ANT_EN_RLOAD_10 ldo_ant_en_rload during gain index=10
14-9 LNA_HGAIN_10	LNA_HGAIN_10 LNA high gain slices during gain index=10
8-7 LNA_LGAIN_10	LNA_LGAIN_10 LNA low gain slices during gain index=10
6 LNA_HATTN_10	LNA_HATTN_10 LNA high gain capacitor attenuation during gain index=10
5-4 LNA_ATTN_10	LNA_ATTN_10 LNA low gain capacitor attenuation during gain index=10
3-1 LNA_RTRIM_10	LNA_RTRIM_10 LNA RTFE matching resistor adjustment value during gain index=10
0 CBPF_GAIN_10	CBPF_GAIN_10 CBPF gain select during gain index=10 0b - -6 dB 1b - 0 dB

52.4.4.2.2.2.5.1.48 AGC IDX9 Gain Config (AGC_IDX9_GAIN_CFG)

Offset

Register	Offset
AGC_IDX9_GAIN_CFG	B8h

Diagram



Fields

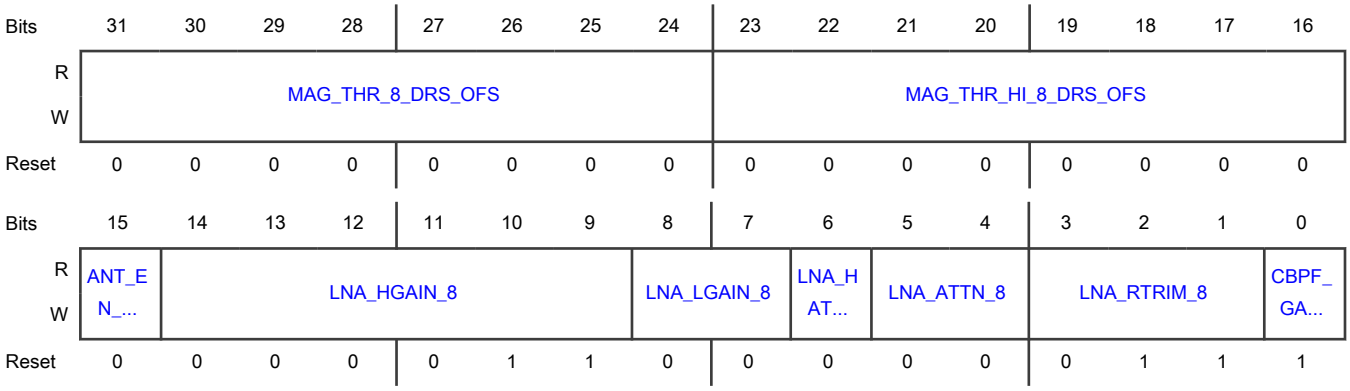
Field	Function
31-24 MAG_THR_9_DRS_OFS	Magnitude threshold offset for AGC gain index 9 when datarate_config_sel = 1
23-16 MAG_THR_HI_9_DRS_OFS	Magnitude threshold high offset for AGC gain index 9 when datarate_config_sel = 1
15 ANT_EN_RLOAD_9	ANT_EN_RLOAD_9 ldo_ant_en_rload during gain index=9
14-9 LNA_HGAIN_9	LNA_HGAIN_9 LNA high gain slices during gain index=9
8-7 LNA_LGAIN_9	LNA_LGAIN_9 LNA low gain slices during gain index=9
6 LNA_HATTN_9	LNA_HATTN_9 LNA high gain capacitor attenuation during gain index=9
5-4 LNA_ATTN_9	LNA_ATTN_9 LNA low gain capacitor attenuation during gain index=9
3-1 LNA_RTRIM_9	LNA_RTRIM_9 LNA RTFE matching resistor adjustment value during gain index=9
0 CBPF_GAIN_9	CBPF_GAIN_9 CBPF gain select during gain index=9 0b - -6 dB 1b - 0 dB

52.4.4.2.2.2.5.1.49 AGC IDX8 Gain Config (AGC_IDX8_GAIN_CFG)

Offset

Register	Offset
AGC_IDX8_GAIN_CFG	BCh

Diagram



Fields

Field	Function
31-24 MAG_THR_8_DRS_OFS	Magnitude threshold offset for AGC gain index 8 when datarate_config_sel = 1
23-16 MAG_THR_HI_8_DRS_OFS	Magnitude threshold high offset for AGC gain index 8 when datarate_config_sel = 1
15 ANT_EN_RLOAD_8	ANT_EN_RLOAD_8 ldo_ant_en_rload during gain index=8
14-9 LNA_HGAIN_8	LNA_HGAIN_8 LNA high gain slices during gain index=8
8-7 LNA_LGAIN_8	LNA_LGAIN_8 LNA low gain slices during gain index=8
6 LNA_HATTN_8	LNA_HATTN_8 LNA high gain capacitor attenuation during gain index=8
5-4	LNA_ATTN_8

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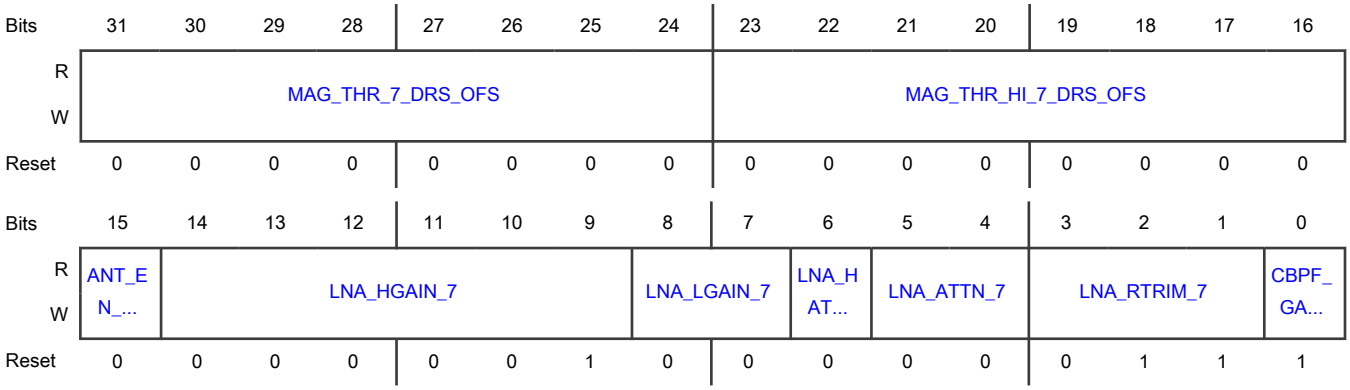
Field	Function
LNA_ATTN_8	LNA low gain capacitor attenuation during gain index=8
3-1 LNA_RTRIM_8	LNA_RTRIM_8 LNA RTFE matching resistor adjustment value during gain index=8
0 CBPF_GAIN_8	CBPF_GAIN_8 CBPF gain select during gain index=8 0b - -6 dB 1b - 0 dB

52.4.4.2.2.2.5.1.50 AGC IDX7 Gain Config (AGC_IDX7_GAIN_CFG)

Offset

Register	Offset
AGC_IDX7_GAIN_CFG	C0h

Diagram



Fields

Field	Function
31-24 MAG_THR_7_DRS_OFS	Magnitude threshold offset for AGC gain index 7 when datarate_config_sel = 1
23-16 MAG_THR_HI_7_DRS_OFS	Magnitude threshold high offset for AGC gain index 7 when datarate_config_sel = 1

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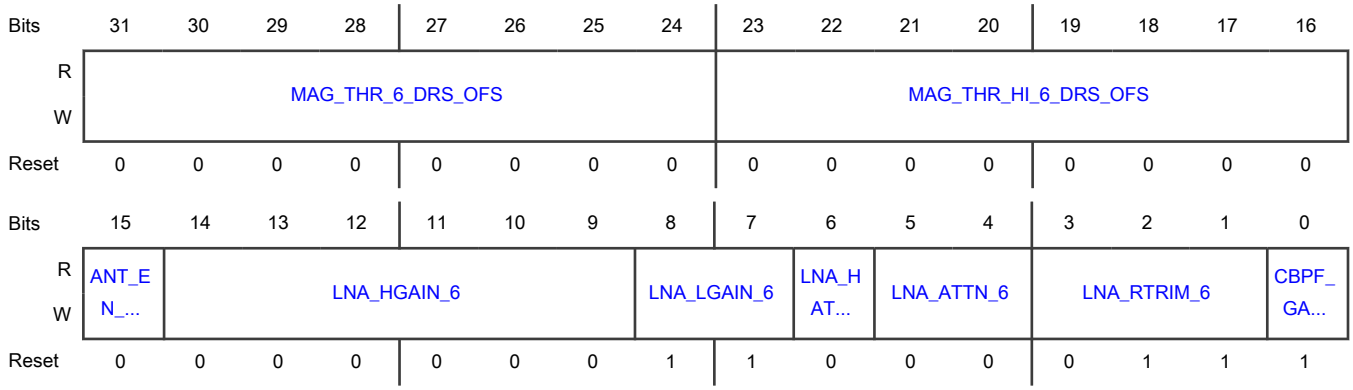
Field	Function
15 ANT_EN_RLOAD_7	ANT_EN_RLOAD_7 ldo_ant_en_rload during gain index=7
14-9 LNA_HGAIN_7	LNA_HGAIN_7 LNA high gain slices during gain index=7
8-7 LNA_LGAIN_7	LNA_LGAIN_7 LNA low gain slices during gain index=7
6 LNA_HATTN_7	LNA_HATTN_7 LNA high gain capacitor attenuation during gain index=7
5-4 LNA_ATTN_7	LNA_ATTN_7 LNA low gain capacitor attenuation during gain index=7
3-1 LNA_RTRIM_7	LNA_RTRIM_7 LNA RTFE matching resistor adjustment value during gain index=7
0 CBPF_GAIN_7	CBPF_GAIN_7 CBPF gain select during gain index=7 0b - -6 dB 1b - 0 dB

52.4.4.2.2.2.5.1.51 AGC IDX6 Gain Config (AGC_IDX6_GAIN_CFG)

Offset

Register	Offset
AGC_IDX6_GAIN_CFG	C4h

Diagram



Fields

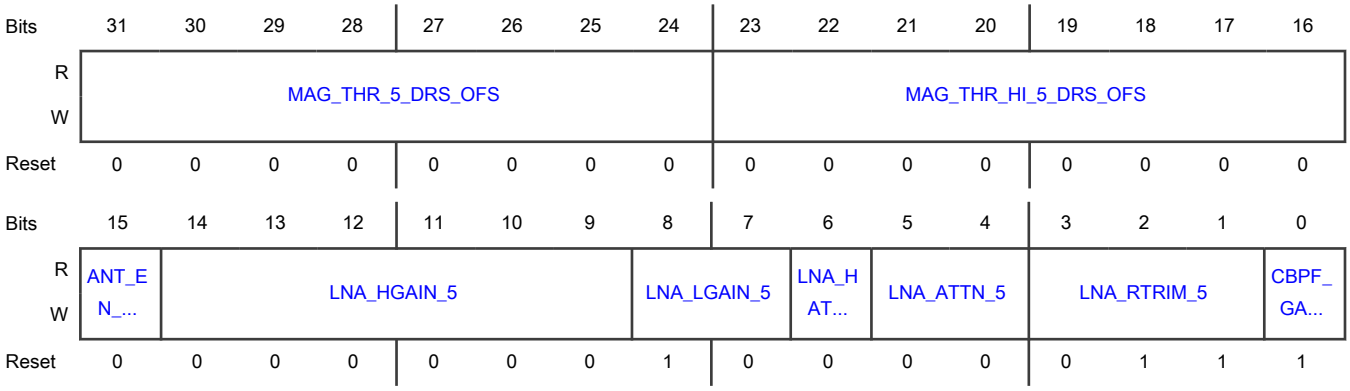
Field	Function
31-24 MAG_THR_6_DRS_OFS	Magnitude threshold offset for AGC gain index 6 when datarate_config_sel = 1
23-16 MAG_THR_HI_6_DRS_OFS	Magnitude threshold high offset for AGC gain index 6 when datarate_config_sel = 1
15 ANT_EN_RLOAD_6	ANT_EN_RLOAD_6 ldo_ant_en_rload during gain index=6
14-9 LNA_HGAIN_6	LNA_HGAIN_6 LNA high gain slices during gain index=6
8-7 LNA_LGAIN_6	LNA_LGAIN_6 LNA low gain slices during gain index=6
6 LNA_HATTN_6	LNA_HATTN_6 LNA high gain capacitor attenuation during gain index=6
5-4 LNA_ATTN_6	LNA_ATTN_6 LNA low gain capacitor attenuation during gain index=6
3-1 LNA_RTRIM_6	LNA_RTRIM_6 LNA RTFE matching resistor adjustment value during gain index=6
0 CBPF_GAIN_6	CBPF_GAIN_6 CBPF gain select during gain index=6 0b - -6 dB 1b - 0 dB

52.4.4.2.2.2.5.1.52 AGC IDX5 Gain Config (AGC_IDX5_GAIN_CFG)

Offset

Register	Offset
AGC_IDX5_GAIN_CFG	C8h

Diagram



Fields

Field	Function
31-24 MAG_THR_5_DRS_OFS	Magnitude threshold offset for AGC gain index 5 when datarate_config_sel = 1
23-16 MAG_THR_HI_5_DRS_OFS	Magnitude threshold high offset for AGC gain index 5 when datarate_config_sel = 1
15 ANT_EN_RLOAD_5	ANT_EN_RLOAD_5 ldo_ant_en_rload during gain index=5
14-9 LNA_HGAIN_5	LNA_HGAIN_5 LNA high gain slices during gain index=5
8-7 LNA_LGAIN_5	LNA_LGAIN_5 LNA low gain slices during gain index=5
6 LNA_HATTN_5	LNA_HATTN_5 LNA high gain capacitor attenuation during gain index=5
5-4	LNA_ATTN_5

Table continues on the next page...

Table continued from the previous page...

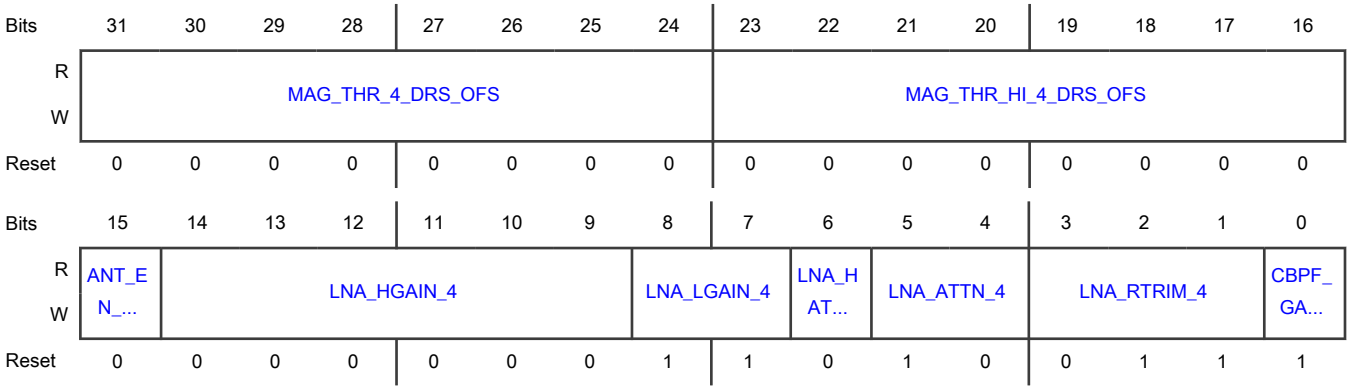
Field	Function
LNA_ATTN_5	LNA low gain capacitor attenuation during gain index=5
3-1 LNA_RTRIM_5	LNA_RTRIM_5 LNA RTFE matching resistor adjustment value during gain index=5
0 CBPF_GAIN_5	CBPF_GAIN_5 CBPF gain select during gain index=5 0b - -6 dB 1b - 0 dB

52.4.4.2.2.2.5.1.53 AGC IDX4 Gain Config (AGC_IDX4_GAIN_CFG)

Offset

Register	Offset
AGC_IDX4_GAIN_CFG	CCh

Diagram



Fields

Field	Function
31-24 MAG_THR_4_DRS_OFS	Magnitude threshold offset for AGC gain index 4 when datarate_config_sel = 1
23-16 MAG_THR_HI_4_DRS_OFS	Magnitude threshold high offset for AGC gain index 4 when datarate_config_sel = 1

Table continues on the next page...

Table continued from the previous page...

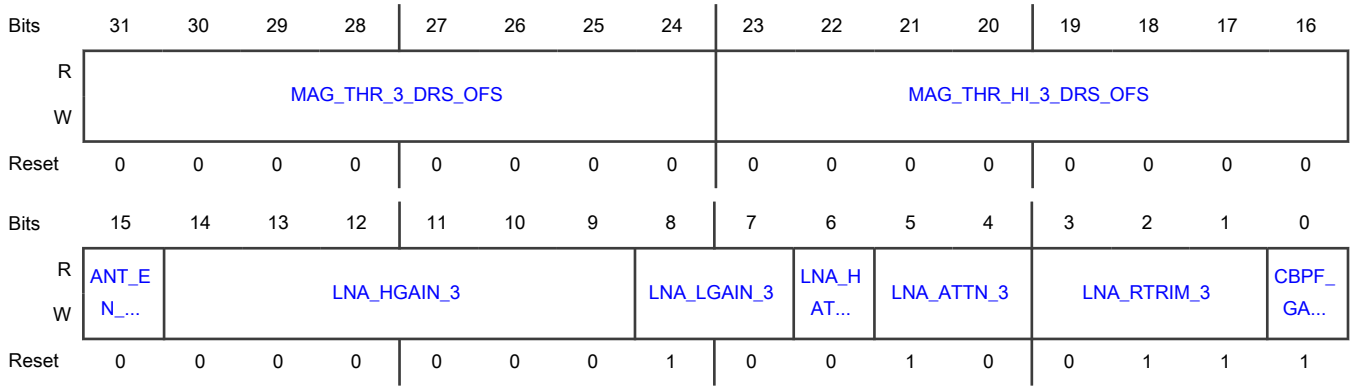
Field	Function
15 ANT_EN_RLOAD_4	ANT_EN_RLOAD_4 ldo_ant_en_rload during gain index=4
14-9 LNA_HGAIN_4	LNA_HGAIN_4 LNA high gain slices during gain index=4
8-7 LNA_LGAIN_4	LNA_LGAIN_4 LNA low gain slices during gain index=4
6 LNA_HATTN_4	LNA_HATTN_4 LNA high gain capacitor attenuation during gain index=4
5-4 LNA_ATTN_4	LNA_ATTN_4 LNA low gain capacitor attenuation during gain index=4
3-1 LNA_RTRIM_4	LNA_RTRIM_4 LNA RTFE matching resistor adjustment value during gain index=4
0 CBPF_GAIN_4	CBPF_GAIN_4 CBPF gain select during gain index=4 0b - -6 dB 1b - 0 dB

52.4.4.2.2.2.5.1.54 AGC IDX3 Gain Config (AGC_IDX3_GAIN_CFG)

Offset

Register	Offset
AGC_IDX3_GAIN_CFG	D0h

Diagram



Fields

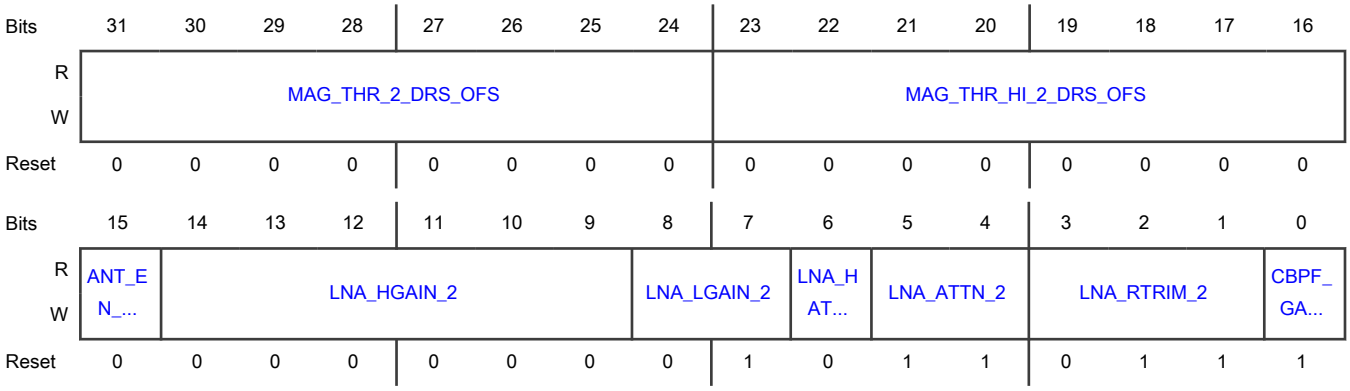
Field	Function
31-24 MAG_THR_3_DRS_OFS	Magnitude threshold offset for AGC gain index 3 when datarate_config_sel = 1
23-16 MAG_THR_HI_3_DRS_OFS	Magnitude threshold high offset for AGC gain index 3 when datarate_config_sel = 1
15 ANT_EN_RLOAD_3	ANT_EN_RLOAD_3 ldo_ant_en_rload during gain index=3
14-9 LNA_HGAIN_3	LNA_HGAIN_3 LNA high gain slices during gain index=3
8-7 LNA_LGAIN_3	LNA_LGAIN_3 LNA low gain slices during gain index=3
6 LNA_HATTN_3	LNA_HATTN_3 LNA high gain capacitor attenuation during gain index=3
5-4 LNA_ATTN_3	LNA_ATTN_3 LNA low gain capacitor attenuation during gain index=3
3-1 LNA_RTRIM_3	LNA_RTRIM_3 LNA RTFE matching resistor adjustment value during gain index=3
0 CBPF_GAIN_3	CBPF_GAIN_3 CBPF gain select during gain index=3 0b - -6 dB 1b - 0 dB

52.4.4.2.2.2.5.1.55 AGC IDX2 Gain Config (AGC_IDX2_GAIN_CFG)

Offset

Register	Offset
AGC_IDX2_GAIN_CFG	D4h

Diagram



Fields

Field	Function
31-24 MAG_THR_2_DRS_OFS	Magnitude threshold offset for AGC gain index 2 when datarate_config_sel = 1
23-16 MAG_THR_HI_2_DRS_OFS	Magnitude threshold high offset for AGC gain index 2 when datarate_config_sel = 1
15 ANT_EN_RLOAD_2	ANT_EN_RLOAD_2 ldo_ant_en_rload during gain index=2
14-9 LNA_HGAIN_2	LNA_HGAIN_2 LNA high gain slices during gain index=2
8-7 LNA_LGAIN_2	LNA_LGAIN_2 LNA low gain slices during gain index=2
6 LNA_HATTN_2	LNA_HATTN_2 LNA high gain capacitor attenuation during gain index=2
5-4	LNA_ATTN_2

Table continues on the next page...

Table continued from the previous page...

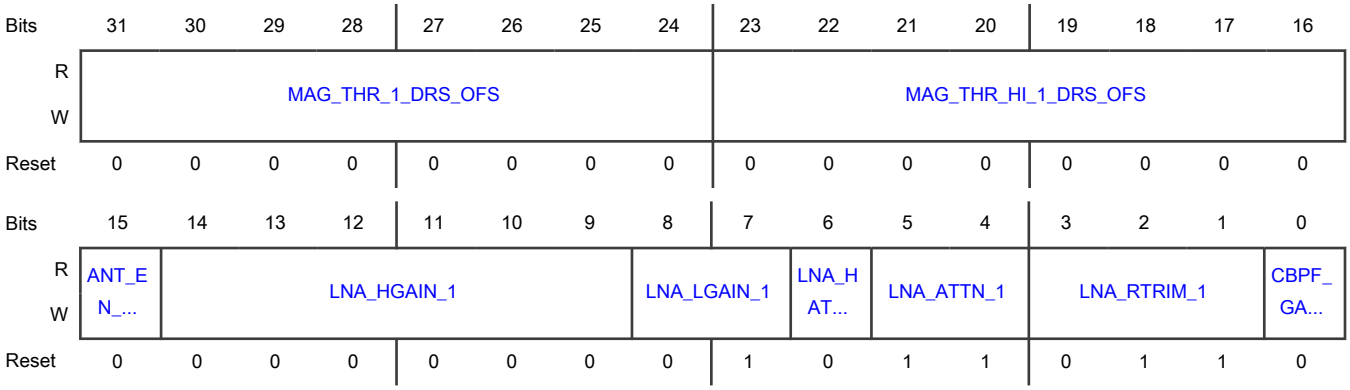
Field	Function
LNA_ATTN_2	LNA low gain capacitor attenuation during gain index=2
3-1 LNA_RTRIM_2	LNA_RTRIM_2 LNA RTFE matching resistor adjustment value during gain index=2
0 CBPF_GAIN_2	CBPF_GAIN_2 CBPF gain select during gain index=2 0b - -6 dB 1b - 0 dB

52.4.4.2.2.2.5.1.56 AGC IDX1 Gain Config (AGC_IDX1_GAIN_CFG)

Offset

Register	Offset
AGC_IDX1_GAIN_CFG	D8h

Diagram



Fields

Field	Function
31-24 MAG_THR_1_DRS_OFS	Magnitude threshold offset for AGC gain index 1 when datarate_config_sel = 1
23-16 MAG_THR_HI_1_DRS_OFS	Magnitude threshold high offset for AGC gain index 1 when datarate_config_sel = 1

Table continues on the next page...

Table continued from the previous page...

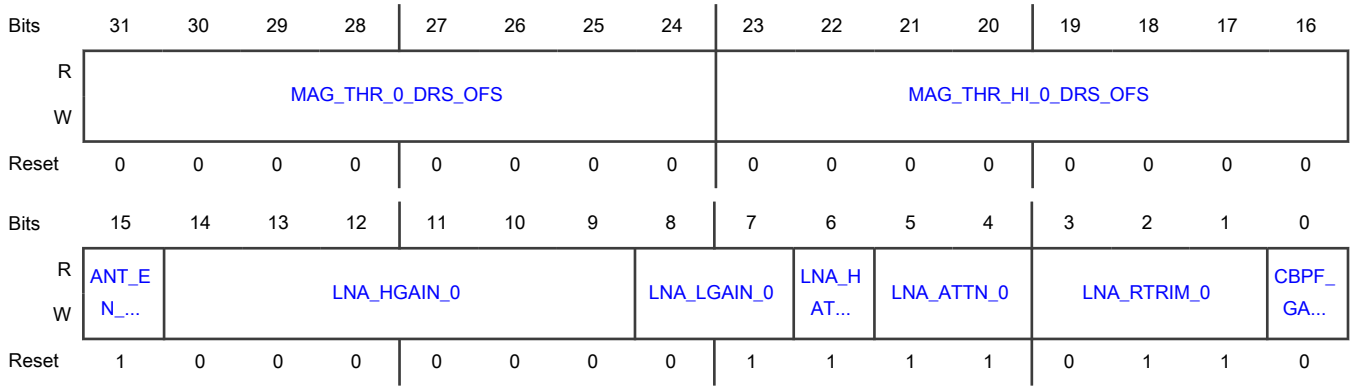
Field	Function
15 ANT_EN_RLOAD_1	ANT_EN_RLOAD_1 ldo_ant_en_rload during gain index=1
14-9 LNA_HGAIN_1	LNA_HGAIN_1 LNA high gain slices during gain index=1
8-7 LNA_LGAIN_1	LNA_LGAIN_1 LNA low gain slices during gain index=1
6 LNA_HATTN_1	LNA_HATTN_1 LNA high gain capacitor attenuation during gain index=1
5-4 LNA_ATTN_1	LNA_ATTN_1 LNA low gain capacitor attenuation during gain index=1
3-1 LNA_RTRIM_1	LNA_RTRIM_1 LNA RTFE matching resistor adjustment value during gain index=1
0 CBPF_GAIN_1	CBPF_GAIN_1 CBPF gain select during gain index=1 0b - -6 dB 1b - 0 dB

52.4.4.2.2.2.5.1.57 AGC IDX0 Gain Config (AGC_IDX0_GAIN_CFG)

Offset

Register	Offset
AGC_IDX0_GAIN_CFG	DCh

Diagram



Fields

Field	Function
31-24 MAG_THR_0_DRS_OFS	Magnitude threshold offset for AGC gain index 0 when datarate_config_sel = 1
23-16 MAG_THR_HI_0_DRS_OFS	Magnitude threshold high offset for AGC gain index 0 when datarate_config_sel = 1
15 ANT_EN_RLOAD_0	ANT_EN_RLOAD_0 ldo_ant_en_rload during gain index=0
14-9 LNA_HGAIN_0	LNA_HGAIN_0 LNA high gain slices during gain index=0
8-7 LNA_LGAIN_0	LNA_LGAIN_0 LNA low gain slices during gain index=0
6 LNA_HATTN_0	LNA_HATTN_0 LNA high gain capacitor attenuation during gain index=0
5-4 LNA_ATTN_0	LNA_ATTN_0 LNA low gain capacitor attenuation during gain index=0
3-1 LNA_RTRIM_0	LNA_RTRIM_0 LNA RTFE matching resistor adjustment value during gain index=0
0 CBPF_GAIN_0	CBPF_GAIN_0 CBPF gain select during gain index=0 0b - -6 dB 1b - 0 dB

52.4.4.2.2.2.5.1.58 AGC Miscellaneous Gain Config (AGC_MIS_GAIN_CFG)

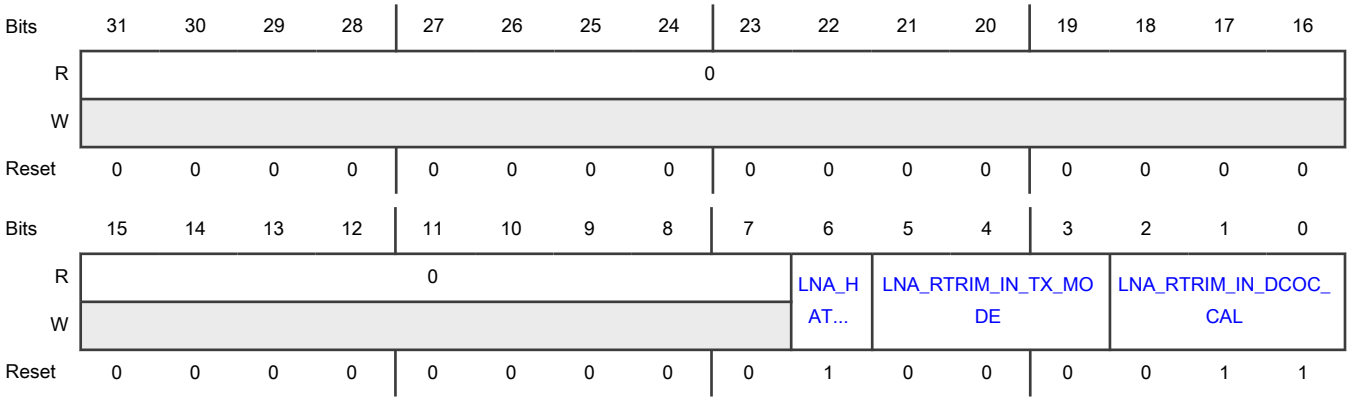
Offset

Register	Offset
AGC_MIS_GAIN_CFG	E0h

Function

{ldo_ant_rload_o,lna_hgain_o,lna_lgain_o,lna_hattn_o,lna_attn_o,lna_rtrim_o,cbpf_gain_o} are signals from AGC to analog , managed to adjust analog gains during AGC sequence.

Diagram



Fields

Field	Function
31-7 —	Reserved
6 LNA_HATTN_IN_TX_MODE	lna_hattn_o AGC signal from register description is driven by this register in TX mode.
5-3 LNA_RTRIM_IN_TX_MODE	lna_rtrim_o AGC signal from register description is driven by this register in TX mode.
2-0 LNA_RTRIM_IN_DCOC_CAL	lna_hattn_o AGC signal from register description is driven by this register during DCOC calibration.

52.4.4.2.2.2.5.1.59 AGC IDX11 Gain Value (AGC_IDX11_GAIN_VAL)

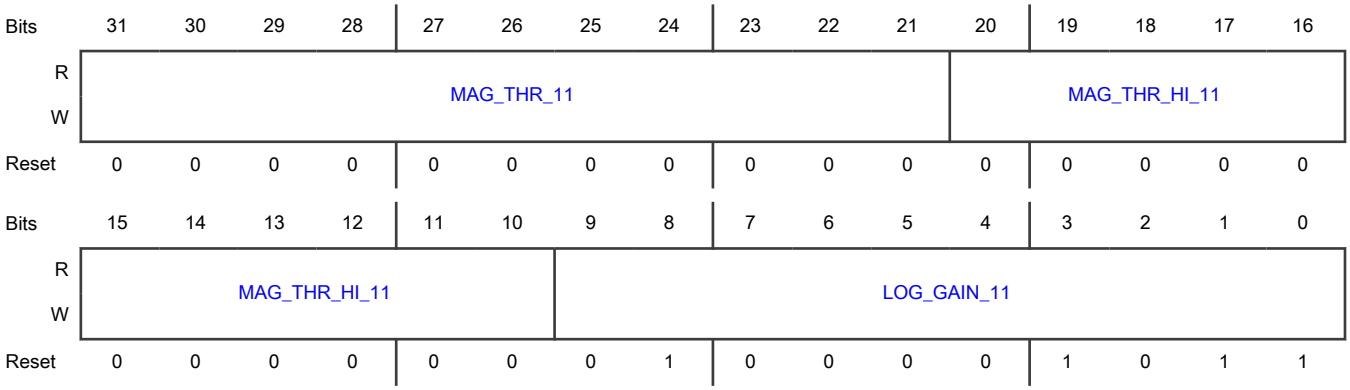
Offset

Register	Offset
AGC_IDX11_GAIN_VAL	E4h

Function

AGC_IDXn_GAIN_VAL(where n can be 11~0) registers store the analog gain values during AGC_GAIN_IDX=n. These values using for WB-RSSI and NB-RSSI calculation and also can be used by PHY or software.

Diagram



Fields

Field	Function
31-21 MAG_THR_11	Magnitude threshold for AGC gain index 11. Check the "AGC PHY Magnitude Threshold" chapter for more information.
20-10 MAG_THR_HI_11	Magnitude threshold high for AGC gain index 11. Check the "AGC PHY Magnitude Threshold" chapter for more information.
9-0 LOG_GAIN_11	LOG_GAIN_11 LOG_GAIN_n represent the logarithmic gain values store in s7.2 format.

52.4.4.2.2.2.5.1.60 AGC_IDX10_GAIN_VAL (AGC_IDX10_GAIN_VAL)

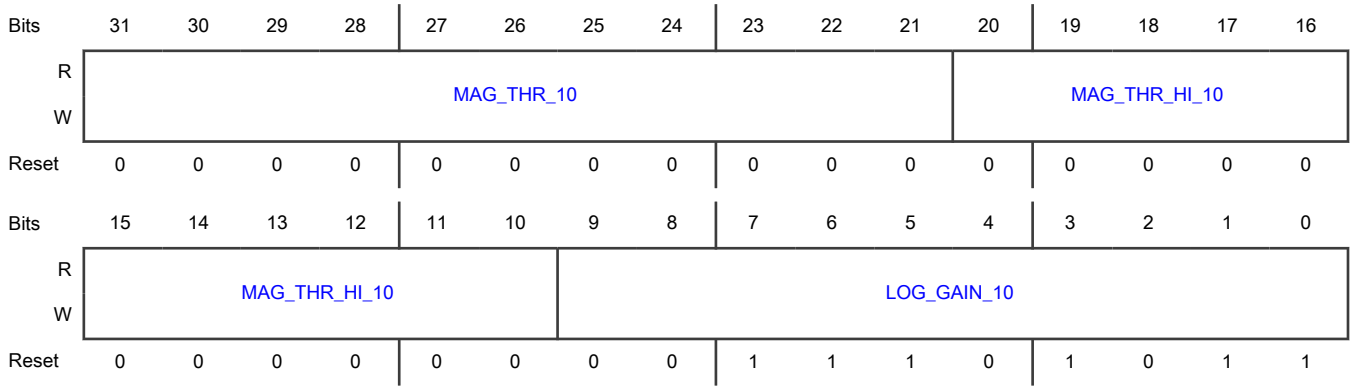
Offset

Register	Offset
AGC_IDX10_GAIN_VAL	E8h

Function

AGC_IDXn_GAIN_VAL(where n can be 11~0) registers store the analog gain values during AGC_GAIN_IDX=n. These values using for WB-RSSI and NB-RSSI calculation and also can be used by PHY or software.

Diagram



Fields

Field	Function
31-21 MAG_THR_10	Magnitude threshold for AGC gain index 10
20-10 MAG_THR_HI_10	Magnitude threshold high for AGC gain index 10
9-0 LOG_GAIN_10	LOG_GAIN_10 LOG_GAIN_n represent the logarithmic gain values store in s7.2 format.

52.4.4.2.2.2.5.1.61 AGC_IDX9_GAIN_VAL (AGC_IDX9_GAIN_VAL)

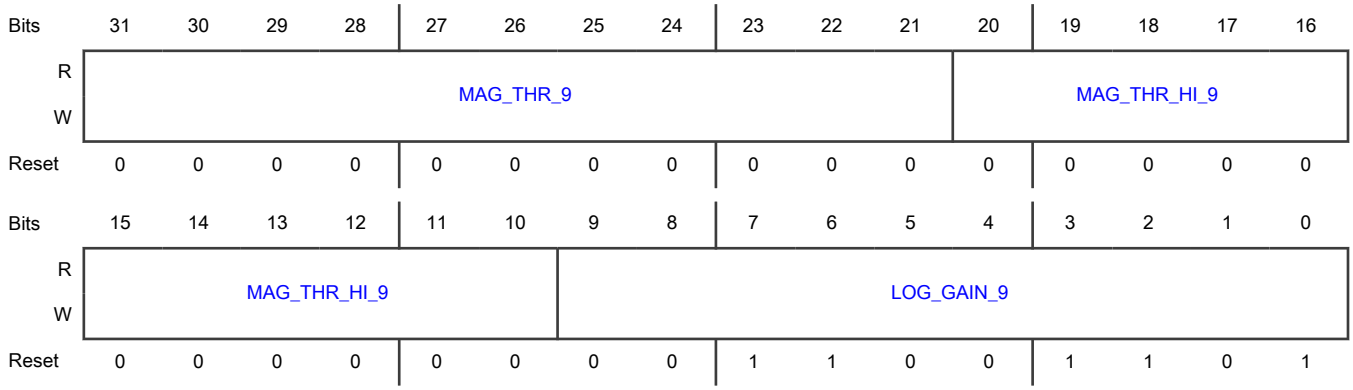
Offset

Register	Offset
AGC_IDX9_GAIN_VAL	ECh

Function

AGC_IDXn_GAIN_VAL(where n can be 11~0) registers store the analog gain values during AGC_GAIN_IDX=n. These values using for WB-RSSI and NB-RSSI calculation and also can be used by PHY or software.

Diagram



Fields

Field	Function
31-21 MAG_THR_9	Magnitude threshold for AGC gain index 9
20-10 MAG_THR_HI_9	Magnitude threshold high for AGC gain index 9
9-0 LOG_GAIN_9	LOG_GAIN_9 LOG_GAIN_n represent the logarithmic gain values store in s7.2 format.

52.4.4.2.2.2.5.1.62 AGC_IDX8_GAIN_VAL (AGC_IDX8_GAIN_VAL)

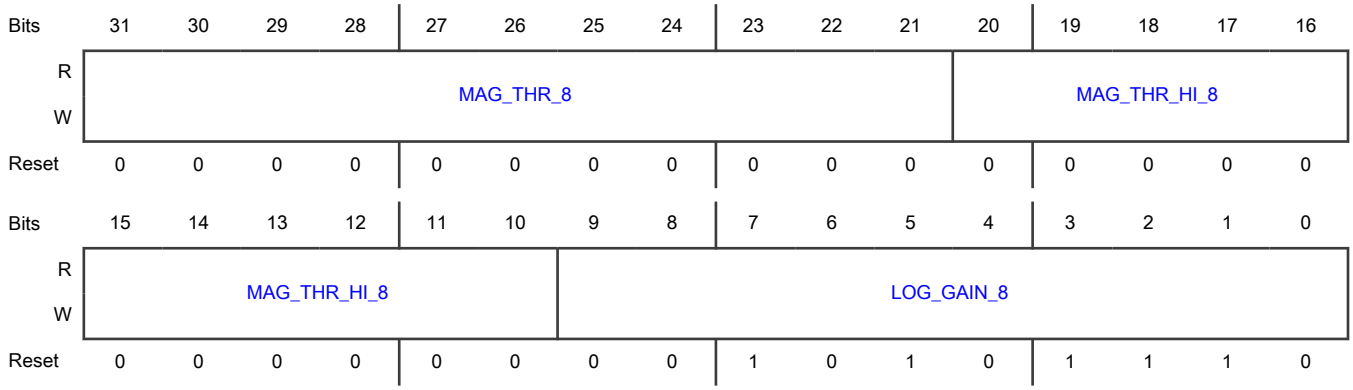
Offset

Register	Offset
AGC_IDX8_GAIN_VAL	F0h

Function

AGC_IDXn_GAIN_VAL(where n can be 11~0) registers store the analog gain values during AGC_GAIN_IDX=n. These values using for WB-RSSI and NB-RSSI calculation and also can be used by PHY or software.

Diagram



Fields

Field	Function
31-21 MAG_THR_8	Magnitude threshold for AGC gain index 8
20-10 MAG_THR_HI_8	Magnitude threshold high for AGC gain index 8
9-0 LOG_GAIN_8	LOG_GAIN_8 LOG_GAIN_n represent the logarithmic gain values store in s7.2 format.

52.4.4.2.2.2.5.1.63 AGC_IDX7_GAIN_VAL (AGC_IDX7_GAIN_VAL)

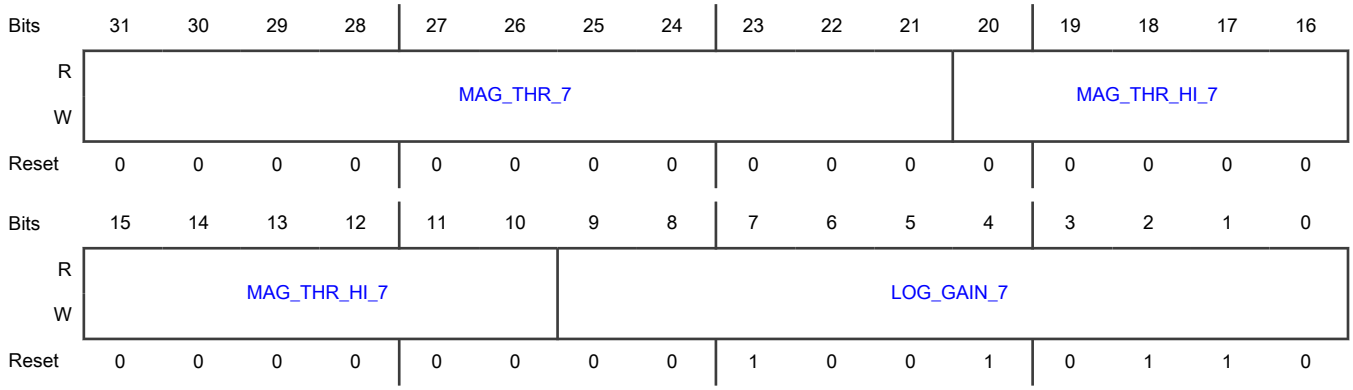
Offset

Register	Offset
AGC_IDX7_GAIN_VAL	F4h

Function

AGC_IDXn_GAIN_VAL(where n can be 11~0) registers store the analog gain values during AGC_GAIN_IDX=n. These values using for WB-RSSI and NB-RSSI calculation and also can be used by PHY or software.

Diagram



Fields

Field	Function
31-21 MAG_THR_7	Magnitude threshold for AGC gain index 7
20-10 MAG_THR_HI_7	Magnitude threshold high for AGC gain index 7
9-0 LOG_GAIN_7	LOG_GAIN_7 LOG_GAIN_n represent the logarithmic gain values store in s7.2 format.

52.4.4.2.2.2.5.1.64 AGC_IDX6_GAIN_VAL (AGC_IDX6_GAIN_VAL)

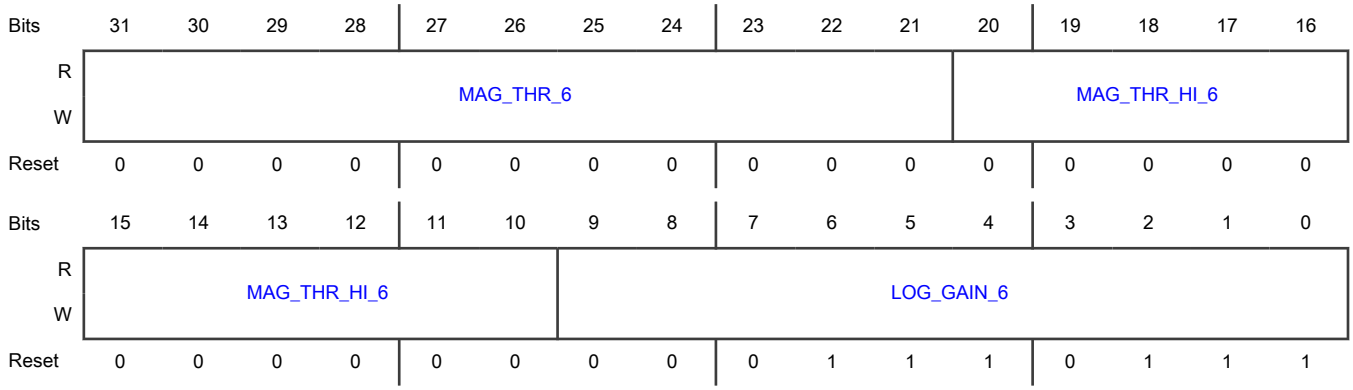
Offset

Register	Offset
AGC_IDX6_GAIN_VAL	F8h

Function

AGC_IDXn_GAIN_VAL(where n can be 11~0) registers store the analog gain values during AGC_GAIN_IDX=n. These values using for WB-RSSI and NB-RSSI calculation and also can be used by PHY or software.

Diagram



Fields

Field	Function
31-21 MAG_THR_6	Magnitude threshold for AGC gain index 6
20-10 MAG_THR_HI_6	Magnitude threshold high for AGC gain index 6
9-0 LOG_GAIN_6	LOG_GAIN_6 LOG_GAIN_n represent the logarithmic gain values store in s7.2 format.

52.4.4.2.2.2.5.1.65 AGC_IDX5_GAIN_VAL (AGC_IDX5_GAIN_VAL)

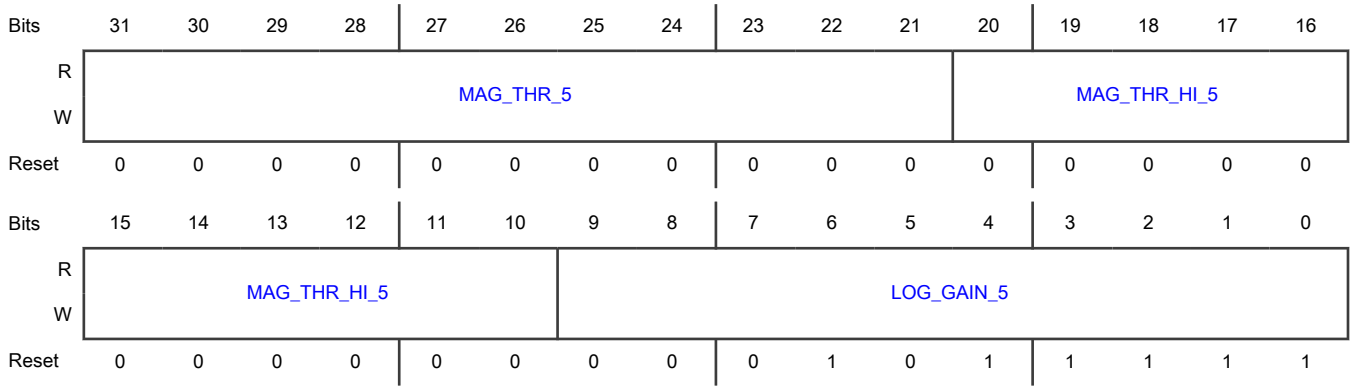
Offset

Register	Offset
AGC_IDX5_GAIN_VAL	FCh

Function

AGC_IDXn_GAIN_VAL(where n can be 11~0) registers store the analog gain values during AGC_GAIN_IDX=n. These values using for WB-RSSI and NB-RSSI calculation and also can be used by PHY or software.

Diagram



Fields

Field	Function
31-21 MAG_THR_5	Magnitude threshold for AGC gain index 5
20-10 MAG_THR_HI_5	Magnitude threshold high for AGC gain index 5
9-0 LOG_GAIN_5	LOG_GAIN_5 LOG_GAIN_n represent the logarithmic gain values store in s7.2 format.

52.4.4.2.2.2.5.1.66 AGC_IDX4_GAIN_VAL (AGC_IDX4_GAIN_VAL)

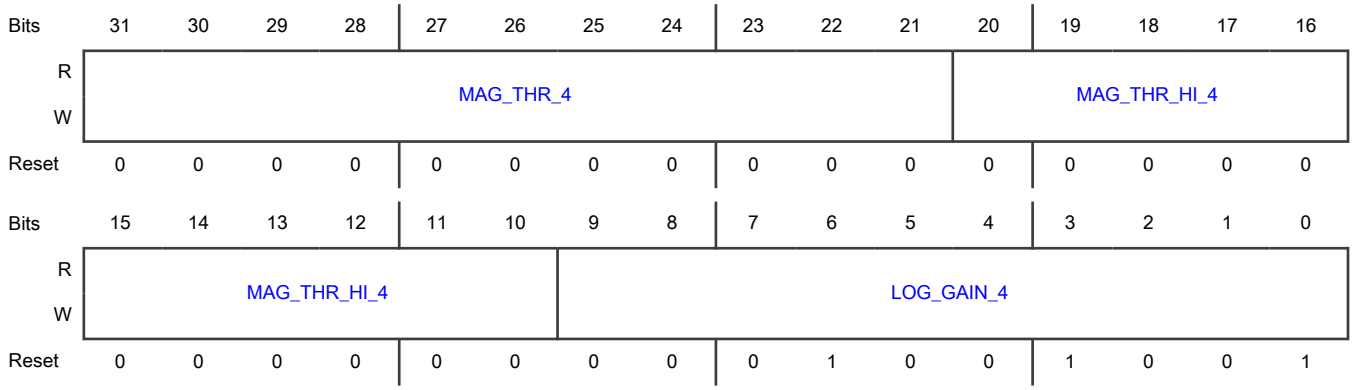
Offset

Register	Offset
AGC_IDX4_GAIN_VAL	100h

Function

AGC_IDXn_GAIN_VAL(where n can be 11~0) registers store the analog gain values during AGC_GAIN_IDX=n. These values using for WB-RSSI and NB-RSSI calculation and also can be used by PHY or software.

Diagram



Fields

Field	Function
31-21 MAG_THR_4	Magnitude threshold for AGC gain index 4
20-10 MAG_THR_HI_4	Magnitude threshold high for AGC gain index 4
9-0 LOG_GAIN_4	LOG_GAIN_4 LOG_GAIN_n represent the logarithmic gain values store in s7.2 format.

52.4.4.2.2.2.5.1.67 AGC_IDX3_GAIN_VAL (AGC_IDX3_GAIN_VAL)

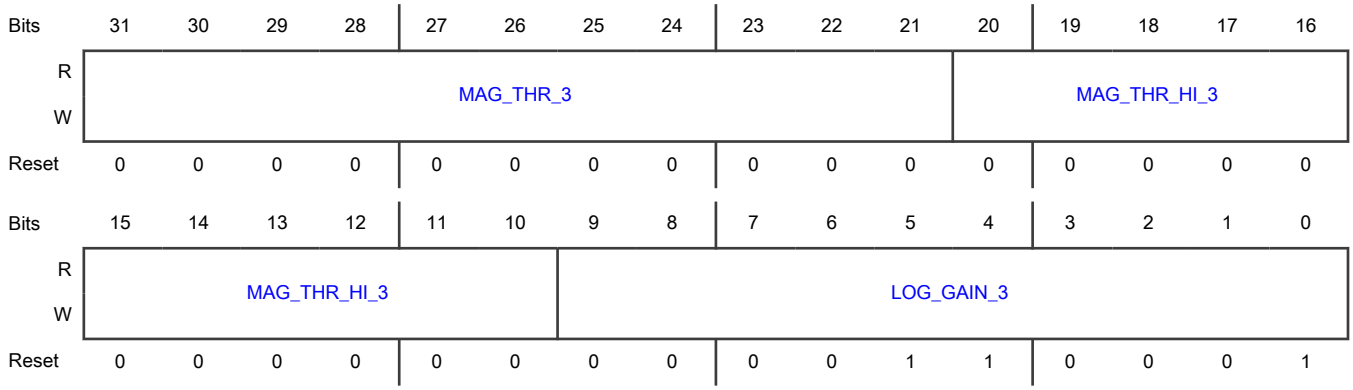
Offset

Register	Offset
AGC_IDX3_GAIN_VAL	104h

Function

AGC_IDXn_GAIN_VAL(where n can be 11~0) registers store the analog gain values during AGC_GAIN_IDX=n. These values using for WB-RSSI and NB-RSSI calculation and also can be used by PHY or software.

Diagram



Fields

Field	Function
31-21 MAG_THR_3	Magnitude threshold for AGC gain index 3
20-10 MAG_THR_HI_3	Magnitude threshold high for AGC gain index 3
9-0 LOG_GAIN_3	LOG_GAIN_3 LOG_GAIN_n represent the logarithmic gain values store in s7.2 format.

52.4.4.2.2.2.5.1.68 AGC_IDX2_GAIN_VAL (AGC_IDX2_GAIN_VAL)

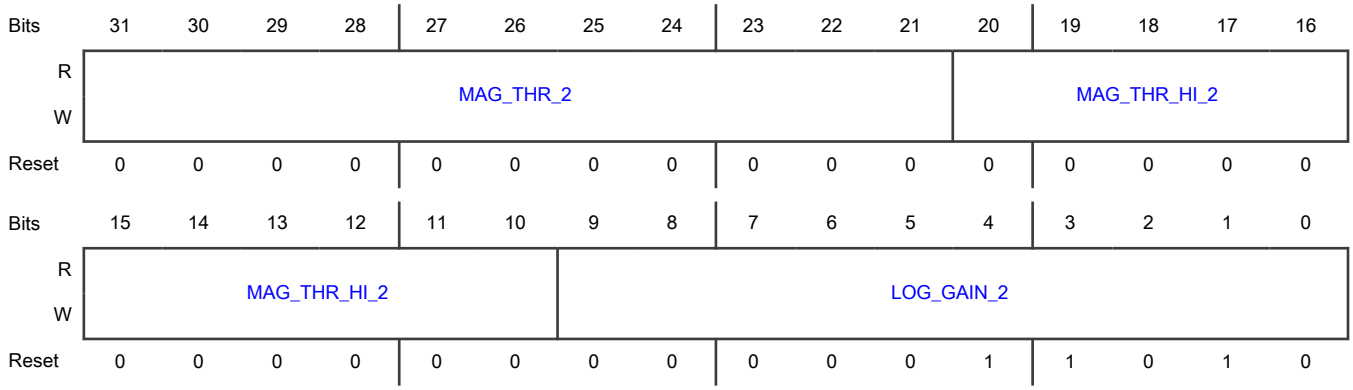
Offset

Register	Offset
AGC_IDX2_GAIN_VAL	108h

Function

AGC_IDXn_GAIN_VAL(where n can be 11~0) registers store the analog gain values during AGC_GAIN_IDX=n. These values using for WB-RSSI and NB-RSSI calculation and also can be used by PHY or software.

Diagram



Fields

Field	Function
31-21 MAG_THR_2	Magnitude threshold for AGC gain index 2
20-10 MAG_THR_HI_2	Magnitude threshold high for AGC gain index 2
9-0 LOG_GAIN_2	LOG_GAIN_2 LOG_GAIN_n represent the logarithmic gain values store in s7.2 format.

52.4.4.2.2.2.5.1.69 AGC_IDX1_GAIN_VAL (AGC_IDX1_GAIN_VAL)

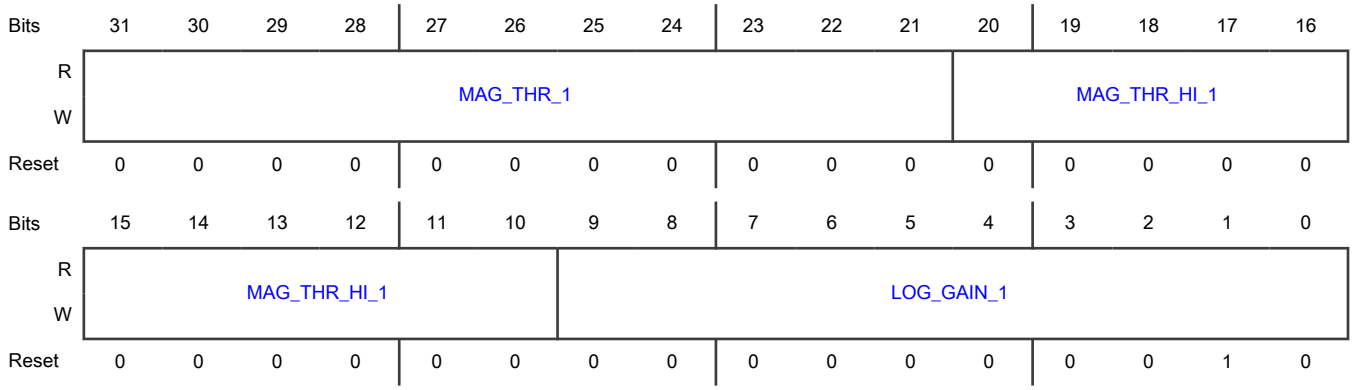
Offset

Register	Offset
AGC_IDX1_GAIN_VAL	10Ch

Function

AGC_IDXn_GAIN_VAL(where n can be 11~0) registers store the analog gain values during AGC_GAIN_IDX=n. These values using for WB-RSSI and NB-RSSI calculation and also can be used by PHY or software.

Diagram



Fields

Field	Function
31-21 MAG_THR_1	Magnitude threshold for AGC gain index 1
20-10 MAG_THR_HI_1	Magnitude threshold high for AGC gain index 1
9-0 LOG_GAIN_1	LOG_GAIN_1 LOG_GAIN_n represent the logarithmic gain values store in s7.2 format.

52.4.4.2.2.2.5.1.70 AGC_IDX0_GAIN_VAL (AGC_IDX0_GAIN_VAL)

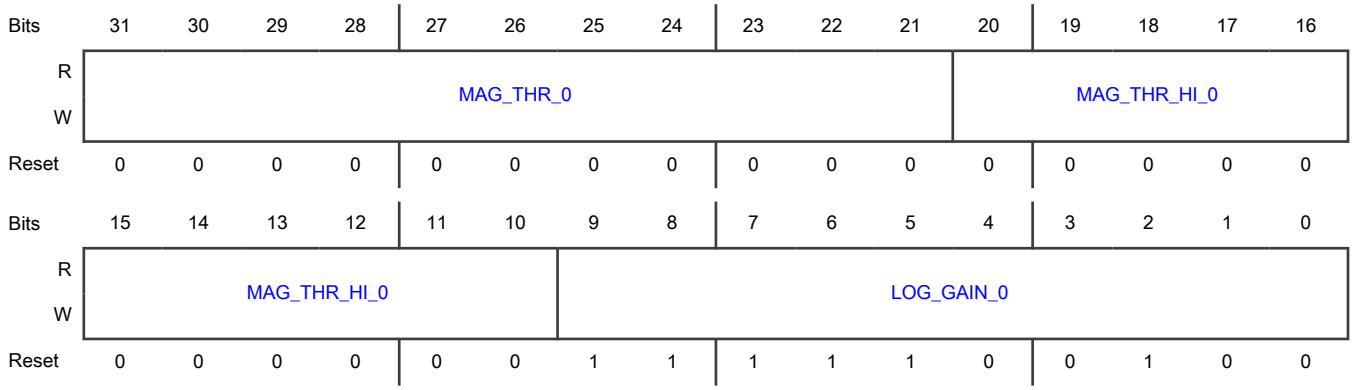
Offset

Register	Offset
AGC_IDX0_GAIN_VAL	110h

Function

AGC_IDXn_GAIN_VAL(where n can be 11~0) registers store the analog gain values during AGC_GAIN_IDX=n. These values using for WB-RSSI and NB-RSSI calculation and also can be used by PHY or software.

Diagram



Fields

Field	Function
31-21 MAG_THR_0	Magnitude threshold for AGC gain index 0
20-10 MAG_THR_HI_0	Magnitude threshold high for AGC gain index 0
9-0 LOG_GAIN_0	LOG_GAIN_0 LOG_GAIN_n represent the logarithmic gain values store in s7.2 format.

52.4.4.2.2.2.5.1.71 AGC Fast Mode Threshold (AGC_THR_FAST)

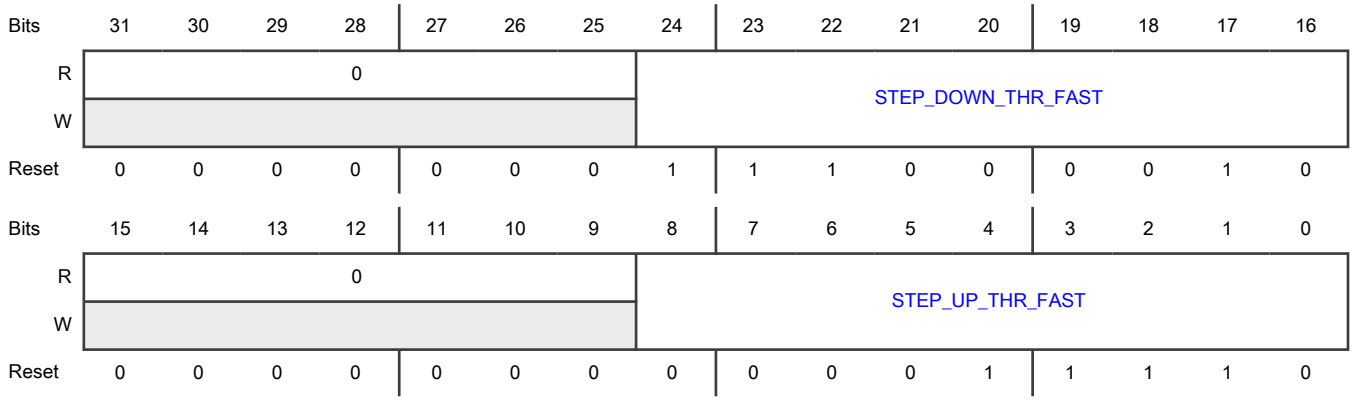
Offset

Register	Offset
AGC_THR_FAST	114h

Function

The threshold for FAST_MAG mode. NOTE: All gain index share the same FAST_MAG mode threshold value.

Diagram



Fields

Field	Function
31-25 —	Reserved
24-16 STEP_DOWN_THR_FAST	Fast mode step down thresholds
15-9 —	Reserved
8-0 STEP_UP_THR_FAST	Fast mode step up thresholds

52.4.4.2.2.2.5.1.72 AGC Fast Mode Threshold DRS (AGC_THR_FAST_DRS)

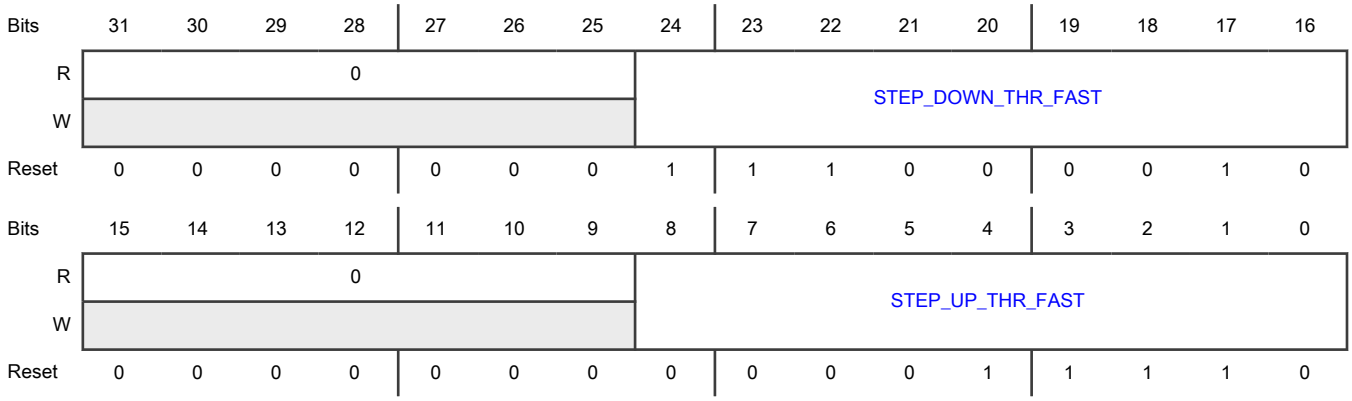
Offset

Register	Offset
AGC_THR_FAST_DRS	118h

Function

AGC_THR_FAST for datarate_config_sel=1

Diagram



Fields

Field	Function
31-25 —	Reserved
24-16 STEP_DOWN_THR_FAST	Fast mode step down thresholds for datarate_config_sel = 1
15-9 —	Reserved
8-0 STEP_UP_THR_FAST	Fast mode step up thresholds for datarate_config_sel = 1

52.4.4.2.2.2.5.1.73 AGC IDX11 Slow Mode Threshold (AGC_IDX11_THR)

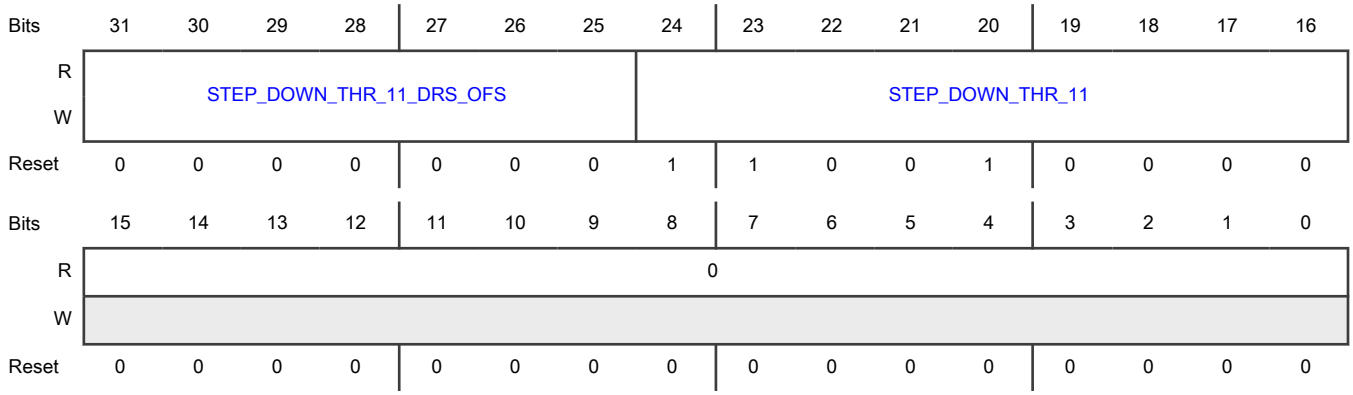
Offset

Register	Offset
AGC_IDX11_THR	11Ch

Function

AGC_IDXn_THR registers store the threshold values for AGC slow mode. Each AGC gain index has it's own step down and step up threshold. When slow_mag > STEP_DOWN_THR, AGC will decrease the gain index. When slow_mag < STEP_UP_THR, AGC will increase the gain index. NOTE: There's no STEP_UP_THR for gain index 11 and no STEP_DOWN_THR for gain index 0.

Diagram



Fields

Field	Function
31-25 STEP_DOWN_THR_11_DRS_OFS	STEP_DOWN_THR_11 DRS Offset When datarate_sel=1, the actual slow mode step down threshold in gain idx 11 is "STEP_DOWN_THR_11 + STEP_DOWN_THR_11_DRS_OFS". NOTE: 1. "STEP_DOWN_THR_*_DRS_OFS" is a signed value. 2. the "STEP_DOWN_THR_* + STEP_DOWN_THR_*_DRS_OFS".should in the range of 0 to 511.
24-16 STEP_DOWN_THR_11	STEP_DOWN_THR_11 When current AGC_GAIN_IDX=n, if slow_mag > STEP_DOWN_THR_n, AGC will decrease the gain index.
15-0 —	Reserved

52.4.4.2.2.2.5.1.74 AGC IDX10 Slow Mode Threshold (AGC_IDX10_THR)

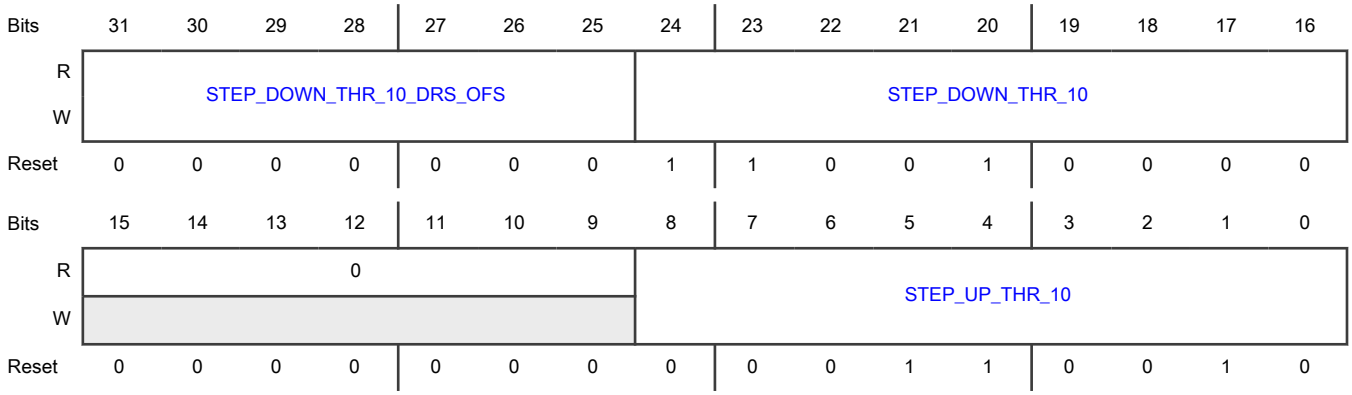
Offset

Register	Offset
AGC_IDX10_THR	120h

Function

See AGC_IDX11_THR for more information.

Diagram



Fields

Field	Function
31-25 STEP_DOWN_THR_10_DRS_OFS	STEP_DOWN_THR_10 DRS Offset When datarate_sel=1, the actual slow mode step down threshold in gain idx 10 is "STEP_DOWN_THR_10 + STEP_DOWN_THR_10_DRS_OFS" NOTE: 1. "STEP_DOWN_THR_*_DRS_OFS" is a signed value. 2. the "STEP_DOWN_THR_* + STEP_DOWN_THR_*_DRS_OFS".should in the range of 0 to 511.
24-16 STEP_DOWN_THR_10	STEP_DOWN_THR_10 When current AGC_GAIN_IDX=n, if slow_mag > STEP_DOWN_THR_n, AGC will decrease the gain index.
15-9 —	Reserved
8-0 STEP_UP_THR_10	STEP_UP_THR_10 When current AGC_GAIN_IDX=n, if slow_mag < STEP_UP_THR_n, AGC will increase the gain index.

52.4.4.2.2.2.5.1.75 AGC IDX9 Slow Mode Threshold (AGC_IDX9_THR)

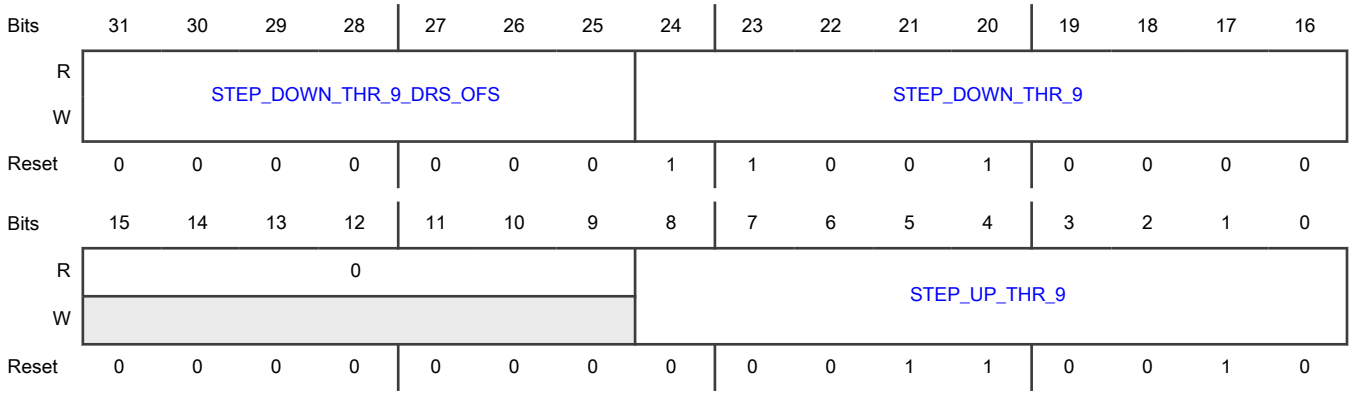
Offset

Register	Offset
AGC_IDX9_THR	124h

Function

AGC_IDXn_THR registers store the threshold values for AGC slow mode. Each AGC gain index has it's own step down and step up threshold. NOTE: There's no STEP_UP_THR for gain index 11 and no STEP_DOWN_THR for gain index 0.

Diagram



Fields

Field	Function
31-25 STEP_DOWN_THR_9_DRS_OFS	STEP_DOWN_THR_9 DRS Offset When datarate_sel=1, the actual slow mode step down threshold in gain idx 9 is "STEP_DOWN_THR_9 + STEP_DOWN_THR_9_DRS_OFS" NOTE: 1. "STEP_DOWN_THR_*_DRS_OFS" is a signed value. 2. the "STEP_DOWN_THR_* + STEP_DOWN_THR_*_DRS_OFS".should in the range of 0 to 511.
24-16 STEP_DOWN_THR_9	STEP_DOWN_THR_9 When current AGC_GAIN_IDX=n, if slow_mag > STEP_DOWN_THR_n, AGC will decrease the gain index.
15-9 —	Reserved
8-0 STEP_UP_THR_9	STEP_UP_THR_9 When current AGC_GAIN_IDX=n, if slow_mag < STEP_UP_THR_n, AGC will increase the gain index.

52.4.4.2.2.2.5.1.76 AGC IDX8 Slow Mode Threshold (AGC_IDX8_THR)

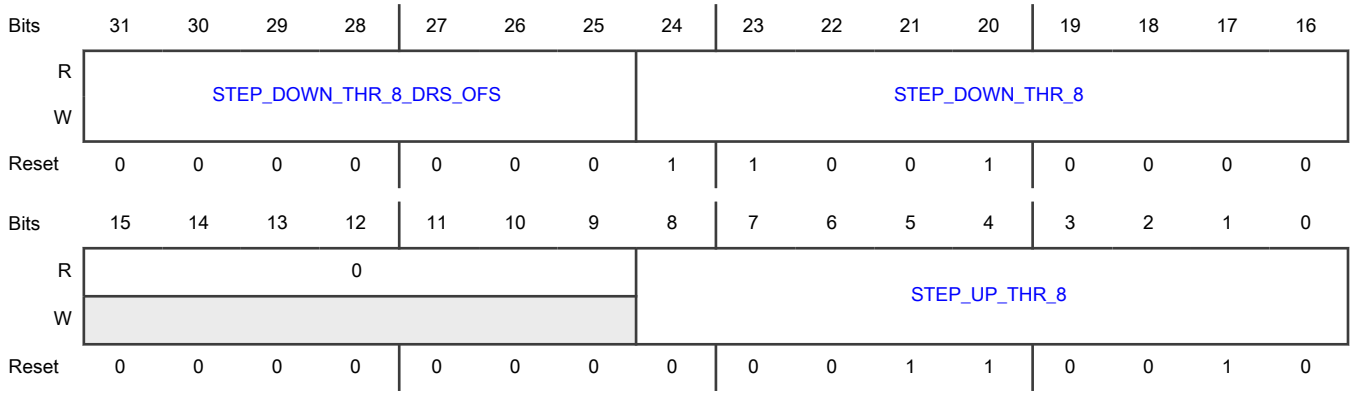
Offset

Register	Offset
AGC_IDX8_THR	128h

Function

AGC_IDXn_THR registers store the threshold values for AGC slow mode. Each AGC gain index has it's own step down and step up threshold. NOTE: There's no STEP_UP_THR for gain index 11 and no STEP_DOWN_THR for gain index 0.

Diagram



Fields

Field	Function
31-25 STEP_DOWN_THR_8_DRS_OFS	STEP_DOWN_THR_8 DRS Offset When datarate_sel=1, the actual slow mode step down threshold in gain idx 8 is "STEP_DOWN_THR_8 + STEP_DOWN_THR_8_DRS_OFS" NOTE: 1. "STEP_DOWN_THR_*_DRS_OFS" is a signed value. 2. the "STEP_DOWN_THR_* + STEP_DOWN_THR_*_DRS_OFS".should in the range of 0 to 511.
24-16 STEP_DOWN_THR_8	STEP_DOWN_THR_8 When current AGC_GAIN_IDX=n, if slow_mag > STEP_DOWN_THR_n, AGC will decrease the gain index.
15-9 —	Reserved
8-0 STEP_UP_THR_8	STEP_UP_THR_8 When current AGC_GAIN_IDX=n, if slow_mag < STEP_UP_THR_n, AGC will increase the gain index.

52.4.4.2.2.2.5.1.77 AGC IDX7 Slow Mode Threshold (AGC_IDX7_THR)

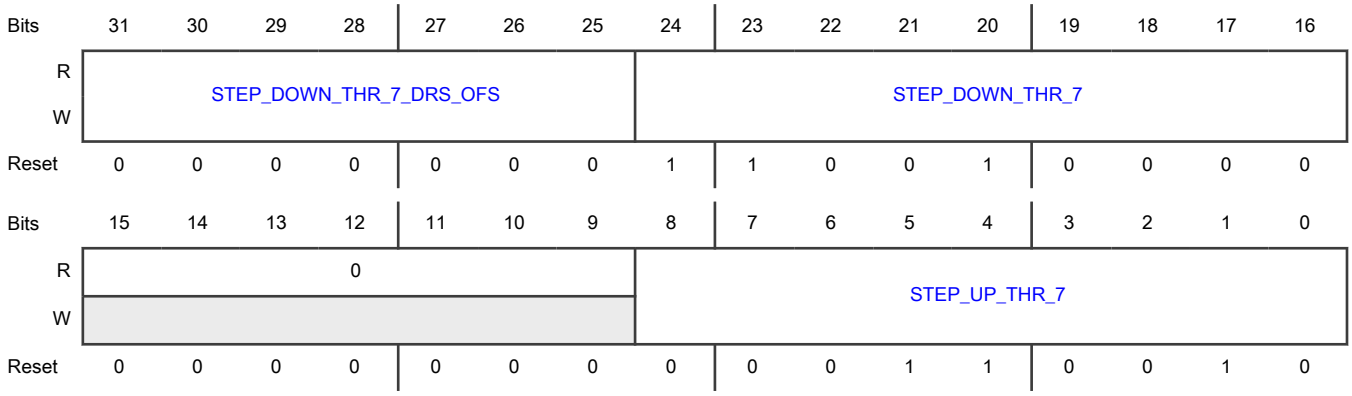
Offset

Register	Offset
AGC_IDX7_THR	12Ch

Function

AGC_IDXn_THR registers store the threshold values for AGC slow mode. Each AGC gain index has it's own step down and step up threshold. NOTE: There's no STEP_UP_THR for gain index 11 and no STEP_DOWN_THR for gain index 0.

Diagram



Fields

Field	Function
31-25 STEP_DOWN_THR_7_DRS_OFS	STEP_DOWN_THR_7 DRS Offset When datarate_sel=1, the actual slow mode step down threshold in gain idx 7 is "STEP_DOWN_THR_7 + STEP_DOWN_THR_7_DRS_OFS" NOTE: 1. "STEP_DOWN_THR_*_DRS_OFS" is a signed value. 2. the "STEP_DOWN_THR_* + STEP_DOWN_THR_*_DRS_OFS".should in the range of 0 to 511.
24-16 STEP_DOWN_THR_7	STEP_DOWN_THR_7 When current AGC_GAIN_IDX=n, if slow_mag > STEP_DOWN_THR_n, AGC will decrease the gain index.
15-9 —	Reserved
8-0 STEP_UP_THR_7	STEP_UP_THR_7 When current AGC_GAIN_IDX=n, if slow_mag < STEP_UP_THR_n, AGC will increase the gain index.

52.4.4.2.2.2.5.1.78 AGC IDX6 Slow Mode Threshold (AGC_IDX6_THR)

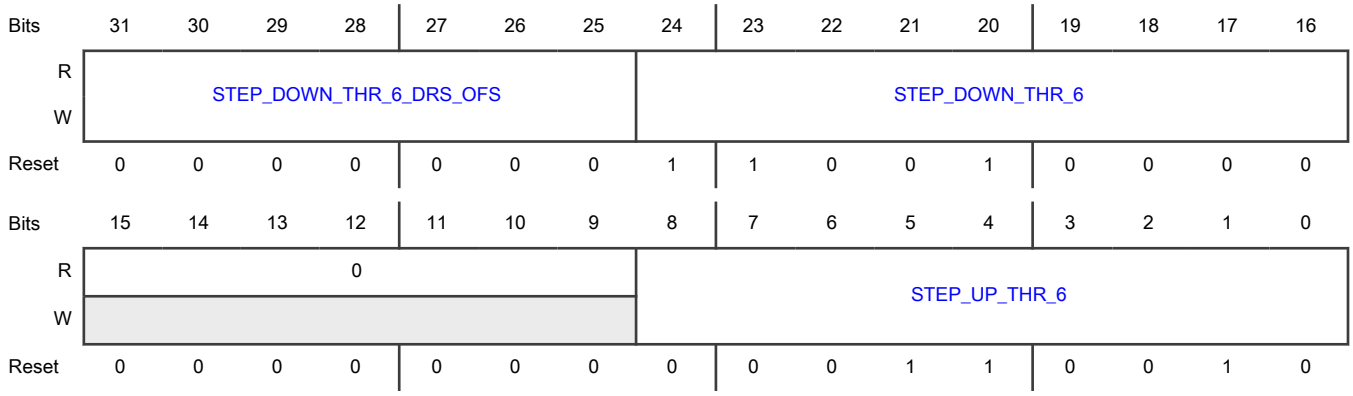
Offset

Register	Offset
AGC_IDX6_THR	130h

Function

AGC_IDXn_THR registers store the threshold values for AGC slow mode. Each AGC gain index has it's own step down and step up threshold. NOTE: There's no STEP_UP_THR for gain index 11 and no STEP_DOWN_THR for gain index 0.

Diagram



Fields

Field	Function
31-25 STEP_DOWN_THR_6_DRS_OFS	STEP_DOWN_THR_6 DRS Offset When datarate_sel=1, the actual slow mode step down threshold in gain idx 6 is "STEP_DOWN_THR_6 + STEP_DOWN_THR_6_DRS_OFS" NOTE: 1. "STEP_DOWN_THR_*_DRS_OFS" is a signed value. 2. the "STEP_DOWN_THR_* + STEP_DOWN_THR_*_DRS_OFS".should in the range of 0 to 511.
24-16 STEP_DOWN_THR_6	STEP_DOWN_THR_6 When current AGC_GAIN_IDX=n, if slow_mag > STEP_DOWN_THR_n, AGC will decrease the gain index.
15-9 —	Reserved
8-0 STEP_UP_THR_6	STEP_UP_THR_6 When current AGC_GAIN_IDX=n, if slow_mag < STEP_UP_THR_n, AGC will increase the gain index.

52.4.4.2.2.2.5.1.79 AGC IDX5 Slow Mode Threshold (AGC_IDX5_THR)

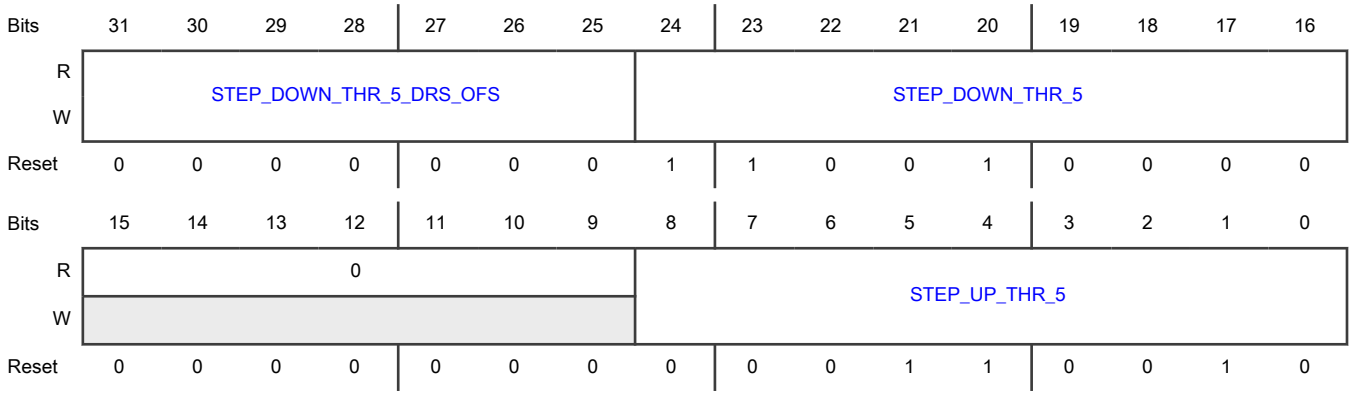
Offset

Register	Offset
AGC_IDX5_THR	134h

Function

AGC_IDXn_THR registers store the threshold values for AGC slow mode. Each AGC gain index has it's own step down and step up threshold. NOTE: There's no STEP_UP_THR for gain index 11 and no STEP_DOWN_THR for gain index 0.

Diagram



Fields

Field	Function
31-25 STEP_DOWN_THR_5_DRS_OFS	STEP_DOWN_THR_5 DRS Offset When datarate_sel=1, the actual slow mode step down threshold in gain idx 5 is "STEP_DOWN_THR_5 + STEP_DOWN_THR_5_DRS_OFS" NOTE: 1. "STEP_DOWN_THR_*_DRS_OFS" is a signed value. 2. the "STEP_DOWN_THR_* + STEP_DOWN_THR_*_DRS_OFS".should in the range of 0 to 511.
24-16 STEP_DOWN_THR_5	STEP_DOWN_THR_5 When current AGC_GAIN_IDX=n, if slow_mag > STEP_DOWN_THR_n, AGC will decrease the gain index.
15-9 —	Reserved
8-0 STEP_UP_THR_5	STEP_UP_THR_5 When current AGC_GAIN_IDX=n, if slow_mag < STEP_UP_THR_n, AGC will increase the gain index.

52.4.4.2.2.2.5.1.80 AGC IDX4 Slow Mode Threshold (AGC_IDX4_THR)

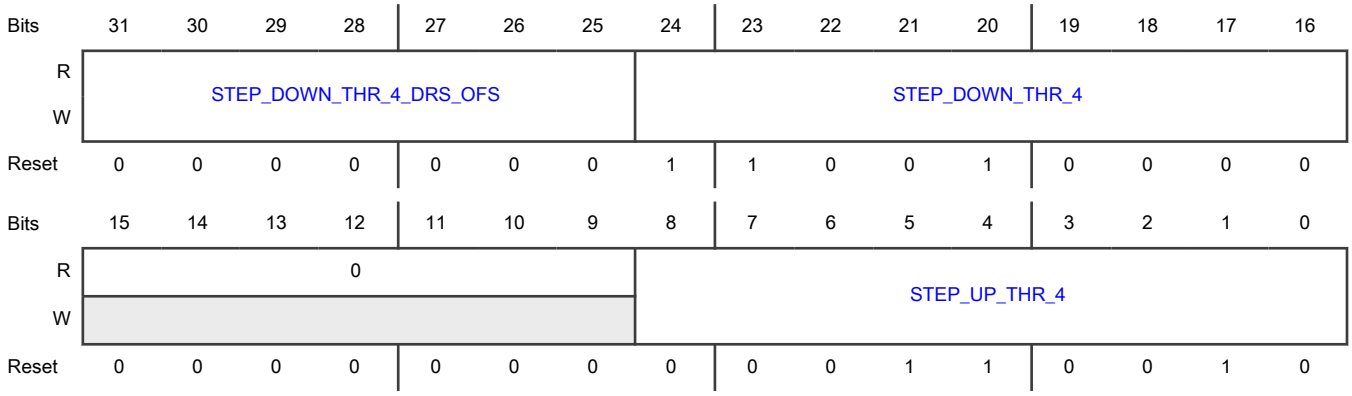
Offset

Register	Offset
AGC_IDX4_THR	138h

Function

AGC_IDXn_THR registers store the threshold values for AGC slow mode. Each AGC gain index has it's own step down and step up threshold. NOTE: There's no STEP_UP_THR for gain index 11 and no STEP_DOWN_THR for gain index 0.

Diagram



Fields

Field	Function
31-25 STEP_DOWN_THR_4_DRS_OFS	STEP_DOWN_THR_4 DRS Offset When datarate_sel=1, the actual slow mode step down threshold in gain idx 4 is "STEP_DOWN_THR_4 + STEP_DOWN_THR_4_DRS_OFS" NOTE: 1. "STEP_DOWN_THR_*_DRS_OFS" is a signed value. 2. the "STEP_DOWN_THR_* + STEP_DOWN_THR_*_DRS_OFS".should in the range of 0 to 511.
24-16 STEP_DOWN_THR_4	STEP_DOWN_THR_4 When current AGC_GAIN_IDX=n, if slow_mag > STEP_DOWN_THR_n, AGC will decrease the gain index.
15-9 —	Reserved
8-0 STEP_UP_THR_4	STEP_UP_THR_4 When current AGC_GAIN_IDX=n, if slow_mag < STEP_UP_THR_n, AGC will increase the gain index.

52.4.4.2.2.2.5.1.81 AGC IDX3 Slow Mode Threshold (AGC_IDX3_THR)

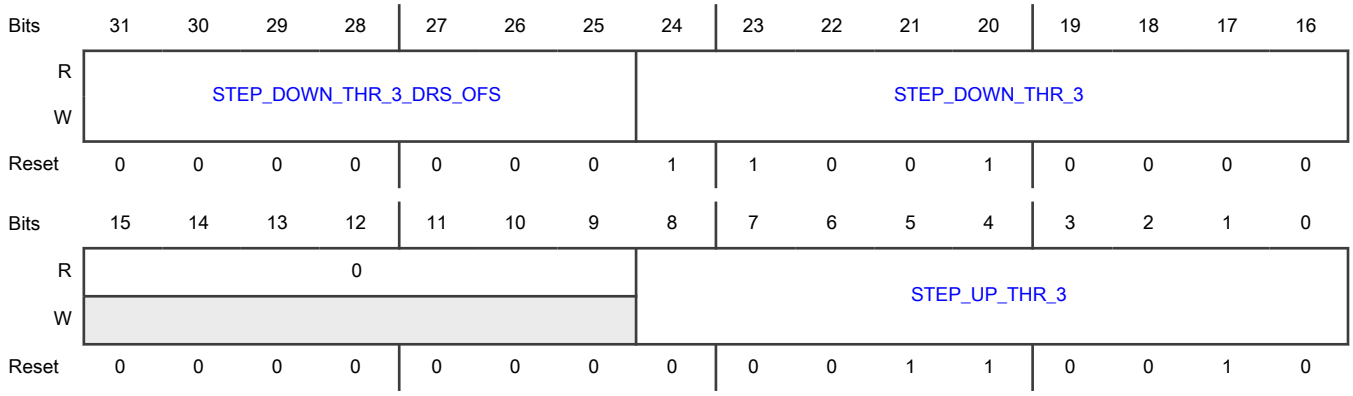
Offset

Register	Offset
AGC_IDX3_THR	13Ch

Function

AGC_IDXn_THR registers store the threshold values for AGC slow mode. Each AGC gain index has it's own step down and step up threshold. NOTE: There's no STEP_UP_THR for gain index 11 and no STEP_DOWN_THR for gain index 0.

Diagram



Fields

Field	Function
31-25 STEP_DOWN_THR_3_DRS_OFS	STEP_DOWN_THR_3 DRS Offset When datarate_sel=1, the actual slow mode step down threshold in gain idx 3 is "STEP_DOWN_THR_3 + STEP_DOWN_THR_3_DRS_OFS" NOTE: 1. "STEP_DOWN_THR_*_DRS_OFS" is a signed value. 2. the "STEP_DOWN_THR_* + STEP_DOWN_THR_*_DRS_OFS".should in the range of 0 to 511.
24-16 STEP_DOWN_THR_3	STEP_DOWN_THR_3 When current AGC_GAIN_IDX=n, if slow_mag > STEP_DOWN_THR_n, AGC will decrease the gain index.
15-9 —	Reserved
8-0 STEP_UP_THR_3	STEP_UP_THR_3 When current AGC_GAIN_IDX=n, if slow_mag < STEP_UP_THR_n, AGC will increase the gain index.

52.4.4.2.2.2.5.1.82 AGC IDX2 Slow Mode Threshold (AGC_IDX2_THR)

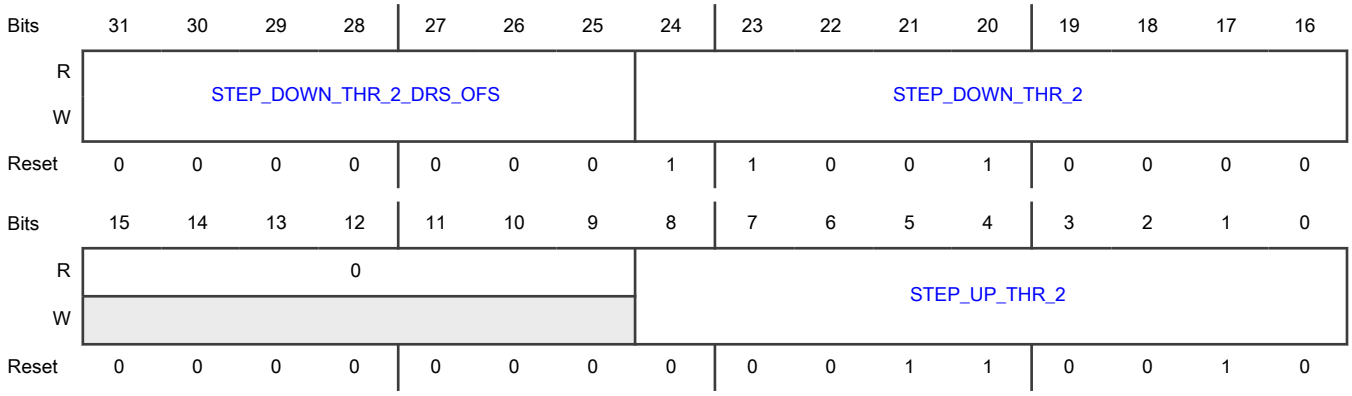
Offset

Register	Offset
AGC_IDX2_THR	140h

Function

AGC_IDXn_THR registers store the threshold values for AGC slow mode. Each AGC gain index has it's own step down and step up threshold. NOTE: There's no STEP_UP_THR for gain index 11 and no STEP_DOWN_THR for gain index 0.

Diagram



Fields

Field	Function
31-25 STEP_DOWN_THR_2_DRS_OFS	STEP_DOWN_THR_2 DRS Offset When datarate_sel=1, the actual slow mode step down threshold in gain idx 2 is "STEP_DOWN_THR_2 + STEP_DOWN_THR_2_DRS_OFS" NOTE: 1. "STEP_DOWN_THR_*_DRS_OFS" is a signed value. 2. the "STEP_DOWN_THR_* + STEP_DOWN_THR_*_DRS_OFS".should in the range of 0 to 511.
24-16 STEP_DOWN_THR_2	STEP_DOWN_THR_2 When current AGC_GAIN_IDX=n, if slow_mag > STEP_DOWN_THR_n, AGC will decrease the gain index.
15-9 —	Reserved
8-0 STEP_UP_THR_2	STEP_UP_THR_2 When current AGC_GAIN_IDX=n, if slow_mag < STEP_UP_THR_n, AGC will increase the gain index.

52.4.4.2.2.2.5.1.83 AGC IDX1 Slow Mode Threshold (AGC_IDX1_THR)

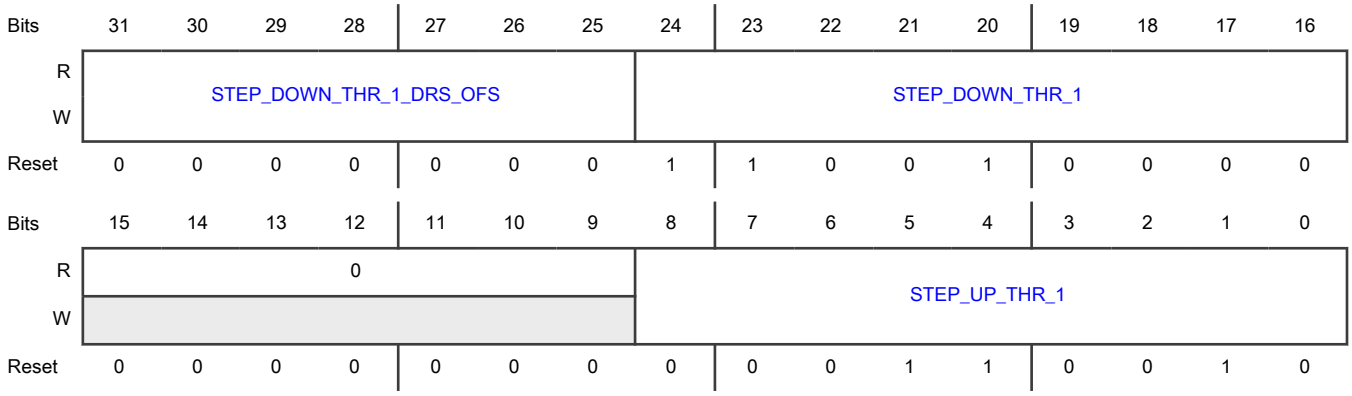
Offset

Register	Offset
AGC_IDX1_THR	144h

Function

AGC_IDXn_THR registers store the threshold values for AGC slow mode. Each AGC gain index has it's own step down and step up threshold. NOTE: There's no STEP_UP_THR for gain index 11 and no STEP_DOWN_THR for gain index 0.

Diagram



Fields

Field	Function
31-25 STEP_DOWN_THR_1_DRS_OFS	STEP_DOWN_THR_1 DRS Offset When datarate_sel=1, the actual slow mode step down threshold in gain idx 1 is "STEP_DOWN_THR_1 + STEP_DOWN_THR_1_DRS_OFS" NOTE: 1. "STEP_DOWN_THR_*_DRS_OFS" is a signed value. 2. the "STEP_DOWN_THR_* + STEP_DOWN_THR_*_DRS_OFS".should in the range of 0 to 511.
24-16 STEP_DOWN_THR_1	STEP_DOWN_THR_1 When current AGC_GAIN_IDX=n, if slow_mag > STEP_DOWN_THR_n, AGC will decrease the gain index.
15-9 —	Reserved
8-0 STEP_UP_THR_1	STEP_UP_THR_1 When current AGC_GAIN_IDX=n, if slow_mag < STEP_UP_THR_n, AGC will increase the gain index.

52.4.4.2.2.2.5.1.84 AGC IDX0 Slow Mode Threshold (AGC_IDX0_THR)

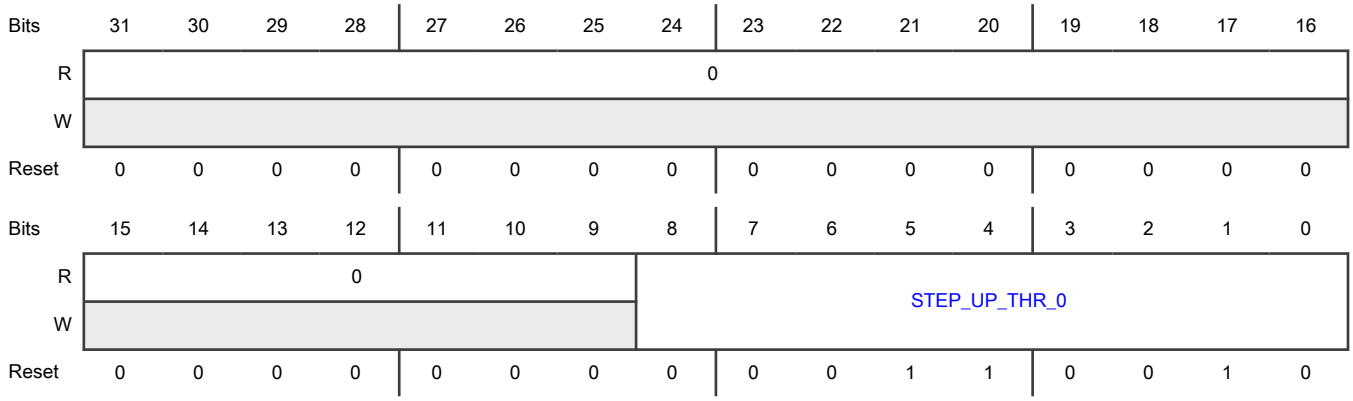
Offset

Register	Offset
AGC_IDX0_THR	148h

Function

AGC_IDXn_THR registers store the threshold values for AGC slow mode. Each AGC gain index has it's own step down and step up threshold. NOTE: There's no STEP_UP_THR for gain index 11 and no STEP_DOWN_THR for gain index 0.

Diagram



Fields

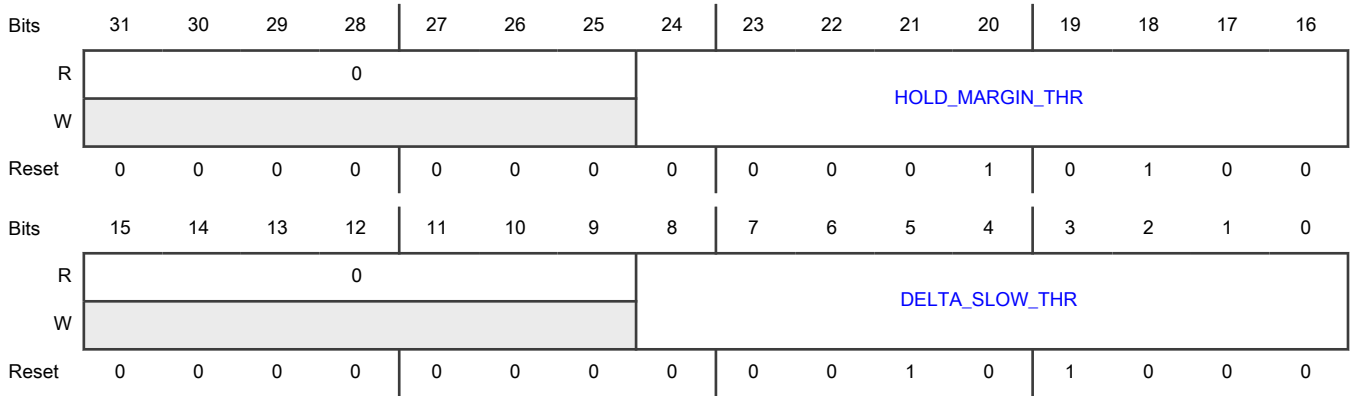
Field	Function
31-9 —	Reserved
8-0 STEP_UP_THR_0	STEP_UP_THR_0 When current AGC_GAIN_IDX=n, if slow_mag < STEP_UP_THR_n, AGC will increase the gain index.

52.4.4.2.2.2.5.1.85 AGC Miscellaneous Thresholds (AGC_THR_MIS)

Offset

Register	Offset
AGC_THR_MIS	14Ch

Diagram



Fields

Field	Function
31-25 —	Reserved
24-16 HOLD_MARGIN_THR	STEP_UP_THR_VLG2large If AGC unhold function enabled, AGC will record the last slow magnitude value(call as hold_mag) before enter into HOLD mode and continue measuring the slow magnitude. If there are two consecutive slow_mag values match the equation "abs(slow_mag-hold_mag) > HOLD_MARGIN_THR", AGC will exit HOLD mode.
15-9 —	Reserved
8-0 DELTA_SLOW_THR	STEP_UP_THR_VLG2 The threshold value for delta slow mode. Check the description of AGC_CTRL[AGC_DELTA_SLOW_EN] and AGC_CTRL[AGC_DELTA_SLOW_STEPS] for more information.

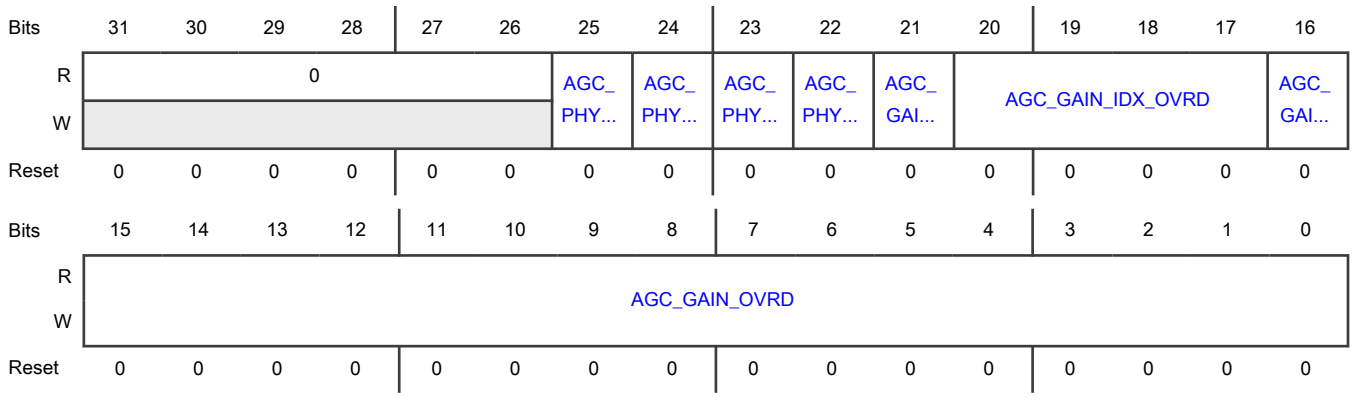
52.4.4.2.2.2.5.1.86 AGC Override Control (AGC_OVRD)

Offset

Register	Offset
AGC_OVRD	150h

Function
AGC override function control.

Diagram



Fields

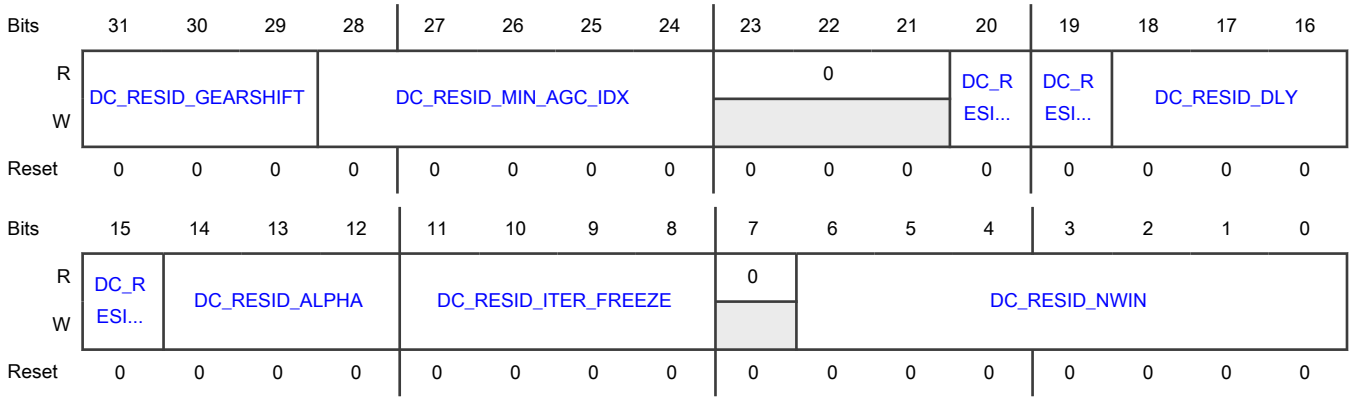
Field	Function
31-26 —	Reserved
25 AGC_PHY_FREEZE_OVRD_EN	PHY_FREEZE_TRIG signal override enable
24 AGC_PHY_FREEZE_OVRD	PHY_FREEZE_TRIG signal override value
23 AGC_PHY_HOLD_OVRD_EN	PHY_HOLD_TRIG signal override enable
22 AGC_PHY_HOLD_OVRD	PHY_HOLD_TRIG signal override value
21 AGC_GAIN_IDX_OVRD_EN	AGC gain index override enable.
20-17 AGC_GAIN_IDX_OVRD	AGC gain index override value.
16 AGC_GAIN_OVRD_EN	AGC gain config override enable
15-0 AGC_GAIN_OVRD	AGC gain config override values. NOTE: AGC Gain Override function has higher priority than AGC Gain Index override function

52.4.4.2.2.2.5.1.87 DC Residual Control (DC_RESID_CTRL)

Offset

Register	Offset
DC_RESID_CTRL	154h

Diagram



Fields

Field	Function
31-29 DC_RESID_GEARSHIFT	DC Residual Gearshift If gearshifting is enabled (DC_RESID_GS_EN = 1), the DC residual will use DC_RESID_ALPHA for DC_RESID_GEARSHIFT windows (DC_RESID_NWIN samples) then will use DC_RESID_ALPHA+1 for the remaining windows.
28-24 DC_RESID_MIN_AGC_IDX	DC Residual Minimum AGC Table Index Specifies the minimum AGC table index value at which DC residual can be enabled. E.g., if this is 5'd0, then the DC residual is enabled for all AGC gain table indexes (assuming RX_DC_RESID_EN is set) if this is 5'd20, then tracking is enabled for AGC gain table indexes 20-26 (assuming RX_DC_RESID_EN is set).
23-21 —	Reserved
20 DC_RESID_EXT_DC_EN	DC Residual External DC Enable 0b - External DC disable. The DC Residual activates at a delay specified by DC_RESID_DLY after an AGC gain change pulse. The DC Residual is initialized with a DC offset of 0. 1b - External DC enable. The DC residual activates after the DCOC's tracking hold timer expires. The DC Residual is initialized with the DC estimate from the DCOC tracking estimator.
19 DC_RESID_SECOND_RUN_EN	DC Residual Second Run Enable This bit enables additional DC residual compensation (primarily intended for Long Range) after the normal DC residual operation has completed. 0b - Second Run disabled 1b - Second Run enabled
18-16 DC_RESID_DLY	DC Residual Delay The delay from activation of the DC residual block to the time when it starts processing. For a 32MHz reference clock, the delay in microseconds matches the value programmed. For other clock frequencies,

Table continues on the next page...

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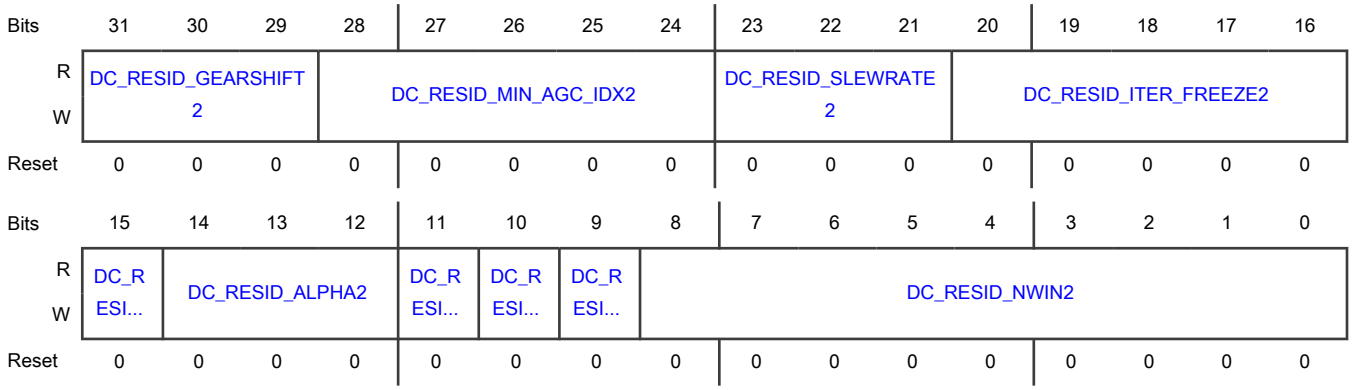
Field	Function
	the delay is scaled based on the clock period. Supported values: 0-7. This delay is only used when EXT_DC_EN=0.
15 DC_RESID_GS_EN	DC Residual Gearshift Enable Controls whether or not gearshifting is enabled. See description of DC_RESID_GEARSHIFT for more information on gearshifting. 0b - Gearshifting disabled 1b - Gearshifting enabled
14-12 DC_RESID_ALPHA	DC Residual Alpha The Alpha parameter controls the rate at which the DC estimate is updated. 000b - Update factor is 1 001b - Update factor is 1/2 010b - Update factor is 1/4 + 1/8 011b - Update factor is 1/4 100b - Update factor is 1/8 + 16 101b - Update factor is 1/8 110b - Update factor is 1/16 + 1/32 111b - Update factor is 1/16
11-8 DC_RESID_ITER_FREEZE	DC Residual Iteration Freeze Number of windows of DC_RESID_NWIN samples before the DC is frozen. Supported values: 1-8
7 —	Reserved
6-0 DC_RESID_NWIN	DC Residual NWIN Number of samples in a window.

52.4.4.2.2.2.5.1.88 DC Residual Control2 (DC_RESID_CTRL2)

Offset

Register	Offset
DC_RESID_CTRL2	158h

Diagram



Fields

Field	Function
31-29 DC_RESID_GEARSHIFT2	DC Residual Gearshift, for Second Run If gearshifting is enabled (DC_RESID_GS2_EN = 1) for Second Run, the DC residual will use DC_RESID_ALPHA2 for DC_RESID_GEARSHIFT2 windows (DC_RESID_NWIN2 samples) then will use DC_RESID_ALPHA2+1 for the remaining windows.
28-24 DC_RESID_MIN_AGC_IDX2	DC Residual Minimum AGC Table Index, for Second Run Specifies the minimum AGC table index value at which DC residual can be enabled while Second Run is active. E.g., if this is 5'd0, then the DC residual is enabled for all AGC gain table indexes (assuming RX_DC_RESID_EN is set) if this is 5'd20, then tracking is enabled for AGC gain table indexes 20-26 (assuming RX_DC_RESID_EN is set).
23-21 DC_RESID_SLEWRATE2	DC Residual Slew rate, for Second Run If Slew rate control is enabled (DC_RESID_SR2_EN = 1), changes in the DC correction will be limited to this maximum absolute value, while Second Run is active.
20-16 DC_RESID_ITER_FREEZE2	DC Residual Iteration Freeze, for Second Run Number of windows of DC_RESID_NWIN samples before the DC is frozen. This is used only when Second Run is active.
15 DC_RESID_GS2_EN	DC Residual Gearshift Enable, for Second Run Controls whether or not gearshifting is enabled for Second Run. See description of DC_RESID_GEARSHIFT2 for more information on gearshifting. 0b - Gearshifting disabled for Second Run 1b - Gearshifting enabled for Second Run
14-12 DC_RESID_ALPHA2	DC Residual Alpha, for Second Run The Alpha parameter controls the rate at which the DC estimate is updated. The update factor is shown below. This is used only when the Second Run is active. 000b - Update factor is 1

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Field	Function
	001b - Update factor is 1/2 010b - Update factor is 1/4 + 1/8 011b - Update factor is 1/4 100b - Update factor is 1/8 + 16 101b - Update factor is 1/8 110b - Update factor is 1/16 + 1/32 111b - Update factor is 1/16
11 DC_RESID_SR2_EN	DC Residual Slew rate Enable, for Second Run When DC Residual is performing Second Run, if this bit is set, then changes in the DC correction will be limited by DC_RESID_SLEWRATE after Gearshifting.
10 DC_RESID_CC_EN	DC Residual Continuous Correction Enable When DC Residual is performing Second Run, if this bit is set, then the DC_RESID_ITER_FREEZE2 will be ignored and the DC Residual will perform continuous corrections.
9 DC_RESID_PHY_STOP_EN	DC Residual PHY Stop Enable When DC Residual is performing Second Run, if this bit is set, then when the PHY's aa found uncoded signal is asserted, further DC correction updates will be stopped.
8-0 DC_RESID_NWIN2	DC Residual NWIN, for Second Run Number of samples in a window. This is used only when DC_RESID_SECOND_RUN_EN=1.

52.4.4.2.2.2.5.1.89 DC Residual Control DataRate1 (DC_RESID_CTRL_DRS)

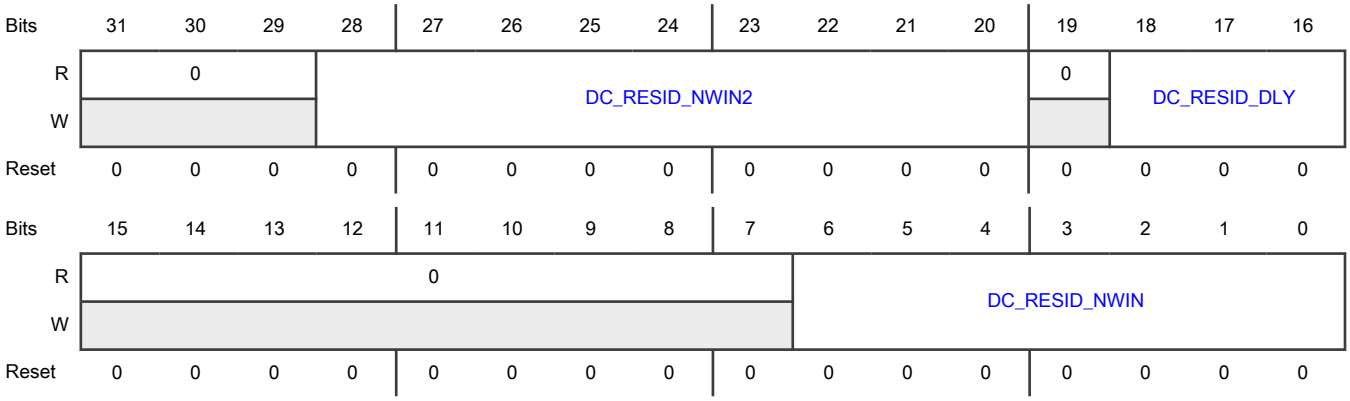
Offset

Register	Offset
DC_RESID_CTRL_DRS	15Ch

Function

The bits in the _DRS registers are only used when the Bluetooth LE signals to request a 2Mbps data rate, or the Generic LL signals using datarate_config_sel to request an alternate data rate.

Diagram



Fields

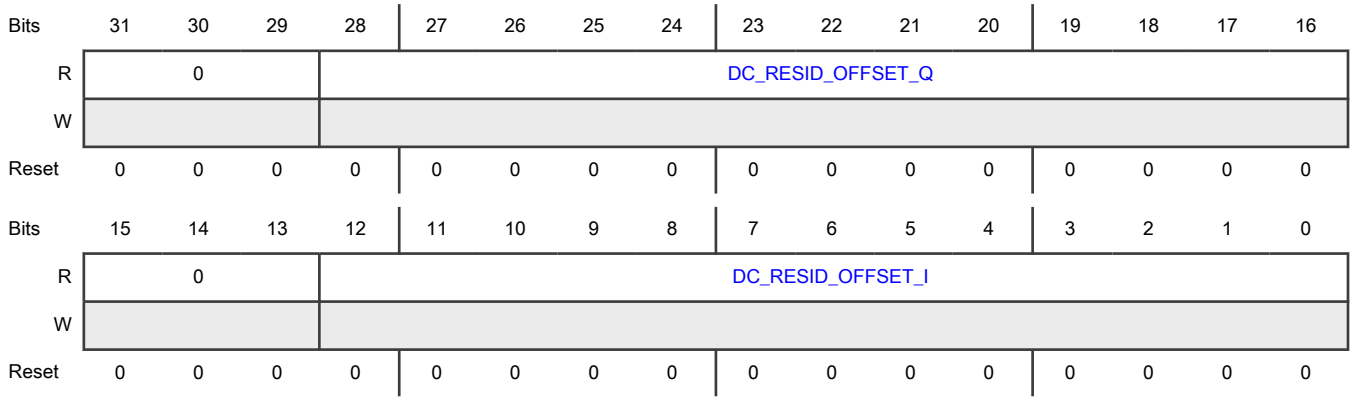
Field	Function
31-29 —	Reserved
28-20 DC_RESID_NWIN2	DC Residual NWIN, for Second Run Number of samples in a window. This is used only when DC_RESID_SECOND_RUN_EN=1.
19 —	Reserved
18-16 DC_RESID_DLY	DC Residual Delay The delay from activation of the DC residual block to the time when it starts processing. For a 32MHz reference clock, the delay in microseconds matches the value programmed. For other clock frequencies, the delay is scaled based on the clock period. Supported values: 0-7. This delay is only used when EXT_DC_EN=0.
15-7 —	Reserved
6-0 DC_RESID_NWIN	DC Residual NWIN Number of samples in a window.

52.4.4.2.2.2.5.1.90 DC Residual Estimate (DC_RESID_EST)

Offset

Register	Offset
DC_RESID_EST	160h

Diagram



Fields

Field	Function
31-29 —	Reserved
28-16 DC_RESID_OFFSET_Q	DC Residual Offset Q Reflects the current DC residual offset estimate for Q channel. Format is s11.1. This is provided for debug and characterization purposes only.
15-13 —	Reserved
12-0 DC_RESID_OFFSET_I	DC Residual Offset I Reflects the current DC residual offset estimate for I channel. Format is s11.1. This is provided for debug and characterization purposes only.

52.4.4.2.2.2.5.1.91 DfT tone analyzer (DFT_TONE_ANALYZER0)

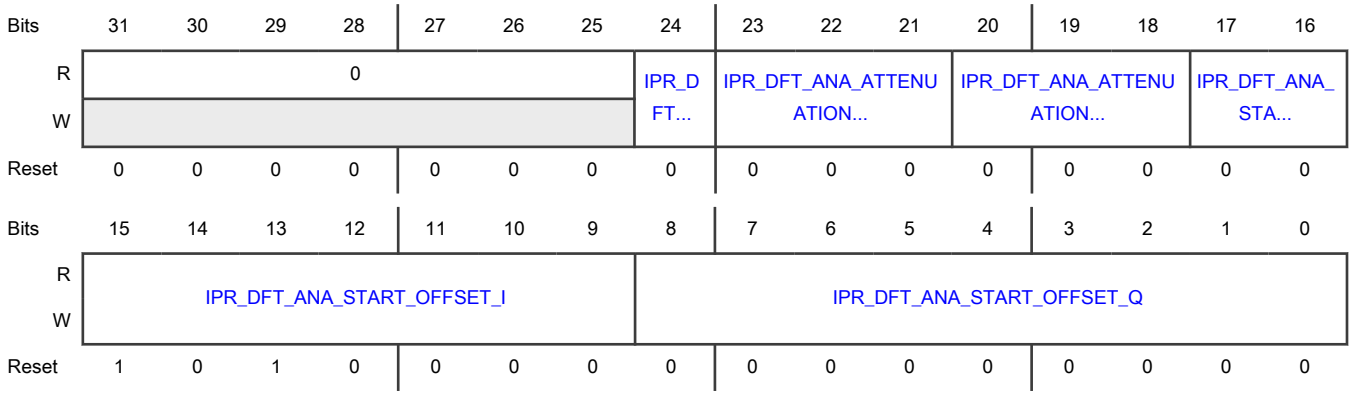
Offset

Register	Offset
DFT_TONE_ANALYZER0	164h

Function

1 of 4 registers required

Diagram



Fields

Field	Function
31-25 —	Reserved
24 IPR_DFT_ANA_EN	Enable for DfT tone analyzer Enable DFT Tone Analyzer module
23-21 IPR_DFT_ANA_ATTENUATION_I	Check description of ipr_dft_ana_attenuation_q
20-18 IPR_DFT_ANA_ATTENUATION_Q	Tone Attenuation For Q Path Full amplitude of tone generator inside the DFT Tone Analyzer is 1024. By set ipr_dft_ana_attenuation_i and/or ipr_dft_ana_attenuation_q can scale down the amplitude for I and/or Q path. The actual scale factor is calculated as: i_scale = 2^(-ipr_dft_ana_attenuation_i), q_scale = 2^(-ipr_dft_ana_attenuation_q),
17-9 IPR_DFT_ANA_START_OFFSET_I	I Initial Phase Check description of ipr_dft_ana_start_offset_q
8-0 IPR_DFT_ANA_START_OFFSET_Q	Q Initial Phase ipr_dft_ana_start_offset_i and ipr_dft_ana_start_offset_q are using for control the initial phase of I and Q of tone generator inside the DFT tone analyzer. By setting different phase of I and Q, the tone generator can produce positive freq or negative freq waveform. Default freq of tone generator is positive. To generate a negative frequency, set ipr_dft_ana_start_offset_i = 0x50 and ipr_dft_ana_start_offset_q = 0xA0.

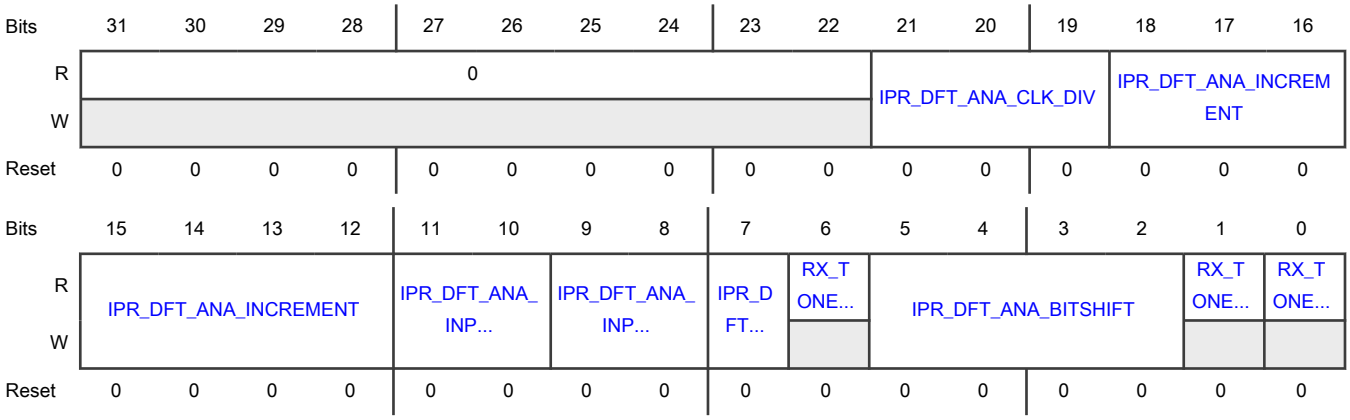
52.4.4.2.2.2.5.1.92 DfT tone analyzer (DFT_TONE_ANALYZER1)

Offset

Register	Offset
DFT_TONE_ANALYZER 1	168h

Function
1 of 4 registers required

Diagram



Fields

Field	Function
31-22 —	Reserved
21-19 IPR_DFT_ANA_CLK_DIV	Clock divider factor for tone generator. Check ipr_dft_ana_increment for more information. 000b - ref_clk 001b - ref_clk div 2 010b - ref_clk div 4 011b - ref_clk div 8 100b - ref_clk div 16
18-12 IPR_DFT_ANA_INCREMENT	ipr_dft_ana_increment and ipr_dft_ana_clk_div determines the tone frequency. Tone_Freq = (ref_clk_freq * ipr_dft_ana_increment) / (320 * 2^(ipr_dft_ana_clk_div))
11-10 IPR_DFT_ANA_INPUT_SEL_1	Should always set 0 for this field
9-8	Should always set 2 for this field

Table continues on the next page...

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Field	Function
IPR_DFT_ANA_INPUT_SEL_2	
7 IPR_DFT_ANA_START	Set 1 to trig the DFT Tone Analyzer. NOTE: Before set this bit, make sure the ipr_dft_ana_en asserted.
6 RX_TONE_ANA_DONE	Read only status bit. Indicating the tone analyze finished.
5-2 IPR_DFT_ANA_BITSHIFT	Accumulator input value scale down factor.
1 RX_TONE_ANA_BITSHIFT_OVF	Indicate the accumulator input has overflow during measurement.
0 RX_TONE_ANA_ACCU_OVF	Indicate the accumulator has overflow during measurement.

52.4.4.2.2.2.5.1.93 DfT tone analyzer (DFT_TONE_ANALYZER2)

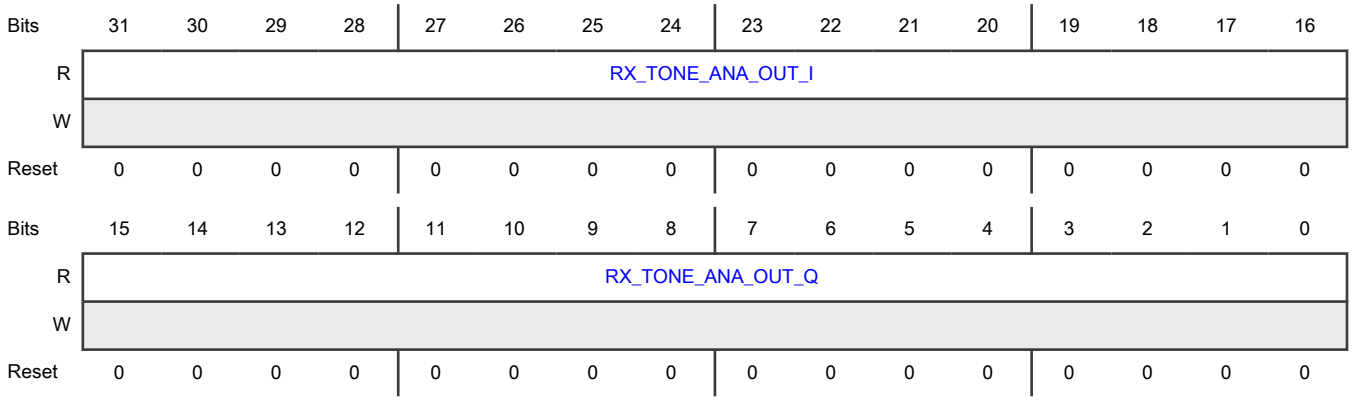
Offset

Register	Offset
DFT_TONE_ANALYZER2	16Ch

Function

1 of 4 registers required

Diagram



Fields

Field	Function
31-16 RX_TONE_ANA_OUT_I	Accumulator I path result If FCFO_ENA set to 1 and OUT_IQ set to 1, I value for X2 probe analysis. Otherwise Accumulator I path result.
15-0 RX_TONE_ANA_OUT_Q	Accumulator Q path result. If FCFO_ENA set to 1 and OUT_IQ set to 1, Q value for X2 probe analysis. Otherwise Accumulator Q-path result.

52.4.4.2.2.2.5.1.94 DfT tone analyzer (DFT_TONE_ANALYZER3)

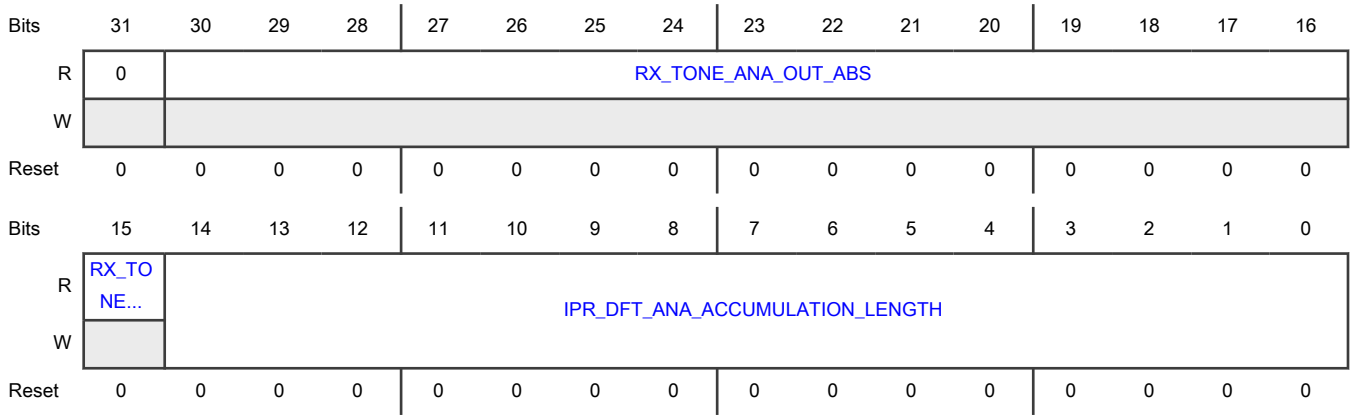
Offset

Register	Offset
DFT_TONE_ANALYZER3	170h

Function

1 of 4 registers required

Diagram



Fields

Field	Function
31 —	Reserved
30-15 RX_TONE_ANA_OUT_ABS	Tone Analyzer Result. ABS Value of the tone analysis
14-0 IPR_DFT_ANA_ACCUMULATION_LENGTH	Number of cycles that the accumulation should do for the analysis

52.4.4.2.2.2.5.1.95 DCOC Digital Correction Result (DCOC_DIG_CORR_RESULT)

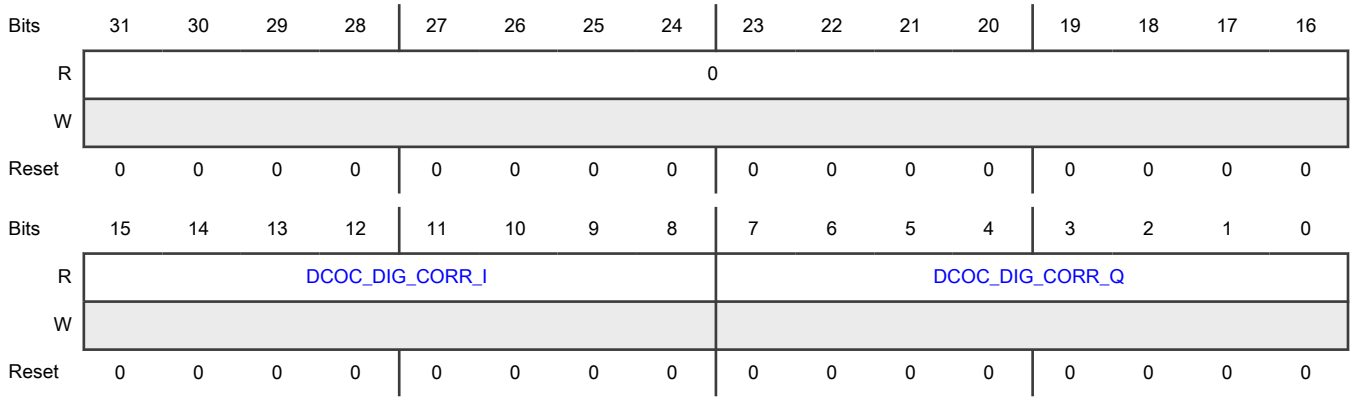
Offset

Register	Offset
DCOC_DIG_CORR_RESULT	174h

Function

This read-only register stores the residual DC value after DCOC ADC and CBPF DAC calibration done. This register updates at the end of each non-fast RX warmup.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-8 DCOC_DIG_CORR_I	DCOC Q-Channel Residual After Calibration
7-0 DCOC_DIG_CORR_Q	DCOC I-Channel Residual After Calibration

52.4.4.2.2.2.5.1.96 IQ Mismatch Control 1 DRS (IQMC_CTRL1_DRS)

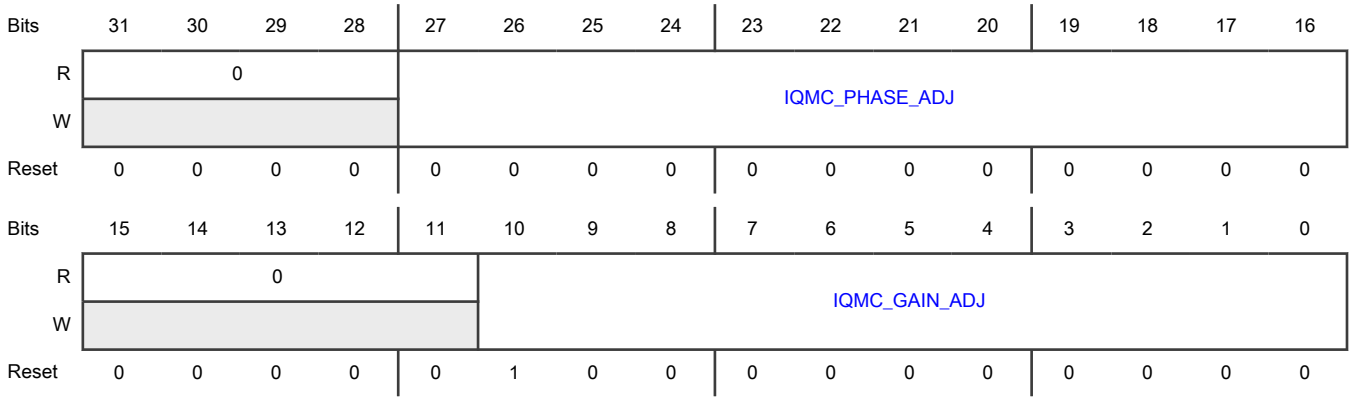
Offset

Register	Offset
IQMC_CTRL1_DRS	178h

Function

When datarate_config_sel=1, the RX_DIG will use these config values instead of IQMC_CTRL1

Diagram



Fields

Field	Function
31-28 —	Reserved
27-16 IQMC_PHASE_ADJ	IQ Mismatch Phase Correction DRS I/Q mismatch correction phase coefficient. This value is updated automatically at the end of the IQMC calibration sequence. It can also be written by software. The format is signed, with the maximum positive value 0x7ff corresponding to a phase coefficient of 0.25, and the maximum negative value 0x800 corresponding to -0.25. The reset value of 0x000 corresponds to a phase coefficient of 0.
15-11 —	Reserved
10-0 IQMC_GAIN_ADJ	IQ Mismatch Correction Gain Coeff DRS I/Q mismatch correction gain coefficient DRS. This value is updated automatically at the end of the IQMC calibration sequence. It can also be written by software. The format is u1.10. The reset value of 0x400 corresponds to a gain coefficient of 1.0.

52.4.4.2.2.2.5.1.97 TQI control fields (TQI_CTRL)

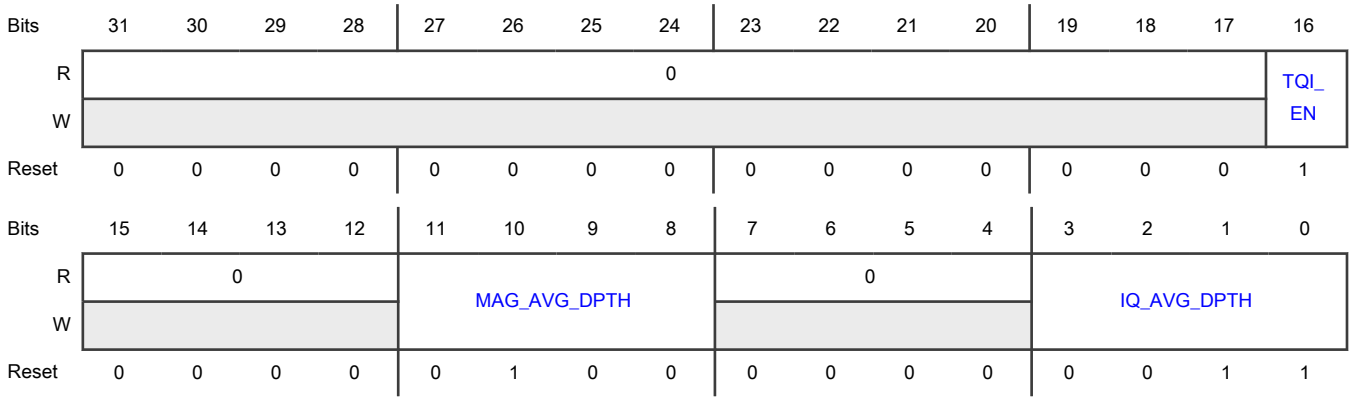
Offset

Register	Offset
TQI_CTRL	17Ch

Function

Parameters for the TQI computation.

Diagram



Fields

Field	Function
31-17 —	Reserved
16 TQI_EN	Enables TQI operation. Enables Tone Quality Indicator operation. 0b - TQI operation is disabled. 1b - TQI operation is enabled.
15-12 —	Reserved
11-8 MAG_AVG_DPTH	Number of magnitude averaging windows, in power of two. Number of magnitude averaging windows, in power of two. 0000b - Magnitude averager is bypassed 0001b - Magnitude averager uses 2 windows 0010b - Magnitude averager uses 4 windows 0011b - Magnitude averager uses 8 windows 0100b - Magnitude averager uses 16 windows 0101b - Magnitude averager uses 32 windows
7-4 —	Reserved
3-0 IQ_AVG_DPTH	Number of IQ samples per IQ averaging window, in power of two. Number of samples in each IQ accumulator window, in power of two. 0000b - IQ averager is bypassed

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Field	Function
	0001b - IQ averager uses 2 samples 0010b - IQ averager uses 4 samples 0011b - IQ averager uses 8 samples 0100b - IQ averager uses 16 samples

52.4.4.2.2.2.5.1.98 TQI thresholds (TQI_THR)

Offset

Register	Offset
TQI_THR	180h

Function

Thresholds for the quality factor(TQI_QF) computation in unsigned fixed-point 0.9 format. To get the register value from fixed-point, get nearest integer to fixed-point value multiplied by 2^9. Ex : value = 0.053, 0.053*2^9 = 27.136, rounded to 27=0x1B.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	INLINE_THR_TQI		0						T2							
W																
Reset	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								T1							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1

Fields

Field	Function
31-30 INLINE_THR_TQI	INLINE_THR_TQI threshold Inline phase return ranging threshold.Used when feature INPR with PA_PUP_TQI_EN activated, this gives possibility to send back or not the packet inline depending of TQI threshold. This can be used to avoid sending back the TQI information via BLE but accuracy is not the same in this case. 00b - Good quality 01b - Medium quality 10b - Low quality 11b - Reserved
29-25	Reserved

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Field	Function
—	
24-16 T2	T2 threshold T2 threshold, unsigned fixed-point 0.9 format.
15-9 —	Reserved
8-0 T1	T1 threshold. T1 threshold, unsigned fixed-point 0.9 format.

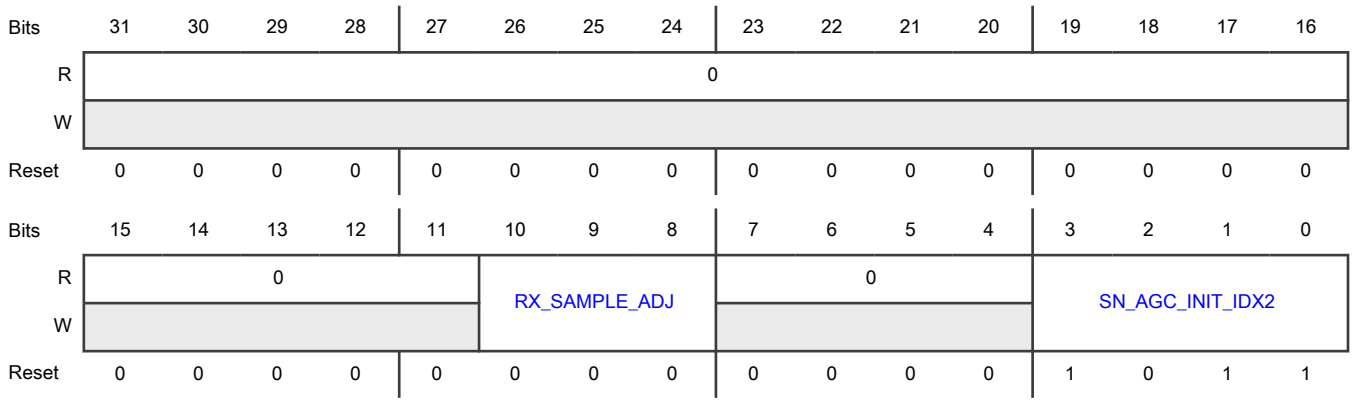
52.4.4.2.2.2.5.1.99 RXDIG Control 2 (CTRL2)

Offset

Register	Offset
CTRL2	184h

Function
RXDIG control register 2

Diagram



Fields

Field	Function
31-16 —	Reserved
15-11	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
10-8 RX_SAMPLE_ADJ	RX sample delay line adjustment This register is used mainly for debug purposes. It allows to adjust the timing by modifying the number of samples @ 4/8 Mhz (after acquisition filter) of the delay line.This could help for Channel Sounding RTT demodulation adjustment.
7-4 —	Reserved
3-0 SN_AGC_INIT_IDX2	AGC Initial Gain Index of the second part of CS sub-event in sniffer mode Initial AGC gain index value of the second part of CS sub-event in sniffer mode. Note: the SN_AGC_INIT_IDX2 should not greater than 11. Also see AGC_MAX_IDX for more information.

52.4.4.2.2.2.5.1.100 Controls for the NADM module (NADM_CTRL)

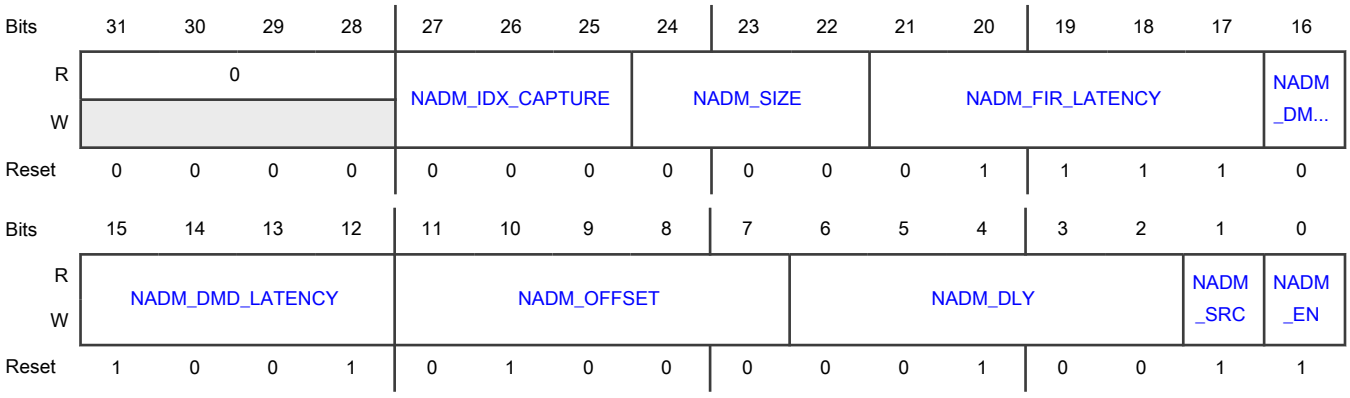
Offset

Register	Offset
NADM_CTRL	188h

Function

Controls for the NADM (Normalized Attack Detection Metric) module.

Diagram



Fields

Field	Function
31-28	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
27-25 NADM_IDX_CAPTURE	Index used to get optimum fm_diff in DMA_DBG Debug feature,Index [0..4] to select best coorelator to get optimum fm_diff in DMA_DBG.
24-22 NADM_SIZE	NADM size aligned on RTT_TYPE standard value Data size for NADM :in nominal mode, it should be set the same as RTT_TYPE. Other setting could be used in case of proprietary mode to add some extra datas.
21-17 NADM_FIR_LATENCY	FM correlator path, delay between reference start and correlator start. Delay in PHY clock cycles between GFSK reference start and phase correlator start. This allows to take into account the propagation time inside the reference GFSK filter.
16-12 NADM_DMD_LATENCY	FM symbol error path, NADM trigger delay after access address reception. Delay in NADM clock cycles after access address reception to trigger NADM symbol error path finite state machine.
11-7 NADM_OFFSET	FM correlator path, offset in the delay array. This selects the delay in PHY clock cycles of the first correlator instance, allowing to align properly center correlator versus reference signal.
6-2 NADM_DLY	FM correlator path, NADM trigger delay after access address reception. Delay in PHY clock cycles after access address reception to trigger NADM finite state machine.
1 NADM_SRC	FM correlator path, select source. Selects the source of the NADM FM correlator path. 0b - CHF in selected. NADM module source is channel filter input signal. 1b - CHF out selected. NADM module source is channel filter output signal.
0 NADM_EN	NADM module enable. Enables NADM module operation. 0b - Nadm operation is disabled. 1b - Nadm operation is enabled.

52.4.4.2.2.2.5.1.101 NADM latest packet results. (NADM_RES)

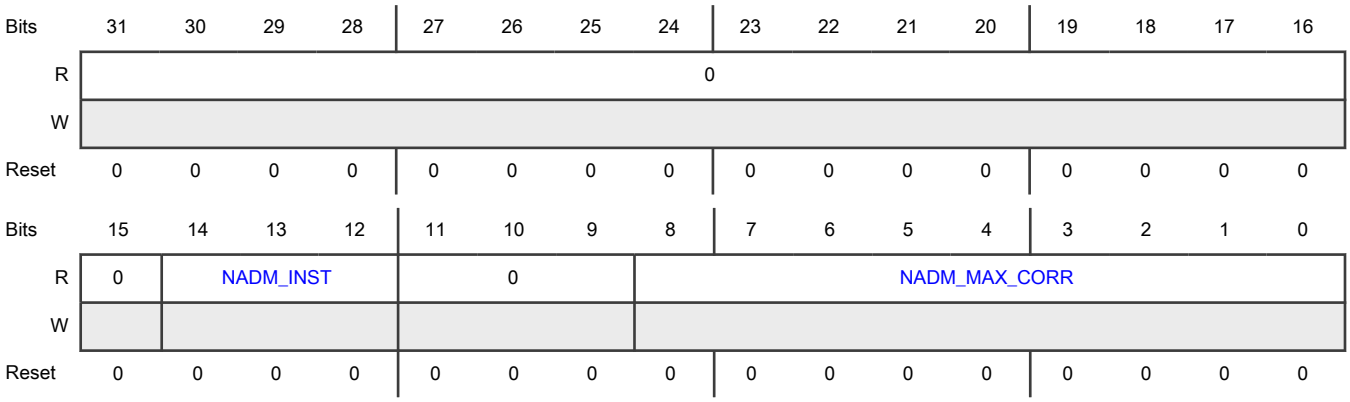
Offset

Register	Offset
NADM_RES	18Ch

Function

Latest packet results for the NADM (Normalized Attack Detection Metric) module. To be used for debug purposes, normal usage of NADM values is done with the packet RAM.

Diagram



Fields

Field	Function
31-15 —	Reserved
14-12 NADM_INST	NADM correlator instance yielding maximum correlation value. Latest packet maximum correlation instance.
11-9 —	Reserved
8-0 NADM_MAX_CORR	NADM maximum correlation value. Latest packet maximum correlation value.This field corresponds to the raw correlation result, before internal truncation. It needs to be divided by two (discard the LSB) to match the nadm value sent to the packet RAM.

52.4.4.2.2.2.5.1.102 Fine CFO module controls. (FCFO_CTRL)

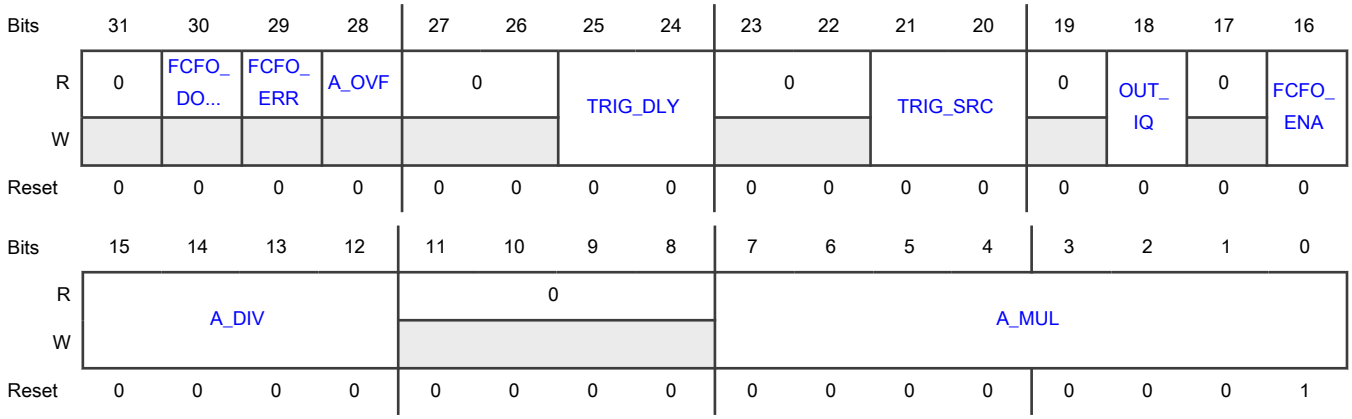
Offset

Register	Offset
FCFO_CTRL	190h

Function

Fine CFO module controls.

Diagram



Fields

Field	Function
31 —	Reserved
30 FCFO_DONE	FCFO done. Fine CFO has run.
29 FCFO_ERR	FCFO value error. FCFO value error occured. Can be caused either by tone analyser overflow (chec ta bits) or alpha multiplier overflow (check fcfo bit).
28 A_OVF	Alpha multiplier overflow. Alpha multiplier overflow occured.
27-26 —	Reserved
25-24 TRIG_DLY	Delay between trigger and fcfo start. Delay between trigger and fcfo start. 00b - Selects 2us trigger delay. 01b - Selects 5us trigger delay. 10b - Selects 10us trigger delay. 11b - Selects 15us trigger delay.
23-22 —	Reserved
21-20 TRIG_SRC	Selects FCFO trigger source. Selects FCFO trigger source.

Table continues on the next page...

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Field	Function
	00b - Selects TPM as trigger source 01b - Selects TFM as trigger source 10b - Selects software as trigger source.
19 —	Reserved
18 OUT_IQ	FCFO output format. Selects FCFO module output format. 0b - Fcfo output are g function values (previous/current). 1b - Fcfo output are IQ values.
17 —	Reserved
16 FCFO_ENA	Enables FCFO module. Enables FCFO module. 0b - Fcfo algorithm disabled. 1b - Fcfo algorithm enabled.
15-12 A_DIV	Alpha linear division coeficient Interpolation linear division coeficient for g function. In powers of two.
11-8 —	Reserved
7-0 A_MUL	Alpha linear multiplication coeficient Interpolation linear coeficient for g function.

52.4.4.2.2.2.5.1.103 Tone parameters. (FCFO_TN)

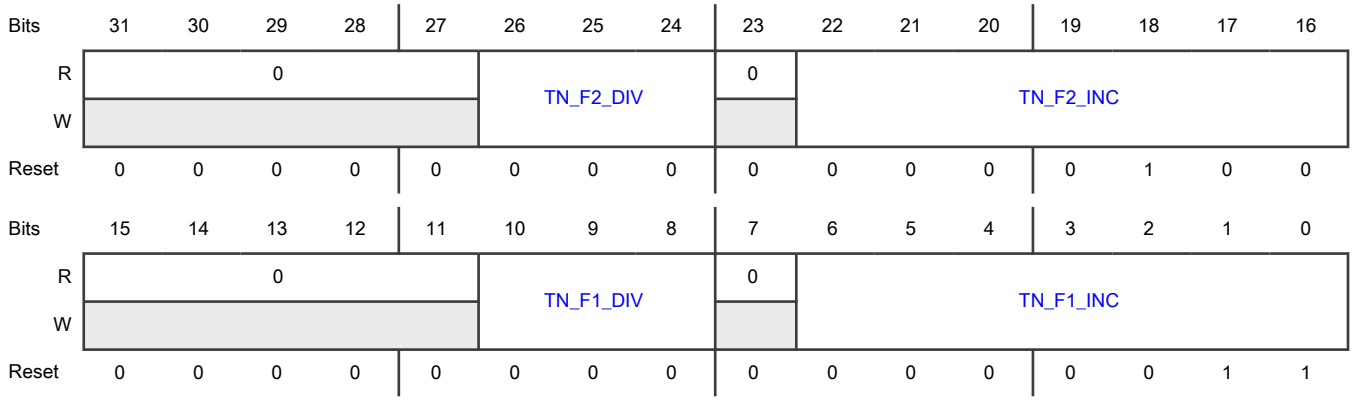
Offset

Register	Offset
FCFO_TN	194h

Function

Tone parameters for FCFO module.

Diagram



Fields

Field	Function
31-27 —	Reserved
26-24 TN_F2_DIV	Tone F2 clock divisor. Tone F2 clock divisor.
23 —	Reserved
22-16 TN_F2_INC	Tone F2 increment. Tone F2 increment.
15-11 —	Reserved
10-8 TN_F1_DIV	Tone F1 clock divisor. Tone F1 clock divisor.
7 —	Reserved
6-0 TN_F1_INC	Tone F1 increment. Tone F1 increment.

52.4.4.2.2.2.5.1.104 F2 carrier iq phases (FCFO_TN_PH)

Offset

Register	Offset
FCFO_TN_PH	198h

Function

Initial phases of the F2 carrier. For F1 settings are in tone analyser register.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0								F2_PH_Q							
W																
Reset	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								F2_PH_I							
W																
Reset	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0

Fields

Field	Function
31-25 —	Reserved
24-16 F2_PH_Q	F2 carrier Q start phase Initial phase offset for the F2 carrier Q element : initial_phase_degrees = start_offset * (360/320). For F1 setting is in tone analyser register.
15-9 —	Reserved
8-0 F2_PH_I	F2 carrier I start phase Initial phase offset for the F2 carrier I element : initial_phase_degrees = start_offset * (360/320). For F1 setting is in tone analyser register.

52.4.4.2.2.2.5.1.105 Fine CFO results. (FCFO_RES)

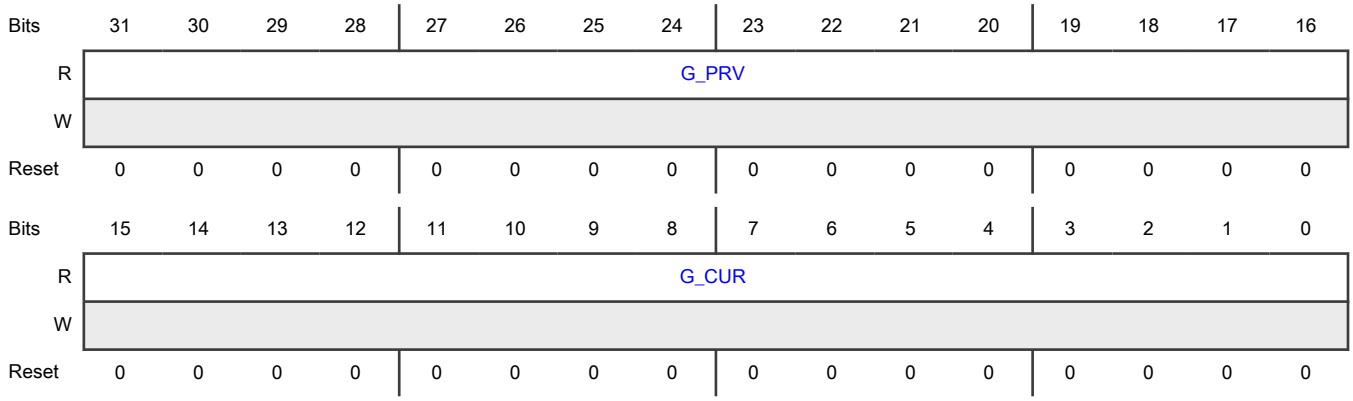
Offset

Register	Offset
FCFO_RES	19Ch

Function

Fine CFO results (g function).

Diagram



Fields

Field	Function
31-16 G_PRV	g function, previous value. If OUT_IQ set to 0, current g function value. If OUT_IQ set to 1, Q value for X1 probe analysis.
15-0 G_CUR	g function, current value. If OUT_IQ set to 0, current g function value. If OUT_IQ set to 1, I value for X1 probe analysis.

52.4.4.2.2.3 PLL Digital Module (PLL_DIG)

52.4.4.2.2.3.1 Overview

The PLL Frequency Synthesizer is a Digital Module that -

1. Selects the Radio Carrier Frequency
2. Coarse Tunes the VCO and Calibrates the High Port DAC
3. Controls the PLL Loop Divider value to lock the VCO at the Carrier Frequency
4. Applies the Baseband Frequency Word as High Port Modulation (HPM) to the VCO High Port DAC
5. Applies the Baseband Frequency Word as Low Port Modulation (LPM) to the PLL Loop Divider
6. Monitors the PLL lock status and flags unlocked conditions
7. Provides DFT features for evaluating the PLL Frequency Synthesizer during factory validation and testing

52.4.4.2.2.3.1.1 Block diagram

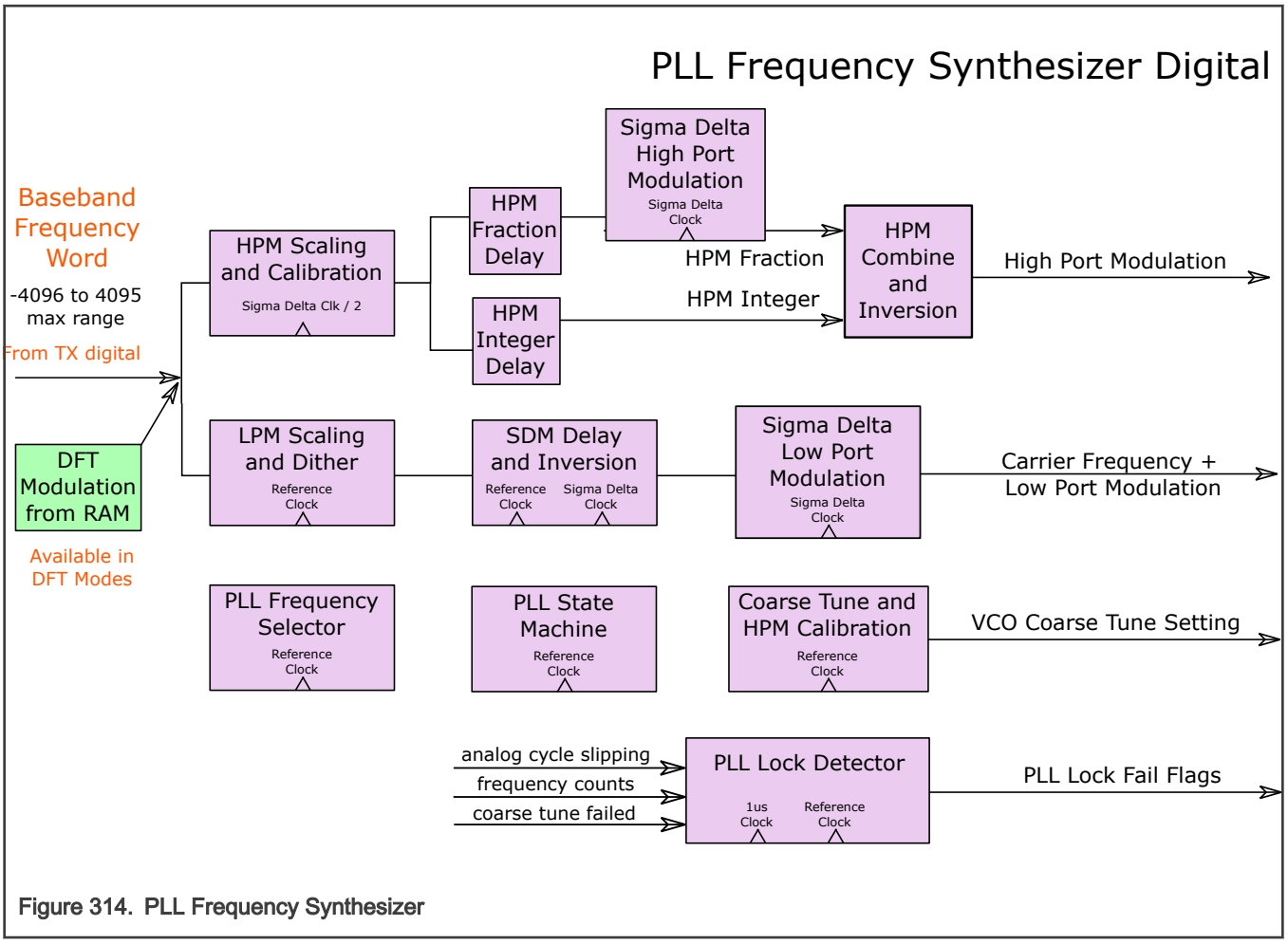


Figure 314. PLL Frequency Synthesizer

52.4.4.2.2.3.1.2 Features

52.4.4.2.2.3.1.2.1 Baseband Frequency Word

52.4.4.2.2.3.1.2.1.1 Range Frequency Word

The Transmitter Digital presents the PLL Frequency Synthesizer with a signed 13-bit Baseband Frequency word to modulate onto the RF Carrier Frequency. The Baseband Frequency Word range is -4096 to 4095, which provides a modulation range of +/- 1000 kHz when using a 32 MHz reference frequency with a PLL Minimum Frequency Step Size of 244.14 Hz. Note, this range can be adjusted using LPM_CTRL[LPM_SCALE] along with LPM_CTRL[HPM_CAL_SCALE] to adjust the PLL Minimum Frequency Step Size.

52.4.4.2.2.3.1.2.1.2 Manual Frequency Word

The Baseband Frequency word can be overridden by software if the MOD_DISABLE bit is set. In this case the PLL Digital will use the MODULATION_WORD_MANUAL register as the source of the modulation.

Note that due to the speeds at which the High Port and Low Port react to changes in the modulation word, and the speed at which software is able to effect such changes, for all practical purposes this can only support low frequency modulation.

52.4.4.2.2.3.2 Functional description

52.4.4.2.2.3.2.1 Carrier Frequency Tuning

52.4.4.2.2.3.2.1.1 Radio Frequency Selection

The PLL Digital has hardware support for 128 RF channels in 1 MHz increments spanning the range from 2.360 GHz to 2.487 GHz.

Each supported carrier frequency is derived by Fractional-N Frequency Synthesis using the Low Port Sigma Delta Modulator. Note, the frequency selection registers should be programmed from the perspective of TX operation. If the PLL is operating in an RX mode then the CHAN_MAP_EXT[NUM_OFFSET] will be utilized to derive the RX channel frequency. The NUM_OFFSET register field represents the IF frequency difference between RX and TX. Also, CFO should be computed during SQTE FCS and the software should program step_cfo[15:0] into packet RAM for each channel, this value is automatically added to the numerator at each step for compensation.

These 128 RF channels are mapped to the various supported RF Protocols through two lookup tables as shown in the figure below.

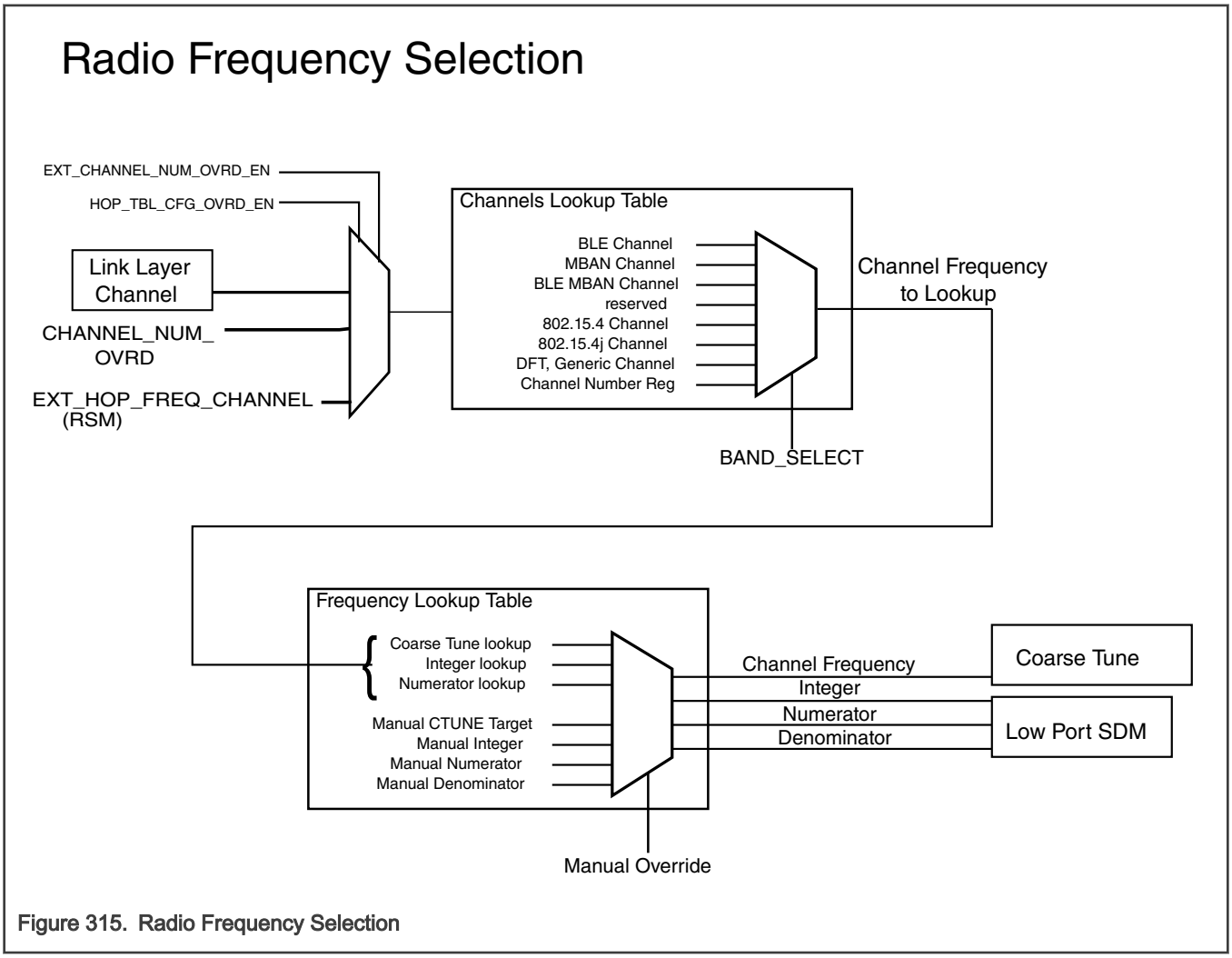


Figure 315. Radio Frequency Selection

52.4.4.2.2.3.2.1.2 RF Channels Supported

The channel frequencies for each protocol are shown in the tables below. The channel mapping is selected based on the register CHAN_MAP[BAND_SELECT].

Table 476. Radio Protocols (1 to 5) Channel Frequencies

Radio Protocols Supported, Channel Frequency in MHz					
Bluetooth Low Energy	MBAN	Bluetooth Low Energy/MBAN	Reserved	802.15.4	802.15.4j MBAN

Table continues on the next page...

Table 476. Radio Protocols (1 to 5) Channel Frequencies (continued)

0		1		2		3				4		5	
Chan	MHz	Chan	MHz	Chan	MHz	Chan	MHz	Chan	MHz	Chan	MHz	Chan	MHz
0	2,402	0	2,360	0	2,402	0	2,400	43	2,443	11	2,405	0	2,363
1	2,404	1	2,361	1	2,404	1	2,401	44	2,444	12	2,410	1	2,368
2	2,406	2	2,362	2	2,406	2	2,402	45	2,445	13	2,415	2	2,373
3	2,408	3	2,363	3	2,408	3	2,403	46	2,446	14	2,420	3	2,378
4	2,410	4	2,364	4	2,410	4	2,404	47	2,447	15	2,425	4	2,383
5	2,412	5	2,365	5	2,412	5	2,405	48	2,448	16	2,430	5	2,388
6	2,414	6	2,366	6	2,414	6	2,406	49	2,449	17	2,435	6	2,393
7	2,416	7	2,367	7	2,416	7	2,407	50	2,450	18	2,440	7	2,367
8	2,418	8	2,368	8	2,418	8	2,408	51	2,451	19	2,445	8	2,372
9	2,420	9	2,369	9	2,420	9	2,409	52	2,452	20	2,450	9	2,377
10	2,422	10	2,370	10	2,422	10	2,410	53	2,453	21	2,455	10	2,382
11	2,424	11	2,371	11	2,424	11	2,411	54	2,454	22	2,460	11	2,387
12	2,426	12	2,372	12	2,426	12	2,412	55	2,455	23	2,465	12	2,392
13	2,428	13	2,373	13	2,428	13	2,413	56	2,456	24	2,470	13	2,397
14	2,430	14	2,374	14	2,430	14	2,414	57	2,457	25	2,475	14	2,395
15	2,432	15	2,375	15	2,432	15	2,415	58	2,458	26	2,480		
16	2,434	16	2,376	16	2,434	16	2,416	59	2,459				
17	2,436	17	2,377	17	2,436	17	2,417	60	2,460				
18	2,438	18	2,378	18	2,438	18	2,418	61	2,461				
19	2,440	19	2,379	19	2,440	19	2,419	62	2,462				
20	2,442	20	2,380	20	2,442	20	2,420	63	2,463				
21	2,444	21	2,381	21	2,444	21	2,421	64	2,464				
22	2,446	22	2,382	22	2,446	22	2,422	65	2,465				
23	2,448	23	2,383	23	2,448	23	2,423	66	2,466				
24	2,450	24	2,384	24	2,450	24	2,424	67	2,467				
25	2,452	25	2,385	25	2,452	25	2,425	68	2,468				
26	2,454	26	2,386	26	2,454	26	2,426	69	2,469				
27	2,456	27	2,387	27	2,456	27	2,427	70	2,470				
28	2,458	28	2,388	28	2,458	28	2,428	71	2,471				
29	2,460	29	2,389	29	2,460	29	2,429	72	2,472				
30	2,462	30	2,390	30	2,390	30	2,430	73	2,473				

Table continues on the next page...

Table 476. Radio Protocols (1 to 5) Channel Frequencies (continued)

31	2,464	31	2,391	31	2,391	31	2,431	74	2,474				
32	2,466	32	2,392	32	2,392	32	2,432	75	2,475				
33	2,468	33	2,393	33	2,393	33	2,433	76	2,476				
34	2,470	34	2,394	34	2,394	34	2,434	77	2,477				
35	2,472	35	2,395	35	2,395	35	2,435	78	2,478				
36	2,474	36	2,396	36	2,396	36	2,436	79	2,479				
37	2,476	37	2,397	37	2,397	37	2,437	80	2,480				
38	2,478	38	2,398	38	2,398	38	2,438	81	2,481				
39	2,480	39	2,399	39*	2,480	39	2,439	82	2,482				
						40	2,440	83	2,483				
						41	2,441						
						42	2,442						

* The Bluetooth Low Energy MBAN Channel Remap bit (BMR) controls the frequency mapping for channel 39 in Bluetooth Low Energy/MBAN, 2480 MHz is the default, but this channel can be remapped to 2399 MHz by setting BMR to a 1.

Table 477. Radio Protocols (6 to 7) Channel Frequencies

Radio Protocols Supported, Channel Frequency in MHz					
DFT, Generic					
6,7					
Channel	MHz	Channel	MHz	Channel	MHz
0	2,360	43	2,403	86	2,446
1	2,361	44	2,404	87	2,447
2	2,362	45	2,405	88	2,448
3	2,363	46	2,406	89	2,449
4	2,364	47	2,407	90	2,450
5	2,365	48	2,408	91	2,451
6	2,366	49	2,409	92	2,452
7	2,367	50	2,410	93	2,453
8	2,368	51	2,411	94	2,454
9	2,369	52	2,412	95	2,455
10	2,370	53	2,413	96	2,456
11	2,371	54	2,414	97	2,457
12	2,372	55	2,415	98	2,458
13	2,373	56	2,416	99	2,459

Table continues on the next page...

Table 477. Radio Protocols (6 to 7) Channel Frequencies (continued)

14	2,374	57	2,417	100	2,460
15	2,375	58	2,418	101	2,461
16	2,376	59	2,419	102	2,462
17	2,377	60	2,420	103	2,463
18	2,378	61	2,421	104	2,464
19	2,379	62	2,422	105	2,465
20	2,380	63	2,423	106	2,466
21	2,381	64	2,424	107	2,467
22	2,382	65	2,425	108	2,468
23	2,383	66	2,426	109	2,469
24	2,384	67	2,427	110	2,470
25	2,385	68	2,428	111	2,471
26	2,386	69	2,429	112	2,472
27	2,387	70	2,430	113	2,473
28	2,388	71	2,431	114	2,474
29	2,389	72	2,432	115	2,475
30	2,390	73	2,433	116	2,476
31	2,391	74	2,434	117	2,477
32	2,392	75	2,435	118	2,478
33	2,393	76	2,436	119	2,479
34	2,394	77	2,437	120	2,480
35	2,395	78	2,438	121	2,481
36	2,396	79	2,439	122	2,482
37	2,397	80	2,440	123	2,483
38	2,398	81	2,441	124	2,484
39	2,399	82	2,442	125	2,485
40	2,400	83	2,443	126	2,486
41	2,401	84	2,444	127	2,487
42	2,402	85	2,445		

52.4.4.2.2.3.2.1.3 Channel Selector

During typical Radio usage, the channel selection is done automatically by the Link Layer.

Channel selection can be overridden using the PLL_CHAN_MAP register bits HOP_TBL_CFG_OVRD_EN and HOP_TBL_CFG_OVRD. If HOP_TBL_CFG_OVRD_EN is set then the CHANNEL_NUM_OVRD register selects the Radio Channel Number instead of the Link Layer. In addition, the HOP_TBL_CFG_OVRD selection will determine how the CHANNEL_NUM_OVRD is interpreted.

52.4.4.2.2.3.2.1.4 Manual Carrier Frequency

The internal frequency mapping can be bypassed and software can directly control the Low Port Sigma Delta inputs to select any channel frequency in the VCO's range (in increments of the Low Port Minimum Frequency Step Size).

The Radio Channel Frequency override is manually selected by setting the SDM_MAP_DISABLE bit along with the LPM_INTG, LPM_NUM, and LPM_DENOM register values.

Any modulation from the TX Digital will be added to this manual frequency selection.

The Manual carrier frequency selected can be calculated using the formula below:

Radio Carrier Frequency = ((Reference Clock Frequency x 2) x (LPM_INTG + (LPM_NUM / LPM_DENOM))

WARNING : The fraction (LPM_NUM / LPM_DENOM) must be in the range of -0.55 to +0.55 for valid Sigma Delta Modulator operation.

52.4.4.2.2.3.2.2 VCO Calibration

52.4.4.2.2.3.2.2.1 Coarse Tune

The VCO Coarse Tune is carried out by a Successive Approximation Register method that computes the best coarse tune setting for the VCO in successive steps from MSB to LSB.

This SAR method uses a Frequency Meter count value that is successively compared to expected counts to determine the best coarse tune setting for the VCO.

The coarse tune setting can be overridden for test and validation purposes, and the individual frequency counts used at each successive step for the coarse tune setting are available for viewing in DTEST mode and also as register values in the PLL register space.

52.4.4.2.2.3.2.2.2 High Port DAC Calibration

The objective of the HPM DAC Calibration is to determine the DAC Step Size and estimate the ratio of this DAC unit step to the Low Port Minimum Frequency Step Size.

Once the step size of the High Port DAC is known, a scaling factor is applied to correctly map the baseband frequency word to the High Port modulation.

The length of the calibration time is set using the HPM_CAL_TIME register and the size of the DAC array used is selected using the HPM_CAL_ARRAY_SIZE register.

The register HPM_COUNT_ADJUST[3:0] provides a (-8/+7) range of adjustment to the HPM Calibration Count Difference for the HPM Calibration lookup table to allow for any count error bias that may be present. This adjusted Count Difference is used with a Lookup Table to choose the HPM Calibration Factor

52.4.4.2.2.3.2.2.2.1 HPM CAL Factor

The HPM_CAL_FACTOR read register shows the value that is currently being used by High Port Modulation Multiplier. This value is from the most recent High Port calibration unless it is being overridden using the HP_CAL_DISABLE and HPM_CAL_FACTOR_MANUAL registers.

For localisation purpose, additional options are available to override HPM cal factor value by HPM_CAL_FACTOR_MANUAL register value or packet RAM table value:

1. HPM calibration result (HPM_CAL_FACTOR) comes from a table inside packet RAM if one or both of the following conditions are met:
    a. RSM_HPM_CAL is set to 1.
    b. HPM_DYNAMIC_SEL is set to 1
        i. in TX mode.
        ii. in RX mode during packets if HPM_DYNAMIC_RX_PKT_TABLE is set to 1.
        iii. in RX mode during tones if HPM_DYNAMIC_RX_TONE_TABLE is set to 1.

2. HPM calibration result ((HPM_CAL_FACTOR) comes from HPM_CAL_FACTOR_MANUAL register If one or both of the following conditions are met:
    a. HP_CAL_DISABLE is set to 1.
    b. HPM_DYNAMIC_SEL is set to 1
        i. in RX mode during packets if HPM_DYNAMIC_RX_PKT_TABLE is set to 0.
        ii. in RX mode during tones if HPM_DYNAMIC_RX_TONE_TABLE is set to 0.

NOTE

HPM dynamic mode enabled by HPM_DYNAMIC_SEL register is meant to be used in channel sounding to get dynamically HPM cal factor in RX (tones and packets) mode either from packet RAM table or HPM_CAL_FACTOR_MANUAL register. In TX mode the factor comes from packet RAM table.

52.4.4.2.2.3.2.3 High Port Modulation

The High Port Modulator multiplies the HPM Calibration Factor and the PLL Baseband Frequency Word to get the High Port Modulation Word.

The High Port Modulation Word is represented by both an Integer and a Fractional portion. The Fraction is processed by the High Port Sigma Delta Modulator and the result is combined with the Integer and used to control the VCO High Port DAC.

52.4.4.2.2.3.2.3.1 High Port DAC

The High Port Digital to Analog Converter is designed to take the High Port Modulation Word and convert it to a control voltage that is applied as modulation to the VCO High Port.

52.4.4.2.2.3.2.3.1.1 HPM DAC Settings

The HPM DAC settings during calibration and normal operation are shown in the table below.

Warning : TX operation with On-Air modulation ranges greater than +/- 250 kHz (+/- 500 kHz at the VCO) require that the VCO Kvm be adjusted using the PLL_VCO_TRIM_KVM[2:0] register.

Table 478. Nominal HPM DAC parameters in various modes

Radio TX Mode		DAC max swing (mV)	DAC output common mode (mV)	DAC swing during operation	Vcm (mV) / HPM_VCM	OPAMP gain setting (R2/R1) / HPM_FDB_RES	Common mode at varactor (mV)	Swing at Varactor input (mV)	Kvm (MHz/Kv)	Deviation at VCO (KHz)[1]
802.15.4/ 2000kHz	HPM calibration	+/-82	82	+/-82	288 / 3'b001	2/ 2'b01	700	+/-164	20	+/-3280
	TX operation	+/-82	82	+/-51.2	391 / 3'b000	1/ 2'b00	700	+/51.2	20	+/-1024
Bluetooth Low Energy/ 1000kHz	HPM calibration	+/-82	82	+/-82	288 / 3'b001	2 / 2'b01	700	+/-164	10	+/-1640
	TX operation	+/-82	82	+/-51.2	391 / 3'b000	1/ 2'b00	700	+/51.2	10	+/-512

Table continues on the next page...

Table 478. Nominal HPM DAC parameters in various modes (continued)

500kHz	HPM calibration	+/-82	82	+/-82	288 / 3'b001	2/ 2'b01	700	+/-164	10	+/-1640
	TX operation	+/-82	82	+/-25.6	391 / 3'b000	1/ 2'b00	700	+/25.6	10	+/-256
250kHz	HPM calibration	+/-82	82	+/-82	288 / 3'b001	2/ 2'b01	700	+/-164	10	+/-1640
	TX operation	+/-82	82	+/-12.8	391 / 3'b000	1/ 2'b00	700	+/12.8	10	+/-128

1. On-Air modulation frequency is a divide by 2 of the VCO frequency.

52.4.4.2.2.3.2.3.1.2 HPM DAC Bump

The HPM DAC Calibration is normally done at 2X the On-Air Modulation Range, this is accomplished by writing the PLL HPM Analog Bump Control (PLL_HPM_BUMP) register bits:

- HPM_VCM_CAL, value applied during HPM DAC Calibration
- HPM_FDB_RES_CAL, value applied during HPM DAC Calibration
- HPM_VCM_TX, value applied during Radio Transmissions or only during Radio TX if HPM_BUMP_RX_TX_EN set to 1
- HPM_FDB_RES_TX, value applied during Radio Transmissions or only during Radio TX if HPM_BUMP_RX_TX_EN set to 1
- HPM_VCM_RX, value applied during Radio RX if HPM_BUMP_RX_TX_EN set to 1
- HPM_FDB_RES_RX, value applied during Radio RX if HPM_BUMP_RX_TX_EN set to 1

If the registers are written in such a way that the DAC range is not doubled, then the HPM_CAL_NOT_BUMPED bit must be set to change the math in the HPM Calibration.

52.4.4.2.2.3.2.3.1.3 HPM DAC 1 MHz Range

TX operation with On-Air modulation ranges greater than +/- 250 kHz (+/- 500 kHz at the VCO) require that the VCO Kvm be adjusted using the PLL_VCO_TRIM_KVM[2:0] register.

This VCO Kvm setting should be made prior to HPM DAC calibration.

52.4.4.2.2.3.2.3.2 High Port Sigma Delta

The High Port fractional modulation is implemented using a 2nd-order MASH Sigma Delta Modulator (SDM), which converts the 6-bit fractional portion of the high port modulation word to a 3-state thermometric code {-1,0,+1}. The resulting code is then added to the integer portion of the high port modulation word and the final result is applied to the HPM DAC.

52.4.4.2.2.3.2.3.2.1 HPM SDM Dither

In addition to the nominal SDM functionality, the HPM SDM design includes a zero-mean dithering to mitigate idle tones that can occur when modulating a string of ones or zeros.

The Dither is implemented using a Linear-Feedback Shift Register (LFSR) which provides a 1-bit pseudo-randomization that adds or subtracts 1-bit to the 6-bit fractional portion before it is processed by the Sigma Delta Modulator.

The length of the LFSR can be selected using the HPM_LFSR_SIZE register, and the scale can be changed using the HPM_DTH_SCL bit. The Dither can also be disabled by clearing the HPM_DTH_EN bit.

52.4.4.2.2.3.2.3.3 High Port Delay, Disable, Invert

The HPM Integer and Fraction portions each have an array of programmable delays available to allow the HPM modulations to be matched to each other and to the LPM modulation and the delay through the PLL Loop Divider and onto the VCO feedback loop.

The HPM delay steps are in increments of the PLL Sigma Delta Clock divided by 2, and the LPM SDM delay steps are in increments of the PLL Sigma Delta Clock. All three delay step settings are in the range of {0 to 15}.

There are several inversion bits that can be used if needed:

- HPM_CAL_INVERT, Invert the High Port Modulator during Calibration
- HPM_MOD_IN_INVERT, Invert the input word to the High Port Modulator
- HPM_INTEGER_INVERT, Invert the High Port Modulation Integer portion
- HPM_SDM_OUT_INVERT, Invert the HPM SDM Fractional Output

High Port Modulation can be disabled by setting the HPM_MOD_DISABLE bit, in this case the HPM_MOD_MANUAL register value is applied to the VCO High Port. Disabling high port modulation can be useful depending on the modulation range required for the desired data rate. For use cases where no high port modulation is required, the TX warm-up time can be reduced by skipping the HPM Calibration. To skip HPM CAL, the register bit HPMCAL_CTRL[HPM_CAL_SKIP] must be set. In this case, the HPM_MOD_MANUAL register should be set to 0x80. Note, the TSM default warm-up sequence must be overridden if HPM_CAL_SKIP is set to recover the HPM CAL warm-up time.

52.4.4.2.2.3.2.4 Low Port Modulation

The Low Port Modulator uses a 3rd order Sigma-Delta to produce a fractional division (Fractional-N Frequency Synthesis) to control the PLL Loop Divider and tune the VCO to the Radio Carrier Frequency.

The Low Port Baseband Frequency Word is added as modulation to the Sigma-Delta input.

52.4.4.2.2.3.2.4.1 Low Port Resolution

The table below shows the PLL Minimum Frequency Step Sizes for Modulation and Carrier Frequency tuning. Note, the PLL Minimum Carrier Frequency Step size is equivalent to the PLL Numerator LSB resolution. This step size is measured at the PLL VCO. This table is calculated using the default numerator value of Numerator = 0x400_0000.

Note that the minimum step size for carrier frequency tuning is a divide by 256 of the modulation step sizes.

Table 479. PLL Minimum Frequency Step Size

Ref Clk Freq (MHz)	32	26
PLL Minimum Modulation Step (Hz)	244.14	198.36
PLL Minimum Carrier Frequency Step (Hz)	0.9536	0.7749

The Integer, Numerator, and Denominator are presented at the input to the Sigma-Delta Modulator.

A 3-level quantized Sigma-Delta output signal {-1, 0, +1} is generated and combined with the Integer divide value to produce the Modulus Divide Ratio for the PLL Loop Divider. The resulting RF Frequency can be calculated using the formula below:

RF Frequency = ((Reference Clock Frequency x 2) x (LPM_INTG + (LPM_NUM / LPM_DENOM))

WARNING : The fraction (LPM_NUM / LPM_DENOM) must be in the range of -0.55 to +0.55 for valid Sigma Delta Modulator operation.

52.4.4.2.2.3.2.4.2 Low Port SDM Dithering

While in Transmit mode the input to the SDM is naturally dithered by the Low Port modulation, which keeps the SDM from generating a pseudo-periodic output. However, in Receive mode, the SDM can potentially generate idle tones (dominant frequency modes at its output) when the input to the SDM is a constant. And in either Transmit or Receive mode the LPM SDM can generate idle tones if the Fraction is near zero.

To mitigate these impairments, the Numerator input to the SDM is dithered whenever the Numerator is in the near zero range { -64 to 63 }, or whenever the Radio is in Receive Mode.

This dither operation can also be overridden using the LPM_D_OVRD and LPM_D_CTRL bits.

52.4.4.2.2.3.2.4.3 Low Port Delay, Disable, Invert

The Low Port Modulator has an array of programmable delays available to allow the HPM modulation to be matched to the LPM modulation and the delay through the PLL Loop Divider and onto the VCO feedback loop.

The Low Port Modulation can be delayed at the PLL Loop Divider by delaying the input to the LPM SDM (LPM_SDM_DELAY).

There is an option to invert the Numerator (LPM_SDM_INV) before it is applied to the SDM in order to invert the sigma-delta modulation to the PLL.

The Low Port Modulation of the Loop Divider can be disabled by setting the LPM_DISABLE bit. When the modulation is disabled the LPM SDM will continue to tune the VCO to the Radio Carrier Frequency.

52.4.4.2.2.3.2.4.4 Inline Phase Return

Inline Phase Return (INPR) is the ability of the hardware to send back the tone in Channel Sounding ranging on the fly, without needed of BLE ranging service.

We have the possibility to get phase information data on initiator during T_PM coming from reflector. To realize that, we adjust phase on reflector for the Transmitter to take into account phase variation for each transfer.

The IQ measured by the initiator can be directly used by the algorithm, because the phase ambiguity is removed during the process.

The correction will be done by adjusting phase with first antenna phase information received on a multiple antenna context.

Additionally, we can shut down the PA for the steps / antenna paths where the TQI measured is very low.

This method eliminates the need of transferring the IQ data over the air.

All fields used below for Inline Phase Return are contained in LPM_SDM_CTRL2 and LPM_SDM_CTRL3 registers.

The significant fields are :

- EN_INPR : 0=Disable / 1=Enable INPR feature .
- EN_INPR_RX_NORM : Enable the integration of phase shift measured from IQ received.
- INPR_DT [2:0] : Integration period (4/8/16/32 sigma-delta modulation cycles).
- INPR_CORR_INV : Possibility to invert corrected number value for INPR.
- INPR_TX_TQI_DIS : Possibility to disable TQI indicator for INPR loopback.

This feature is only available on the reflector side.

It is important to mention that when INPR is enabled, the TQI measured affects the next TX transmission that will be done by the reflector's side : If the TQI indicator measured is bad , the Reflector will cut the powering of TX and therefore prevents it from transmitting, meaning the importance of setting a good TQI thresholds (TQI_THR[T1] and TQI_THR[T2]),this condition can be disabled by Writing 1 in INPR_TX_TQI_DIS .

The mechanism offers 2 operational modes :

52.4.4.2.2.3.2.4.4.1 Normal Mode (INPR from IQ norm return)

EN_INPR = 1 & EN_INPR_RX_NORM = 1 (Can be offset with Packet Ram phase value if needed, 0 by default) .

Apply a phase shift based on the integration of : value in Packet Ram and norm measured from the received IQ .

52.4.4.2.2.3.2.4.4.2 Test Mode (INPR from Only Packet Ram)

EN_INPR = 1 & EN_INPR_RX_NORM = 0

It is possible to apply a phase shift directly and only from the Packet Ram (by programming it in fstep_ram_rdata_req[87:80], register is signed, see Section Packet Ram Data Structures). This functionality might be helpful while validating product since it gives the ability to pre-program a phase shift while ranging.

52.4.4.2.2.3.2.5 Lock Detector

The PLL Lock Detector has two methods to measure the stability of the PLL and check that it is tuned to the selected Radio Frequency.

The real-time results of the PLL Lock Detect module can be read as register bits, and flags are set and can be cleared to provide software long-term access to any PLL unlock events.

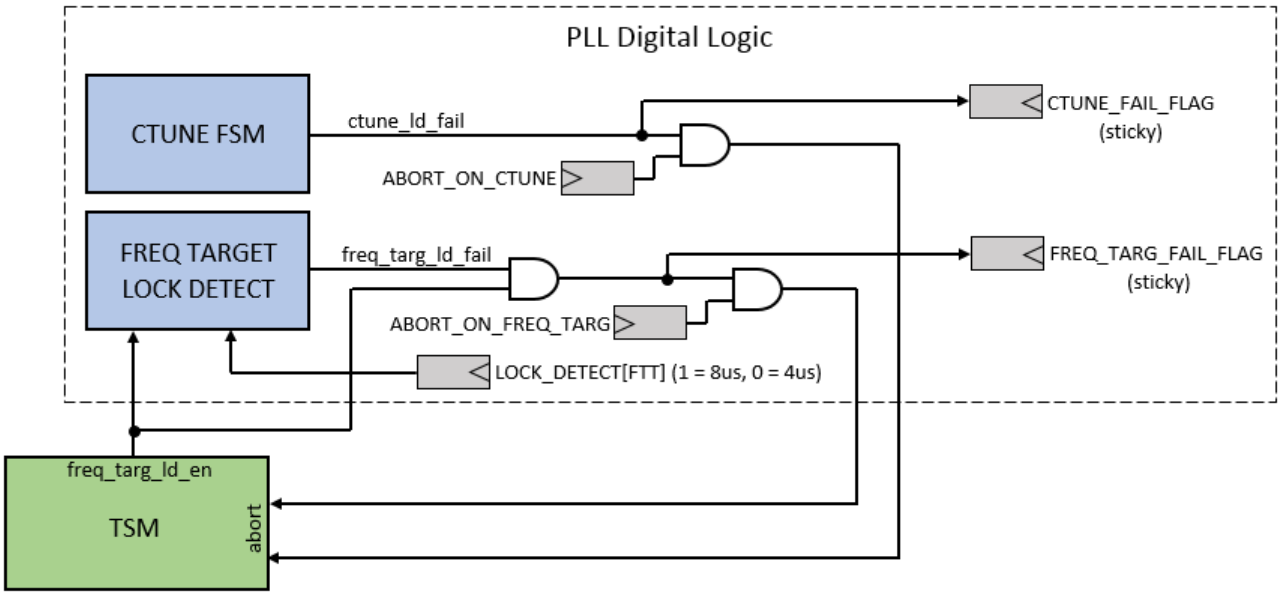


Figure 316. PLL Lock Detect Block Diagram

52.4.4.2.2.3.2.5.1 Coarse Tune Fail

During every Radio start-up sequence the PLL does a Coarse Tune Calibration to select a VCO setting that will allow the PLL to correctly tune and lock the VCO when the PLL/VCO loop is closed.

During the coarse tune calibration a count is maintained that indicates how close the coarse tune is to the targeted Radio Frequency, if this count is outside of the threshold selected by the Coarse Tune Lock Detect Fail Level register (LOCK_DETECT[CTUNE_LDF_LEV]), then the Coarse Tune Failure Flag bit (CTFF) will be set.

The CTFF bit is cleared by writing a 1 to it.

The CT_FAIL bit always shows the real time status of the latest Coarse Tune Calibration. If the absolute count difference was out of the range selected by CTUNE_LDF_LEV, then this bit will be set.

52.4.4.2.2.3.2.5.2 Fine Tune Fail

An additional lock detect method, Fine Tune Lock Detect, can be added to the end of a start-up sequence. The PLL turns on the PLL Frequency Meter for a time that is requested by the Frequency Target Window time select register bits, separately selected for RX (FTW_RX) and TX (FTW_TX).

By default, the pll frequency meter will be turned off after the standard warm-up routine (HPM CAL in TX Mode, CTUNE in RX Mode). The Fine Tune Lock Detect sequence required that the frequency meter remain on after standard warm-up. To override the default behaviour, the LOCK_DETECT[FCAL_HOLD_EN] bit must be set. This will keep the frequency meter on until the Fine Tune Lock Detect sequence has been ran. Note, to trigger the fine tune lock detect sequence, the TSM will also need to be programmed to insert a lock detect at the end of warm-up.

These bits select either a 4us or an 8us count period and if the frequency counter is outside of the threshold selected by the Frequency Target Fail Threshold registers, FTF_RX_THRSH and FTF_TX_THRSH, then the Frequency Target Fail Flag bit (FTFF) will be set.

The FTFF bit is cleared by writing a 1 to it

The FT_FAIL bit always shows the real time status of the latest Fine Tune Frequency Measurement. If the absolute count difference was out of the range selected by Frequency Target Fail Threshold registers, then this bit will be set.

52.4.4.2.2.3.3 Initialization

To enable the digital PLL block, no specific procedure is needed for the clocks or reset. The registers must be programmed in the correct mode, as described in the chapter Functional description.

52.4.4.2.2.3.4 Application information

The procedures to use this module are described in the sub_chapters and register definition.

52.4.4.2.2.3.5 Memory Map and Register Definition

The PLL Digital memory map and detailed descriptions of all its registers are as follows.

52.4.4.2.2.3.5.1 XCVR_PLL_DIG register descriptions

52.4.4.2.2.3.5.1.1 XCVR_PLL_DIG_ADDR memory map

RADIO.XCVR_PLL_DIG base address: 48A0_7300h

Offset	Register	Width (In bits)	Access	Reset value
0h	PLL HPM Analog Bump Control (HPM_BUMP)	32	RW	0844_1012h
4h	PLL Modulation Control (MOD_CTRL)	32	RW	0000_0000h
8h	PLL Channel Mapping (CHAN_MAP)	32	RW	0000_0000h
10h	PLL Channel Mapping Extended (CHAN_MAP_EXT)	32	RW	0010_0000h
18h	PLL Lock Detect Control (LOCK_DETECT)	32	RW	0060_6800h
1Ch	PLL High Port Modulator Control (HPM_CTRL)	32	RW	0084_0000h
2Ch	PLL High Port Sigma Delta Results (HPM_SDM_RES)	32	RW	0100_0000h
30h	PLL Low Port Modulator Control (LPM_CTRL)	32	RW	0800_0800h
34h	PLL Low Port Sigma Delta Control 1 (LPM_SDM_CTRL1)	32	RW	2000_0000h
38h	PLL Low Port Sigma Delta Control 2 (LPM_SDM_CTRL2)	32	RW	0200_0000h
3Ch	PLL Low Port Sigma Delta Control 3 (LPM_SDM_CTRL3)	32	RW	1400_0000h
40h	PLL Low Port Sigma Delta Result 1 (LPM_SDM_RES1)	32	R	0E20_0000h
44h	PLL Low Port Sigma Delta Result 2 (LPM_SDM_RES2)	32	R	0400_0000h
48h	PLL Delay Matching (DELAY_MATCH)	32	RW	0000_0204h
4Ch	Tuning Cap Settings in Transmit Mode (TUNING_CAP_TX_CTRL)	32	RW	006D_B6DBh
50h	Tuning Cap Settings in Receive Mode (TUNING_CAP_RX_CTRL)	32	RW	006D_B6DBh

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
58h	Max and Min Transmit Frequencies For TX Configuration 1 (MAX_MIN_TX_CFG1_FREQ)	32	RW	0000_0FFFh
5Ch	PLL Coarse Tune Control (CTUNE_CTRL)	32	RW	0000_0000h
60h	PLL Data Rate Override Control (DATA_RATE_OVRD_CTRL1)	32	RW	0800_0188h
64h	PLL Data Rate Override Control (DATA_RATE_OVRD_CTRL2)	32	RW	0018_0000h
84h	PLL Coarse Tune Results (CTUNE_RES)	32	R	0000_0000h
A0h	PLL HPM Calibration Timing Attributes (HPM_CAL_TIMING)	32	RW	0000_0000h
A4h	PLL Offset Control (PLL_OFFSET_CTRL)	32	RW	0000_0000h
A8h	PLL Data Rate Switch Control (PLL_DATARATE_CTRL)	32	RW	0000_6612h

52.4.4.2.2.3.5.1.2 PLL HPM Analog Bump Control (HPM_BUMP)

Offset

Register	Offset
HPM_BUMP	0h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	HPM_FDB_RES_RX		0		HPM_VCM_RX		0	HPM_BUM...	0	PLL_VCO_TRIM_KVM_CAL			0	PLL_VCO_TRIM_KVM_TX		
W																
Reset	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		HPM_FDB_RES_CAL		0		HPM_FDB_RES_TX		0	HPM_VCM_CAL			0	HPM_VCM_TX		
W																
Reset	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0

Fields

Field	Function
31-30 HPM_FDB_RES_RX	a_ip_2p4ghz_reg_dac_trim_rfbk_dig[1:0] during Reception This is the value applied to the a_ip_2p4ghz_reg_dac_trim_rfbk_dig[1:0] port during Radio Receptions. This register sets the HPM DAC feedback resistor during receptions.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	00b - 38.0k (1.0) 01b - 76.0k (0.5) 10b - 32.5k (1.14) 11b - 25.3k (1.4)
29 —	Reserved
28-26 HPM_VCM_RX	a_ip_2p4ghz_reg_dac_trim_vcm_dig[2:0] during Reception This is the value applied to the a_ip_2p4ghz_reg_dac_trim_vcm_dig[2:0] port during Radio Receptions. This register sets the HPM DAC Op-Amp reference voltage during receptions. Trim of amplifier reference voltage (amplifier output voltage for dac_code = 127). 000b - 0.120 (0.122) 001b - 0.153 (0.189) 010b - 0.182 (0.247) 011b - 0.209 (0.300) 100b - 0.234 (0.348) 101b - 0.258 (0.393) 110b - 0.279 (0.434) 111b - 0.318 (0.509)
25 —	Reserved
24 HPM_BUMP_RX_TX_EN	Enable HPM BUMP management with alternate RX/TX mode, if set to 1: - HPM_VCM_TX and HPM_FDB_RES_TX are used in TX mode - HPM_VCM_RX and HPM_FDB_RES_RX are used in RX mode
23 —	Reserved
22-20 PLL_VCO_TRIM_KVM_CAL	reg_vco_trim_kvm_dig[2:0] for calibration kv mod control for calibration (for modulation index control). 000b - 10MHz/V 100b - 20MHz/V 110b - 30MHz/V 111b - 40MHz/V

Table continues on the next page...

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Field	Function
19 —	Reserved
18-16 PLL_VCO_TRIM_KVM_TX	reg_vco_trim_kvm_dig[2:0] for transmit kv mod control for transmit (for modulation index control). 000b - 10MHz/V 100b - 20MHz/V 110b - 30MHz/V 111b - 40MHz/V
15-14 —	Reserved
13-12 HPM_FDB_RES_CAL	a_ip_2p4ghz_reg_dac_trim_rfbk_dig[1:0] during Calibration This is the value applied to the a_ip_2p4ghz_reg_dac_trim_rfbk_dig[1:0] port during High Port Calibration. This register sets the HPM DAC feedback resistor to increase the modulation gain during calibration. 00b - 38.0k (1.0) 01b - 76.0k (0.5) 10b - 32.5k (1.14) 11b - 25.3k (1.4)
11-10 —	Reserved
9-8 HPM_FDB_RES_TX	a_ip_2p4ghz_reg_dac_trim_rfbk_dig[1:0] during Transmission This is the value applied to the a_ip_2p4ghz_reg_dac_trim_rfbk_dig[1:0] port during Radio Transmissions. This register sets the HPM DAC feedback resistor during transmissions. 00b - 38.0k (1.0) 01b - 76.0k (0.5) 10b - 32.5k (1.14) 11b - 25.3k (1.4)
7 —	Reserved
6-4 HPM_VCM_CAL	a_ip_2p4ghz_reg_dac_trim_vcm_dig[2:0] during Calibration This is the value applied to the a_ip_2p4ghz_reg_dac_trim_vcm_dig[2:0] port during High Port Calibration. This field sets the HPM DAC Op-Amp reference voltage during calibration.

Table continues on the next page...

Table continued from the previous page...

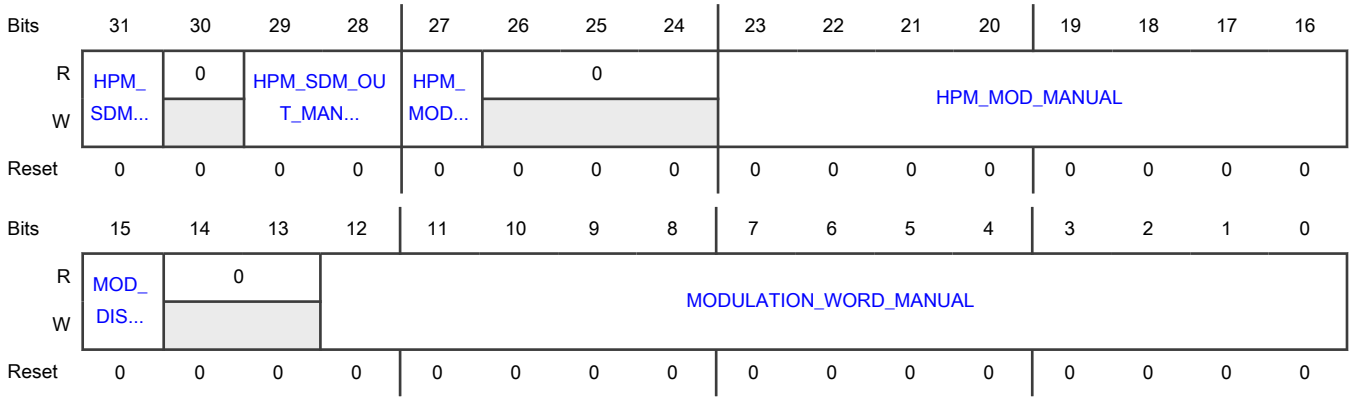
Field	Function
	Trim of amplifier reference voltage (amplifier output voltage for dac_code = 127). 000b - 0.120 (0.122) 001b - 0.153 (0.189) 010b - 0.182 (0.247) 011b - 0.209 (0.300) 100b - 0.234 (0.348) 101b - 0.258 (0.393) 110b - 0.279 (0.434) 111b - 0.318 (0.509)
3 —	Reserved
2-0 HPM_VCM_TX	a_ip_2p4ghz_reg_dac_trim_vcm_dig[2:0] during Transmission This is the value applied to the a_ip_2p4ghz_reg_dac_trim_vcm_dig[2:0] port during Radio Transmissions. This register sets the HPM DAC Op-Amp reference voltage during transmissions. Trim of amplifier reference voltage (amplifier output voltage for dac_code = 127). 000b - 0.120 (0.122) 001b - 0.153 (0.189) 010b - 0.182 (0.247) 011b - 0.209 (0.300) 100b - 0.234 (0.348) 101b - 0.258 (0.393) 110b - 0.279 (0.434) 111b - 0.318 (0.509)

52.4.4.2.2.3.5.1.3 PLL Modulation Control (MOD_CTRL)

Offset

Register	Offset
MOD_CTRL	4h

Diagram



Fields

Field	Function
31 HPM_SDM_OUT_DISABLE	Disable HPM SDM out If this bit is set, the High Port Sigma Delta Modulator output is disabled, and the High Port Fractional value applied to the VCO comes from the HPM_SDM_OUT_MANUAL register.
30 —	Reserved
29-28 HPM_SDM_OUT_MANUAL	Manual HPM SDM out If HPM_SDM_OUT_DISABLE is set, this register is the Fractional value that is applied to the VCO High Port.
27 HPM_MOD_DISABLE	Disable HPM Modulation If this bit is set, the High Port Modulation is disabled, and the High Port Modulation value applied to the VCO comes from the HPM_MOD_MANUAL register.
26-24 —	Reserved
23-16 HPM_MOD_MANUAL	Manual HPM Modulation If HPM_MOD_DISABLE is set, this register is the modulation value that is applied to the VCO High Port.
15 MOD_DISABLE	Disable Modulation Word If this bit is set, any modulation from the TX Digital is disabled and the source of the Baseband Frequency Word is the MODULATION_WORD_MANUAL register.
14-13 —	Reserved
12-0	Manual Modulation Word

Table continues on the next page...

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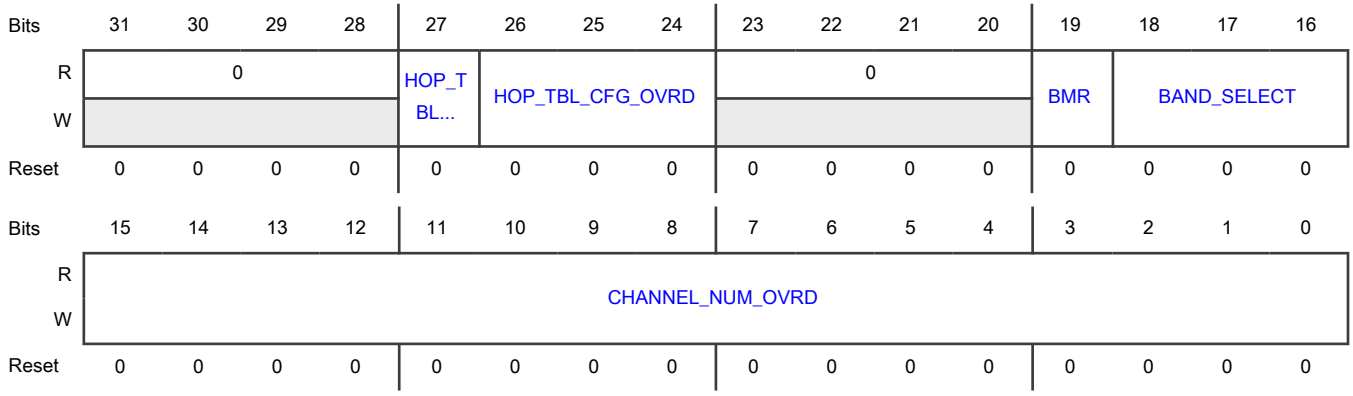
Field	Function
MODULATION_WORD_MANUAL	If MOD_DISABLE is set, the signed 12 bit value that is represented by this register is the Baseband Frequency Word.

52.4.4.2.2.3.5.1.4 PLL Channel Mapping (CHAN_MAP)

Offset

Register	Offset
CHAN_MAP	8h

Diagram



Fields

Field	Function
31-28 —	Reserved
27 HOP_TBL_CFG_OVRD_EN	Hop Table Configuration Override Enable If this bit is set then the HOP_TBL_CFG_OVRD and CHANNEL_NUM_OVRD Registers will be used to control the Coarse Tune, Channel Number, and Hop Table for the PLL Carrier Frequency Selection.
26-24 HOP_TBL_CFG_OVRD	Hop Table Configuration Override If the HOP_TBL_CFG_OVRD_EN bit is set, then the CHANNEL_NUM_OVRD Register will be used to control the Hop Table for the PLL Carrier Frequency Selection. 000b-001b - CHANNEL_NUM_OVRD[6:0] is used as the mapped channel number. CHANNEL_NUM_OVRD[15:7] is unused.

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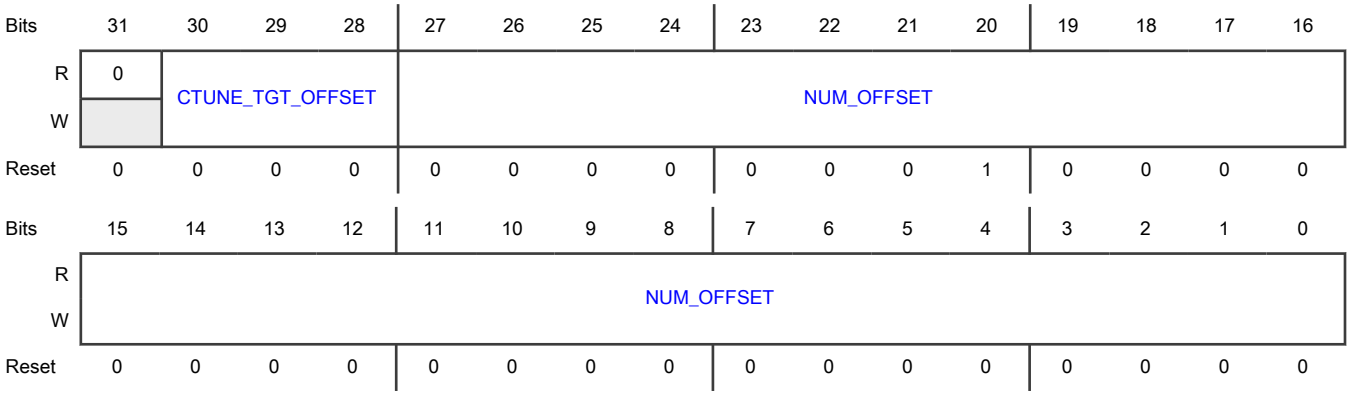
Field	Function
	010b - CHANNEL_NUM_OVRD[15:7] is signed Numerator offset to CHANNEL_NUM_OVRD[6:0] mapped channel number 011b - CHANNEL_NUM_OVRD[15:1] is selected as the signed Numerator, CHANNEL_NUM_OVRD[0] is integer selection
23-20 —	Reserved
19 BMR	Bluetooth Low Energy MBAN Channel Remap This bit controls the mapping of Bluetooth Low Energy channel 39 in Radio Protocol 2, Bluetooth Low Energy overlap MBAN mode. 0b - Bluetooth Low Energy channel 39 is mapped to Bluetooth Low Energy channel 39, 2.480 GHz 1b - Bluetooth Low Energy channel 39 is mapped to MBAN channel 39, 2.399 GHz
18-16 BAND_SELECT	Channel Mapping Band Select This register field is used to map the PLL input channel to a specific frequency band. Note, all link layer channel selections are MUXed into a single PLL input. This register field will select how the input channel is mapped to a specific carrier frequency. See section Carrier Frequency Tuning for a table outlining the channel vs. frequency relationship for all supported protocols. 000b - Bluetooth Low Energy 001b - Bluetooth Low Energy in MBAN 010b - Bluetooth Low Energy overlap MBAN 011b - RESERVED 100b - IEEE 802.15.4 O-QPSK PHY in ISM band 101b - IEEE 802.15.4 O-QPSK PHY in MBAN band 110b-111b - Radio Channels 0-127 selectable
15-0 CHANNEL_NUM_OVRD	Channel Selection Override When the HOP_TBL_CFG_OVRD_EN register field is set to 0b1, the CHANNEL_NUM_OVRD will be selected for the input PLL channel. The HOP_TBL_CFG_OVRD register field is used to decode CHANNEL_NUM_OVRD to determine the final PLL locking frequency.

52.4.4.2.2.3.5.1.5 PLL Channel Mapping Extended (CHAN_MAP_EXT)

Offset

Register	Offset
CHAN_MAP_EXT	10h

Diagram



Fields

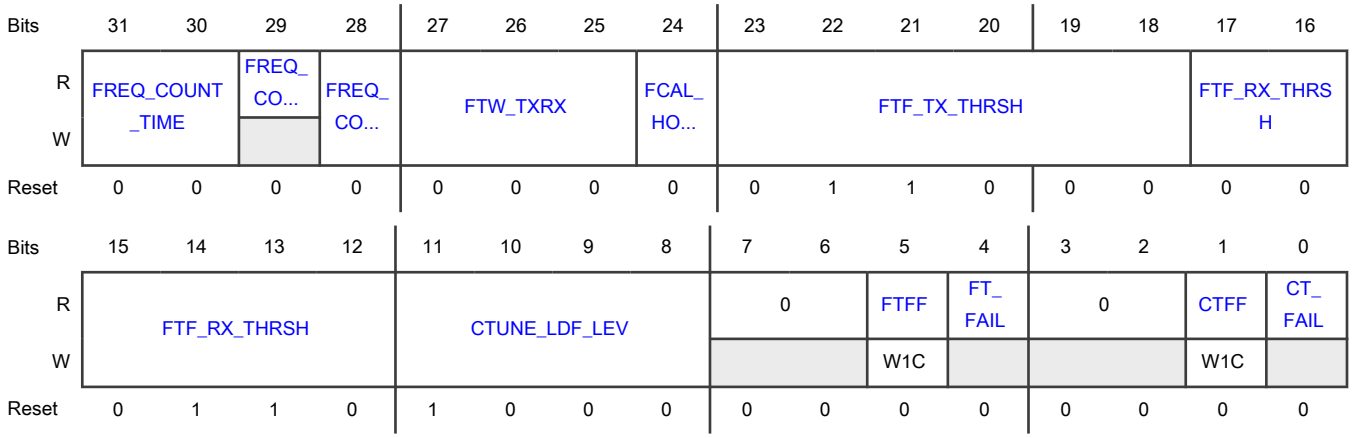
Field	Function
31 —	Reserved
30-28 CTUNE_TGT_OFFSET	Coarse Tune Target Frequency Offset In RX Mode, the PLL Coarse Tune Target Frequency will be subtracted from the CTUNE_TGT_OFFSET to form the final CTUNE Target Frequency. Note, if this register field is left as zero, then it will have no effect. A value should only written here if the NUM_OFFSET is large enough to require a CTUNE modification. This value should be written as a 3-bit two's compliment number. Register bit 30 is the CTUNE_TGT_OFFSET sign bit. The unit for CTUNE_TGT_OFFSET is MHz. This register can provide a maximum offset of +3 MHz or -4 MHz from the internally calculated CTUNE Target.
27-0 NUM_OFFSET	Numerator Offset The NUM_OFFSET register field represents the IF frequency difference between RX and TX. To achieve this offset, the NUM_OFFSET value will be subtracted from the internally derived PLL Numerator value. Note that the numerator LSB will change the PLL target frequency according to the table in section Low Port Modulation . This value represents a multiple of the pll minimum frequency step size. In RX Mode, this register holds a signed two's compliment offset which will be subtracted from the PLL Numerator value calculated using the PLL internal channel mapping logic. Warm-up in RX mode will automatically subtract this value from the PLL Numerator. If NUM_OFFSET == 0 then no frequency offset will exist between Tx to Rx. Bit 27 of this register provides the sign bit for RX_NUM_OFSET. The largest positive number supported is 0x3FF_FFFF. The largest negative number supported is 0xC00_0000. Note, manual override mode won't use this register field.

52.4.4.2.2.3.5.1.6 PLL Lock Detect Control (LOCK_DETECT)

Offset

Register	Offset
LOCK_DETECT	18h

Diagram



Fields

Field	Function
31-30 FREQ_COUNT_TIME	Frequency Meter Count Time This is the length of time that the Frequency Meter will count VCO clocks. 00b - 800 us 01b - 25 us 10b - 50 us 11b - 100 us
29 FREQ_COUNT_FINISHED	Frequency Meter has finished the Count Time This bit is set when the FREQ_COUNT_TIME value is reached, it is cleared when FREQ_COUNT_GO is cleared.
28 FREQ_COUNT_GO	Start the Frequency Meter The Frequency Meter starts when this bit is set and runs until the FREQ_COUNT_TIME value is reached. The bit should not be cleared until after the counting is finished. After the Counting Time finishes, the FREQ_COUNT_FINISHED bit will read as a one. Then the measured frequency can be calculated by reading the frequency counts in the DFT_FREQ_COUNTER register (PLL_DFT_OCR_1[DFT_FREQ_COUNTER]) and dividing by the FREQ_COUNT_TIME. Note that the counting is done at the VCO frequency which is 2X the Carrier Frequency
27-25 FTW_TXRX	TX and RX Frequency Target Window time select In Radio Receive Mode, register field is decoded to select the length of time to count for the estimation of PLL lock frequency, which is compared with the Frequency Target Window, we refer to this decoding as FTW_RX. In Radio Transmit Mode, register field is decoded to select the length of time to count for the estimation of PLL lock frequency, which is compared with the Frequency Target Window, we refer to this decoding as FTW_TX.

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Field	Function
	000b - FTW_TX = 4us ; FTW_RX = 4us 001b - FTW_TX = 4us ; FTW_RX = 8us 010b - FTW_TX = 8us ; FTW_RX = 4us 011b - FTW_TX = 8us ; FTW_RX = 8us 100b - FTW_TX = 16us ; FTW_RX = 16us 101b - FTW_TX = 16us ; FTW_RX = 32us 110b - FTW_TX = 32us ; FTW_RX = 16us 111b - FTW_TX = 32us ; FTW_RX = 32us
24 FCAL_HOLD_EN	Frequency Counter Hold Enable This bit controls if the pll ripple counter stays on after the PLL warm-up sequence (TX or RX). By default (FCAL_HOLD_EN==0b0), the ripple counter will be turned off after completing CTUNE in RX mode and HPM CAL in TX mode. If the ripple counter is turned off after the standard warm-up sequence, then a lock detect sequence cannot be inserted during warm-up. To support this lock detect sequence, FCAL_HOLD_EN can be asserted to ensure the PLL ripple counter is maintained in an on state after the default CTUNE or HPM CAL state. In addition, the TSM should be programmed to run the lock detect sequence at the appropriate time during warmup. 0b - The frequency counter is turned off after CTUNE (RX Mode) or HPM CAL (TX Mode) 1b - The frequency counter is held on after CTUNE (RX Mode) or HPM CAL (TX Mode) for an optional lock detect sequence.
23-18 FTF_TX_THRSH	TX Frequency Target Fail Threshold In Radio Transmit Mode, the FT_FAIL and FTFF bits will be set after the Frequency Target Count completes if the absolute value of the count difference from the frequency target count is greater than this register value.
17-12 FTF_RX_THRSH	RX Frequency Target Fail Threshold In Radio Receive Mode, the FT_FAIL and FTFF bits will be set after the Frequency Target Count completes if the absolute value of the count difference from the frequency target count is greater than this register value.
11-8 CTUNE_LDF_LEV	CTUNE Lock Detect Fail Level The CT_FAIL and CTFF bits will be set after Coarse Tune Calibration completes if the absolute value of the Coarse Tune best count difference (CTUNE_BEST_DIFF in the PLL_CTUNE_RESULTS register) is greater than this register value.
7-6 —	Reserved
5 FTFF	Frequency Target Failure Flag This bit is set when FT_FAIL is first set, and this bit is cleared by writing a 1 to it.
4	Real time status of Frequency Target Failure

Table continues on the next page...

Table continued from the previous page...

Field	Function
FT_FAIL	If the Frequency Target Count has completed and the count was out of the range selected by FTW_TX or FTW_RX, then this bit will be set.
3-2 —	Reserved
1 CTFF	CTUNE Failure Flag, held until cleared This bit is set when CT_FAIL is first set, and this bit is cleared by writing a 1 to it.
0 CT_FAIL	Real time status of Coarse Tune Fail signal If the Coarse Tune Calibration has completed and the best count difference is out of the range selected by CTUNE_LDF_LEV, then this bit will be set.

52.4.4.2.2.3.5.1.7 PLL High Port Modulator Control (HPM_CTRL)

Offset

Register	Offset
HPM_CTRL	1Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	HPM_MOD...	HPM_CAL_TIME		HPM_CAL...	HPM_INT...	HPM_SCALE			HPM_DTH...	HPM_DYN...	HPM_DYN...	HPM_DTH...	RX_HPM_...	HPM_LFSR_SIZE		
W																
Reset	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	HPM_SDM...	HPM_SDM...	HPFF	HPM_CLK...	0	HPM_DYN...	HPM_SDM_IN_MANUAL									
W			W1C													
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 HPM_MOD_IN_INVERT	Invert High Port Modulation If this bit is set then the High Port Modulation Word is inverted before it is multiplied and split into Integer and Fractional values.
30-29	High Port Modulation Calibration Time

Table continues on the next page...

Table continued from the previous page...

Field	Function
HPM_CAL_TIME	This bit selects the length of time to count during HPM Calibration and is used by the math implemented in the HPM Calibration Factor lookup table. 00b - 25 us 01b - 50 us 10b - 100 us 11b - N/A
28 HPM_CAL_INVERT	Invert High Port Modulator Calibration If this bit is set then the order of the High Port Calibration is reversed in order to get a positive count difference between the Maximum and Minimum settings of the HPM DAC.
27 HPM_INTEGER_INVERT	Invert High Port Modulation Integer If this bit is set then the High Port Modulation Integer value, after the multiply and split into Integer and Fractional values, will be inverted before it is applied to the VCO High Port DAC Array.
26-24 HPM_SCALE	High Port Modulation Scale This register controls the scaling of the High Port Modulation word. 000b - No Scaling 001b - Divide by 2 010b - Multiply by 2 011b - Multiply by 4 100b - Divide by 4 101b - Multiply by 8 110b - Divide by 8 111b - N/A
23 HPM_DTH_EN	Dither Enable for HPM LFSR If this bit is set, the High Port Fraction will be Dithered by the High Port LFSR before it is applied to the High Port SDM.
22 HPM_DYNAMIC_RX_TONE_TABLE	If HPM_DYNAMIC_SEL is set to 1, RX tone will be applied following HPM calibration factor: 0b - constant value from HPM_CAL_FACTOR_MANUAL register 1b - table value from packet RAM
21 HPM_DYNAMIC_RX_PKT_TABLE	If HPM_DYNAMIC_SEL is set to 1, RX packet will be applied following HPM calibration factor: 0b - constant value from HPM_CAL_FACTOR_MANUAL register 1b - table value from packet RAM
20	HPM Dither Scale

Table continues on the next page...

Table continued from the previous page...

Field	Function
HPM_DTH_SCL	If this bit is set, the LFSR dithering of the High Port Fraction will be multiplied by 2.
19 RX_HPM_CAL_EN	Receive HPM Calibration Enable If this bit is set, HPM Calibration takes place in receive mode.
18-16 HPM_LFSR_SIZE	HPM LFSR Length This register selects the length of the HPM LFSR and the associated LFSR Tap Mask 000b - LFSR 9, tap mask 100010000 001b - LFSR 10, tap mask 1001000000 010b - LFSR 11, tap mask 11101000000 011b - LFSR 13, tap mask 1101100000000 100b - LFSR 15, tap mask 111010000000000 101b - LFSR 17, tap mask 11110000000000000 110b - Reserved 111b - Reserved
15 HPM_SDM_IN_DISABLE	Disable HPM SDM Input If this bit is set, the Fractional portion of the High Port Modulation to the High Port SDM is disabled, and the High Port SDM input comes from the HPM_SDM_IN_MANUAL register.
14 HPM_SDM_OUT_INVERT	Invert HPM SDM Output If this bit is set the High Port SDM result will be Inverted before it is applied to the VCO High Port DAC Array.
13 HPFF	HPM SDM Invalid Flag This bit is set if the High Port Sigma Delta Modulator output is invalid due to an error in the fraction applied, and this bit is cleared by writing a 1 to it.
12 HPM_CLK_CONFIG	HPM Clock Config When this bit is set, the HPM modulation path including the HPM_SDM operate at the CLK_SDM clock (which is the 2x reference clock derived from PLL loop divider). By default they operate at the reference clock.
11 —	Reserved
10 HPM_DYNAMIC_SEL	HPM dynamic calibration factor source selection for channel sounding If set to 1, HPM calibration factor will be automatically applied as following during channel sounding: - for TX mode, factor will be from a table (packet RAM)

Table continues on the next page...

Table continued from the previous page...

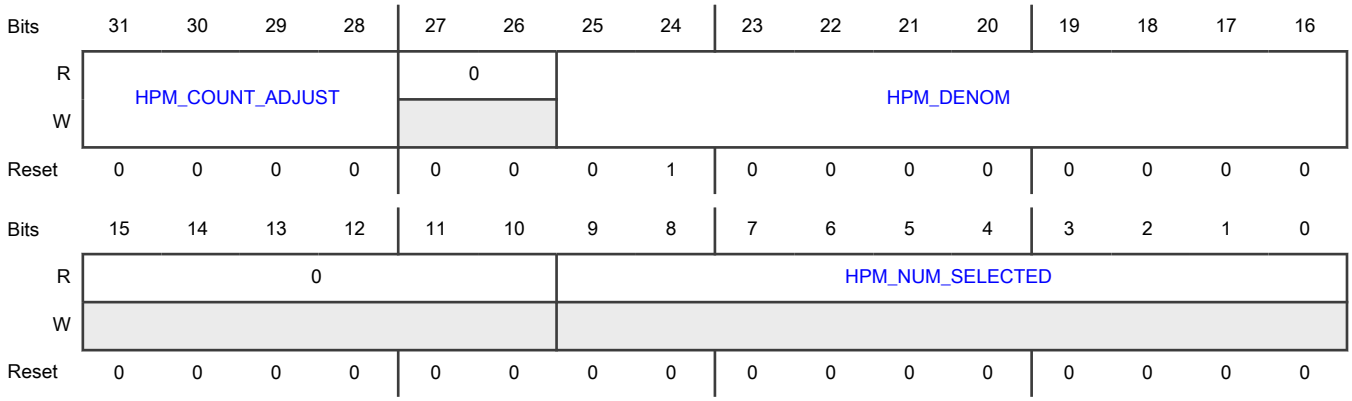
Field	Function
	- for packet RX mode, factor will be either from a table (packet RAM) or constant (HPM_CAL_FACTOR_MANUAL) according to HPM_DYNAMIC_RX_PKT_TABLE bit - for tone RX mode, factor will be either from a table (packet RAM) or constant (HPM_CAL_FACTOR_MANUAL) according to HPM_DYNAMIC_RX_TONE_TABLE bit
9-0 HPM_SDM_IN_MANUAL	Manual High Port SDM Fractional value If HPM_SDM_IN_DISABLE is set, this register is the value that is applied as the Fractional value to the input of the High Port SDM.

52.4.4.2.2.3.5.1.8 PLL High Port Sigma Delta Results (HPM_SDM_RES)

Offset

Register	Offset
HPM_SDM_RES	2Ch

Diagram



Fields

Field	Function
31-28 HPM_COUNT_ADJUST	HPM_COUNT_ADJUST This register represents a signed three bit value that is used to adjust the High Port Calibration Frequency Count Difference. The range of adjustment is -8 to +7, applied to the difference between Count 1 and Count 2.
27-26 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
25-16 HPM_DENOM	High Port Modulator SDM Denominator This is the denominator that is currently being applied to the High Port Sigma Delta Modulator, for valid Sigma Delta operation the resulting fraction NUM/DENOM must be in the range -0.6 to +0.6
15-10 —	Reserved
9-0 HPM_NUM_SELECTED	High Port Modulator SDM Numerator This is the numerator that is currently being applied to the High Port Sigma Delta Modulator, for valid Sigma Delta operation the resulting fraction NUM/DENOM must be in the range -0.6 to +0.6

52.4.4.2.2.3.5.1.9 PLL Low Port Modulator Control (LPM_CTRL)

Offset

Register	Offset
LPM_CTRL	30h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LPM_SDM...	LPM_SKI...	LPM_COD...	LPM_FAS...	LPM_SCALE				LPM_D_O...	LPM_D_C...	0		LPM_DTH_SCL			
W																
Reset	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	LPM_DIS...	LPM_SDM...	LPFF	PLL_LD_...	HPM_CAL_SCALE				0			PLL_LD_MANUAL				
W			W1C													
Reset	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 LPM_SDM_USE_NEG	Use the Negedge of the Sigma Delta clock If this bit is set then the negative edge of the Sigma Delta clock is used to launch the Low Port Modulation word to the VCO Loop Divider.
30	LPM SDM Skip Counter Delay

Table continues on the next page...

Table continued from the previous page...

Field	Function
LPM_SKIP_CNT_DELAY	This bit gives possibility to bypass 3 flops delay between sigma_delta output and codes output digital, could be use to speed up transition between 2 domains for SDM codes
29 LPM_CODES_ADJ	LPM SDM Codes Adjustment This bit enable the SDM code adjustment at the clock switching transition between ref_clk and sdm_clk (adjust with FCODES_VAL and LPM_FCODES_CNT fields of LPM_SDM_CTRL1) SDM codes corrections are applied when this field set to 1 or when register lpm_fast_sw=1.
28 LPM_FAST_SW	LPM Fast Switch mode If set to 1, this will send sdm codes just after pll loop is closed and use sigma_delta clock from analog as the sdm codes generator . This will speed up transition after loop is closed. This will also force some codes at the beginning of closed loop (FCODES_VAL and LPM_FCODES_CNT fields of LPM_SDM_CTRL1)
27-24 LPM_SCALE	LPM Scale Factor This register controls the scaling of the Baseband Frequency Word and is used to match the Modulation Frequency Deviation required to the Low Port Sigma Delta Modulator LSB size in Hz. 0000b - No Scaling 0001b - Multiply by 2 0010b - Multiply by 4 0011b - Multiply by 8 0100b - Multiply by 16 0101b - Multiply by 32 0110b - Multiply by 64 0111b - Multiply by 128 1000b - Multiply by 256
23 LPM_D_OVRD	LPM Dither Override Mode Select When this bit is set, the Scaled Baseband Frequency Word applied to the Low Port Sigma Delta Modulator will be dithered if LPM_D_CTRL is set, and not dithered if LPM_D_CTRL is cleared. If this bit is cleared, then the LPM Numerator will be dithered in Radio Receive mode, and also in Radio Transmit mode when the LPM Numerator approaches an Integer value in order to preserve the validity of the Sigma Delta Modulator output.
22 LPM_D_CTRL	LPM Dither Control in Override Mode If LPM_D_OVRD is set, this bit turns LPM Dithering on and off.
21-20 —	Reserved
19-16 LPM_DTH_SCL	LPM Dither Scale

Table continues on the next page...

Table continued from the previous page...

Field	Function
	This register controls the scale of the Dithering added to the Scaled Baseband Frequency Word before it is applied to the Low Port Sigma Delta Modulator as the LPM Numerator. The unit for the ranges shown below is the LP SDM LSB in Hz. 0000b - Reserved 0001b - Reserved 0010b - Reserved 0011b - Reserved 0100b - Reserved 0101b - -128 to 96 0110b - -256 to 192 0111b - -512 to 384 1000b - -1024 to 768 1001b - -2048 to 1536 1010b - -4096 to 3072 1011b - -8192 to 6144 1100b - Reserved 1101b - Reserved 1110b - Reserved 1111b - Reserved
15 LPM_DISABLE	Disable LPM SDM This bit controls the Modulation of the Low Port Sigma Delta. If this bit is set, the Low Port Sigma Delta Modulator will be active and control the PLL to maintain a steady frequency based on the current Integer, Numerator, and Denominator values that are being applied. No Modulation or Dithering will be added to the steady frequency result.
14 LPM_SDM_INV	Invert LPM SDM If this bit is set the Scaled Baseband Frequency Word, including any Dithering, will be Inverted before it is applied to the Low Port Sigma Delta Modulator.
13 LPFF	LPM SDM Invalid Flag This bit is set if the Low Port Sigma Delta Modulator output is invalid due to an error in the fraction applied, and this bit is cleared by writing a 1 to it.
12 PLL_LD_DISABLE	Disable PLL Loop Divider If this bit is set, the Low Port Sigma Delta Modulator output is disabled, and the PLL Loop Divider value applied to the PLL comes from the PLL_LD_MANUAL register.
11-8	High Port Calibration Word Scaling

Table continues on the next page...

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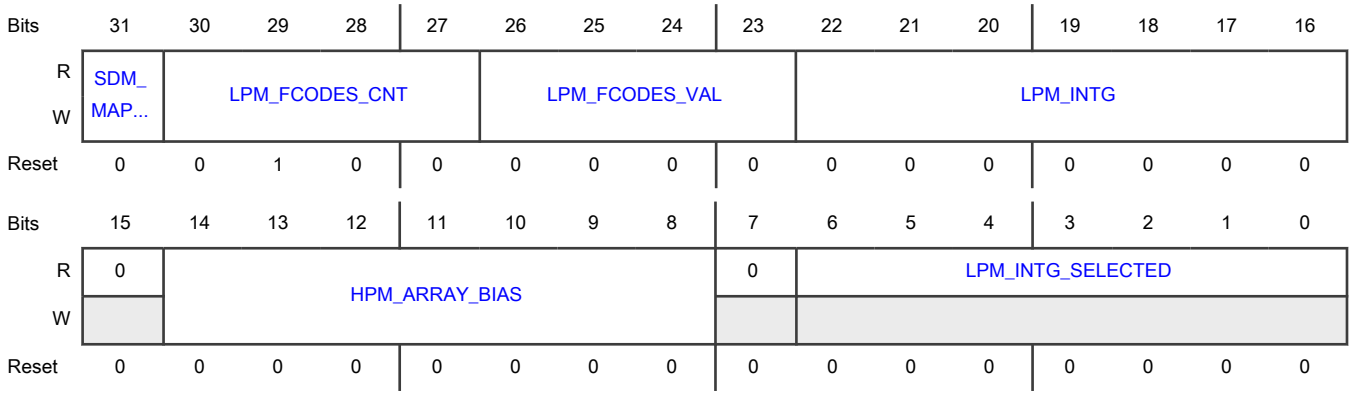
Field	Function
HPM_CAL_SCALE	The calibration factor LPM_LSB/HPM_LSB will be scaled using the following bitfield settings. This bit field should be adjusted in conjunction with LPM_SCALE according to the modulation range. The default setting is no scaling factor applied. 0000b-0010b - No Scaling 0011b - Divide by 32 0100b - Divide by 16 0101b - Divide by 8 0110b - Divide by 4 0111b - Divide by 2 1000b - No Scaling 1001b - Multiply by 2 1010b - Multiply by 4 1011b - Multiply by 8 1011b-1111b - No Scaling
7-5 —	Reserved
4-0 PLL_LD_MANUAL	Manual PLL Loop Divider value If PLL_LD_DISABLE is set, this register is the value that is applied to the PLL Loop Divider.

52.4.4.2.2.3.5.1.10 PLL Low Port Sigma Delta Control 1 (LPM_SDM_CTRL1)

Offset

Register	Offset
LPM_SDM_CTRL1	34h

Diagram



Fields

Field	Function
31 SDM_MAP_DISABLE	Disable SDM Mapping If this bit is set, the Low Port Sigma Delta Modulator internal frequency mapping based on Protocol specific channel numbers is disabled, and the Radio Channel Frequency is selected by setting the LPM_INTG, LPM_NUM, and LPM_DENOM registers to get a frequency that equals : ((Reference Clock Frequency x 2) x (LPM_INTG + (LPM_NUM / LPM_DENOM))
30-27 LPM_FCODES_CNT	LPM SDM Forced Counter When feature LPM_FAST_SW or LPM_CODES_ADJ are activated, we can force the sigma delta output with LPM_FCODES_VAL during this period value. This is in number of clock_switcher_period.
26-23 LPM_FCODES_VAL	LPM SDM Forced Value When feature LPM_FAST_SW or LPM_CODES_ADJ are activated, we can force the sigma delta output with this value. There is an offset of 32, so value 0 represents a code SDM of 32.
22-16 LPM_INTG	Manual Low Port Modulation Integer Value If SDM_MAP_DISABLE is set, this register is the value that is applied to the Low Port Sigma Delta Modulator for the Integer, the nominal range is 36 to 39 in decimal.
15 —	Reserved
14-8 HPM_ARRAY_BIAS	Bias value for High Port DAC Array Midpoint The value of this register represents a signed six bit value that can be used to adjust the midpoint of the High Port Modulator DAC. The range of adjustment is -64 to +63, and the adjustment is made to the High Port Modulation Word before the multiply, and before the split into Integer and Fractional values. The range of adjustment in Hz is approximately +/- 62.5 kHz
7 —	Reserved

Table continues on the next page...

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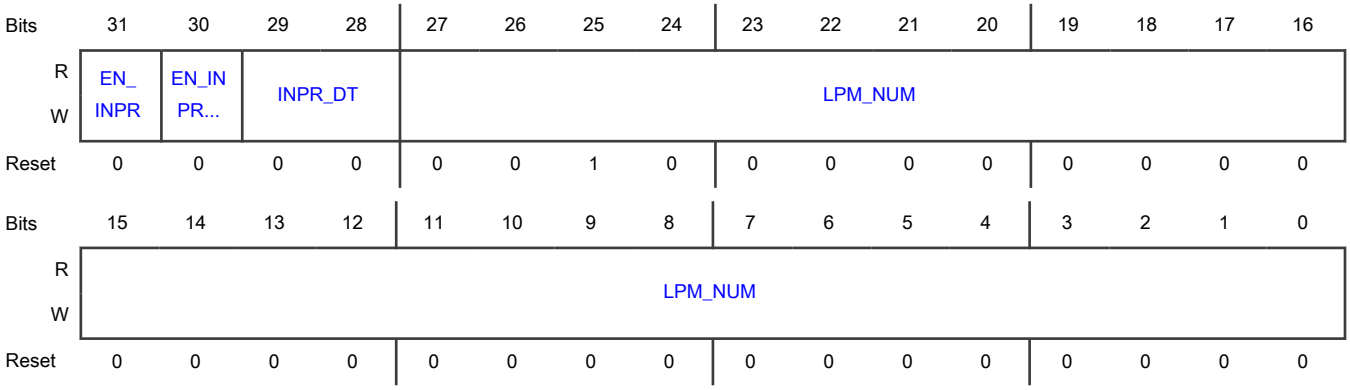
Field	Function
6-0 LPM_INTG_SELECTED	Low Port Modulation Integer Value Selected This shows the Integer value that is currently being applied to the Low Port Sigma Delta Modulator.

52.4.4.2.2.3.5.1.11 PLL Low Port Sigma Delta Control 2 (LPM_SDM_CTRL2)

Offset

Register	Offset
LPM_SDM_CTRL2	38h

Diagram



Fields

Field	Function
31 EN_INPR	Enable for feature Inline phase return ranging Enables full feature inline phase return
30 EN_INPR_RX_NORM	Enable for Inline phase return feature, rx_norm contribution Enables phase from rx_norm_nb to be used as input of pll_narrowband_lpm_sdm, for inline phase return ranging feature. This phase is mandatory to send back inline value on the fly with phase information coming from RX path, but could be bypassed for debug and keep only a phase value coming from pktram.
29-28 INPR_DT	Inline phase return ranging integration period dt=integration period = 4/8/16/32 'SDM clock' cycles 00b - 4 SDM clock cycles, 0.0625us

Table continues on the next page...

Table continued from the previous page...

Field	Function
	01b - 8 SDM clock cycles, 0.125us 10b - 16 SDM clock cycles, 0.25us 11b - 32 SDM clock cycles, 0.5us
27-0 LPM_NUM	Low Port Modulation Numerator If SDM_MAP_DISABLE is set, this register is the signed 27 bit value that is applied to the Low Port Sigma Delta Modulator for the Numerator. For valid Sigma Delta operation the resulting fraction NUM/DENOM must be in the range -0.6 to +0.6

52.4.4.2.2.3.5.1.12 PLL Low Port Sigma Delta Control 3 (LPM_SDM_CTRL3)

Offset

Register	Offset
LPM_SDM_CTRL3	3Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	INPR_TX...	INPR_CO...	LPM_SDM_INT_SHI...		LPM_DENOM											
Reset	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	LPM_DENOM															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 INPR_TX_TQI_DIS	INPR_TX_TQI_DIS Disable inline phase return's (INPR) control to cut TX at loopback. 0b - INPR control to cut TX at loopback is enabled. 1b - INPR control to cut TX at loopback is disabled.
30 INPR_CORR_INV	INPR_CORR_INV Invert corrected num value for inline phase return.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - Inversion is disabled. 1b - Inversion is enabled.
29-28 LPM_SDM_INT_SHIFT	Low Port Modulation Denominator This field adds a delay on LPM sdm integer part to have compensate delay due to path in the sigma delta for fractional part (at least 3 accumulator in this bloc)
27-0 LPM_DENOM	Low Port Modulation Denominator If SDM_MAP_DISABLE is set, this register is the signed 27 bit value that is applied to the Low Port Sigma Delta Modulator for the Denominator. For valid Sigma Delta operation the resulting fraction NUM/DENOM must be in the range -0.6 to +0.6

52.4.4.2.2.3.5.1.13 PLL Low Port Sigma Delta Result 1 (LPM_SDM_RES1)

Offset

Register	Offset
LPM_SDM_RES1	40h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				LPM_NUM_SELECTED											
W																
Reset	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	LPM_NUM_SELECTED															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

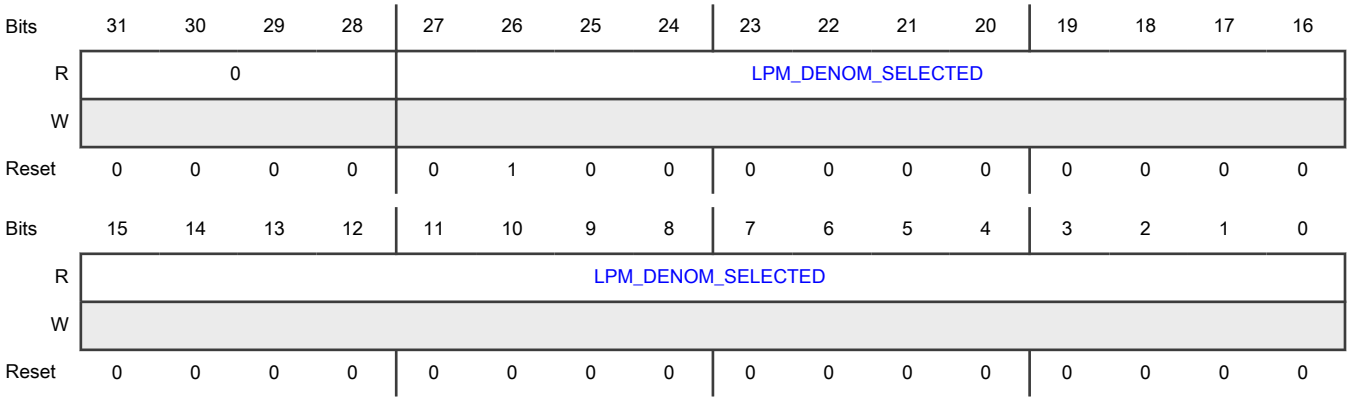
Field	Function
31-28 —	Reserved
27-0 LPM_NUM_SELECTED	Low Port Modulation Numerator Applied This is the value that is currently being applied to the Low Port Sigma Delta Modulator, for valid Sigma Delta operation the resulting fraction NUM/DENOM must be in the range -0.6 to +0.6

52.4.4.2.2.3.5.1.14 PLL Low Port Sigma Delta Result 2 (LPM_SDM_RES2)

Offset

Register	Offset
LPM_SDM_RES2	44h

Diagram



Fields

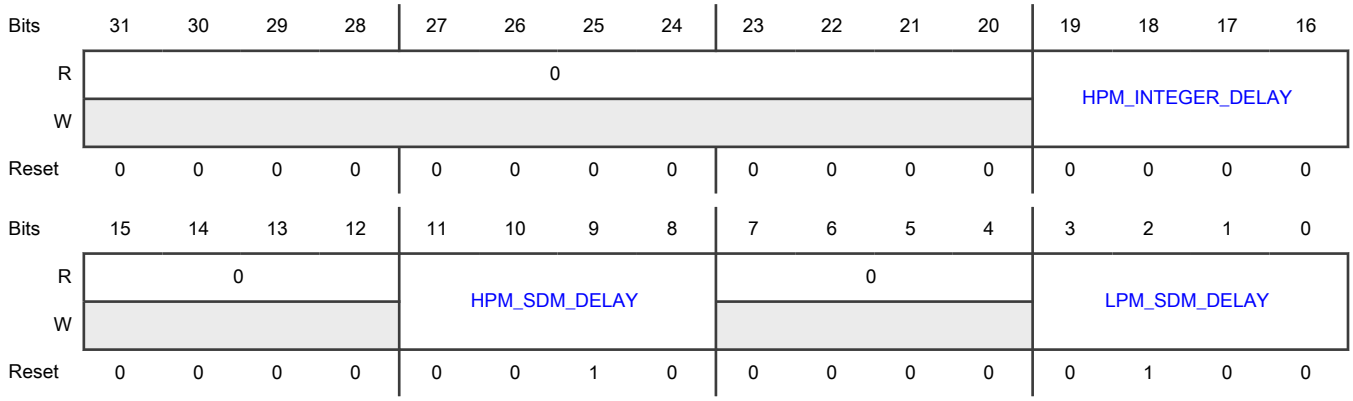
Field	Function
31-28 —	Reserved
27-0 LPM_DENOM_SELECTED	Low Port Modulation Denominator Selected This is the value that is currently being applied to the Low Port Sigma Delta Modulator, for valid Sigma Delta operation the resulting fraction NUM/DENOM must be in the range -0.6 to +0.6

52.4.4.2.2.3.5.1.15 PLL Delay Matching (DELAY_MATCH)

Offset

Register	Offset
DELAY_MATCH	48h

Diagram



Fields

Field	Function
31-20 —	Reserved
19-16 HPM_INTEGER_DELAY	High Port Integer Delay Matching This register selects the number of clock cycles of the PLL Sigma Delta Clock divided by 2 to delay the High Port Integer modulation of the VCO High Port DAC Array.
15-12 —	Reserved
11-8 HPM_SDM_DELAY	High Port SDM Delay Matching This register selects the number of clock cycles of the PLL Sigma Delta Clock divided by 2 to delay the High Port Sigma Delta modulation of the VCO High Port Fraction. Note that the High Port SDM is clocked by the PLL Sigma Delta Clock but the modulation is based on a divide by 2 version of this same clock.
7-4 —	Reserved
3-0 LPM_SDM_DELAY	Low Port SDM Delay Matching This register selects the number of clock cycles of the PLL Sigma Delta Clock to delay the Low Port Sigma Delta modulation of the PLL Loop Divider.

52.4.4.2.2.3.5.1.16 Tuning Cap Settings in Transmit Mode (TUNING_CAP_TX_CTRL)

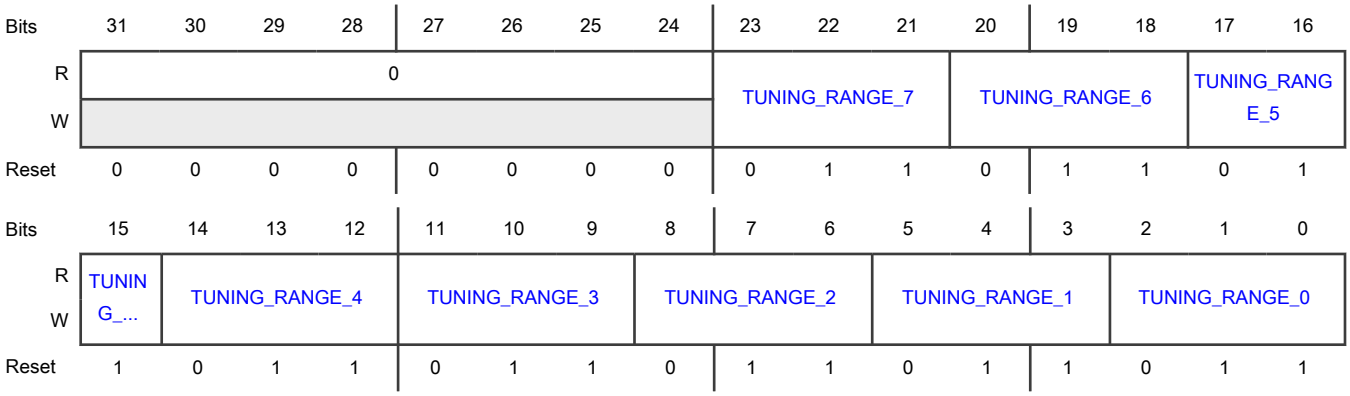
Offset

Register	Offset
TUNING_CAP_TX_CTRL	4Ch

Function

Tuning Cap Settings in Transmit Mode. This register contains the Cap Settings for Eight Tuning Ranges. This CTRIM value will be selected by PLL to have optimum frequency in functionalmode

Diagram



Fields

Field	Function
31-24 —	Reserved
23-21 TUNING_RANGE_7	Tuning Range 7 Radio channel above 2465 MHz.
20-18 TUNING_RANGE_6	Tuning Range 6 Radio channel between 2450 and 2465 MHz.
17-15 TUNING_RANGE_5	Tuning Range 5 Radio channel between 2435 and 2450 MHz.
14-12 TUNING_RANGE_4	Tuning Range 4 Radio channel between 2420 and 2435 MHz.
11-9 TUNING_RANGE_3	Tuning Range 3 Radio channel between 2405 and 2420 MHz.
8-6 TUNING_RANGE_2	Tuning Range 2 Radio channel between 2390 and 2405 MHz.

Table continues on the next page...

Table continued from the previous page...

Field	Function
5-3 TUNING_RANGE_1	Tuning Range 1 Radio channel between 2375 and 2390 MHz.
2-0 TUNING_RANGE_0	Tuning Range 0 Radio channel less than or equal to 2375 MHz.

52.4.4.2.2.3.5.1.17 Tuning Cap Settings in Receive Mode (TUNING_CAP_RX_CTRL)

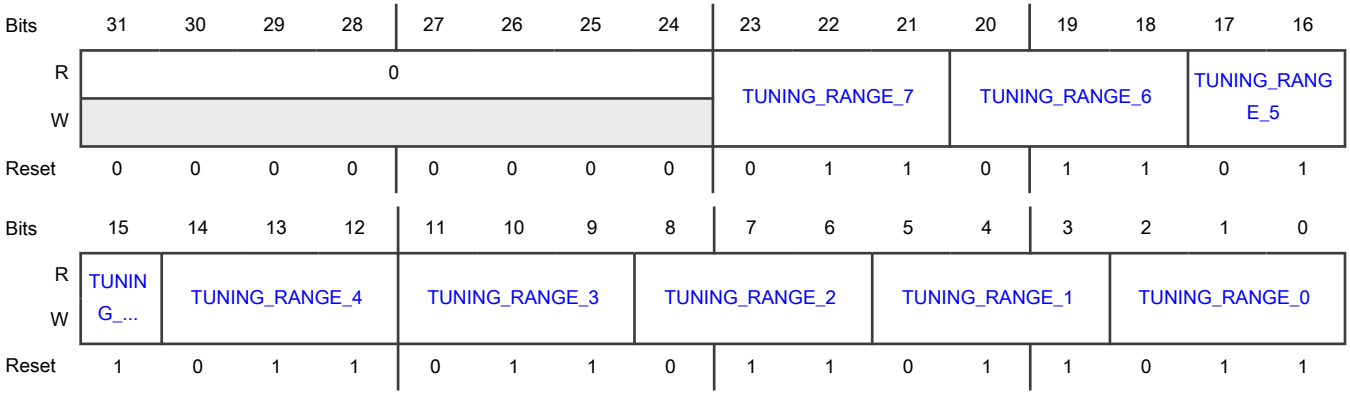
Offset

Register	Offset
TUNING_CAP_RX_CTRL	50h

Function

Tuning Cap Settings in Receive Mode. This register contains the Cap Settings for Eight Tuning Ranges.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-21	Tuning Range 7 Radio channel above 2465 MHz.

Table continues on the next page...

Table continued from the previous page...

Field	Function
TUNING_RANGE_7	
20-18 TUNING_RANGE_6	Tuning Range 6 Radio channel between 2450 and 2465 MHz.
17-15 TUNING_RANGE_5	Tuning Range 5 Radio channel between 2435 and 2450 MHz.
14-12 TUNING_RANGE_4	Tuning Range 4 Radio channel between 2420 and 2435 MHz.
11-9 TUNING_RANGE_3	Tuning Range 3 Radio channel between 2405 and 2420 MHz.
8-6 TUNING_RANGE_2	Tuning Range 2 Radio channel between 2390 and 2405 MHz.
5-3 TUNING_RANGE_1	Tuning Range 1 Radio channel between 2375 and 2390 MHz.
2-0 TUNING_RANGE_0	Tuning Range 0 Radio channel less than or equal to 2375 MHz.

52.4.4.2.2.3.5.1.18 Max and Min Transmit Frequencies For TX Configuration 1 (MAX_MIN_TX_CFG1_FREQ)

Offset

Register	Offset
MAX_MIN_TX_CFG1_FREQ	58h

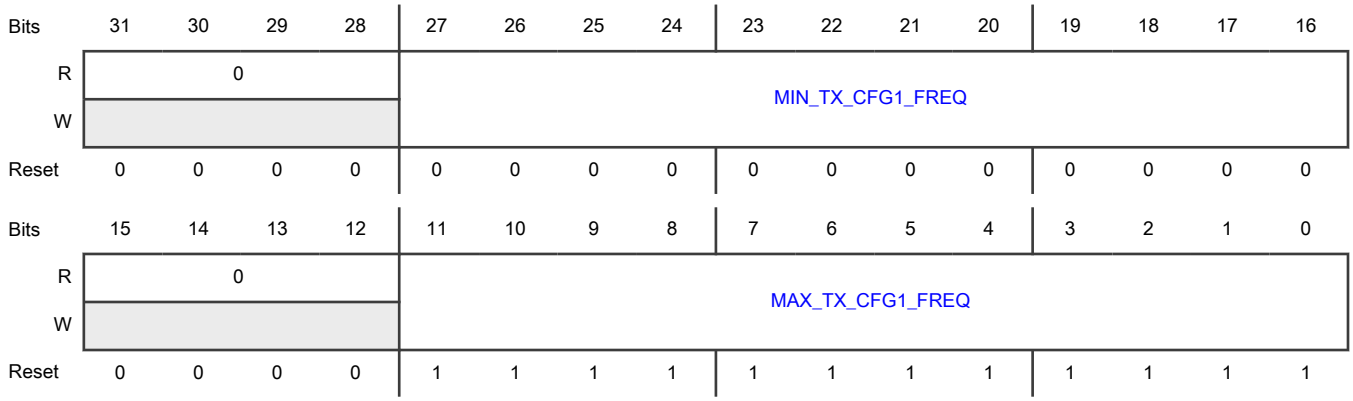
Function

Due to regulatory compliance requirements, more than one set of TX configuration settings may be required to meet out-of-band spectral emission requirements for TX frequencies near either the upper or lower limit of a frequency band. The PLL has a built in capability to detect when the TX carrier frequency is below or above a carrier frequency in MHz.

The MAX_TX_CFG1_FREQ register field should be programmed with a frequency threshold to detect when an alternate TX configuration must be utilized. When the PLL center frequency is selected to be greater than this threshold, a signal will be sent to the TX Digital logic indicating the need to use an alternate configuration. Note, to disable this feature, program the MAX_TX_CFG1_FREQ to 12'hFFF. This will ensure the alternative TX configuration is not selected.

The MIN_TX_CFG1_FREQ register field should be programmed with a frequency threshold to detect when an alternate TX configuration must be utilized. When the PLL center frequency is selected to be lower than this threshold, a signal will be sent to the TX Digital logic indicating the need to use an alternate configuration. Note, to disable this feature, program the MIN_TX_CFG1_FREQ to 12'h000. This will ensure the alternative TX configuration is not selected.

Diagram



Fields

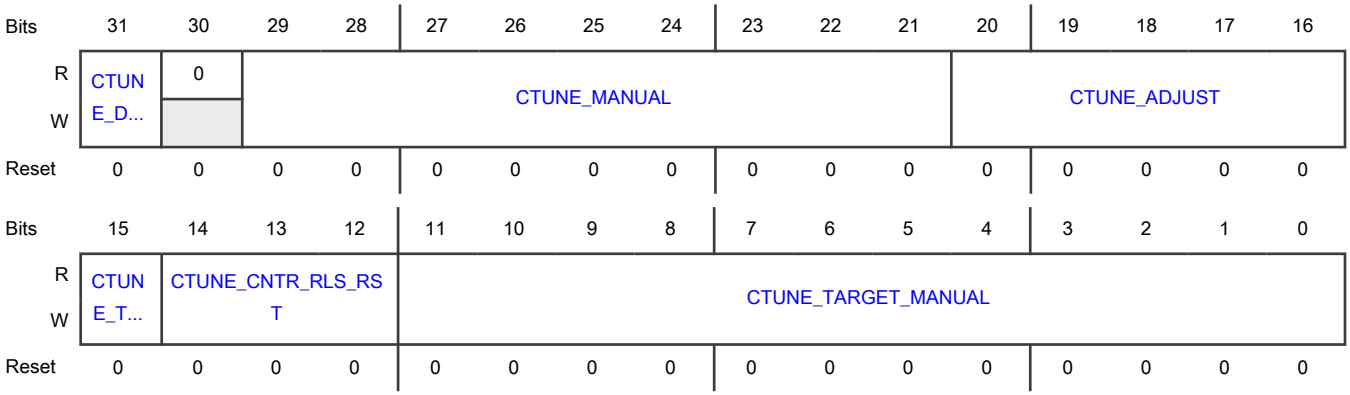
Field	Function
31-28 —	Reserved
27-16 MIN_TX_CFG1_FREQ	Minimum Transmit Frequency for Standard TX Settings This register should be programmed with the frequency threshold (MHz) to be used by PLL Digital to determine when to switch to alternate TX settings. If the PLL center frequency is lower than this programmed value, the TX digital will select an alternate configuration for modulation.
15-12 —	Reserved
11-0 MAX_TX_CFG1_FREQ	Maximum Transmit Frequency for Standard TX Settings This register should be programmed with the frequency threshold (MHz) to be used by PLL Digital to determine when to switch to alternate TX settings. If the PLL center frequency is greater than this programmed value, the TX digital will select an alternate configuration for modulation.

52.4.4.2.2.3.5.1.19 PLL Coarse Tune Control (CTUNE_CTRL)

Offset

Register	Offset
CTUNE_CTRL	5Ch

Diagram



Fields

Field	Function
31 CTUNE_DISABLE	Coarse Tune Disable If this bit is set, the Coarse Tune Setting applied to the VCO comes from the CTUNE_MANUAL register.
30 —	Reserved
29-21 CTUNE_MANUAL	Manual Coarse Tune Setting If CTUNE_DISABLE is set, this register is the value that is applied to the VCO as the Coarse Tune Setting.
20-16 CTUNE_ADJUST	Coarse Tune Count Adjustment This register is a signed four bit value that adjusts the PLL Frequency Meter count used in the Coarse Tune Calibration. The range of adjustment is -16 to +15, and the adjustment is only made to the PLL Frequency count used by the Coarse Tune Calibration sequence.
15 CTUNE_TARGET_DISABLE	Disable Coarse Tune Target If this bit is set, the Frequency Target presented to the Coarse Tune Calibrator comes from the CTUNE_TARGET_MANUAL register.
14-12 CTUNE_CNTR_RLS_RST	Coarse Tune Counter Release Reset This field adds up to 7 ref_clk cycles to ctune_counter_release_rst.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	The programmed number of cycles is 2 + CTUNE_CNTR_RLS_RST, thus the maximum programmed value could be 9. Field should be limited to 6 (32MHz ref_clk) and 3 (26MHz ref_clk) to fit PLL state machine timings.
11-0 CTUNE_TARGET_MANUAL	Manual Coarse Tune Target If CTUNE_TARGET_DISABLE or LPM_SDM_CTRL1[SDM_MAP_DISABLE] is set, this register is the value that is presented to the Coarse Tune Calibrator as the Frequency Target in MHz.

52.4.4.2.2.3.5.1.20 PLL Data Rate Override Control (DATA_RATE_OVRD_CTRL1)

Offset

Register	Offset
DATA_RATE_OVRD_CTRL1	60h

Function

The Bluetooth Low Energy LL defines test cases with asymmetric data rates in multiple connection modes. The PLL configuration must be switched by hardware when a new configuration is requested. The DATA_RATE_SWITCH register is intended to provide an override for various control registers in the PLL. The following register fields will be overridden when the Bluetooth Low Energy LL requests the updated data rate:

PLL_LPM_CTRL[LPM_SCALE]

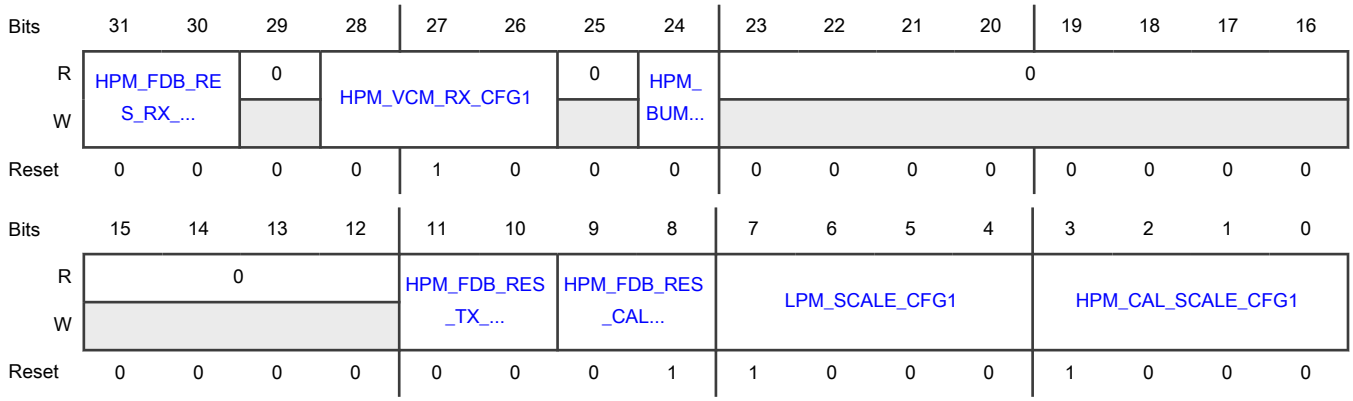
PLL_LPM_CTRL[HPM_CAL_SCALE]

HPM_BUMP[HPM_FDB_RES_CAL]

HPM_BUMP[HPM_FDB_RES_TX]

Note that the alternate datarate can also be requested by the GENFSK, the RSM (for Channel Sounding) and by software, via the RF_CTRL[RIF_SEL_2MBPS_OVRD] register.

Diagram



Fields

Field	Function
31-30 HPM_FDB_RES_RX_CFG1	HPM FDB RES RX Configuration1 This register will be used to override HPM_BUMP[HPM_FDB_RES_RX] when the Bluetooth Low Energy LL selects a data rate configuration switch.
29 —	Reserved
28-26 HPM_VCM_RX_CFG1	HPM VCM RX Configuration1 This register will be used to override HPM_BUMP[HPM_VCM_RX] when the Bluetooth Low Energy LL selects a data rate configuration switch.
25 —	Reserved
24 HPM_BUMP_RX_TX_EN_CFG1	HPM BUMP RX/TX enable Configuration1 This register will be used to override HPM_BUMP[HPM_BUMP_RX_TX_EN] when the Bluetooth Low Energy LL selects a data rate configuration switch.
23-12 —	Reserved
11-10 HPM_FDB_RES_TX_CFG1	HPM FDB RES Transmit Configuration1 This register will be used to override HPM_BUMP[HPM_FDB_RES_TX] when the Bluetooth Low Energy LL selects a data rate configuration switch.
9-8 HPM_FDB_RES_CAL_CFG1	HPM FDB RES Calibration Configuration1 This register will be used to override HPM_BUMP[HPM_FDB_RES_CAL] when the Bluetooth Low Energy LL selects a data rate configuration switch.
7-4 LPM_SCALE_CFG1	LPM Scale Configuration1 This register will be used to override PLL_LPM_CTRL[LPM_SCALE] when the Bluetooth Low Energy LL selects a data rate configuration switch.
3-0 HPM_CAL_SCALE_CFG1	HPM Scale Configuration1 This register will be used to override PLL_LPM_CTRL[HPM_CAL_SCALE] when the Bluetooth Low Energy LL selects a data rate configuration switch.

52.4.4.2.2.3.5.1.21 PLL Data Rate Override Control (DATA_RATE_OVRD_CTRL2)

Offset

Register	Offset
DATA_RATE_OVRD_CTRL2	64h

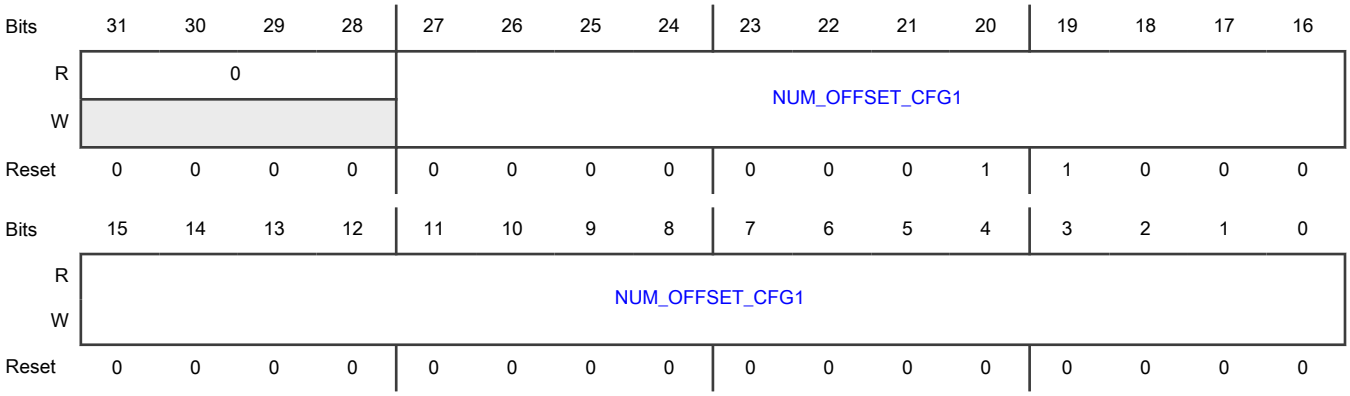
Function

The Bluetooth Low Energy LL defines test cases with asymmetric data rates in multiple connection modes. The PLL configuration must be switched by hardware when a new configuration is requested. The DATA_RATE_SWITCH register is intended to provide an override for various control registers in the PLL. The following register fields will be overridden when the Bluetooth Low Energy LL requests the updated data rate:

`CHAN_MAP_EXT[NUM_OFFSET]`

Note that the alternate datarate can also be requested by the GENFSK, the RSM (for Channel Sounding) and by software, via the RF_CTRL[RIF_SEL_2MBPS_OVRD] register.

Diagram



Fields

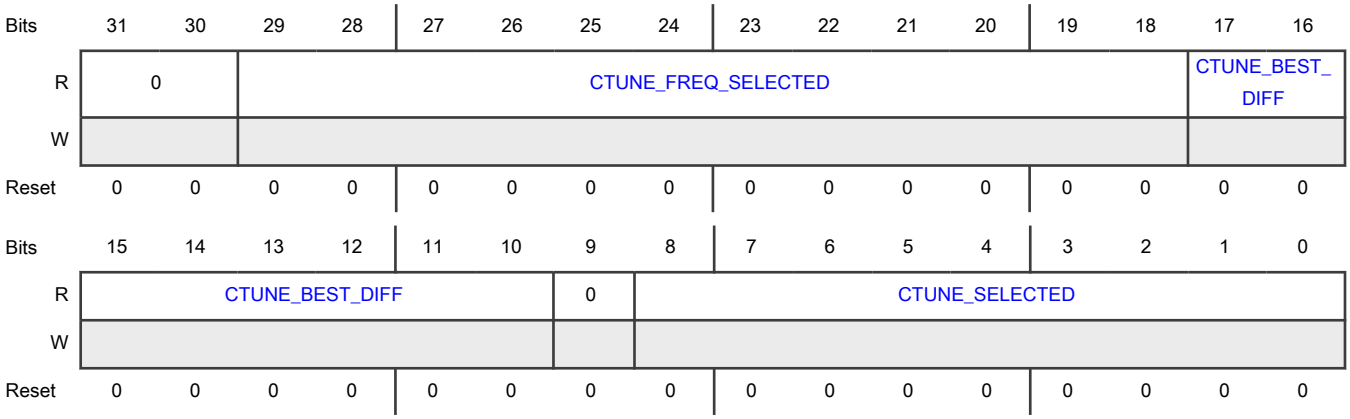
Field	Function
31-28 —	Reserved
27-0 NUM_OFFSET_CFG1	Numerator Offset Configuration1 This register will be used to override CHAN_MAP_EXT[NUM_OFFSET] when the Bluetooth Low Energy LL selects a data rate configuration switch.

52.4.4.2.2.3.5.1.22 PLL Coarse Tune Results (CTUNE_RES)

Offset

Register	Offset
CTUNE_RES	84h

Diagram



Fields

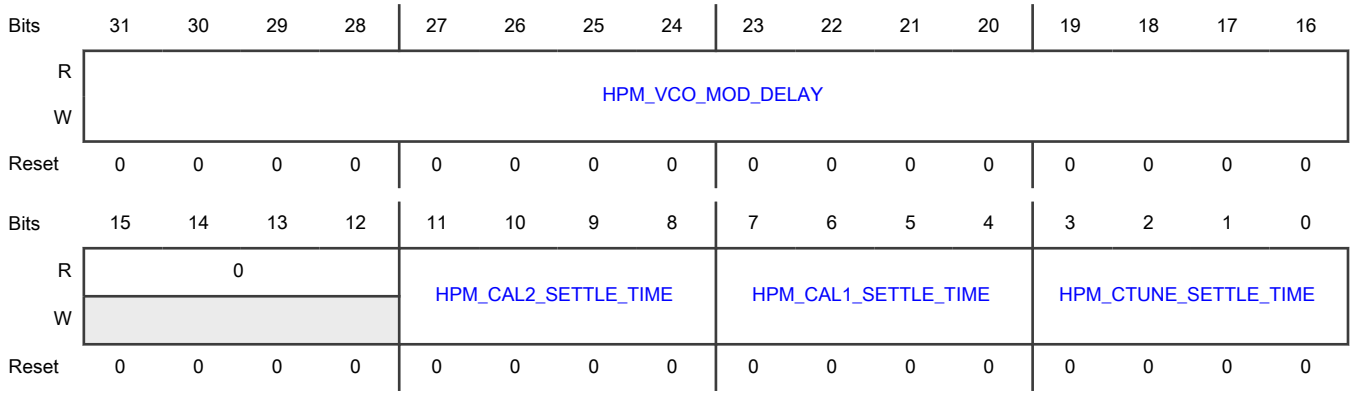
Field	Function
31-30 —	Reserved
29-18 CTUNE_FREQ_SELECTED	Coarse Tune Frequency Selected This is the Frequency Target in MHz that is currently being presented to the Coarse Tune Calibrator.
17-10 CTUNE_BEST_DIFF	Coarse Tune Absolute Best Difference This is the absolute value of the best difference found during Coarse Tune between the targeted frequency count and the actual frequency count.
9 —	Reserved
8-0 CTUNE_SELECTED	Coarse Tune Setting to VCO This is the current VCO Coarse Tune setting, it is the result of the Coarse Tune Calibration, unless overridden using CTUNE_DISABLE.

52.4.4.2.2.3.5.1.23 PLL HPM Calibration Timing Attributes (HPM_CAL_TIMING)

Offset

Register	Offset
HPM_CAL_TIMING	A0h

Diagram



Fields

Field	Function
31-16 HPM_VCO_MOD_DELAY	HPM VCO Modification Output Delay This 16-bit value specifies the delay time from a calibration state change to a new VCO DAC code. This delay time is equal to (HPM_VCO_MOD_DELAY + 2) x 62.5ns.
15-12 —	Reserved
11-8 HPM_CAL2_SETTLE_TIME	HPM Calibration2 Settling Time The HPM calibration2 setting time specifies addition time for the analog circuits to settle when transitioning out of the HPM calibration2 tuning stage. Settling time is (HPM_CAL2_SETTLE_TIME + 1)us.
7-4 HPM_CAL1_SETTLE_TIME	HPM Calibration1 Settling Time The HPM calibration1 setting time specifies addition time for the analog circuits to settle when transitioning out of the HPM calibration1 tuning stage. Settling time is (HPM_CAL1_SETTLE_TIME + 1)us.
3-0 HPM_CTUNE_SETTLE_TIME	CTUNE Settling Time The CTUNE setting time specifies addition time for the analog circuits to settle when transitioning out of the course tuning stage. Settling time is (HPM_CTUNE_SETTLE_TIME + 1)us.

52.4.4.2.2.3.5.1.24 PLL Offset Control (PLL_OFFSET_CTRL)

Offset

Register	Offset
PLL_OFFSET_CTRL	A4h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				PLL_NUMERATOR_OFFSET											
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	PLL_NUMERATOR_OFFSET															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 —	Reserved
27-0 PLL_NUMERATOR_OFFSET	PLL Numerator Offset Signed value that allows for a carrier frequency offset of up to +/-100ppm be added to the PLL numerator to allow for a SW controlled static shift of PLL frequency.

52.4.4.2.2.3.5.1.25 PLL Data Rate Switch Control (PLL_DATARATE_CTRL)

Offset

Register	Offset
PLL_DATARATE_CTRL	A8h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	HPM_COUNT_ADJUST_DRS				HPM_INTEGER_DELAY_DRS				HPM_SDM_DELAY_DRS				LPM_SDM_DELAY_DRS			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	PLL_VCO_TRIM_KVM_CAL_DRS			0	PLL_VCO_TRIM_KVM_TX_DRS			0	HPM_VCM_CAL_DRS			0	HPM_VCM_TX_DRS		
W																
Reset	0	1	1	0	0	1	1	0	0	0	0	1	0	0	1	0

Fields

Field	Function
31-28 HPM_COUNT_ADJUST_DRS	HPM_COUNT_ADJUST_DRS 2mbps setting - this register represents a signed three bit value that is used to adjust the High Port Calibration Frequency Count Difference. The range of adjustment is -8 to +7, applied to the difference between Count 1 and Count 2.
27-24 HPM_INTEGER_DELAY_DRS	DRS HPM_SDM_DELAY This field selects the number of clock cycles of the PLL Sigma Delta Clock divided by 2 to delay the High Port Integer modulation of the VCO High Port DAC Array during Data Rate Switch.
23-20 HPM_SDM_DELAY_DRS	DRS HPM_SDM_DELAY This field selects the number of clock cycles of the PLL Sigma Delta Clock divided by 2 to delay the High Port Sigma Delta modulation of the VCO High Port Fraction during Data Rate Switch. Note that the High Port SDM is clocked by the PLL Sigma Delta Clock but the modulation is based on a divide by 2 version of this same clock.
19-16 LPM_SDM_DELAY_DRS	DRS LPM_SDM_DELAY This field selects the number of clock cycles of the PLL Sigma Delta Clock to delay the Low Port Sigma Delta modulation of the PLL Loop Divider during Data Rate Switch.
15 —	Reserved
14-12 PLL_VCO_TRIM_KVM_CAL_DRS	Data Rate Switch for pll_vco_trim_kvm_cal 000b - 10MHz/V 100b - 20MHz/V 110b - 30MHz/V 111b - 40MHz/V
11 —	Reserved
10-8 PLL_VCO_TRIM_KVM_TX_DRS	Data Rate Switch for pll_vco_trim_kvm_tx. 000b - 10MHz/V 100b - 20MHz/V 110b - 30MHz/V 111b - 40MHz/V
7 —	Reserved
6-4	Data Rate Switch for hpm_vcm_cal

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Field	Function
HPM_VCM_CAL_DRS	000b - 432 mV 001b - 328 mV 010b - 456 mV 011b - 473 mV 100b - 488 mV 101b - 408 mV 110b - 392 mV 111b - 376 mV
3 —	Reserved
2-0 HPM_VCM_TX_DRS	Data Rate Switch for hpm_vcm_tx 000b - 432 mV 001b - 328 mV 010b - 456 mV 011b - 473 mV 100b - 488 mV 101b - 408 mV 110b - 392 mV 111b - 376 mV

52.4.4.2.2.4 Transceiver Sequence Manager (TSM)

52.4.4.2.2.4.1 Introduction

52.4.4.2.2.4.1.1 Overview

The Transceiver Sequence Manager controls the warmup and warmdown processes for all radio sequences. The TSM provides for a TX sequence, and an RX sequence. For both TX and RX, a warmup and a warmdown sequence is supported. The length of each sequence is programmable, from 1 – 254us. The resolution of the TSM is 1us. Controls for all analog and digital transceiver blocks are provided. Each TSM output enables, or otherwise provides control for, a transceiver-related block. Each TSM output has 4 8-bit registers, with which to control the point at which the output asserts during the warmup (1 register for TX, 1 for RX), and the point at which it deasserts (1 register for TX, 1 for RX). Some TSM outputs, which are known in advance to require identical timing, are “ganged together”, to reduce area and required programming. For DFT, and non-mission-mode validation, each TSM output can be placed under direct software control, using register overrides. Any sequence can be temporarily halted, by setting an optional, programmable breakpoint.

52.4.4.2.2.4.1.2 Features

The TSM includes the following features:

- TX warmup and warmdown sequence and RX warmup and warmdown sequence for every controllable output.
- Programmable sequence length from 1 to 254 microseconds for each sequence in 1 microsecond increments.
- Multi-protocol

- Ability to place TSM outputs under software control for test and non-mission mode validation.
- Ability to signal link layers upon PLL unlock or RF_NOT_ALLOWED conditions.
- Fast Warmup Capability for TX and RX
- LPPS Support
- Programmable breakpoint capability to halt any sequence temporarily.

52.4.4.2.2.4.2 Functional Description

52.4.4.2.2.4.2.1 Sequence Counter

The TSM supports 1 TX and 1 RX sequence. Each sequence consists of 3 phases:

1. WARMUP phase
2. ON phase
3. WARMDOWN phase

The central element of the TSM is an 8-bit counter. The counter is held at 0 during the idle state. From idle state, any sequence can be launched, by an initiating event. (See Section “Sequence Initiation”). At an initiating event, the TSM counter counts up from 0 to a programmed stop point during the WARMUP phase, determined by the END_OF_TX_WU or END_OF_RX_WU register, depending on whether the sequence is TX or RX. At the end-of-warmup “stop point”, the TSM counter holds its count, and the TSM sequence enters the ON phase. The TSM counter will remain in the ON phase, and hold its count, until the initiating event deasserts (See Sequence Termination). When either of these conditions occurs during the ON phase, the TSM will resume counting from the point it was holding during the ON phase, and the sequence will enter the WARMDOWN phase. The counter will continue counting until a programmed stop point is reached. This stop point is determined by the END_OF_TX_WD or END_OF_RX_WD register, depending on whether the sequence is TX or RX. Once this point is reached, the sequence returns to idle, and the TSM counter returns to 0.

The 4 8-bit registers which control the duration of the WARMUP phase (END_OF_TX_WU[7:0] and END_OF_RX_WU[7:0]), and the duration of the WARMDOWN phase (END_OF_TX_WD[7:0] and END_OF_RX_WD[7:0]), reside in the END_OF_SEQ register.

All TSM-controlled outputs are active-high. Any TSM-controlled output can be asserted once during a sequence (either TX or RX sequence), and then deasserted once. Or, the output can be held in a deasserted state for the duration of the sequence. The precise timing for the assertion and deassertion of each TSM-controlled output, for both TX and RX sequences, is determined by 4 8-bit registers assigned to that output (see TSM-Controlled Outputs). The TSM resolution is 1us. This is the update rate for the TSM counter, and sets the granularity with which warmup and warmdown processes can be controlled.

52.4.4.2.2.4.2.2 TSM-Controlled Outputs

The TSM-controlled outputs are shown in the table below. In general, each output signal is assigned a unique TSM_TIMING register to control its timing, but in cases where output signals will always be asserted and deasserted at the same time, the signals can share a TSM_TIMING register (e.g., seq_ldo_gang_pup).

Output Signal Name	TSM_TIMING #	TSM_TIMING Name
tsm_rf_active	0	tsm_rf_active
tsm_rf_status	1	tsm_rf_status
tsm_rf_priority	2	tsm_rf_priority
tsm_irq0_start_trig	3	tsm_irq0_start_trig
tsm_irq1_stop_trig	4	tsm_irq1_stop_trig
gpio0_trig_en	5	gpio0_trig_en

Table continues on the next page...

Table continued from the previous page...

Output Signal Name	TSM_TIMING #	TSM_TIMING Name
gpio1_trig_en	6	gpio1_trig_en
gpio2_trig_en	7	gpio2_trig_en
gpio3_trig_en	8	gpio3_trig_en
dcoc_gain_cfg_en	9	dcoc_gain_cfg_en
ldo_cal_en	10	ldo_cal_en
pll_dig_en	11	pll_dig_en
sigma_delta_en	12	sigma_delta_en
dcoc_cal_en	13	dcoc_cal_en
tx_dig_en	14	tx_dig_en
freq_targ_ld_en	15	freq_targ_ld_en
rx_init	16	rx_init
rx_dig_en	17	rx_dig_en
rx_phy_en	18	rx_phy_en
seq_bg_pup_ibg_cal	19	seq_bg_pup_ibg_cal
seq_ldotrim_pup	20	seq_ldotrim_pup
seq_ldo_cal_pup	21	seq_ldo_cal_pup
seq_bg_fc	22	seq_bg_fc
seq_ldo_pll_fc	23	seq_ldo_gang_fc
seq_ldo_vco_fc		
seq_ldo_rxtxhf_fc		
seq_ldo_rxtxlf_fc		
seq_ldo_ant_pup	24	seq_ldo_gang_pup
seq_ldo_pll_pup		
seq_ldo_vco_pup		
seq_ldo_xo_dist_pup		
seq_ldo_rxtxhf_pup		
seq_ldo_rxtxlf_pup		
seq_ldo_lv_pup	25	seq_ldo_lv_pup
seq_bg_pup	26	seq_bg_pup
seq_bg_pup_ibg_ant	27	seq_bg_pup_ibg_ant
seq_bg_pup_ibg_xo_dist	28	seq_bg_pup_ibg_xo_dist
seq_bg_pup_ibg_tx	29	seq_bg_pup_ibg_tx

Table continues on the next page...

Table continued from the previous page...

Output Signal Name	TSM_TIMING #	TSM_TIMING Name
seq_bg_pup_ibg_rx	30	seq_bg_pup_ibg_rx
seq_tsm_iso_b_2p4ghz	31	seq_tsm_iso_b_2p4ghz
seq_rccal_pup	32	seq_rccal_pup
seq_pd_en_fcal_bias	33	seq_pd_en_fcal_bias
seq_pd_pup	34	seq_pd_pup
seq_vco_pup	35	seq_vco_pup
seq_xo_dist_en	36	seq_xo_dist_en
seq_xo_dist_en_clk_ref	37	seq_xo_dist_en_clk_ref
seq_xo_en_clk_2p4g	38	seq_xo_en_clk_2p4g
seq_xo_dist_en_clk_adcdac	39	seq_xo_dist_en_clk_adcdac
seq_dac_pup	40	seq_dac_pup
seq_vco_en_hpm	41	seq_vco_en_hpm
seq_lo_pup_vlo_fbk	42	seq_lo_pup_vlo_fbk
seq_lo_pup_vlo_rx	43	seq_lo_pup_vlo_rx
seq_lo_pup_vlo_rxdrv	44	seq_lo_pup_vlo_rxdrv
seq_lo_pup_vlo_tx	45	seq_lo_pup_vlo_tx
seq_lo_pup_vlo_txdrv	46	seq_lo_pup_vlo_txdrv
seq_divn_pup	47	seq_divn_pup
seq_divn_openloop[1]	48	seq_divn_closedloop
seq_pd_en_pd_drv	49	seq_pd_en_pd_drv
seq_cbpf_en_dcoc	50	seq_cbpf_en_dcoc
seq_rx_lna_pup	51	seq_rx_gang_pup
seq_adc_pup		
seq_cbpf_pup		
seq_rx_mix_pup		
seq_spare1[2]		
seq_spare3	52	seq_spare3
gear_shift	53	gear_shift
seq_pic_core_en	54	seq_pic_core_en
seq_pic_short_cint_short_en	55	seq_pic_short_cint_short_en
seq_pic_filter_low_bw_sm_en	56	seq_pic_filter_low_bw_sm_en
seq_pic_rfb_open_sm_en	57	seq_pic_rfb_open_sm_en

Table continues on the next page...

Table continued from the previous page...

Output Signal Name	TSM_TIMING #	TSM_TIMING Name
seq_pic_rint2_short_fm_en	58	seq_pic_rint2_short_fm_en
seq_lodiv_sync_reset_en	59	seq_lodiv_sync_reset_en
seq_lodiv_sync_en	60	seq_lodiv_sync_en
seq_lodiv_sync_spare_en	61	seq_lodiv_sync_spare_en

1. This signal is inverted with respect to the timing signal
2. This is the pup for the RX peak detector

During the WARMUP and WARMDOWN phases of any sequence, any TSM-controlled output can be programmed to assert once and then deassert once, by programming the timing registers associated with the output. Each output has 4 8-bit timing registers associated with it. The name of the register matches the name of the output:

*OUTPUTNAME*_TX_HI[7:0]

*OUTPUTNAME*_TX_LO[7:0]

*OUTPUTNAME*_RX_HI[7:0]

*OUTPUTNAME*_RX_LO[7:0]

In the case of grouped outputs, the timing registers associated with the signal controlling the group, control timing for the entire group.

During the WARMUP phase of a TX sequence, as the 8-bit TSM counter increments, once the TSM counter equals or exceeds the programmed value of *OUTPUTNAME*_TX_HI[7:0], but is less than the programmed value of *OUTPUTNAME*_TX_LO[7:0], the corresponding TSM output will transition high. During the WARMUP or WARMDOWN phase of the TX sequence, once the TSM counter equals or exceeds the programmed value of *OUTPUTNAME*_TX_LO[7:0], the TSM output will transition low. If the programmed value of *OUTPUTNAME*_TX_HI[7:0], is greater than the length of the TX sequence (set by register END_OF_TX_WD[7:0]), then that signal will never transition high during the TX sequence. A convenient way of ensuring a signal does not assert during a TX sequence, is to set its *OUTPUTNAME*_TX_HI[7:0]=255.

During the WARMUP phase of a RX sequence, as the 8-bit TSM counter increments, once the TSM counter equals or exceeds the programmed value of *OUTPUTNAME*_RX_HI[7:0], but is less than the programmed value of *OUTPUTNAME*_RX_LO[7:0], the corresponding TSM output will transition high. During the WARMUP or WARMDOWN phase of the RX sequence, once the TSM counter equals or exceeds the programmed value of *OUTPUTNAME*_RX_LO[7:0], the TSM output will transition low. If the programmed value of *OUTPUTNAME*_RX_HI[7:0], is greater than the length of the RX sequence (set by register END_OF_RX_WD[7:0]), then that signal will never transition high during the RX sequence. A convenient way of assuring a signal does not assert during a RX sequence, is to set its *OUTPUTNAME*_RX_HI[7:0]=255.

The following diagram depicts the TSM counter, and the control logic used to assert and deassert the TSM-controlled outputs. For clarity, logic for only 2 of the outputs (pll_dig_en, sigma_delta_en) are shown.

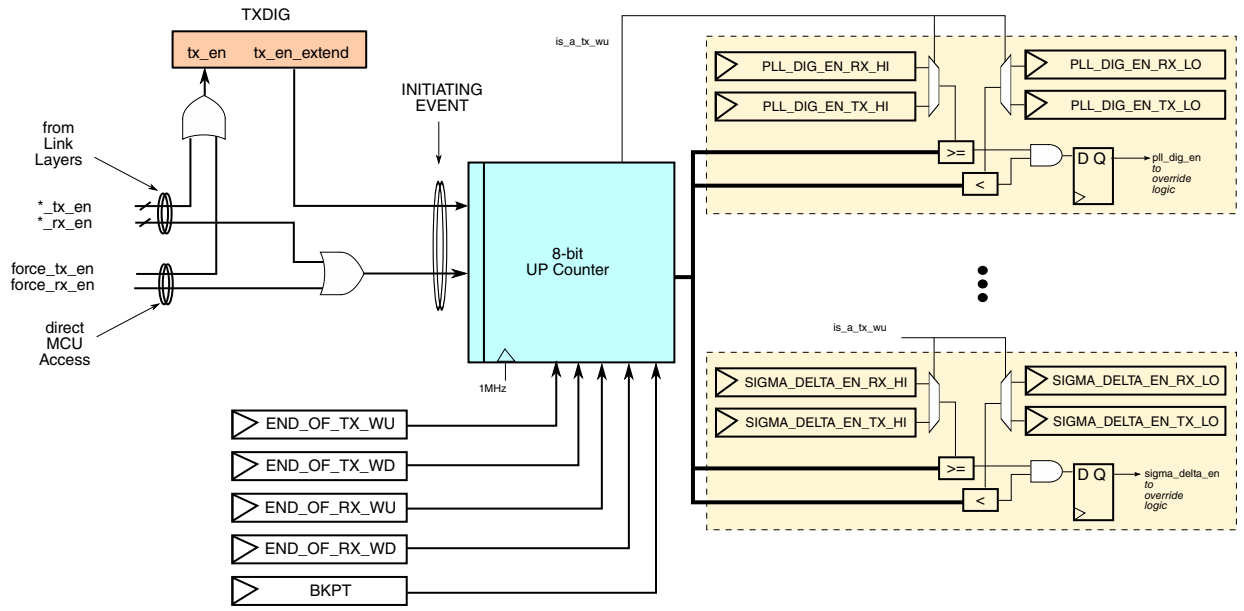

Figure 317. TSM BLOCK DIAGRAM

52.4.4.2.2.4.2.3 Timing Registers

There are a set of timing registers for each TSM-controlled output (or, for the signal controlling the group for the “grouped” outputs). Each register set consists of 4 bitfields: one to control the assertion time of the output for TX sequences, one to control the assertion time for RX sequence, one to control the deassertion time for TX sequences, and one to control the deassertion time for RX sequences. For TSM-controlled outputs that are grouped, one set of timing registers controls the timing for all members of the group. For each of these sets, the following table lists the SoC register name, and 4 timing register names associated with each.

SOC REGISTER NAME	BITS [31:24]	BITS [23:16]	BITS [15:8]	BITS [7:0]
TIMINGxx	RX_LO[7:0]	RX_HI[7:0]	TX_LO[7:0]	TX_HI[7:0]

Some of the TSM outputs have relevance for TX sequences only. For those, timing registers are only provided for TX assertion and deassertion times. The RX timings for such outputs are essentially hardwired to 255, meaning there will be no signal assertion during RX sequences.

Some of the TSM outputs have relevance for RX sequences only. For those, timing registers are only provided for RX assertion and deassertion times. The TX timings for such outputs are essentially hardwired to 255, meaning there will be no signal assertion during TX sequences.

52.4.4.2.2.4.2.4 Sequence Initiation

The SoC will include one or more protocol engines. Any of the protocol engines, can launch a TSM sequence. Each protocol engine will have an initiating signal for a TX sequence, and another for an RX sequence.

For direct software control, the MCU/Host can initiate a TX sequence warmup directly, by setting the FORCE_TX_EN bit, and later initiate a TX sequence warmdown by clearing the bit. The MCU/Host can initiate a RX sequence warmup directly, by setting the FORCE_RX_EN bit, and later initiate a RX sequence warmdown by clearing the bit. These bits reside in the TSM_CTRL register.

From idle state, the asserting of any initiating event (*source*_tx_en or *source*_rx_en), will begin the TSM WARMUP phase and begin incrementing the TSM counter from 0. The initiating source needs to hold the initiating signal asserted (high) through the

course of the WARMUP, and then for the duration of the desired ON phase. Deasserting the initiating signal transitions the TSM to the WARMDOWN phase (see Section “Sequence Termination”).

Needless to say, from idle state, a TX-initiating event (assertion of any TSM *source*_tx_en input) will launch a TX sequence. The TSM output **tx_mode** will go high to indicate a TX sequence is underway. Also, from idle state, an RX-initiating event (assertion of any TSM *source*_rx_en input) will launch an RX sequence. The TSM output **rx_mode** will go high to indicate a RX sequence is underway.

Only 1 initiating source can be allowed to assert at any given time. Under no circumstances should a TX and RX initiating source be asserted simultaneously.

Once a TSM sequence has been launched, the WARMUP phase is entered and TSM counter incrementing will commence. Up-counting will continue until one of the following conditions is met:

1. Deassertion of the initiating event. TSM will transition to WARMDOWN phase
2. tsm_count=END_OF_*SEQ*_WU, where *SEQ*=TX or RX. TSM will transition to ON phase
3. Breakpoint. TSM stay in its current phase and hold its count

A transition from WARMUP to ON phase means TSM will hold its count at END_OF_*SEQ*_WU, where *SEQ*=TX or RX.

A transition from ON to WARMDOWN phase means TSM will cease its hold, and resume counting at END_OF_*SEQ*_WU+1, where *SEQ* = TX or RX. (see Section “Sequence Termination”).

A transition from WARMUP to WARMDOWN phase means the tsm_count will jump to END_OF_*SEQ*_WU+1 (where *SEQ* = TX or RX), and resume counting from there. (see Section “Sequence Termination”).

The 4 8-bit registers which control the duration of the WARMUP phase (END_OF_TX_WU[7:0] and END_OF_RX_WU[7:0]), and the duration of the WARMDOWN phase (END_OF_TX_WD[7:0] and END_OF_RX_WD[7:0]), reside in the END_OF_SEQ register.

52.4.4.2.2.4.2.5 Sequence Termination

A sequence may be terminated during the WARMUP on ON phase by deassertion of the initiating event (*source*_tx_en or *source*_rx_en). This will cause a transition to WARMDOWN phase, at which point the TSM counter will resume counting from END_OF_*SEQ*_WU+1 (where *SEQ*=TX or RX).

NOTE

For TX, deassertion of the initiating tx_en event does not cause an immediate transition to TSM WARMDOWN phase. The tx_en deassertion is first recognized by the TXDIG to ramp-down the PA. After the TXDIG completes the PA ramp-down, its tx_en_extend output to the TSM will de-assert causing the TSM to transition to WARMDOWN. See more on PA ramp timing in the next section.

52.4.4.2.2.4.2.6 PA Ramp Timing

In previous generation of radios, the PA ramp was controlled in the TSM. The PA ramp-up was started near the end of the TSM TX warmup sequence and completed before the end of the TSM TX warmup sequence. The PA ramp-down started at beginning of the TSM TX warmdown sequence and completed before the end of the TSM TX warmdown sequence. In addition to the PA ramp timing, the TSM also output the PA ramp values from a programmable look-up table.

For the current generation of radio, the PA ramp will be controlled in the TXDIG instead of the TSM. The operation is described as follows.

When a Link Layer asserts *source*_tx_en (or software sets the FORCE_TX_EN bit) to start a TX burst, the TSM TX warmup sequence will begin. Near the end of the TSM TX warmup sequence, a TSM timing signal (tx_dig_en) will signal to the TXDIG to ramp-up the PA and start sending TX data. The TXDIG will also control the PA power-up signal (seq_tx_pa_pup in figure below) to the analog to turn on the PA. After the TXDIG completes the PA ramp-up, it outputs pa_wu_complete to the TSM, and the TSM in turn creates 1us-width pulses tsm_wu_almost_complete and tsm_wu_complete. Note that the TSM count may or may not have reached end_of_tx_wu by the time the TXDIG finishes ramping up the PA; in the example below, the PA ramp-up does not complete until after TSM count has reached end_of_tx_wu. Note also that the figure shows the link layer (or force tx_en signal)

is a direct input to the TXDIG, and the TXDIG outputs a tx_en_extend (which asserts at the same time as tx_en) to the TSM; the TXDIG takes no action on assertion of tx_en but the de-assertion is used in ramp-down as described in the next paragraph.

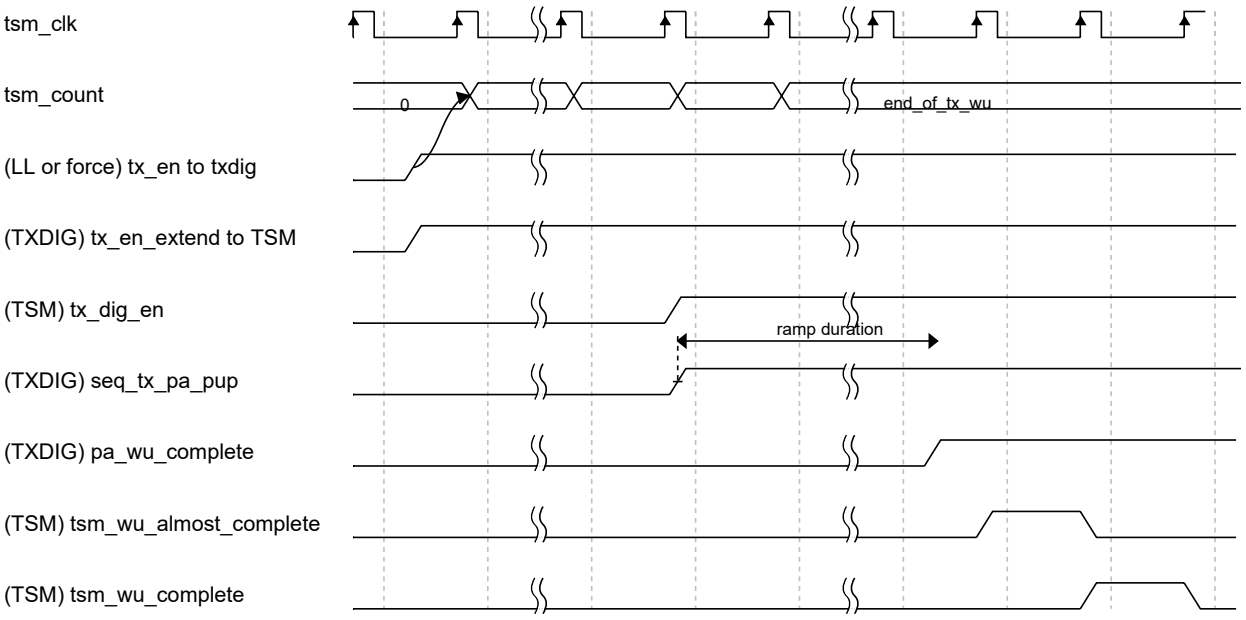

Figure 318. PA Ramp-Up Timing

When the Link Layer deasserts *source*_tx_en (or software clears the FORCE_TX_EN bit) to end a TX burst, the TXDIG will begin to ramp-down the PA. The TSM will not begin its warmdown until after the TXDIG has completed ramp-down of the PA. The TXDIG will provide an output signal (tx_en_extend) to the TSM which asserts at the same time as *source*_tx_en but does not de-assert until after the PA ramp-down has completed by the TXDIG. At that time, the TSM will complete its TX warm-down sequence (deasserting tx_dig_en, and turning off the PLL and other circuits in the analog, etc.) . Since the PA ramp-down is handled in the TXDIG, the TSM TX warm-down timing is expected to be shorter than in previous generation radios.

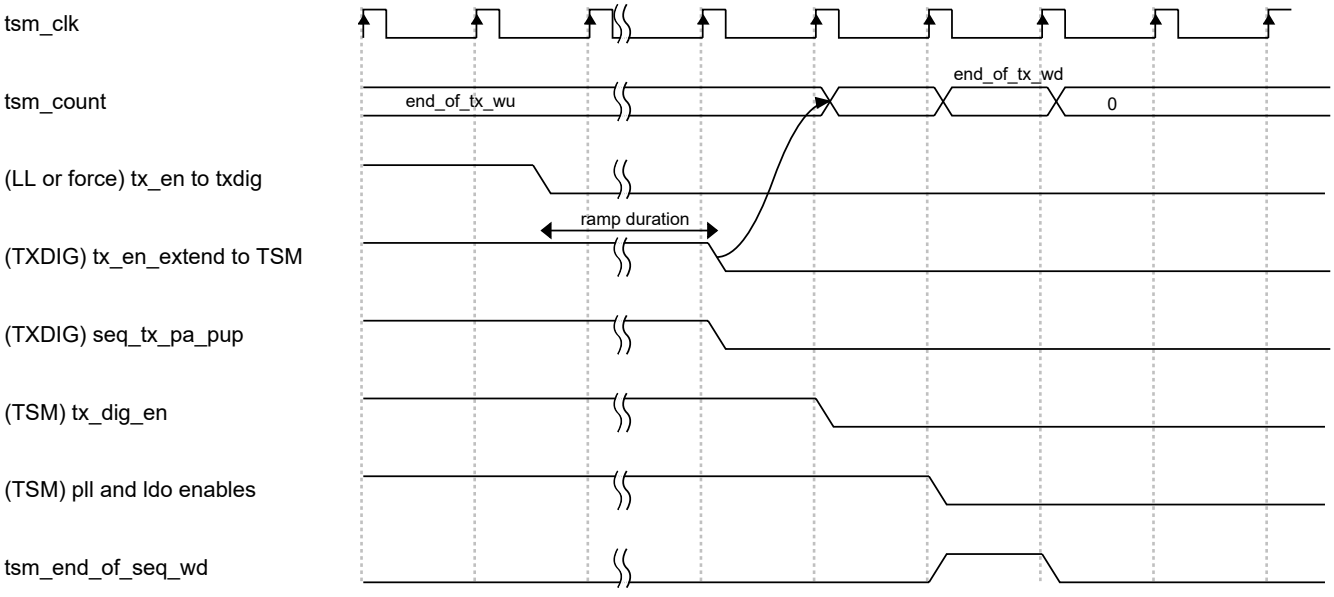

Figure 319. PA Ramp-Down Timing

For all link layers, if a TX PLL unlock or RF_NOT_ALLOWED condition occurs the link layer will need to de-assert the tx_en. Then the PA ramp-down and TSM TX warmdown will proceed as described in the figure above. (See also Abort conditions)

52.4.4.2.2.4.2.7 Overrides

Each of the TSM-controlled outputs has independent override control, except for the 4 GPIO triggers. In addition, two special TSM outputs, tx_mode and rx_mode, also have their own override controls.

Two register bits are assigned to each output, to implement the override function. The bits are named:

*OUTPUTNAME*_OVRD_EN

*OUTPUTNAME*_OVRD

Setting the *OUTPUTNAME*_OVRD_EN=1, allows the *OUTPUTNAME*_OVRD bit to directly control the state of the output. Clearing *OUTPUTNAME*_OVRD_EN=0 returns control of the output to the TSM.

The override bit-pairs reside in the TSM_OVRDyy registers.

Overrides have no effect on TSM operation, TSM counting, sequence initiation, or sequence termination. Overrides may be engaged at any time, during any TSM phase, including during idle state.

52.4.4.2.2.4.2.8 Breakpoint

Breakpoint can be used to temporarily suspend a TSM sequence. A breakpoint can be set during the WARMUP or WARMDOWN phase of any TSM sequence. An 8-bit BKPT[7:0] register field resides in the TSM_CTRL register. During a TSM sequence, when the TSM counter matches the BKPT register value, counting stops and the counter holds in its current state. Deassertion of the initiating event will be ignored during the breakpoint. The breakpoint can be lifted by modifying the BKPT[7:0] register. Once the breakpoint is lifted, the TSM proceeds in the phase it was in prior to the breakpoint match, and the TSM counter begins incrementing again from the point at which the breakpoint occurred. Deassertion of the initiaing event will then be recognized and handled as described in Sequence Termination. The default value for BKPT[7:0] is 255, which is greater than the length of any allowed sequence, so a breakpoint will not trigger during a sequence, unless a lower value is programmed.

52.4.4.2.2.4.2.9 Abort conditions

In some situations, it may be desirable to abort an RX or TX sequence. The TSM can detect these situations and alert the link layers. The link layer can then decide to de-assert its rx_en and tx_en outputs to the TSM which causes the sequence to end.

52.4.4.2.2.4.2.9.1 PLL Unlock

The TSM can be configured to detect and signal the link layer for any of the following PLL unlock conditions:

1. Coarse Tune Unlock
2. Frequency Target Unlock

The TSM is configured to react to PLL unlock condition via the TSM CTRL register's , ABORT_ON_FREQ_TARG, ABORT_ON_CTUNE,RX_ABORT_DIS and TX_ABORT_DIS bits. Additionally, the table below shows the TSM controlling signal for each the mechanism.

Lock Detect Mechanism	TSM Controlling Signal
Coarse Tune	pll_dig_en (indirect)
Freq. Target	freq_targ_ld_en

52.4.4.2.2.4.2.9.2 RF_NOT_ALLOWED

As of the Gen4.5 radio, the RF_NOT_ALLOWED is not qualified by the TSM. The RF_NOT_ALLOWED signal will be used directly by the link layer(s), which will take appropriate action to de-assert their tx_en or rx_en signal as needed.

52.4.4.2.2.4.2.10 TSM RF_ACTIVE Extension

The TSM RF_ACTIVE can be used as the radio's RF_ACTIVE coexistence output. As such, this signal needs to be asserted high a programmable amount of time before a radio event takes place and remains high until either the radio event has been completed or aborted. There should be no glitches/unwanted transitions between successive radio events (e.g., RX->TX or TX->RX). This can be a problem for protocols, such as Bluetooth LE or 802.15.4, which require the transmission of an acknowledge packet shortly after reception and reception of an acknowledge packet shortly after transmission. Bluetooth LE Advertising and Scan states offer other scenarios where closely-spaced (but not adjoining) TX and RX operations are required. The inter-frame spacing between the successive RX and TX operations is long enough such that TSM RF_ACTIVE would normally deassert and reassert between operations, creating the unwanted transitions which must be avoided.

To remedy this, a feature has been added to TSM which allows the TSM RF_ACTIVE output to be optionally extended by a programmable amount, after the nominal TSM sequence completes. The programmable limit is long enough to accommodate the RF_ACTIVE glitch which would otherwise occur using the 802.15.4 192µs turnaround time. The TSM RF_ACTIVE extension will occur for all sequences (TX and RX) for which TSM RF_ACTIVE is programmed to assert, whenever register TSM_SPARE1_EXTEND>0. The hardware mechanism for extending TSM RF_ACTIVE is illustrated in the following diagram:

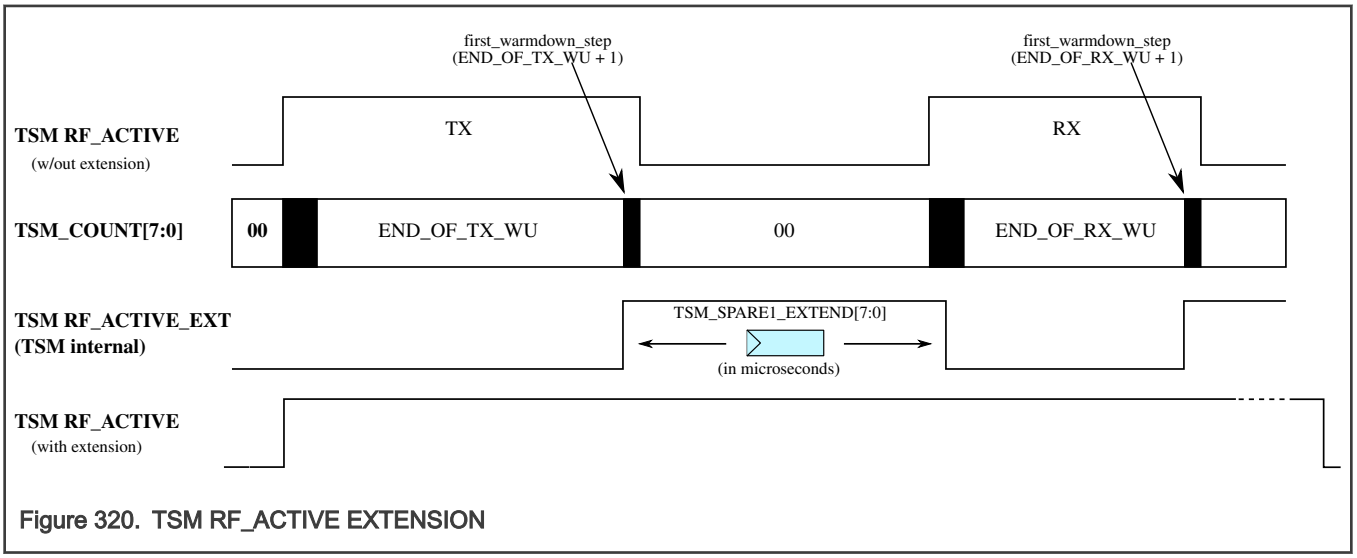

Figure 320. TSM RF_ACTIVE EXTENSION

The trigger for the extension is the TSM's first warmdown step (END_OF_xx_WU + 1), which will be reached whenever the Link Layer deasserts its TX/RX command. If enabled, the extension signal will assert (high) at this point, and will remain high for *TSM_SPARE1_EXTEND* microseconds. The extension signal (TSM RF_ACTIVE_EXT) is logically "OR-ed" with the existing TSM-controlled output TSM RF_ACTIVE, to generate the composite, extended RF_ACTIVE signal. Software can cut short the extension at any time by writing TSM_SPARE1_EXTEND=0. Setting this register to 0 also disables the extension feature from activating on any new TSM sequence. The register TSM_SPARE1_EXTEND[7:0] yields an extension range from 0 to 255µs.

52.4.4.2.2.4.2.11 Low Power Preamble Search (LPPS)

To reduce power consumption during 802.15.4 preamble-search receive state, a low-power-preamble-search (LPPS) mode can be optionally enabled. When engaged, the correlators are disabled approximately 50% of the time during preamble search. The same signal used to dynamically enable/disable the correlators, can be used to enable/disable selected analog and RF blocks in tandem, to further reduce power consumption. The LPPS_CTRL register in XCVR space, has one bit to master-enable LPPS mode (LPPS_ENABLE), and several other bits to allow selected analog and RF blocks to be “duty-cycled” in sync with the correlators. For more details on the LPPS algorithm, see Chapter Multi-standard PHY, Section *IEEE Low-power Preamble Search* for more details on the LPPS algorithm.

By default, LPPS mode is not enabled.

During LPPS mode, correlators and RF blocks are duty-cycled with timing controlled by the LPPS signal **lpps_lp_en**, which is a single-wire output from the 802.15.4 demodulator. In general, eligible blocks will be powered off when **lpps_lp_en** is high, and perform normal operation when **lpps_lp_en** is low. Transitions on **lpps_lp_en** will be handled by the TSM in the following ways:

lpps_lp_en 1 → 0:

1. TSM outputs which are programmed to be eligible for LPPS duty-cycling (e.g, those associated with TZA, BBA, ADC) shall be reasserted at this point.
2. TSM shall recycle to a programmable point in the RX warmup. The TSM RECYCLE_COUNT2[7:0] register selects the TSM_COUNT to recycle to.
3. After jumping to the TSM_COUNT indicated in RECYCLE_COUNT2, TSM shall from this point forward execute a Fast RX Warmup (see Section FAST TSM Fast Warmups later in this chapter). For the Fast RX Warmup, the registers LPPS_START_RX[7:0] and LPPS_DEST_RX[7:0] shall be used to program the TSM "jump" start and end points, as defined in the Fast RX Warmup section. The LPPS_START_RX and LPPS_DEST_RX registers reside in the LPPS_CTRL register. These registers are specific to LPPS fast warmups, and do not apply to non-LPPS fast warmups.

lpps_lp_en 0 → 1:

1. TSM outputs which are programmed to be eligible for LPPS duty-cycling (e.g, those associated with TZA, BBA, ADC) shall be deasserted at this point.
2. TSM outputs which are not eligible for LPPS duty-cycling shall remain asserted.

Note that several LPPS timing parameters are configurable (see Chapter Multi-standard PHY, Section *IEEE Low-power Preamble Search*), and LPPS_FILL_COUNT[6:0] is based on the LPPS fast warmup time. Software configuring LPPS parameters, such as LPPS_FILL_COUNT, must calculate the LPPS fast warmup time, in µs, based on the register programming described in the section above. Here is the equation:

LPPS_FAST_WARMUP_DURATION = END_OF_RX_WU - RECYCLE_COUNT2 + 1 - (LPPS_DEST_RX - LPPS_START_RX - 1)

for example,

LPPS_FAST_WARMUP_DURATION = 104 - 28 + 1 - (102 - 40 - 1)

LPPS_FAST_WARMUP_DURATION = 16µs

Note that the penalty for the reduced power consumption in LPPS mode during preamble search, is a slight degradation in receiver sensitivity. Note also that the TSM override bits, also override LPPS functionality. The override bits provide ultimate control over all TSM outputs.

Programming control for LPPS, includes a master-enable register bit for the LPPS state-machine, as well as individual control bits to enable selected analog and digital blocks to be turned on-and-off during LPPS operation. The following table lists the LPPS register bits, and the TSM outputs controlled by each.

Table 480. LPPS Register Controls

LPPS Register Bit	Description
LPPS_ENABLE	Master enable for LPPS mode. Allows correlators to be duty-cycled during Preamble Search, and selected analog and digital blocks to be duty-cycled simultaneously.
LPPS_LNA_MIX_ALLOW	When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: seq_rx_lna_pup, seq_rx_mix_pup , seq_spare1 for peak detector
LPPS_CBPF_ALLOW	When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: seq_cbpf_pup, seq_cbpf_en_dcoc
LPPS_ADC_ALLOW	When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: seq_adc_pup
LPPS_LO_RX_ALLOW	When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: seq_lo_pup_vlo_rx
LPPS_LO_RXDRV_ALLOW	When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: seq_lo_pup_vlo_rxdrv

Table continues on the next page...

Table 480. LPPS Register Controls (continued)

LPPS Register Bit	Description
LPPS_RX_DIG_ALLOW	When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: rx_dig_en
LPPS_RX_PHY_ALLOW	When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: rx_phy_en

52.4.4.2.2.4.2.12 Powersave warmup and fast rx2tx transition

The previous sections illustrate the detailed control and timing generated by the TSM, operating in nominal-timing mode. There are situations that allow for the possibility to streamline and shorten the TSM warmup sequences. These situations arise when the transceiver is operating on the same RF channel for many consecutive transmit and/or receive operations. Multiple closely-spaced TX operations on the same channel allow the HPM calibration to be skipped, after such a calibration is performed once on a given RF channel; similarly, multiple closely spaced RX operations on the same channel allow DC offset calibration to be skipped, after such a calibration is performed once on a given RF channel.

Fast and Power-saving TSM warmups have been devised to accomplish this streamlining. Once engaged, during a fast or power-saving warmup, a portion of the nominal, programmed warmup is bypassed, or skipped over, by instructing the TSM counter to jump, once it reaches a certain count, to a new count that is not just an increment-by-one. The starting point for the “jump” as well as the destination count, or end point for the “jump”, are TSM programmable registers. There are one pair of start/destination registers for TX, and another for RX, allowing one such jump per sequence.

Power-saving warmups can be used in conjuction with any of the link layers. In a power-saving warmup, the PLL sends a pwrsave_tx_wu_ok (or pwrsave_rx_wu_ok) signal to the TSM to let the TSM known that that the PLL is on the same channel as the previous tx (or rx) channel. For a power-saving warmup, the TSM will insert some idle time after the link layer asserts tx_en (or rx_en) so that the overall time from the link layer asserting tx_en (or rx_en) to when the radio is on-air remains constant. The link layer is therefore unaware that a power-saving warmup has occurred. The power savings benefit is that the analog and calibration circuits are on for a shorter during during warmup.

Fast TSM warmup is required by the link layer. Currently, only the Generic LL supports fast TSM warmups. A fast warmup is similar to a power-saving warmup, except that the TSM does not insert any idle time after the link layers tx_en (or rx_en). So the time from the link layer asserting tx_en (or rx_en) to when the radio is on-air is shorter for a fast warmup. A fast warmup request from the link layer has higher priority than a power-saving warmup ok from the PLL. In fact, the TSM does not qualify a fast warmup request with the pwrsave_tx_wu_ok (or pwrsave_rx_wu_ok) signal from the PLL; the Generic LL programmer must ensure that previous warmup calibrations can be skipped before requesting a fast warmup.

Enables bits provide software with fine control over precisely when fast and power-saving warmups are allowed, versus nominal warmups.

In addition, TSM sequences have in the past been discrete TX or RX operations, with a required software command to initiate the sequence, and a return-to-idle after the sequence is complete, before a new sequence-start command can be issued. For some link layers, it is highly desirable to be able to jump directly from the end of a CCA measurement (CCA = Clear Channel Assessment), which is essentially an RX operation, to a packet transmit operation, without returning the TSM to IDLE in between, if CCA deems the channel to be free. A new TSM transition called “Fast RX2TX” accomplishes this. The Generic or 802.15.4 Link Layer will signal to TSM when to perform such a transition, and TSM will respond by jumping from the RX “ON” phase, to a programmable point within the TX warmup. At the very least, this will allow the re-warmup of the required analog regulators to be skipped, since they can stay on during the transition. Also, since the PLL is staying on the same channel, there is no need to cycle the VCO off, and then on again, so the VCO-related TSM controls can be programmed to maintain their states during the transition. Enable bits provide software with fine control over precisely when a “Fast RX2TX” is allowed, versus a nominal RX-to-IDLE-to-TX ordering of events.

Fast RX2TX can also be combined with a Fast TX Warmup to yield an ultrafast TX warmup sequence, if, as is likely, the RF channel has not changed since the previous TX warmup. In this case, the Fast TX warmup is conditioned by the PLL's pwrsave_tx_wu_ok.

Interaction with other blocks is required to support TSM fast warmup capability. The PLL digital block is responsible for selecting the correct frequency for RF operations, and will keep track of whether consecutive warmup operations utilize the same channel or

not; it will signal this information to the TSM. The PLL digital block will maintain such tracking separately for TX and RX warmups. The TSM will then signal back to the PLL digital block when a TX warmup is actually “fast” or not; the PLL digital block will use this information to instruct its state machine to skip HPM calibration. For RX warmups, the TSM will signal to the RX digital block, when to skip DC calibration, and instead use stored values.

The new inter-block signaling to support fast TSM warmups is illustrated in the following diagram, followed by a table which describes the new signaling.

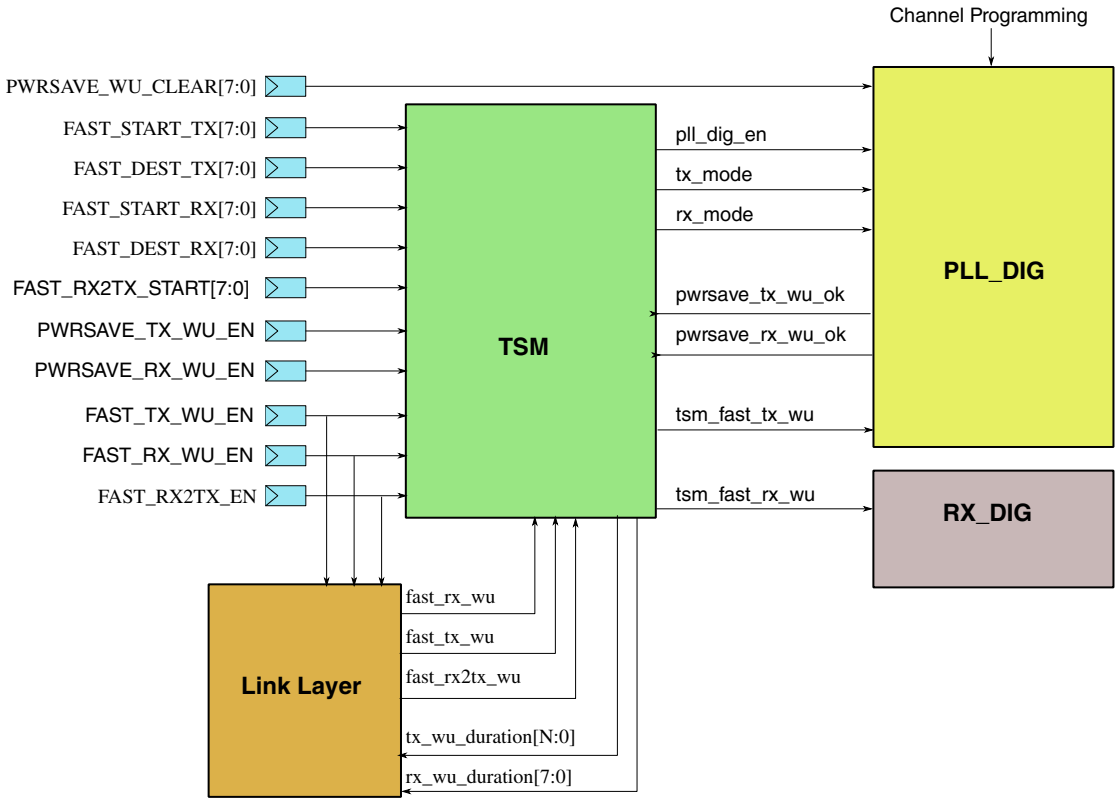

Figure 321. XCVR SIGNALLING TO SUPPORT TSM FAST WARMUPS

“Fast Warmup” Signal	Source	Destination	Description
pll_dig_en	TSM	PLL Digital	Rising edge of this signal used by PLL_DIG to capture the Channel Programming for the current warmup
tx_mode	TSM	PLL Digital	Used in conjunction with pll_dig_en to capture the Channel Programming for TX sequences
rx_mode	TSM	PLL Digital	Used in conjunction with pll_dig_en to capture the Channel Programming for RX sequences

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"Fast Warmup" Signal	Source	Destination	Description
fast_rx_wu	Generic LL	TSM	Link layer requests a Fast RX warmup
fast_tx_wu	Generic LL	TSM	Link layer requests a Fast TX warmup
fast_rx2tx_wu	ZSM (802.15.4) or Generic LL	TSM	The RF channel is free to transmit immediately after an RX burst. TSM should jump directly from RX "ON" phase to TX "WARMUP" phase, entering at the FAST_RX2TX_START point.
pwrsave_rx_wu_ok	PLL Digital	TSM	Indicates that the Channel Programming on the *current* RX warmup has not changed since the *last* RX warmup
pwrsave_tx_wu_ok	PLL Digital	TSM	Indicates that the Channel Programming on the *current* TX warmup has not changed since the *last* TX warmup
tsm_fast_tx_wu	TSM	PLL Digital	This is a fast or power-saving TX warmup. PLL_DIG should skip calibration.
tsm_fast_rx_wu	TSM	RX Digital	This is a fast or power-saving RX warmup. RX Dig should skip DCOC Cal.
rx_warmup_duration[7:0]	TSM	Link Layer	Indicates the RX warmup time.
tx_warmup_duration[7:0]	TSM	Link Layer	Indicates the TX warmup time, including PA ramp time

TSM Registers to support Fast TSM Warmups and Fast RX2TX are described in the following table.

Field	R/W	Description
PWRSAVE_TX_WU_EN	rw	1: Enable Power-Saving TX Warmup (if pwrsave_tx_wu_ok asserted by PLL_DIG) 0: Disable Power-Saving TX Warmups
PWRSAVE_RX_WU_EN	rw	1: Enable Power-Saving RX Warmup (if pwrsave_rx_wu_ok asserted by PLL_DIG)

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Field	R/W	Description
		0: Disable Power-Saving RX Warmups
PWRSAVE_WU_CLR	rw	This is not used directly by the TSM. It creates a signal to the PLL to clear its wu_ok. It should be set and then cleared by software. 1: Direct the PLL to clear the *wu_ok signals 0: Do nothing
FAST_TX_WU_EN	rw	1: Enable Fast TX Warmup (if fast_tx_wu_ok asserted by PLL_DIG) 0: Disable Fast TX Warmups
FAST_RX_WU_EN	rw	1: Enable Fast RX Warmup (if fast_rx_wu_ok asserted by PLL_DIG) 0: Disable Fast RX Warmups
FAST_RX2TX_EN	rw	1: Enable Fast RX-to-TX transitions (if fast_rx2tx_wu is asserted by ZSM) 0: Disable Fast RX-to-TX transitions
FAST_START_TX[7:0]	rw	During a Fast or Power-Saving TX Warmup, this value represents the starting TSM count for the portion of the warmup that is to be skipped over. If Fast or Power-Saving TX Warmups are enabled, this count will never be reached; its place in the TSM warmup will be replaced by the contents of FAST_DEST_TX[7:0], thereby executing the jump.
FAST_DEST_TX[7:0]	rw	During a Fast or Power-Saving TX Warmup, this value represents the ending TSM count for the portion of the warmup that is to be skipped over. If Fast or Power-Saving TX Warmups are enabled, FAST_START_TX[7:0] will never be reached and will instead be

Table continues on the next page...

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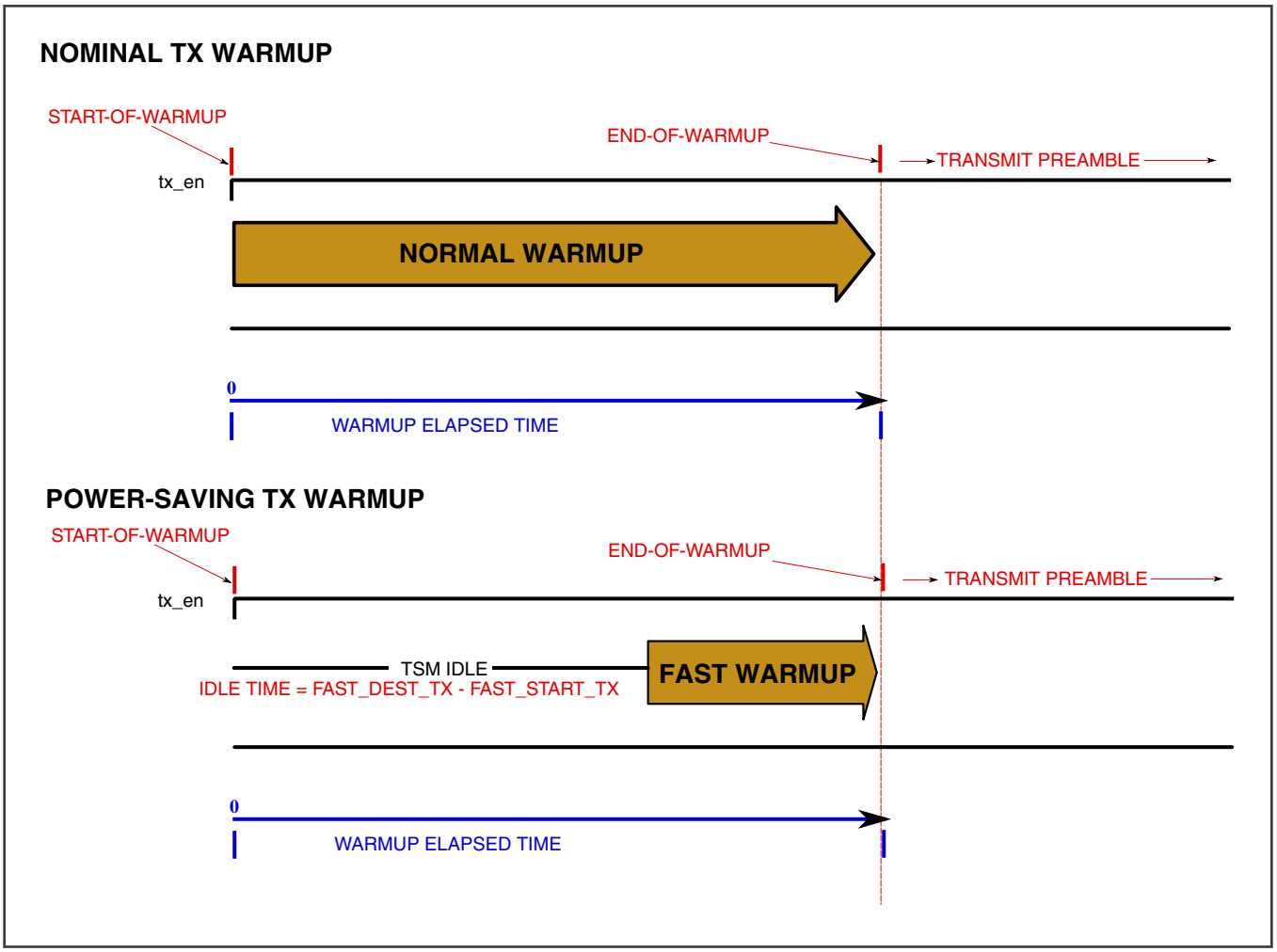
Field	R/W	Description
		replaced by the contents of this register, thereby executing the jump. Example: FAST_START_TX = 10 FAST_DEST_TX = 15 The TSM will count as follows: … 7,8,9,15,16,17 …
FAST_START_RX[7:0]	rw	During a Fast or Power-Saving RX Warmup, this value represents the starting TSM count for the portion of the warmup that is to be skipped over. If Fast or Power-Saving RX Warmups are enabled, this count will never be reached; its place in the TSM warmup will be replaced by the contents of FAST_DEST_RX[7:0], thereby executing the jump.
FAST_DEST_RX[7:0]	rw	During a Fast or Power-Saving RX Warmup, this value represents the ending TSM count for the portion of the warmup that is to be skipped over. If Fast or Power-Saving RX Warmups are enabled, FAST_START_RX[7:0] will never be reached and will instead be replaced by the contents of this register, thereby executing the jump. Example: FAST_START_TX = 10 FAST_DEST_TX = 15 The TSM will count as follows: … 7,8,9,15,16,17 …
FAST_RX2TX_START[7:0]	rw	During a Fast RX-to-TX transition (FAST_RX2TX_EN=1) the contents of this register represent the entry point (TSM count) in the TX warmup sequence to which the TSM jumps to when Link Layer asserts fast_rx2tx_wu. The TSM will jump from the RX “ON” phase to the TX “WARMUP” phase, starting at this count.

Software running on the various protocol engines which utilize the TSM to provide access to the channel, need not be aware that the total warmup time has been reduced, when the TSM executes a power-saving warmup, as opposed to a nominal warmup. (With the exception of the Generic LL), Link Layer software expects TSM warmup times to be a fixed constant, actually 2 fixed

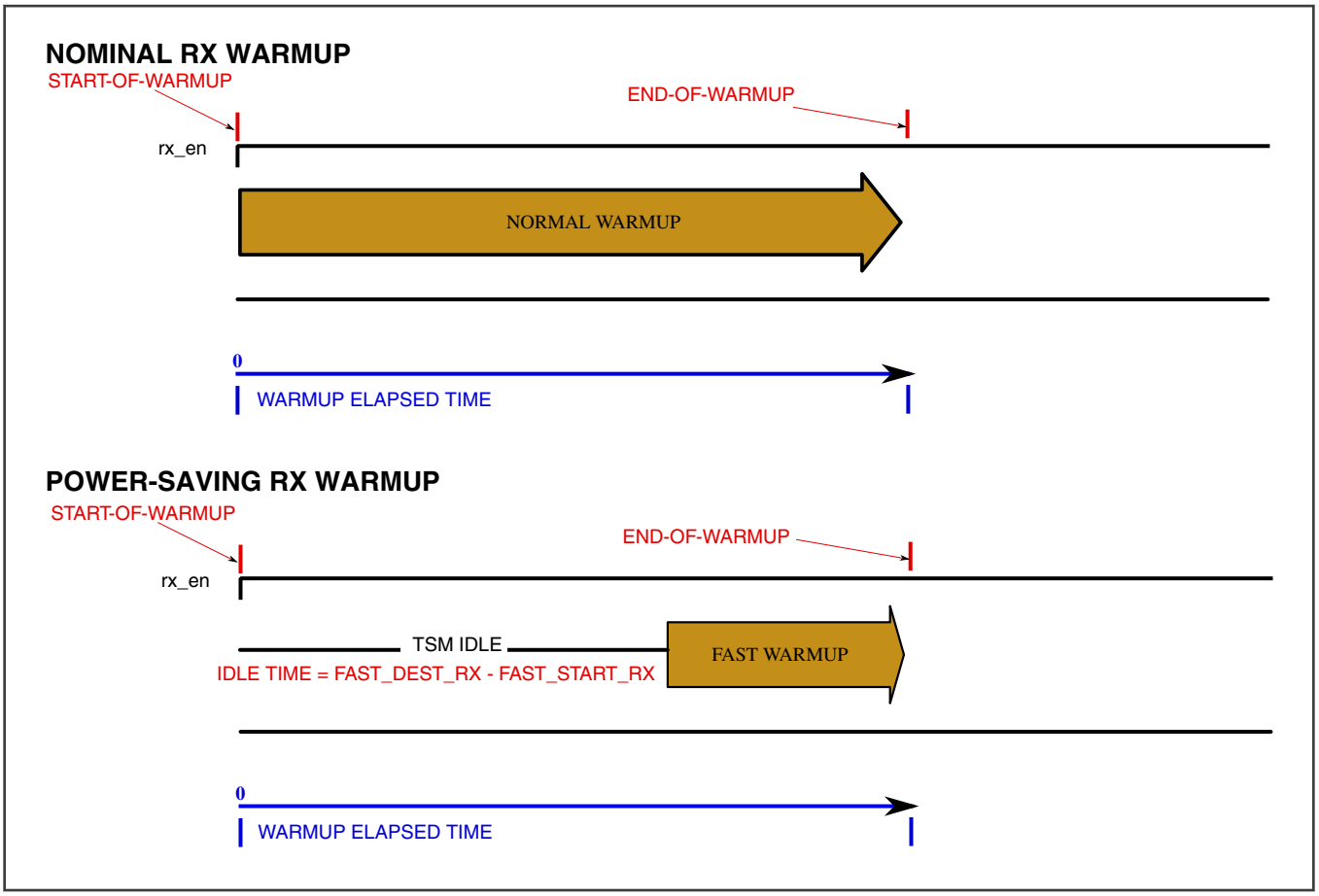
constants, one for TX warmups and one for RX warmups. Software must account for these TX and RX warmup times when they are scheduling transceiver operations, so that the first symbol of preamble is transmitted at the correct instant for transmit operations, and that the receiver is ready to receive the first symbol of preamble at the correct instant for receive operations. Software views these warmup times as fixed lead times that must be accounted for in advance of a transceiver operation.

In order to make the power-saving warmup time reduction transparent to software, when a power-saving TSM warmup is executed, the TSM will delay the start of the warmup, by the amount of time skipped by the jump. That keeps the total elapsed time, from the instant the software launches the TSM sequence, to the point at which the warmup completes, identical for power-saving and nominal warmups.

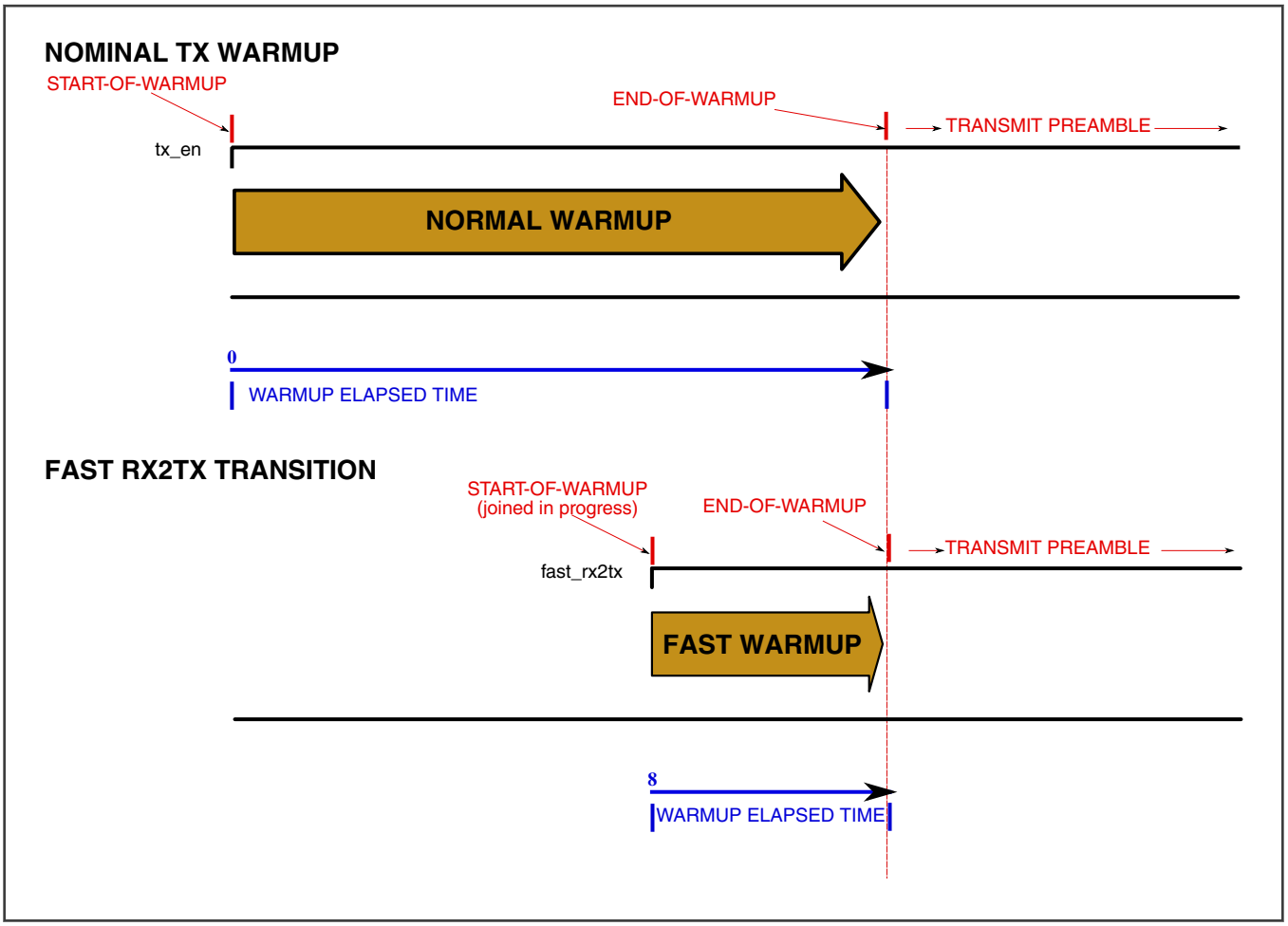
The following diagram illustrates how the TSM delays the start of the Power-saving TX sequence, relative to the nominal TX sequence, so that the delta time between tx_en (TSM launch signal), and the transmission of the first bit of preamble, is the same in either case.



The following diagram illustrates how the TSM delays the start of the Power-saving RX sequence, relative to the nominal RX sequence, so that the delta time between rx_en (TSM launch signal), and the ability to receive first bit of preamble, is the same in either case.



The FAST RX2TX transition is handled differently. The objective in such a transition is to get to the point of transmitting the first bit of preamble ASAP. There is no warmup time that software needs to account for in this case, since the RX-to-TX transition is handled completely by hardware. The following diagram compares a nominal TX warmup, with a foreshortened “Fast RX2TX” warmup.



52.4.4.2.2.4.2.13 FAST Transition Support for Ranging Sequence Manager

For the Ranging Sequence Manager (RSM), the TSM supports the following additional features:

- Ability for the RSM to request Fast RX-to-TX transition described in previous section. The RSM outputs a fast_rx2tx_wu signal to the TSM to request this transition
- Fast TX-to-RX feature, analogous to the Fast RX-to-TX feature. The RSM outputs a fast_tx2rx_wu signal to the TSM to request this transition.
- An alternate set of START times for the Fast RX-to-TX and Fast TX-to-RX features. This allows the RSM to use the primary set of START times for its IP (Interlude Period) transitions and the alternate set for its FC (Frequency Change) transitions. The RSM outputs a signal fast_fc_wu to the TSM to select which set to use.
- Ability for the RSM to request FAST RX in conjunction with Fast TX-to-RX transiiton. These use the FAST_START_RX[7:0] and FAST_DEST_RX[7:0] as described in the previous section. The RSM outputs a fast_rx_wu signal to request FAST RX.
- Ability for the RSM to request FAST TX in conjunction with Fast RX-to-TX transiiton. These use the FAST_START_TX[7:0] and FAST_DEST_TX[7:0] as described in the previous section. The RSM outputs a fast_tx_wu signal to request FAST TX.

Refer to Role Swap and Frequency Change Transitions section in the Ranging Sequence Manager topic for more information about RSM use of these TSM features.

The TSM Registers added to support these additional features for the RSM are described in the following table.

Field	R/W	Description
FAST_TX2RX_EN	rw	1: Enable Fast TX-to-RX transitions (if fast_tx2rx_wu is asserted by RSM) 0: Disable Fast TX-to-RX transitions
FAST_TX2RX_START[7:0]	rw	During a Fast TX-to-RX transition (FAST_TX2RX_EN=1) the contents of this register represent the entry point (TSM count) in the RX warmup sequence to which the TSM jumps to when RSM asserts fast_tx2rx_wu with fast_fc_wu=0. The TSM will jump from the TX “ON” phase to the RX “WARMUP” phase, starting at this count.
FAST_RX2TX_START_FC[7:0]	rw	During a Fast RX-to-TX transition (FAST_RX2TX_EN=1) the contents of this register represent the entry point (TSM count) in the TX warmup sequence to which the TSM jumps to when RSM asserts fast_rx2tx_wu with fast_fc_wu=1. (If fast_fc_wu=0, the TSM will use FAST_RX2TX_START[7:0]) The TSM will jump from the RX “ON” phase to the TX “WARMUP” phase, starting at this count.
FAST_TX2RX_START_FC[7:0]	rw	During a Fast TX-to-RX transition (FAST_TX2RX_EN=1) the contents of this register represent the entry point (TSM count) in the RX warmup sequence to which the TSM jumps to when RSM asserts fast_tx2rx_wu with fast_fc_wu=1. (If fast_fc_wu=0, the TSM will use FAST_TX2RX_START[7:0]) The TSM will jump from the TX “ON” phase to the RX “WARMUP” phase, starting at this count.

52.4.4.2.2.4.2.14 Programming Restrictions

The following restrictions are imposed on TSM programming. Violating the restrictions may result in unpredictable behavior.

1. The maximum value for END_OF_TX_WU[7:0] is 253
2. The maximum value for END_OF_RX_WU[7:0] is 253
3. The maximum value for END_OF_TX_WD[7:0] is 254
4. The maximum value for END_OF_RX_WD[7:0] is 254
5. END_OF_TX_WD[7:0] – END_OF_TX_WU[7:0] >= 1

6. END_OF_RX_WD[7:0] – END_OF_RX_WU[7:0] >= 1
7. BKPT[7:0] != END_OF_TX_WD[7:0]
8. BKPT[7:0] != END_OF_RX_WD[7:0]
9. For any TSM output: OUTPUTNAME_TX_HI[7:0] <= OUTPUTNAME_TX_LO[7:0]
10. For any TSM output: OUTPUTNAME_RX_HI[7:0] <= OUTPUTNAME_RX_LO[7:0]

Restrictions 9 and 10 above, if violated, will result in the TSM-controlled output held in a deasserted state throughout the sequence.

To guarantee non-assertion of a particular TSM-controlled output throughout the course of a sequence, simply program its OUTPUTNAME_SEQ_HI = OUTPUTNAME_SEQ_LO = 255 (where SEQ = TX or RX).

52.4.4.2.2.4.2.15 Interrupts

For debug purposes, TSM has two timing control outputs (tsm_irq0_start_trigger_en and tsm_irq1_stop_trigger_en) which can be used to either generate interrupts to the host processor. Like all other TSM-controlled outputs, the point during the TX or RX warmup at which the interrupt is triggered, is fully programmable.

To use either tsm_irq0_start_trigger_en or tsm_irq1_stop_trigger_en as an interrupt, set the TSM_IRQ0_EN or TSM_IRQ1_EN bit, respectively, in the TSM_CTRL registers. Because the TSM is part of XCVR space, and XCVR space does not have its own interrupt vector, the TSM interrupt is "assigned" to the Link Layer currently in possession of the radio. Each Link Layer controller has in its address space, a TSM_IRQ status bit, as well as a enable bit to allow/disallow the TSM interrupt to assert the Link Layer's interrupt line to the MCU. The TSM_IRQ status bit, as it appears in each Link Layer's address space, is a logical "OR" of the TSM's TSM0_IRQ and TSM1_IRQ. The Link Layer TSM_IRQ is read-only. It can be cleared by clearing both TSM0_IRQ and TSM1_IRQ in the XCVR's XCVR_STATUS register. In the XCVR_STATUS register, TSM0_IRQ and TSM1_IRQ are both write-1-to-clear bits. See the Register Description for each individual Link Layer, for a description of the TSM_IRQ read-only interrupt status bit, and its bit positioning within the Link Layer's address space.

The tsm_irq0_start_trigger_en can also be used as a start trigger source for the Transceiver DMA or Packet RAM Debug mode. The tsm_irq1_stop_trigger_en can also be used as a stop trigger source for the Packet RAM Debug mode.

52.4.4.2.2.4.3 Memory Map and Register Definition

52.4.4.2.2.4.3.1 XCVR_TSM register descriptions

52.4.4.2.2.4.3.1.1 XCVR_TSM_REG memory map

RADIO.XCVR_TSM base address: 48A0_7800h

Offset	Register	Width (In bits)	Access	Reset value
0h	TSM CONTROL (CTRL)	32	RW	FF00_0000h
4h	TSM CONTROL (LPPS_CTRL)	32	RW	FFFF_0000h
8h	TSM END OF SEQUENCE (END_OF_SEQ)	32	RW	5C5A_7270h
Ch	WARMUP LATENCY (WU_LATENCY)	32	RW	0000_0000h
10h	TSM RECYCLE COUNT (RECYCLE_COUNT)	32	RW	002A_1258h
14h	TSM FAST WARMUP CONTROL 1 (FAST_CTRL1)	32	RW	FF00_FF00h
18h	TSM FAST WARMUP CONTROL 2 (FAST_CTRL2)	32	RW	FFFF_FFFFh
1Ch	TSM FAST WARMUP CONTROL 3 (FAST_CTRL3)	32	RW	0000_FF00h

Table continues on the next page...

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Offset	Register	Width (In bits)	Access	Reset value
20h	TSM_TIMING00 (TIMING00)	32	RW	FFFF_FFFFh
24h	TSM_TIMING01 (TIMING01)	32	RW	FFFF_FFFFh
28h	TSM_TIMING02 (TIMING02)	32	RW	FFFF_FFFFh
2Ch	TSM_TIMING03 (TIMING03)	32	RW	FFFF_FFFFh
30h	TSM_TIMING04 (TIMING04)	32	RW	FFFF_FFFFh
34h	TSM_TIMING05 (TIMING05)	32	RW	FFFF_FFFFh
38h	TSM_TIMING06 (TIMING06)	32	RW	FFFF_FFFFh
3Ch	TSM_TIMING07 (TIMING07)	32	RW	FFFF_FFFFh
40h	TSM_TIMING08 (TIMING08)	32	RW	FFFF_FFFFh
44h	TSM_TIMING09 (TIMING09)	32	RW	5700_FFFFh
48h	TSM_TIMING10 (TIMING10)	32	RW	1108_1108h
4Ch	TSM_TIMING11 (TIMING11)	32	RW	5B13_7113h
50h	TSM_TIMING12 (TIMING12)	32	RW	5B19_714Fh
54h	TSM_TIMING13 (TIMING13)	32	RW	572D_FFFFh
58h	TSM_TIMING14 (TIMING14)	32	RW	0000_716Fh
5Ch	TSM_TIMING15 (TIMING15)	32	RW	5B58_716Fh
60h	TSM_TIMING16 (TIMING16)	32	RW	5958_0000h
64h	TSM_TIMING17 (TIMING17)	32	RW	5B58_0000h
68h	TSM_TIMING18 (TIMING18)	32	RW	5B58_0000h
6Ch	TSM_TIMING19 (TIMING19)	32	RW	1100_1100h
70h	TSM_TIMING20 (TIMING20)	32	RW	1100_1100h
74h	TSM_TIMING21 (TIMING21)	32	RW	1900_1100h
78h	TSM_TIMING22 (TIMING22)	32	RW	5800_6F00h
7Ch	TSM_TIMING23 (TIMING23)	32	RW	5800_6F00h
80h	TSM_TIMING24 (TIMING24)	32	RW	5B00_7100h
84h	TSM_TIMING25 (TIMING25)	32	RW	5C00_7200h
88h	TSM_TIMING26 (TIMING26)	32	RW	5C00_7200h
8Ch	TSM_TIMING27 (TIMING27)	32	RW	5C00_7200h
90h	TSM_TIMING28 (TIMING28)	32	RW	5C00_7200h
94h	TSM_TIMING29 (TIMING29)	32	RW	FFFF_7200h
98h	TSM_TIMING30 (TIMING30)	32	RW	5C00_FFFFh

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Offset	Register	Width (In bits)	Access	Reset value
9Ch	TSM_TIMING31 (TIMING31)	32	RW	5B08_7108h
A0h	TSM_TIMING32 (TIMING32)	32	RW	1911_FFFFh
A4h	TSM_TIMING33 (TIMING33)	32	RW	2311_5A11h
A8h	TSM_TIMING34 (TIMING34)	32	RW	5B11_7111h
ACh	TSM_TIMING35 (TIMING35)	32	RW	5B11_7111h
B0h	TSM_TIMING36 (TIMING36)	32	RW	5B11_7111h
B4h	TSM_TIMING37 (TIMING37)	32	RW	5B11_7111h
B8h	TSM_TIMING38 (TIMING38)	32	RW	5B11_7111h
BCh	TSM_TIMING39 (TIMING39)	32	RW	5B2B_7111h
C0h	TSM_TIMING40 (TIMING40)	32	RW	FFFF_7111h
C4h	TSM_TIMING41 (TIMING41)	32	RW	FFFF_7111h
C8h	TSM_TIMING42 (TIMING42)	32	RW	5B12_7112h
CCh	TSM_TIMING43 (TIMING43)	32	RW	5B12_FFFFh
D0h	TSM_TIMING44 (TIMING44)	32	RW	5B12_FFFFh
D4h	TSM_TIMING45 (TIMING45)	32	RW	FFFF_7112h
D8h	TSM_TIMING46 (TIMING46)	32	RW	FFFF_7112h
DCh	TSM_TIMING47 (TIMING47)	32	RW	5B13_7157h
E0h	TSM_TIMING48 (TIMING48)	32	RW	5B23_715Ah
E4h	TSM_TIMING49 (TIMING49)	32	RW	5B23_715Ah
E8h	TSM_TIMING50 (TIMING50)	32	RW	5B2B_FFFFh
ECh	TSM_TIMING51 (TIMING51)	32	RW	5B2B_FFFFh
F0h	TSM_TIMING52 (TIMING52)	32	RW	FFFF_FFFFh
F4h	TSM TIMING_53 (TIMING53)	32	RW	5B23_715Ah
F8h	TSM TIMING_54 (TIMING54)	32	RW	FFFF_FFFFh
FCh	TSM TIMING_55 (TIMING55)	32	RW	FFFF_FFFFh
100h	TSM TIMING_56 (TIMING56)	32	RW	FFFF_FFFFh
104h	TSM TIMING_57 (TIMING57)	32	RW	FFFF_FFFFh
108h	TSM TIMING_58 (TIMING58)	32	RW	FFFF_FFFFh
10Ch	TSM TIMING_59 (TIMING59)	32	RW	FFFF_FFFFh
110h	TSM TIMING_60 (TIMING60)	32	RW	FFFF_FFFFh
114h	TSM TIMING_61 (TIMING61)	32	RW	FFFF_FFFFh

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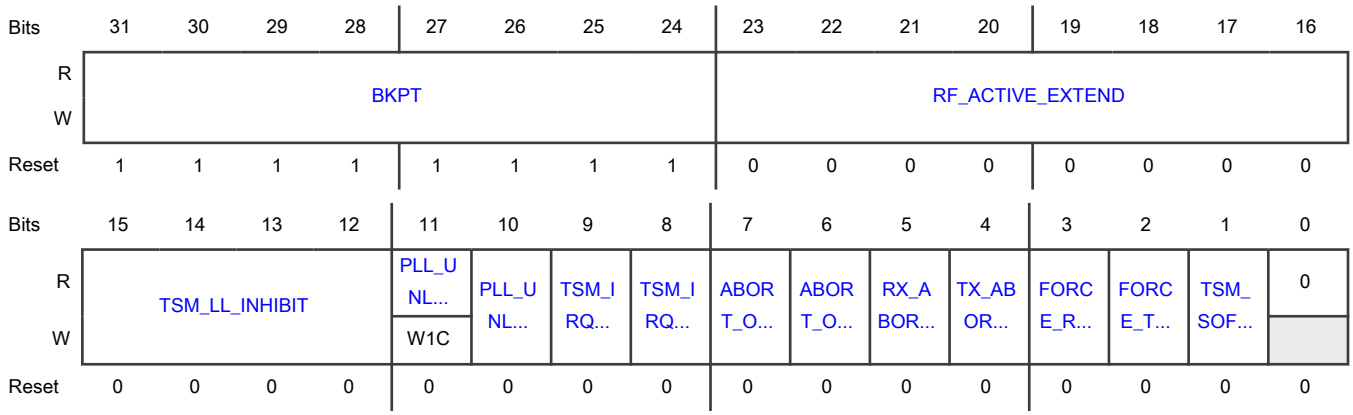
Offset	Register	Width (In bits)	Access	Reset value
118h	TSM OVERRIDE REGISTER 0 (OVRD0)	32	RW	0000_0000h
11Ch	TSM OVERRIDE REGISTER 1 (OVRD1)	32	RW	0000_0000h
120h	TSM OVERRIDE REGISTER 2 (OVRD2)	32	RW	0000_0000h
124h	TSM OVERRIDE REGISTER 3 (OVRD3)	32	RW	0000_0000h
128h	TSM OVERRIDE REGISTER 4 (OVRD4)	32	RW	0000_0000h
12Ch	TSM CONTROL 2 (CTRL2)	32	RW	0000_0003h

52.4.4.2.2.4.3.1.2 TSM CONTROL (CTRL)

Offset

Register	Offset
CTRL	0h

Diagram



Fields

Field	Function
31-24 BKPT	TSM Breakpoint Temporarily halt a TSM sequence during the warmup or warmdown phase. When the TSM counter matches the value of BKPT[7:0], breakpoint will take effect and the TSM counter will stop and hold its count. Breakpoint will remain in effect as long as BKPT[7:0] matches the TSM counter value. The TSM Breakpoint can be lifted by modifying the contents of this register. The default value of this register, 0xFF, is greater than the length of the longest possible sequence, so a breakpoint will never be triggered unless BKPT[7:0] is programmed to a value less than the length of sequence.

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Field	Function
23-16 RF_ACTIVE_EXTEND	TSM RF_ACTIVE Extension Duration When TSM output RF_ACTIVE is enabled to assert during any TX or RX sequence and TSM_SPARE1_EXTEND[7:0] > 0, this register specifies the number of microseconds for which RF_ACTIVE is to remain asserted beyond the end of the TSM warmdown. This extension is intended to close any gap in the coexistence output RF_ACTIVE that may occur between consecutive TX/RX or RX/TX TSM operations.
15-12 TSM_LL_INHIBIT	TSM Per-Link-Layer Inhibit Nominally, any protocol engine can request TSM to start a TX or RX sequence at any time. In a multiprotocol setting, individual protocol engines can (optionally) be selectively blocked from accessing TSM by setting one of the following bits of TSM_LL_INHIBIT[3:0]: xxx1: Bluetooth LE commands to TSM are inhibited xxx0: Bluetooth LE commands to TSM are permitted 1xxx: GENERIC_FSK commands to TSM are inhibited 0xxx: GENERIC_FSK commands to TSM are permitted
11 PLL_UNLOCK_IRQ	PLL Unlock IRQ PLL Un-lock Interrupt Status bit. A '1' indicates an unlock event has occurred in the PLL. This is write a '1' to clear bit. 0b - A PLL Unlock Interrupt has not occurred 1b - A PLL Unlock Interrupt has occurred
10 PLL_UNLOCK_IRQ_EN	PLL Unlock Interrupt Enable 0b - allows PLL unlock event to generate an interrupt 1b - A PLL unlock event will set the PLL_UNLOCK_IRQ status bit, but an interrupt is not generated
9 TSM_IRQ1_EN	TSM_IRQ1 Enable/Disable bit TSM_IRQ1 Enable/Disable bit. Intended for debug purposes only. 0b - TSM_IRQ1 is disabled 1b - TSM_IRQ1 is enabled
8 TSM_IRQ0_EN	TSM_IRQ0 Enable/Disable bit TSM_IRQ0 Enable/Disable bit. Intended for debug purposes only. 0b - TSM_IRQ0 is disabled 1b - TSM_IRQ0 is enabled
7 ABORT_ON_FREQ_TARG	Abort On Frequency Target Lock Detect Failure 0b - don't allow TSM abort on Frequency Target Unlock Detect 1b - allow TSM abort on Frequency Target Unlock Detect

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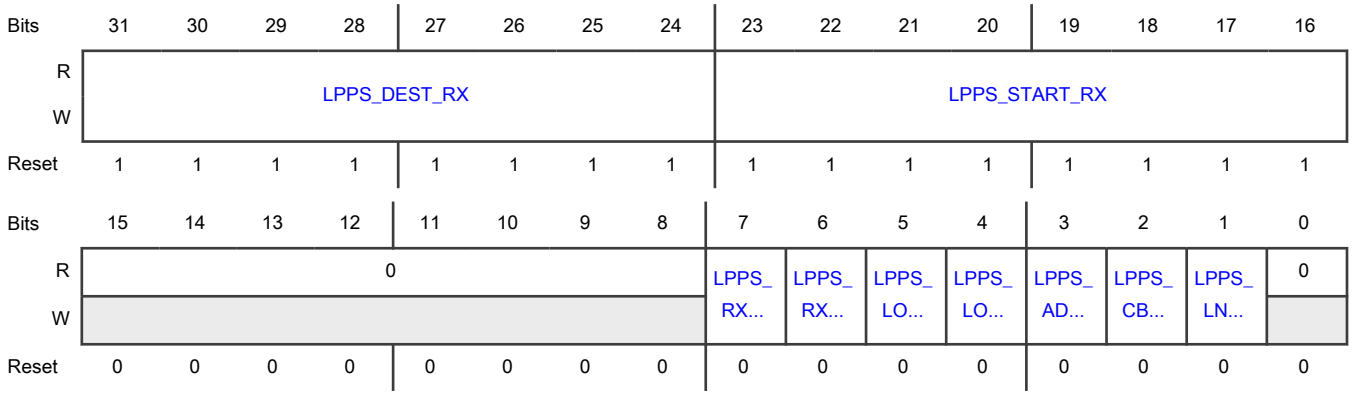
Field	Function
6 ABORT_ON_CTUNE	Abort On Coarse Tune Lock Detect Failure 0b - don't allow TSM abort on Coarse Tune Unlock Detect 1b - allow TSM abort on Coarse Tune Unlock Detect
5 RX_ABORT_DIS	Receive Abort Disable RX Abort disable. When set, prevents PLL unlock events during RX sequences from aborting the sequence.
4 TX_ABORT_DIS	Transmit Abort Disable TX Abort disable. When set, prevents PLL unlock events during TX sequences from aborting the sequence.
3 FORCE_RX_EN	Force Receive Enable Direct software control to launch a RX TSM sequence. Initiates RX Warmup on a 0 to 1 transition and RX Warmdown on a 1 to 0 transition. 0b - TSM Idle 1b - TSM executes a RX sequence
2 FORCE_TX_EN	Force Transmit Enable Direct software control to launch a TX TSM sequence. Initiates a TX Warmup sequence on a 0 to 1 transition and a TX Warmdown sequence on a 1 to 0 transition. 0b - TSM Idle 1b - TSM executes a TX sequence
1 TSM_SOFT_RESET	TSM Soft Reset Writing 1 to this bit returns TSM to its IDLE state, with TSM_COUNT=0. Writing 0 to this bit removes the forced-reset condition and resumes normal operation. The bit is not self-clearing. For contingency purposes only 0b - TSM Soft Reset removed. Normal operation. 1b - TSM Soft Reset engaged. TSM forced to IDLE, and holds there until the bit is cleared.
0 —	Reserved

52.4.4.2.2.4.3.1.3 TSM CONTROL (LPPS_CTRL)

Offset

Register	Offset
LPPS_CTRL	4h

Diagram



Fields

Field	Function
31-24 LPPS_DEST_RX	LPPS Fast TSM RX Warmup "Jump-to" Point During a LPPS Fast RX Warmup, this value represents the ending TSM count for the portion of the warmup that is to be skipped over. In an LPPS Fast RX Warmup, LPPS_START_RX[7:0] will never be reached and will instead be replaced by the contents of this register, thereby executing the jump. Example: LPPS_START_RX = 10 LPPS_DEST_RX = 15 The TSM will count as follows: … 7,8,9,15,16,17 …
23-16 LPPS_START_RX	LPPS Fast TSM RX Warmup "Jump-from" Point During a LPPS Fast RX Warmup, this value represents the starting TSM count for the portion of the warmup that is to be skipped over. In an LPPS Fast RX Warmup, this count will never be reached; its place in the TSM warmup will be replaced by the contents of LPPS_DEST_RX[7:0], thereby executing the jump.
15-8 —	Reserved
7 LPPS_RX_PHY_ALLOW	LPPS_RX_PHY_ALLOW When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: rx_phy_en
6 LPPS_RX_DIG_ALLOW	LPPS_RX_DIG_ALLOW When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: rx_dig_en
5 LPPS_LO_RXDRV_ALLOW	LPPS_LO_RXDRV_ALLOW When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: seq_lo_pup_vlo_rxdrv

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Field	Function
4 LPPS_LO_RX_ALLOW	LPPS_LO_RX_ALLOW When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: seq_lo_pup_vlo_rx
3 LPPS_ADC_ALLOW	LPPS_ADC_ALLOW When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: seq_adc_pup
2 LPPS_CBPF_ALLOW	LPPS_CBPF_ALLOW When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: seq_adc_pup, seq_cbpf_en_dcoc
1 LPPS_LNA_MIX_ALLOW	LPPS_LNA_MIX_ALLOW When set to one, allows the following TSM outputs to be controlled by the LPPS state machine: seq_rx_lna_pup, seq_rx_mix_pup, seq_spare1
0 —	Reserved

52.4.4.2.2.4.3.1.4 TSM END OF SEQUENCE (END_OF_SEQ)

Offset

Register	Offset
END_OF_SEQ	8h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	END_OF_RX_WD								END_OF_RX_WU							
Reset	0	1	0	1	1	1	0	0	0	1	0	1	1	0	1	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	END_OF_TX_WD								END_OF_TX_WU							
Reset	0	1	1	1	0	0	1	0	0	1	1	1	0	0	0	0

Fields

Field	Function
31-24 END_OF_RX_WD	End of RX Warmdown This register defines the point at which the TSM RX sequence warmdown completes, and the TSM returns to idle. The duration of the TSM warmdown phase is determined by: END_OF_RX_WD – END_OF_RX_WU.
23-16 END_OF_RX_WU	End of RX Warmup This register defines the length of the TSM RX warmup sequence. After the assertion of a RX sequence-initiating event, when the TSM counter reaches the count matching this register, it will stop and hold its count, and the TSM will transition from the WARMUP to the ON phase.
15-8 END_OF_TX_WD	End of TX Warmdown This register defines the point at which the TSM TX sequence warmdown completes, and the TSM returns to idle. The duration of the TSM warmdown phase is determined by: END_OF_TX_WD – END_OF_TX_WU.
7-0 END_OF_TX_WU	End of TX Warmup This register defines the length of the TSM TX warmup sequence. After the assertion of a TX sequence-initiating event, when the TSM counter reaches the count matching this register, it will stop and hold its count, and the TSM will transition from the WARMUP to the ON phase.

52.4.4.2.2.4.3.1.5 WARMUP LATENCY (WU_LATENCY)

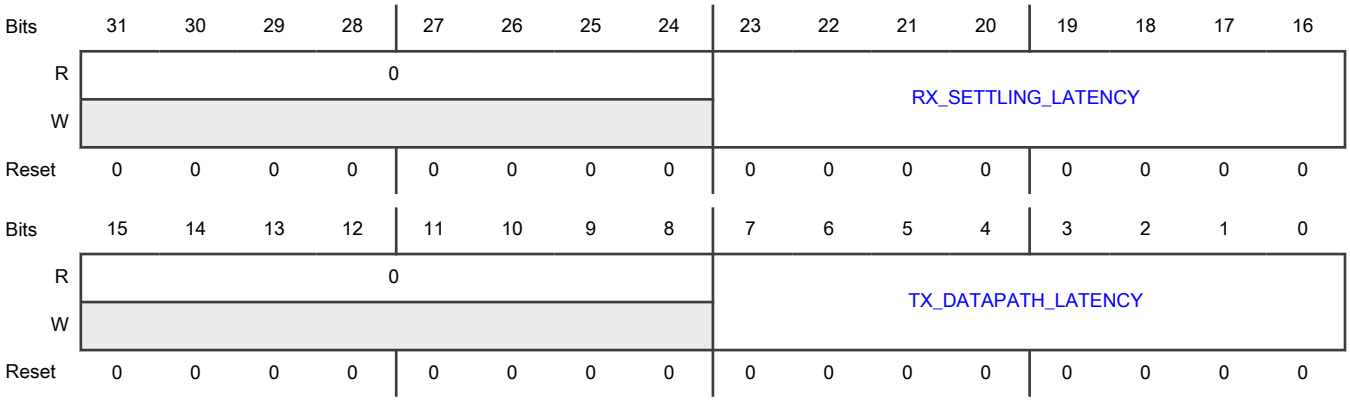
Offset

Register	Offset
WU_LATENCY	Ch

Function

This register contains the RX and TX latency values. These are added to the TSM's warmup duration to provide the Generic link layer a total warmup time.

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 RX_SETTLING_LATENCY	RX Settling Latency RX_SETTLING_LATENCY allows for a bulk delay value (in microseconds) to be added to the RX TSM warm-up time for link layer scheduling. The programmed value corresponds to the time that the RX data path may need for RX filters and clocks to settle and/or any post-warm-up RX activities that need to be completed before a valid RF signal can be correctly processed.
15-8 —	Reserved
7-0 TX_DATAPATH_LATENCY	TX Datapath Latency TX_DATAPATH_LATENCY allows for a bulk delay value (in microseconds) to be added to the TX TSM warm-up time for link layer scheduling. This value comprises cumulative TX data path processing latency including contributions by RBME, TX-Dig, PLL and Antenna Interface as per TX configuration.

52.4.4.2.2.4.3.1.6 TSM RECYCLE COUNT (RECYCLE_COUNT)

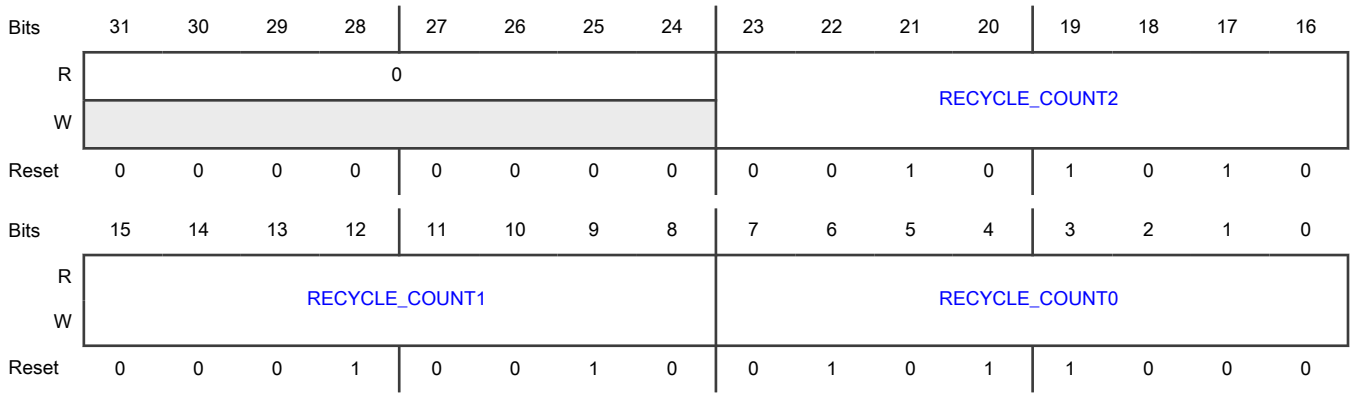
Offset

Register	Offset
RECYCLE_COUNT	10h

Function

This register contains the TSM Recycle "Jump-to" points for the different types of TSM Recycle

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 RECYCLE_COUNT2	TSM RX Recycle Count 2 The RECYCLE_COUNT2[7:0] register determines the TSM count value to which the TSM "recycles" when, in LPPS mode, an LPPS power save cycle completes and the receiver is switched back on, necessitating a foreshortened RX warmup. The intention is for this register to be programmed to a TSM count value that is just prior to the assertion of rx_lna_en, but there are no restrictions on programming this register. An LPPS recycle is a command from the LPPS state machine to TSM, requesting a jump from the TSM ON phase back to a programmable point in the WARMUP phase, and resume counting from there.
15-8 RECYCLE_COUNT1	TSM RX Recycle Count 1 The RECYCLE_COUNT1 register determines the TSM count value to which the TSM "recycles" when a link layer asserts the tsm_recycle[1] signal. The intention is for RECYCLE_COUNT1 to be programmed to a TSM count value such that the TSM de-asserts, and then re-asserts its "pll_dig_en" output, to effectuate a Dual PAN on-the-fly channel change, but there are no restrictions on programming this register. For 802.15.4 Sequence Manager (ZSM), tsm_recycle[1] is associated with the "RX_PAN1" state. For Generic_FSK Link Layer, tsm_recycle[1] is associated with the "RX_PAN1" state.
7-0 RECYCLE_COUNT0	TSM RX Recycle Count 0 The RECYCLE_COUNT0[7:0] register determines the TSM count value to which the TSM "recycles" when the 802.15.4 Sequence Manager (ZSM) state "RX_CYC" is reached and the ZSM asserts tsm_recycle[0] to TSM. This register also determines the TSM count value to which the TSM recycles when the ZSM state RX_CCCA is reached because tsm_recycle[0] is also asserted in this state. This register also determines the TSM count value to which the TSM recycles when the Generic_FSK Link Layer asserts a tsm_recycle to TSM. The intention is for this register to be programmed to a TSM count value such that the TSM re-asserts its "rx_init" output, but there are no restrictions on programming this register. An RX recycle is a command from any protocol engine to TSM, requesting a jump from the TSM ON phase back to a programmable point in the WARMUP phase, and resume counting from there. A recycle will result from the reception of a packet with bad CRC or one which fails packet-filtering rules, or the end of a CCA operation in Continuous CCA mode which results in a channel indicating "busy".

52.4.4.2.2.4.3.1.7 TSM FAST WARMUP CONTROL 1 (FAST_CTRL1)

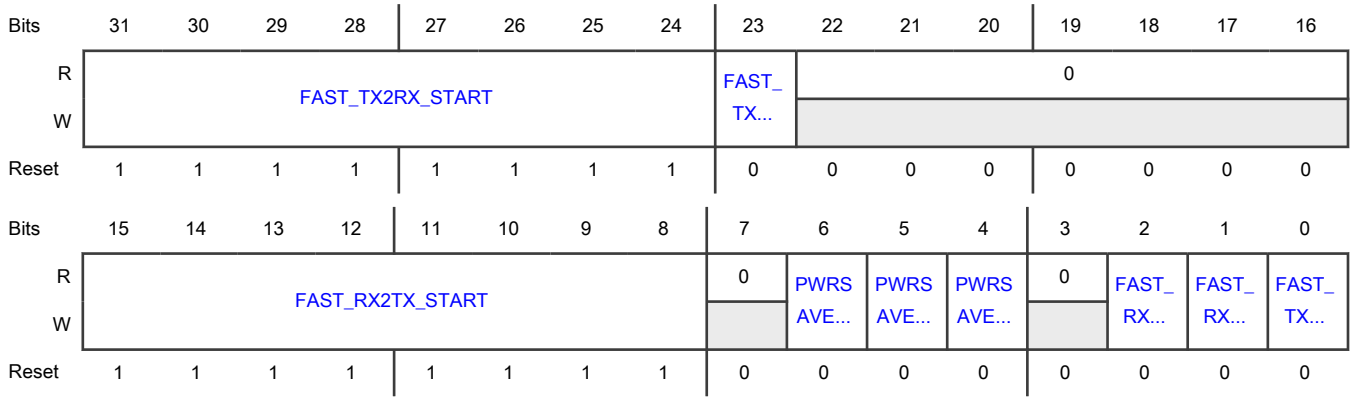
Offset

Register	Offset
FAST_CTRL1	14h

Function

This register provides enabling and control for Fast TSM Mode

Diagram



Fields

Field	Function
31-24 FAST_TX2RX_START	TSM "Jump-to" point for a Fast TSM TX-to-RX Transition. During a Fast TX-to-RX transition (FAST_TX2RX_EN=1), the contents of this register represent the entry point (TSM count) in the RX warmup sequence to which the TSM jumps to when Ranging sequence manager asserts fast_tx2rx_wu. The TSM will jump from the TX “ON” phase to the RX “WARMUP” phase, starting at this count.
23 FAST_TX2RX_EN	Fast TSM TX-to-RX Transition Enable This bit enables a special state transition in the Ranging Sequence Manager, combined with a TSM jump from the TX "ON" phase to the RX "Warmup" phase 0b - Disable Fast TX-to-RX transitions 1b - Enable Fast TX-to-RX transitions (if fast_tx2rx_wu is asserted by Ranging sequence manager)
22-16 —	Reserved
15-8 FAST_RX2TX_START	TSM "Jump-to" point for a Fast TSM RX-to-TX Transition. During a Fast RX-to-TX transition (FAST_RX2TX_EN=1) the contents of this register represent the entry point (TSM count) in the TX warmup sequence to which the TSM jumps to when fast_rx2tx_wu is asserted by the Link Layer state machine. The TSM will jump from the RX “ON” phase to the TX “WARMUP” phase, starting at this count.
7 —	Reserved
6 PWRSAVE_WU_CLEAR	PowerSave TSM Warmup Clear State This bit clears the RF channel memory in the PLL Digital Block, forcing the next TSM TX Warmup to be normal (not powersave), and the next TSM RX Warmup to be normal (not powersave), regardless of whether the RF channel has actually changed or not. This bit is not self-clearing. Write '1' to clear channel memory, then write '0' to proceed with TSM operations.

Table continues on the next page...

Table continued from the previous page...

Field	Function
5 PWRSAVE_RX_WU_EN	Power Save TSM RX Warmup Enable 0b - PowerSave TSM RX Warmups are disabled 1b - PowerSave TSM RX Warmups are enabled, if the RF channel has not changed since the last RX warmup.
4 PWRSAVE_TX_WU_EN	Power Save TSM TX Warmup Enable 0b - PowerSave TSM TX Warmups are disabled 1b - PowerSave TSM TX Warmups are enabled, if the RF channel has not changed since the last TX warmup.
3 —	Reserved
2 FAST_RX2TX_EN	Fast TSM RX-to-TX Transition Enable This bit enables a special state transition in the Link Layer, combined with a TSM jump from the RX "ON" phase to the TX "Warmup" phase, to accelerate the CCA-to-TX transition in the Link Layer autosequences 0b - Disable Fast RX-to-TX transitions 1b - Enable Fast RX-to-TX transitions (if fast_rx2tx_wu is asserted by the Link Layer)
1 FAST_RX_WU_EN	Fast TSM RX Warmup Enable 0b - Fast TSM RX Warmups are disabled 1b - Fast TSM RX Warmups are enabled, if the RF channel has not changed since the last RX warmup, and for Bluetooth LE mode, the RF channel is not an advertising channel.
0 FAST_TX_WU_EN	Fast TSM TX Warmup Enable 0b - Fast TSM TX Warmups are disabled 1b - Fast TSM TX Warmups are enabled, if the RF channel has not changed since the last TX warmup, and for Bluetooth LE mode, the RF channel is not an advertising channel.

52.4.4.2.2.4.3.1.8 TSM FAST WARMUP CONTROL 2 (FAST_CTRL2)

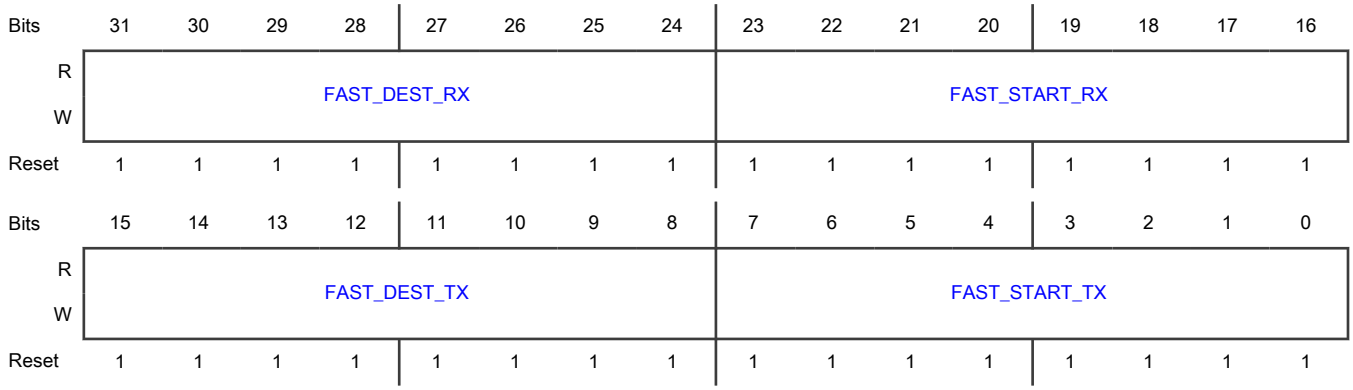
Offset

Register	Offset
FAST_CTRL2	18h

Function

This register provides configuration for Fast TSM Mode

Diagram



Fields

Field	Function
31-24 FAST_DEST_RX	Fast TSM RX "Jump-to" Point During a Fast RX Warmup, this value represents the ending TSM count for the portion of the warmup that is to be skipped over. If Fast RX Warmups are enabled, FAST_START_RX[7:0] will never be reached and will instead be replaced by the contents of this register, thereby executing the jump. Example: FAST_START_RX = 10 FAST_DEST_RX = 15 The TSM will count as follows: … 7,8,9,15,16,17 …
23-16 FAST_START_RX	Fast TSM RX "Jump-from" Point During a Fast RX Warmup, this value represents the starting TSM count for the portion of the warmup that is to be skipped over. If Fast RX Warmups are enabled, this count will never be reached; its place in the TSM warmup will be replaced by the contents of FAST_DEST_RX[7:0], thereby executing the jump.
15-8 FAST_DEST_TX	Fast TSM TX "Jump-to" Point During a Fast TX Warmup, this value represents the ending TSM count for the portion of the warmup that is to be skipped over. If Fast TX Warmups are enabled, FAST_START_TX[7:0] will never be reached and will instead be replaced by the contents of this register, thereby executing the jump. Example: FAST_START_TX = 10 FAST_DEST_TX = 15 The TSM will count as follows: … 7,8,9,15,16,17 …
7-0 FAST_START_TX	Fast TSM TX "Jump-from" Point During a Fast TX Warmup, this value represents the starting TSM count for the portion of the warmup that is to be skipped over. If Fast TX Warmups are enabled, this count will never be reached; its place in the TSM warmup will be replaced by the contents of FAST_DEST_TX[7:0], thereby executing the jump.

52.4.4.2.2.4.3.1.9 TSM FAST WARMUP CONTROL 3 (FAST_CTRL3)

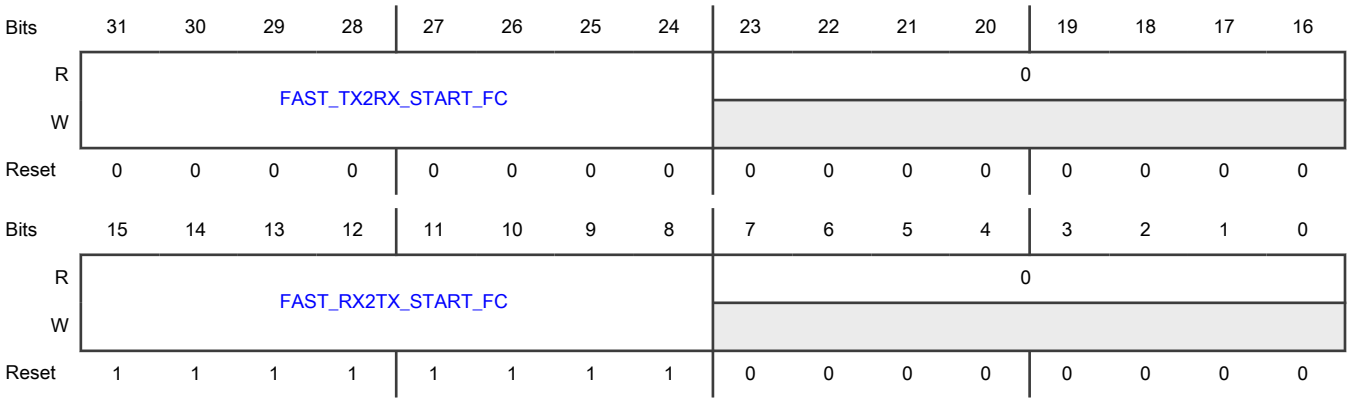
Offset

Register	Offset
FAST_CTRL3	1Ch

Function

This register provides enabling and control for Fast TSM Mode

Diagram



Fields

Field	Function
31-24 FAST_TX2RX_START_FC	TSM "Jump-to" point for RSM's FC TX-to-RX Transition During a Fast TX-to-RX transition (FAST_TX2RX_EN=1), the contents of this register represent the entry point (TSM count) in the RX warmup sequence to which the TSM jumps to when Ranging sequence manager asserts fast_tx2rx_wu and fast_fc_wu. The TSM will jump from the TX “ON” phase to the RX “WARMUP” phase, starting at this count.
23-16 —	Reserved
15-8 FAST_RX2TX_START_FC	TSM "Jump-to" point for RSM's FC RX-to-TX Transition During a Fast RX-to-TX transition (FAST_RX2TX_EN=1) the contents of this register represent the entry point (TSM count) in the TX warmup sequence to which the TSM jumps to when the Ranging Sequence Manager asserts fast_rx2tx_wu and fast_fc_wu. The TSM will jump from the RX “ON” phase to the TX “WARMUP” phase, starting at this count.
7-0 —	Reserved

52.4.4.2.2.4.3.1.10 TSM_TIMING00 (TIMING00)

Offset

Register	Offset
TIMING00	20h

Function

This register contains the timing values to control the assertion and deassertion times for both TX and RX sequences for the RF_ACTIVE TSM signal or signal group.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	RF_ACTIVE_RX_LO								RF_ACTIVE_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	RF_ACTIVE_TX_LO								RF_ACTIVE_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

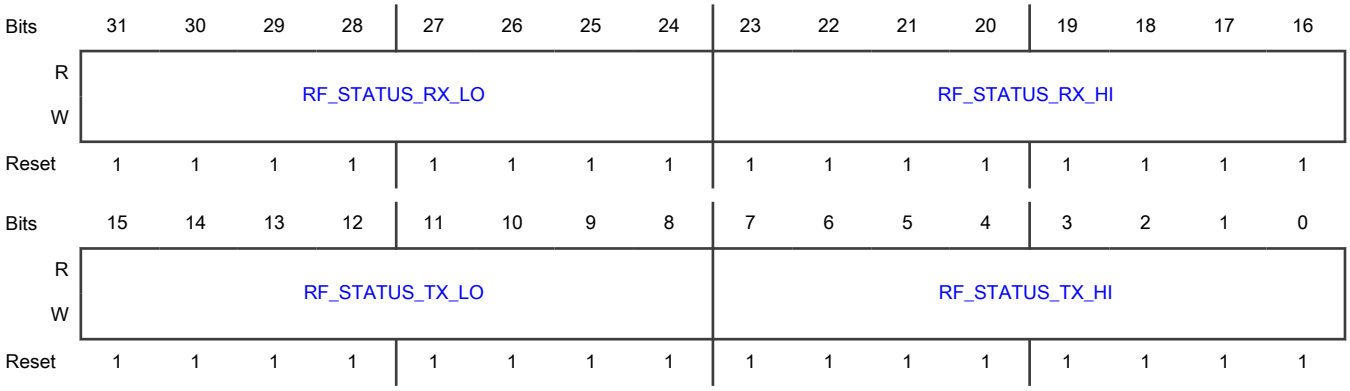
Field	Function
31-24 RF_ACTIVE_RX_LO	De-assertion time setting for RF_ACTIVE (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the RF_ACTIVE signal or group will transition from HI to LO.
23-16 RF_ACTIVE_RX_HI	Assertion time setting for RF_ACTIVE_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the RF_ACTIVE signal or group will transition from LO to HI.
15-8 RF_ACTIVE_TX_LO	De-assertion time setting for RF_ACTIVE (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the RF_ACTIVE signal or group will transition from HI to LO.
7-0 RF_ACTIVE_TX_HI	Assertion time setting for RF_ACTIVE (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the RF_ACTIVE signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.11 TSM_TIMING01 (TIMING01)

Offset

Register	Offset
TIMING01	24h

Diagram



Fields

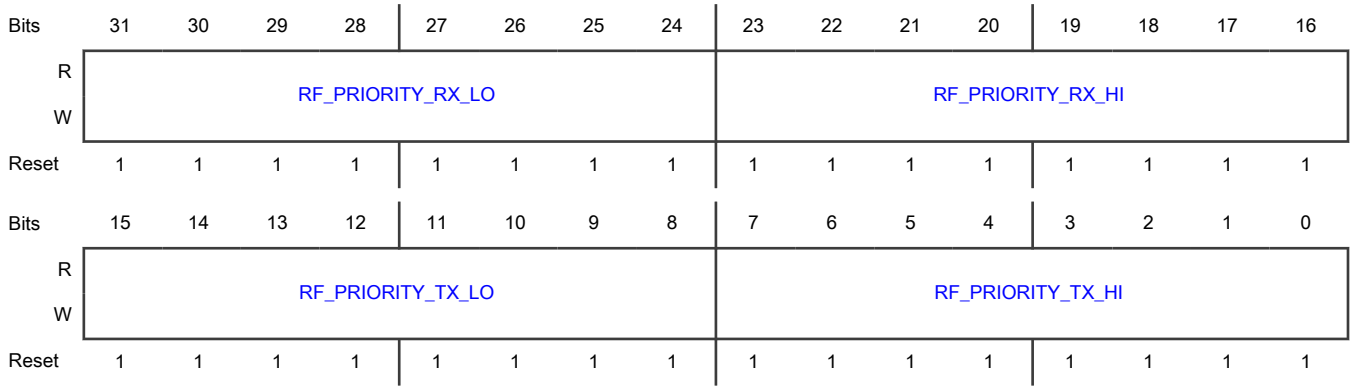
Field	Function
31-24 RF_STATUS_RX_LO	De-assertion time setting for RF_STATUS (RX) This field feedback status during a TSM RX sequence (the tsm_count[7:0] value) at which the RF_STATUS signal or group will transition from HI to LO.
23-16 RF_STATUS_RX_HI	Assertion time setting for RF_STATUS (RX) This field feedback status during a TSM RX sequence (the tsm_count[7:0] value) at which the RF_STATUS signal or group will transition from LO to HI.
15-8 RF_STATUS_TX_LO	De-assertion time setting for RF_STATUS (TX) This field feedback status during a TSM TX sequence (the tsm_count[7:0] value) at which the RF_STATUS signal or group will transition from HI to LO.
7-0 RF_STATUS_TX_HI	Assertion time setting for RF_STATUS (TX) This field feedback status during a TSM TX sequence (the tsm_count[7:0] value) at which the RF_STATUS signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.12 TSM_TIMING02 (TIMING02)

Offset

Register	Offset
TIMING02	28h

Diagram



Fields

Field	Function
31-24 RF_PRIORITY_RX_LO	De-assertion time setting for RF_PRIORITY (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the RF_PRIORITY signal or group will transition from HI to LO.
23-16 RF_PRIORITY_RX_HI	Assertion time setting for RF_PRIORITY (RX) This field sets the point during a TSM RF_PRIORITY RX sequence (the tsm_count[7:0] value) at which the RF_PRIORITY signal or group will transition from LO to HI.
15-8 RF_PRIORITY_TX_LO	De-assertion time setting for RF_PRIORITY (TX) This field feedback priority during a TSM TX sequence (the tsm_count[7:0] value) at which the RF_PRIORITY signal or group will transition from HI to LO.
7-0 RF_PRIORITY_TX_HI	Assertion time setting for RF_PRIORITY (TX) This field feedback priority during a TSM TX sequence (the tsm_count[7:0] value) at which the RF_PRIORITY signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.13 TSM_TIMING03 (TIMING03)

Offset

Register	Offset
TIMING03	2Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	IRQ0_START_TRIG_RX_LO								IRQ0_START_TRIG_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	IRQ0_START_TRIG_TX_LO								IRQ0_START_TRIG_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 IRQ0_START_TRIG_RX_LO	De-assertion time setting for IRQ0_START_TRIG (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the IRQ0_START_TRIG signal or group will transition from HI to LO.
23-16 IRQ0_START_TRIG_RX_HI	Assertion time setting for IRQ0_START_TRIG (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the IRQ0_START_TRIG signal or group will transition from LO to HI.
15-8 IRQ0_START_TRIG_TX_LO	De-assertion time setting for IRQ0_START_TRIG (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the IRQ0_START_TRIG signal or group will transition from HI to LO.
7-0 IRQ0_START_TRIG_TX_HI	Assertion time setting for IRQ0_START_TRIG (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the IRQ0_START_TRIG signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.14 TSM_TIMING04 (TIMING04)

Offset

Register	Offset
TIMING04	30h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	IRQ1_STOP_TRIG_RX_LO								IRQ1_STOP_TRIG_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	IRQ1_STOP_TRIG_TX_LO								IRQ1_STOP_TRIG_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

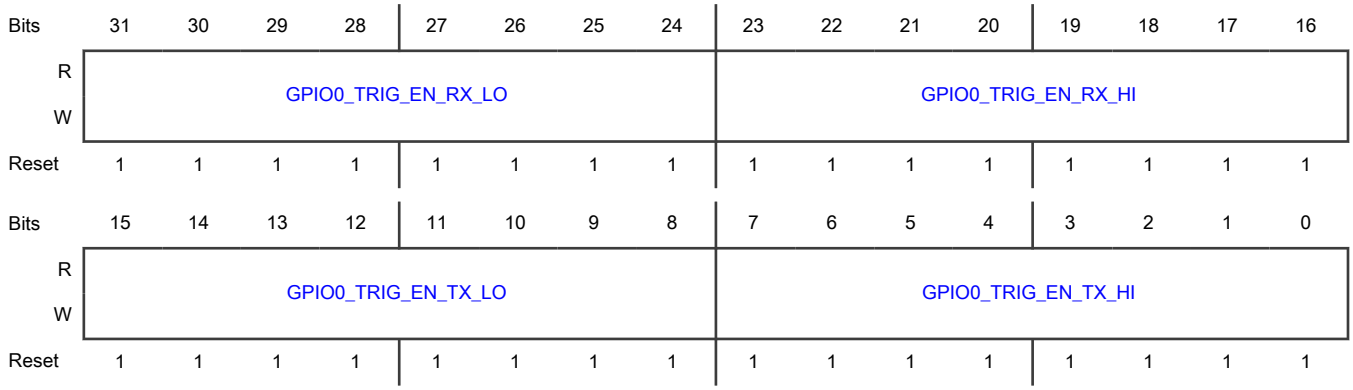
Field	Function
31-24 IRQ1_STOP_TRIG_RX_LO	De-assertion time setting for IRQ1_STOP_TRIG (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the IRQ1_STOP_TRIG signal or group will transition from HI to LO.
23-16 IRQ1_STOP_TRIG_RX_HI	Assertion time setting for IRQ1_STOP_TRIG (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the IRQ1_STOP_TRIG signal or group will transition from LO to HI.
15-8 IRQ1_STOP_TRIG_TX_LO	De-assertion time setting for IRQ1_STOP_TRIG (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the IRQ1_STOP_TRIG signal or group will transition from HI to LO.
7-0 IRQ1_STOP_TRIG_TX_HI	Assertion time setting for IRQ1_STOP_TRIG (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the IRQ1_STOP_TRIG signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.15 TSM_TIMING05 (TIMING05)

Offset

Register	Offset
TIMING05	34h

Diagram



Fields

Field	Function
31-24 GPIO0_TRIG_EN_RX_LO	De-assertion time setting for GPIO0_TRIG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the GPIO0_TRIG_EN signal or group will transition from HI to LO.
23-16 GPIO0_TRIG_EN_RX_HI	Assertion time setting for GPIO0_TRIG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the GPIO0_TRIG_EN signal or group will transition from LO to HI.
15-8 GPIO0_TRIG_EN_TX_LO	De-assertion time setting for GPIO0_TRIG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the GPIO0_TRIG_EN signal or group will transition from HI to LO.
7-0 GPIO0_TRIG_EN_TX_HI	Assertion time setting for GPIO0_TRIG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the GPIO0_TRIG_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.16 TSM_TIMING06 (TIMING06)

Offset

Register	Offset
TIMING06	38h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	GPIO1_TRIG_EN_RX_LO								GPIO1_TRIG_EN_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	GPIO1_TRIG_EN_TX_LO								GPIO1_TRIG_EN_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 GPIO1_TRIG_EN_RX_LO	De-assertion time setting for GPIO1_TRIG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the GPIO1_TRIG_EN signal or group will transition from HI to LO.
23-16 GPIO1_TRIG_EN_RX_HI	Assertion time setting for GPIO1_TRIG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the GPIO1_TRIG_EN signal or group will transition from LO to HI.
15-8 GPIO1_TRIG_EN_TX_LO	De-assertion time setting for GPIO1_TRIG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the GPIO1_TRIG_EN signal or group will transition from HI to LO.
7-0 GPIO1_TRIG_EN_TX_HI	Assertion time setting for GPIO1_TRIG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the GPIO1_TRIG_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.17 TSM_TIMING07 (TIMING07)

Offset

Register	Offset
TIMING07	3Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	GPIO2_TRIG_EN_RX_LO								GPIO2_TRIG_EN_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	GPIO2_TRIG_EN_TX_LO								GPIO2_TRIG_EN_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 GPIO2_TRIG_EN_RX_LO	De-assertion time setting for GPIO2_TRIG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the GPIO2_TRIG_EN signal or group will transition from HI to LO.
23-16 GPIO2_TRIG_EN_RX_HI	Assertion time setting for GPIO2_TRIG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the GPIO2_TRIG_EN signal or group will transition from LO to HI.
15-8 GPIO2_TRIG_EN_TX_LO	De-assertion time setting for GPIO2_TRIG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the GPIO2_TRIG_EN signal or group will transition from HI to LO.
7-0 GPIO2_TRIG_EN_TX_HI	Assertion time setting for GPIO2_TRIG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the GPIO2_TRIG_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.18 TSM_TIMING08 (TIMING08)

Offset

Register	Offset
TIMING08	40h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	GPIO3_TRIG_EN_RX_LO								GPIO3_TRIG_EN_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	GPIO3_TRIG_EN_TX_LO								GPIO3_TRIG_EN_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 GPIO3_TRIG_EN_RX_LO	De-assertion time setting for GPIO3_TRIG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the GPIO3_TRIG_EN signal or group will transition from HI to LO.
23-16 GPIO3_TRIG_EN_RX_HI	Assertion time setting for GPIO3_TRIG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the GPIO3_TRIG_EN signal or group will transition from LO to HI.
15-8 GPIO3_TRIG_EN_TX_LO	De-assertion time setting for GPIO3_TRIG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the GPIO3_TRIG_EN signal or group will transition from HI to LO.
7-0 GPIO3_TRIG_EN_TX_HI	Assertion time setting for GPIO3_TRIG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the GPIO3_TRIG_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.19 TSM_TIMING09 (TIMING09)

Offset

Register	Offset
TIMING09	44h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	DCOC_GAIN_CFG_EN_RX_LO								DCOC_GAIN_CFG_EN_RX_HI							
Reset	0	1	0	1	0	1	1	1	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	DCOC_GAIN_CFG_EN_TX_LO								DCOC_GAIN_CFG_EN_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

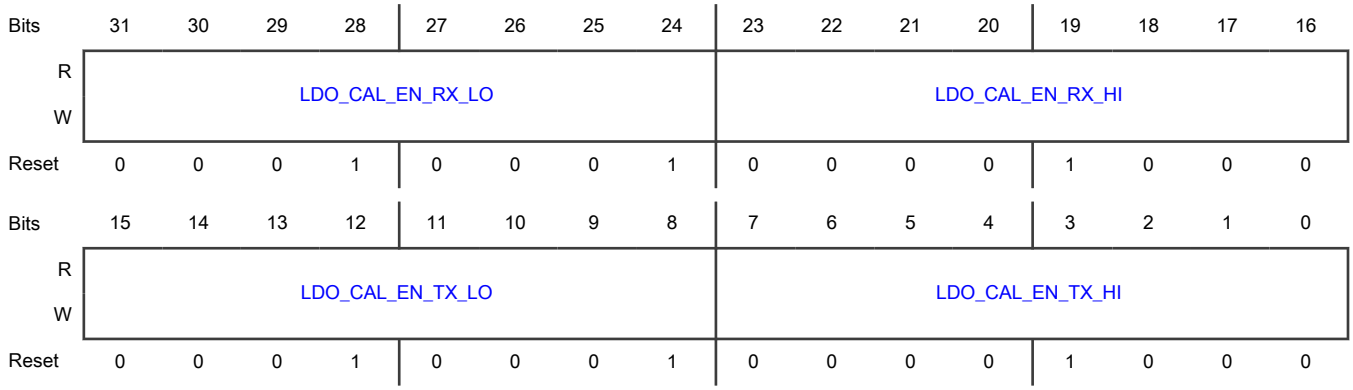
Field	Function
31-24 DCOC_GAIN_CFG_EN_RX_LO	De-assertion time setting for DCOC_GAIN_CFG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the DCOC_GAIN_CFG_EN signal or group will transition from HI to LO.
23-16 DCOC_GAIN_CFG_EN_RX_HI	Assertion time setting for DCOC_GAIN_CFG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the DCOC_GAIN_CFG_EN signal or group will transition from LO to HI.
15-8 DCOC_GAIN_CFG_EN_TX_LO	De-assertion time setting for DCOC_GAIN_CFG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the DCOC_GAIN_CFG_EN signal or group will transition from HI to LO. **NOTE** This signal can be asserted in most of the time except for IP RX2TX.
7-0 DCOC_GAIN_CFG_EN_TX_HI	Assertion time setting for DCOC_GAIN_CFG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the DCOC_GAIN_CFG_EN signal or group will transition from LO to HI. **NOTE** This signal can be asserted in most of the time except for IP RX2TX.

52.4.4.2.2.4.3.1.20 TSM_TIMING10 (TIMING10)

Offset

Register	Offset
TIMING10	48h

Diagram



Fields

Field	Function
31-24 LDO_CAL_EN_RX_LO	De-assertion time setting for LDO_CAL_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the LDO_CAL_EN signal or group will transition from HI to LO.
23-16 LDO_CAL_EN_RX_HI	Assertion time setting for LDO_CAL_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the LDO_CAL_EN signal or group will transition from LO to HI.
15-8 LDO_CAL_EN_TX_LO	De-assertion time setting for LDO_CAL_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the LDO_CAL_EN signal or group will transition from HI to LO.
7-0 LDO_CAL_EN_TX_HI	Assertion time setting for LDO_CAL_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the LDO_CAL_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.21 TSM_TIMING11 (TIMING11)

Offset

Register	Offset
TIMING11	4Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	PLL_DIG_EN_RX_LO								PLL_DIG_EN_RX_HI							
Reset	0	1	0	1	1	0	1	1	0	0	0	1	0	0	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	PLL_DIG_EN_TX_LO								PLL_DIG_EN_TX_HI							
Reset	0	1	1	1	0	0	0	1	0	0	0	1	0	0	1	1

Fields

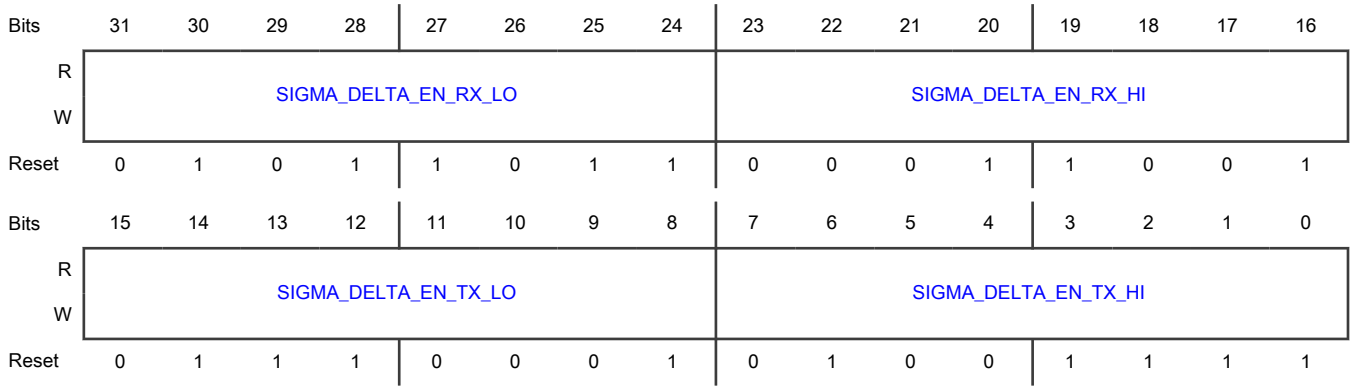
Field	Function
31-24 PLL_DIG_EN_RX_LO	De-assertion time setting for PLL_DIG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the PLL_DIG_EN signal or group will transition from HI to LO.
23-16 PLL_DIG_EN_RX_HI	Assertion time setting for PLL_DIG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the PLL_DIG_EN signal or group will transition from LO to HI.
15-8 PLL_DIG_EN_TX_LO	De-assertion time setting for PLL_DIG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the PLL_DIG_EN signal or group will transition from HI to LO.
7-0 PLL_DIG_EN_TX_HI	Assertion time setting for PLL_DIG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the PLL_DIG_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.22 TSM_TIMING12 (TIMING12)

Offset

Register	Offset
TIMING12	50h

Diagram



Fields

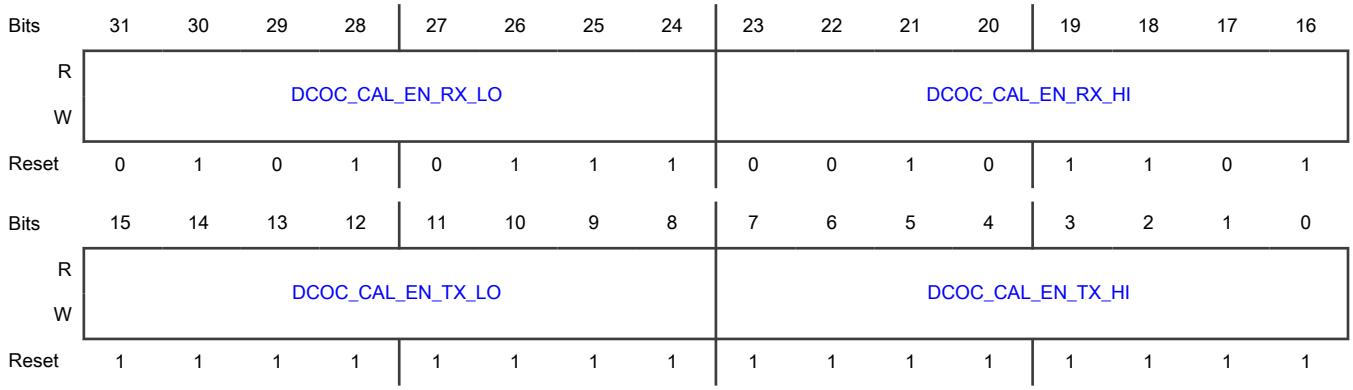
Field	Function
31-24 SIGMA_DELTA_EN_RX_LO	De-assertion time setting for SIGMA_DELTA_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SIGMA_DELTA_EN signal or group will transition from HI to LO.
23-16 SIGMA_DELTA_EN_RX_HI	Assertion time setting for SIGMA_DELTA_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SIGMA_DELTA_EN signal or group will transition from LO to HI.
15-8 SIGMA_DELTA_EN_TX_LO	De-assertion time setting for SIGMA_DELTA_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SIGMA_DELTA_EN signal or group will transition from HI to LO.
7-0 SIGMA_DELTA_EN_TX_HI	Assertion time setting for SIGMA_DELTA_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SIGMA_DELTA_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.23 TSM_TIMING13 (TIMING13)

Offset

Register	Offset
TIMING13	54h

Diagram



Fields

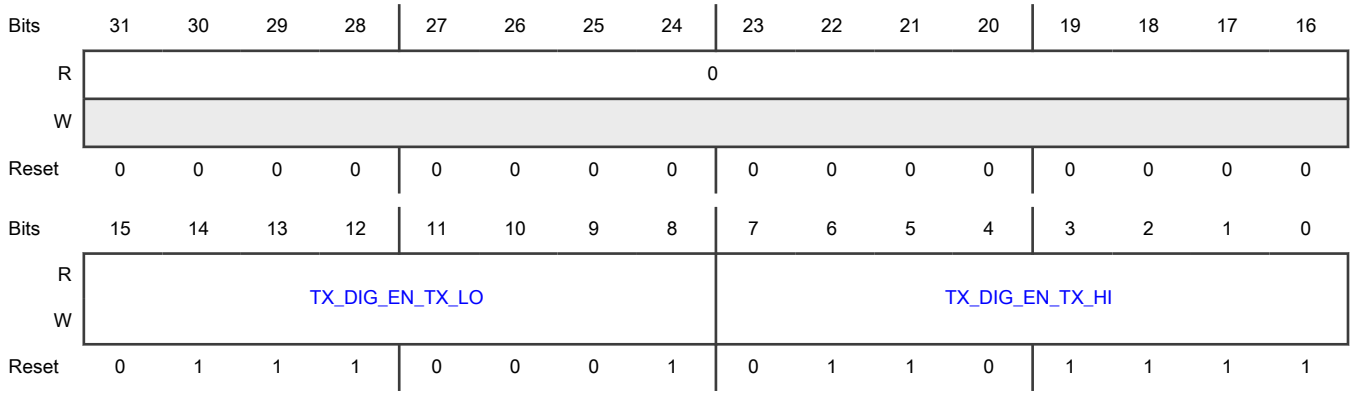
Field	Function
31-24 DCOC_CAL_EN_RX_LO	De-assertion time setting for DCOC_CAL_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the DCOC_CAL_EN signal or group will transition from HI to LO.
23-16 DCOC_CAL_EN_RX_HI	Assertion time setting for DCOC_CAL_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the DCOC_CAL_EN signal or group will transition from LO to HI.
15-8 DCOC_CAL_EN_TX_LO	De-assertion time setting for DCOC_CAL_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the DCOC_CAL_EN signal or group will transition from HI to LO. **NOTE** This signal can be asserted in most of the time except for IP RX2TX.
7-0 DCOC_CAL_EN_TX_HI	Assertion time setting for DCOC_CAL_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the DCOC_CAL_EN signal or group will transition from LO to HI. **NOTE** This signal can be asserted in most of the time except for IP RX2TX.

52.4.4.2.2.4.3.1.24 TSM_TIMING14 (TIMING14)

Offset

Register	Offset
TIMING14	58h

Diagram



Fields

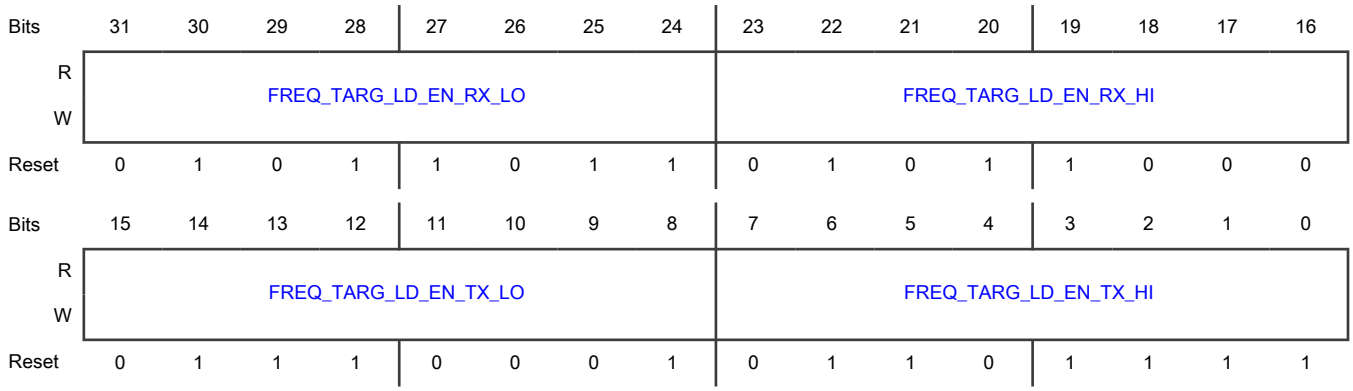
Field	Function
31-16 —	Reserved
15-8 TX_DIG_EN_TX_LO	De-assertion time setting for TX_DIG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the TX_DIG_EN signal or group will transition from HI to LO.
7-0 TX_DIG_EN_TX_HI	Assertion time setting for TX_DIG_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the TX_DIG_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.25 TSM_TIMING15 (TIMING15)

Offset

Register	Offset
TIMING15	5Ch

Diagram



Fields

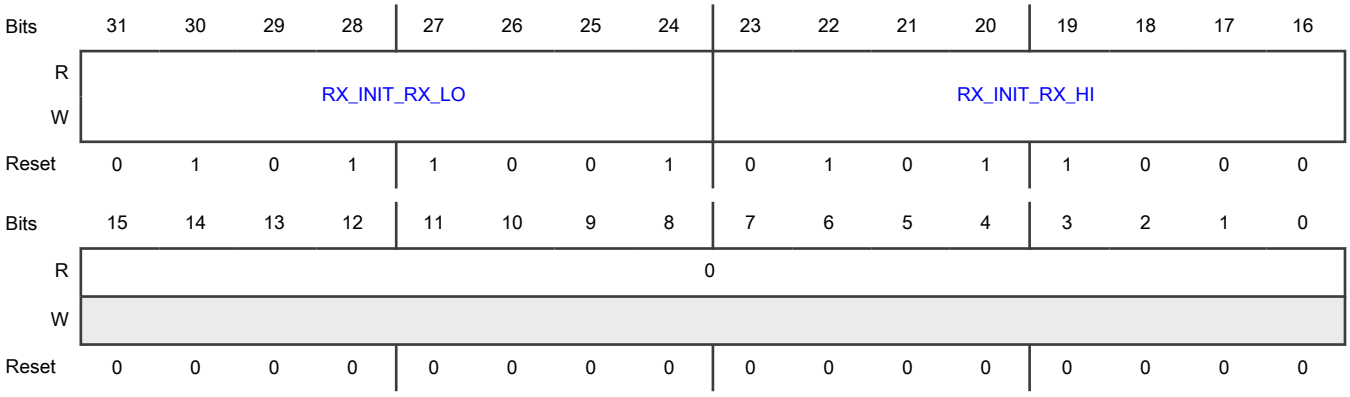
Field	Function
31-24 FREQ_TARG_LD_EN_RX_LO	De-assertion time setting for FREQ_TARG_LD_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the FREQ_TARG_LD_EN signal or group will transition from HI to LO.
23-16 FREQ_TARG_LD_EN_RX_HI	Assertion time setting for FREQ_TARG_LD_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the FREQ_TARG_LD_EN signal or group will transition from LO to HI.
15-8 FREQ_TARG_LD_EN_TX_LO	De-assertion time setting for FREQ_TARG_LD_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the FREQ_TARG_LD_EN signal or group will transition from HI to LO.
7-0 FREQ_TARG_LD_EN_TX_HI	Assertion time setting for FREQ_TARG_LD_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the FREQ_TARG_LD_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.26 TSM_TIMING16 (TIMING16)

Offset

Register	Offset
TIMING16	60h

Diagram



Fields

Field	Function
31-24	De-assertion time setting for RX_INIT (RX)

Table continues on the next page...

Table continued from the previous page...

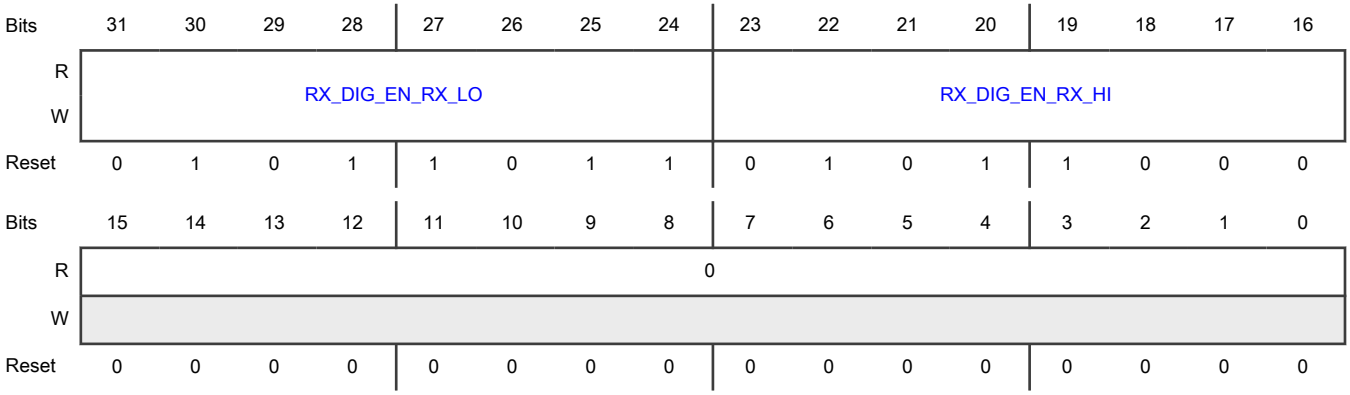
Field	Function
RX_INIT_RX_LO	This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the RX_INIT signal or group will transition from HI to LO.
23-16 RX_INIT_RX_HI	Assertion time setting for RX_INIT (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the RX_INIT signal or group will transition from LO to HI.
15-0 —	Reserved

52.4.4.2.2.4.3.1.27 TSM_TIMING17 (TIMING17)

Offset

Register	Offset
TIMING17	64h

Diagram



Fields

Field	Function
31-24 RX_DIG_EN_RX_LO	De-assertion time setting for RX_DIG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the RX_DIG_EN signal or group will transition from HI to LO.
23-16 RX_DIG_EN_RX_HI	Assertion time setting for RX_DIG_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the RX_DIG_EN signal or group will transition from LO to HI.

Table continues on the next page...

Table continued from the previous page...

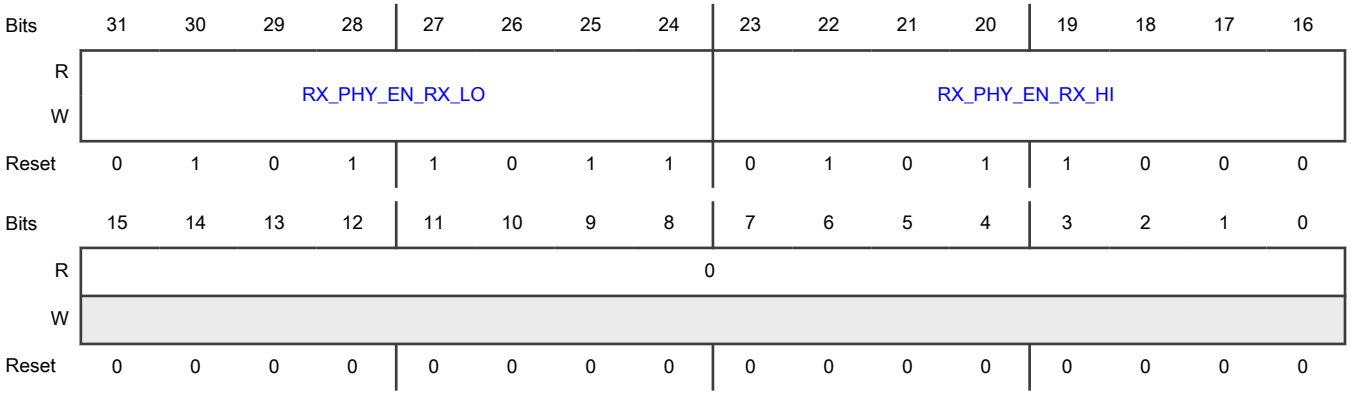
Field	Function
15-0 —	Reserved

52.4.4.2.2.4.3.1.28 TSM_TIMING18 (TIMING18)

Offset

Register	Offset
TIMING18	68h

Diagram



Fields

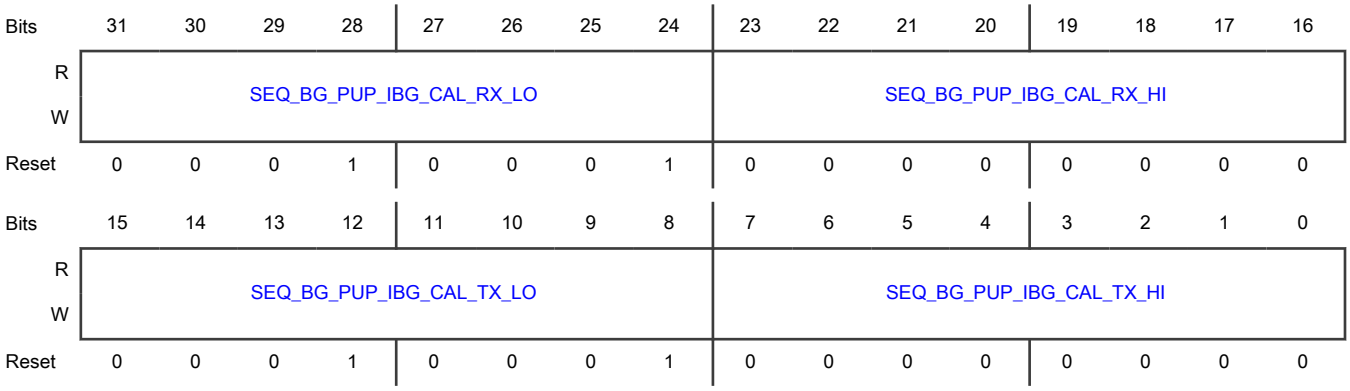
Field	Function
31-24 RX_PHY_EN_RX_LO	De-assertion time setting for RX_PHY_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the RX_PHY_EN signal or group will transition from HI to LO.
23-16 RX_PHY_EN_RX_HI	Assertion time setting for RX_PHY_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the RX_PHY_EN signal or group will transition from LO to HI.
15-0 —	Reserved

52.4.4.2.2.4.3.1.29 TSM_TIMING19 (TIMING19)

Offset

Register	Offset
TIMING19	6Ch

Diagram



Fields

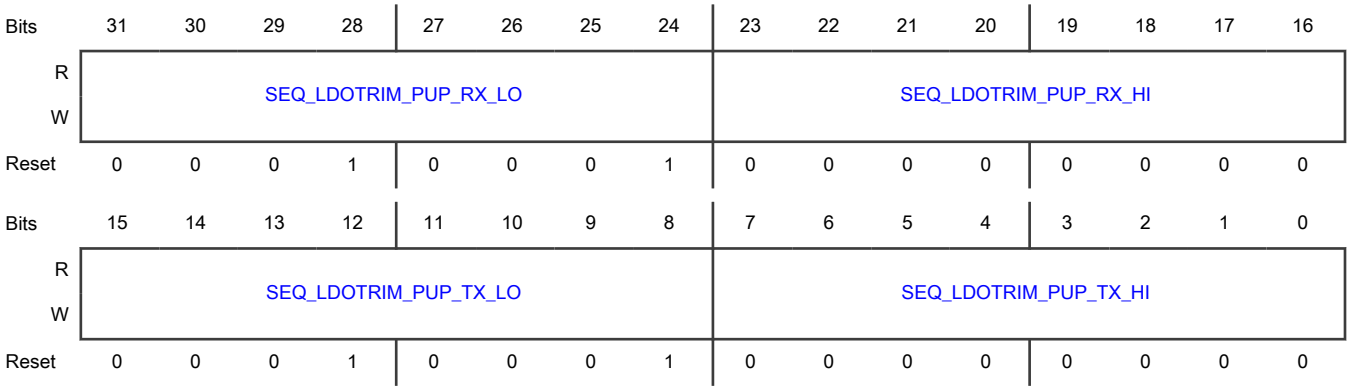
Field	Function
31-24 SEQ_BG_PUP_IBG_CAL_RX_LO	De-assertion time setting for SEQ_BG_PUP_IBG_CAL (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_CAL signal or group will transition from HI to LO.
23-16 SEQ_BG_PUP_IBG_CAL_RX_HI	Assertion time setting for SEQ_BG_PUP_IBG_CAL (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_CAL signal or group will transition from LO to HI.
15-8 SEQ_BG_PUP_IBG_CAL_TX_LO	De-assertion time setting for SEQ_BG_PUP_IBG_CAL (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_CAL signal or group will transition from HI to LO.
7-0 SEQ_BG_PUP_IBG_CAL_TX_HI	Assertion time setting for SEQ_BG_PUP_IBG_CAL (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_CAL signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.30 TSM_TIMING20 (TIMING20)

Offset

Register	Offset
TIMING20	70h

Diagram



Fields

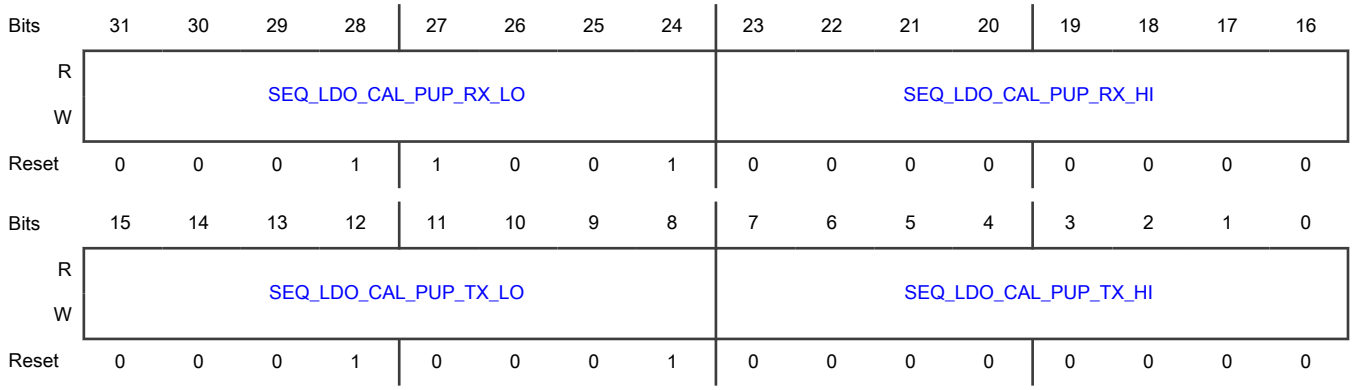
Field	Function
31-24 SEQ_LDOTRIM_PUP_RX_LO	De-assertion time setting for SEQ_LDOTRIM_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LDOTRIM_PUP signal or group will transition from HI to LO.
23-16 SEQ_LDOTRIM_PUP_RX_HI	Assertion time setting for SEQ_LDOTRIM_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LDOTRIM_PUP signal or group will transition from LO to HI.
15-8 SEQ_LDOTRIM_PUP_TX_LO	De-assertion time setting for SEQ_LDOTRIM_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LDOTRIM_PUP signal or group will transition from HI to LO.
7-0 SEQ_LDOTRIM_PUP_TX_HI	Assertion time setting for SEQ_LDOTRIM_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LDOTRIM_PUP signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.31 TSM_TIMING21 (TIMING21)

Offset

Register	Offset
TIMING21	74h

Diagram



Fields

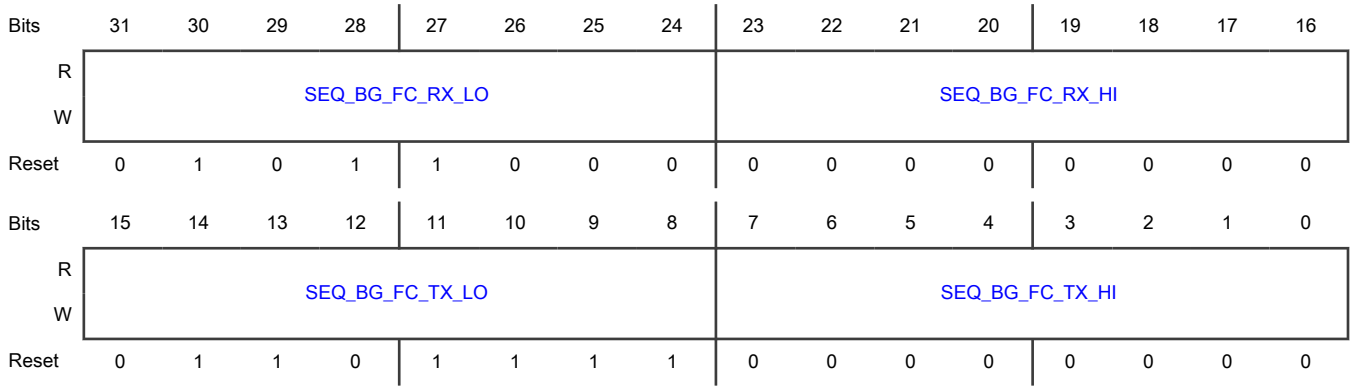
Field	Function
31-24 SEQ_LDO_CAL_PUP_RX_LO	De-assertion time setting for SEQ_LDO_CAL_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_CAL_PUP signal or group will transition from HI to LO.
23-16 SEQ_LDO_CAL_PUP_RX_HI	Assertion time setting for SEQ_LDO_CAL_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_CAL_PUP signal or group will transition from LO to HI.
15-8 SEQ_LDO_CAL_PUP_TX_LO	De-assertion time setting for SEQ_LDO_CAL_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_CAL_PUP signal or group will transition from HI to LO.
7-0 SEQ_LDO_CAL_PUP_TX_HI	Assertion time setting for SEQ_LDO_CAL_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_CAL_PUP signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.32 TSM_TIMING22 (TIMING22)

Offset

Register	Offset
TIMING22	78h

Diagram



Fields

Field	Function
31-24 SEQ_BG_FC_RX_LO	De-assertion time setting for SEQ_BG_FC (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_FC signal or group will transition from HI to LO.
23-16 SEQ_BG_FC_RX_HI	Assertion time setting for SEQ_BG_FC (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_FC signal or group will transition from LO to HI.
15-8 SEQ_BG_FC_TX_LO	De-assertion time setting for SEQ_BG_FC (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_FC signal or group will transition from HI to LO.
7-0 SEQ_BG_FC_TX_HI	Assertion time setting for SEQ_BG_FC (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_FC signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.33 TSM_TIMING23 (TIMING23)

Offset

Register	Offset
TIMING23	7Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_LDO_GANG_FC_RX_LO								SEQ_LDO_GANG_FC_RX_HI							
Reset	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_LDO_GANG_FC_TX_LO								SEQ_LDO_GANG_FC_TX_HI							
Reset	0	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 SEQ_LDO_GANG_FC_RX_LO	De-assertion time setting for SEQ_LDO_(PLL/RXTXHF/RXTXLF/VCO)_FC (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_(PLL/RXTXHF/RXTXLF/VCO)_FC signal or group will transition from HI to LO.
23-16 SEQ_LDO_GANG_FC_RX_HI	Assertion time setting for SEQ_LDO_(PLL/RXTXHF/RXTXLF/VCO)_FC (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_(PLL/RXTXHF/RXTXLF/VCO)_FC signal or group will transition from LO to HI.
15-8 SEQ_LDO_GANG_FC_TX_LO	De-assertion time setting for SEQ_LDO_(PLL/RXTXHF/RXTXLF/VCO)_FC (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_(PLL/RXTXHF/RXTXLF/VCO)_FC signal or group will transition from HI to LO.
7-0 SEQ_LDO_GANG_FC_TX_HI	Assertion time setting for SEQ_LDO_GANG_FC (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_GANG_FC signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.34 TSM_TIMING24 (TIMING24)

Offset

Register	Offset
TIMING24	80h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_LDO_GANG_PUP_RX_LO								SEQ_LDO_GANG_PUP_RX_HI							
Reset	0	1	0	1	1	0	1	1	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_LDO_GANG_PUP_TX_LO								SEQ_LDO_GANG_PUP_TX_HI							
Reset	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0

Fields

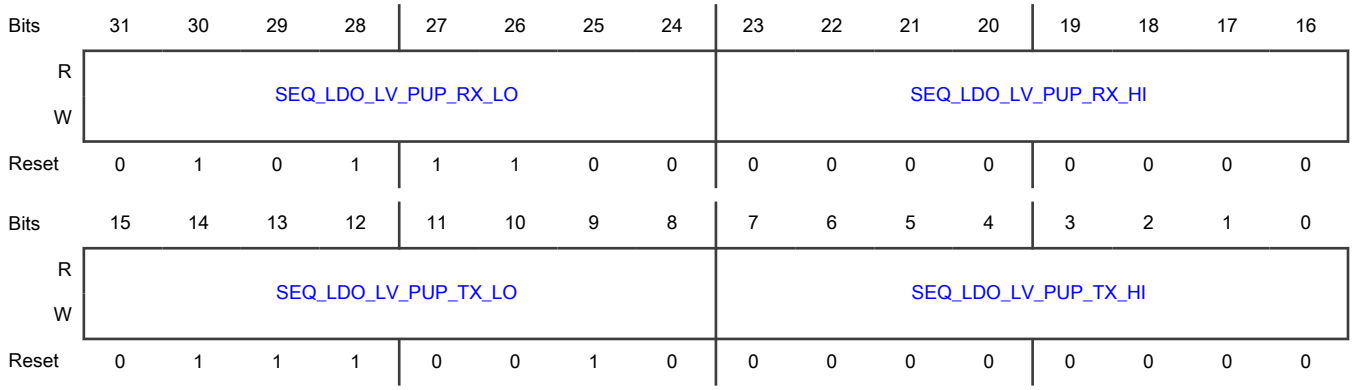
Field	Function
31-24 SEQ_LDO_GANG_PUP_RX_LO	De-assertion time setting for SEQ_LDO_(ANT/PLL/RXTXHF/RXTXLF/VCO/XO_DIST)_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_(ANT/PLL/RXTXHF/RXTXLF/VCO/XO_DIST)_PUP signal or group will transition from HI to LO.
23-16 SEQ_LDO_GANG_PUP_RX_HI	Assertion time setting for SEQ_LDO_(ANT/PLL/RXTXHF/RXTXLF/VCO/XO_DIST)_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_(ANT/PLL/RXTXHF/RXTXLF/VCO/XO_DIST)_PUP signal or group will transition from LO to HI.
15-8 SEQ_LDO_GANG_PUP_TX_LO	De-assertion time setting for SEQ_LDO_(ANT/PLL/RXTXHF/RXTXLF/VCO/XO_DIST)_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_(ANT/PLL/RXTXHF/RXTXLF/VCO/XO_DIST)_PUP signal or group will transition from HI to LO.
7-0 SEQ_LDO_GANG_PUP_TX_HI	Assertion time setting for SEQ_LDO_(ANT/PLL/RXTXHF/RXTXLF/VCO/XO_DIST)_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_(ANT/PLL/RXTXHF/RXTXLF/VCO/XO_DIST)_PUP signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.35 TSM_TIMING25 (TIMING25)

Offset

Register	Offset
TIMING25	84h

Diagram



Fields

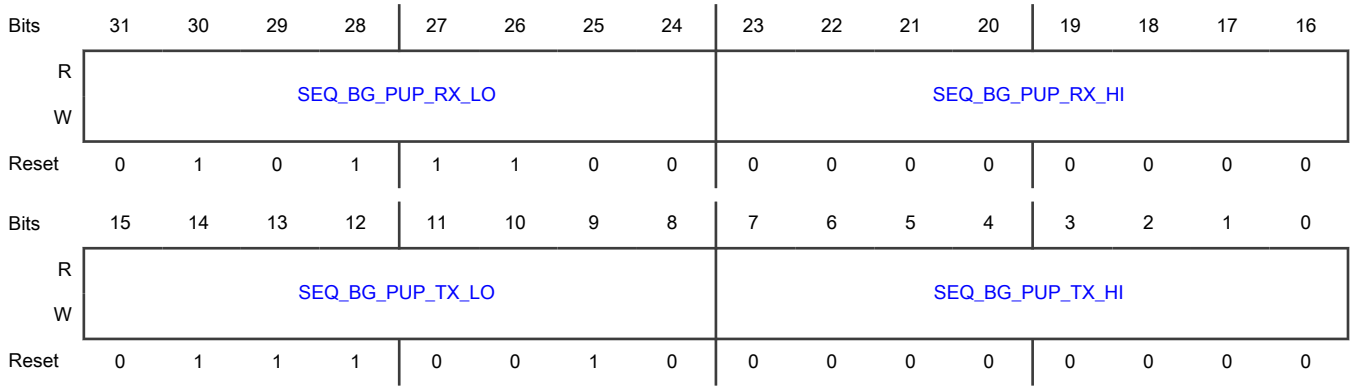
Field	Function
31-24 SEQ_LDO_LV_PUP_RX_LO	De-assertion time setting for SEQ_LDO_LV_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_LV_PUP signal or group will transition from HI to LO.
23-16 SEQ_LDO_LV_PUP_RX_HI	Assertion time setting for SEQ_LDO_LV_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_LV_PUP signal or group will transition from LO to HI.
15-8 SEQ_LDO_LV_PUP_TX_LO	De-assertion time setting for SEQ_LDO_LV_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_LV_PUP signal or group will transition from HI to LO.
7-0 SEQ_LDO_LV_PUP_TX_HI	Assertion time setting for SEQ_LDO_LV_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LDO_LV_PUP signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.36 TSM_TIMING26 (TIMING26)

Offset

Register	Offset
TIMING26	88h

Diagram



Fields

Field	Function
31-24 SEQ_BG_PUP_RX_LO	De-assertion time setting for SEQ_BG_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP signal or group will transition from HI to LO.
23-16 SEQ_BG_PUP_RX_HI	Assertion time setting for SEQ_BG_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP signal or group will transition from LO to HI.
15-8 SEQ_BG_PUP_TX_LO	De-assertion time setting for SEQ_BG_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP signal or group will transition from HI to LO.
7-0 SEQ_BG_PUP_TX_HI	Assertion time setting for SEQ_BG_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.37 TSM_TIMING27 (TIMING27)

Offset

Register	Offset
TIMING27	8Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_BG_PUP_IBG_ANT_RX_LO								SEQ_BG_PUP_IBG_ANT_RX_HI							
Reset	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_BG_PUP_IBG_ANT_TX_LO								SEQ_BG_PUP_IBG_ANT_TX_HI							
Reset	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-24 SEQ_BG_PUP_IBG_ANT_RX_LO	De-assertion time setting for SEQ_BG_PUP_IBG_ANT (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_ANT signal or group will transition from HI to LO.
23-16 SEQ_BG_PUP_IBG_ANT_RX_HI	Assertion time setting for SEQ_BG_PUP_IBG_ANT (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_ANT signal or group will transition from LO to HI.
15-8 SEQ_BG_PUP_IBG_ANT_TX_LO	De-assertion time setting for SEQ_BG_PUP_IBG_ANT (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_ANT signal or group will transition from HI to LO.
7-0 SEQ_BG_PUP_IBG_ANT_TX_HI	Assertion time setting for SEQ_BG_PUP_IBG_ANT (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_ANT signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.38 TSM_TIMING28 (TIMING28)

Offset

Register	Offset
TIMING28	90h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_BG_PUP_IBG_XO_DIST_RX_LO								SEQ_BG_PUP_IBG_XO_DIST_RX_HI							
Reset	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_BG_PUP_IBG_XO_DIST_TX_LO								SEQ_BG_PUP_IBG_XO_DIST_TX_HI							
Reset	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0

Fields

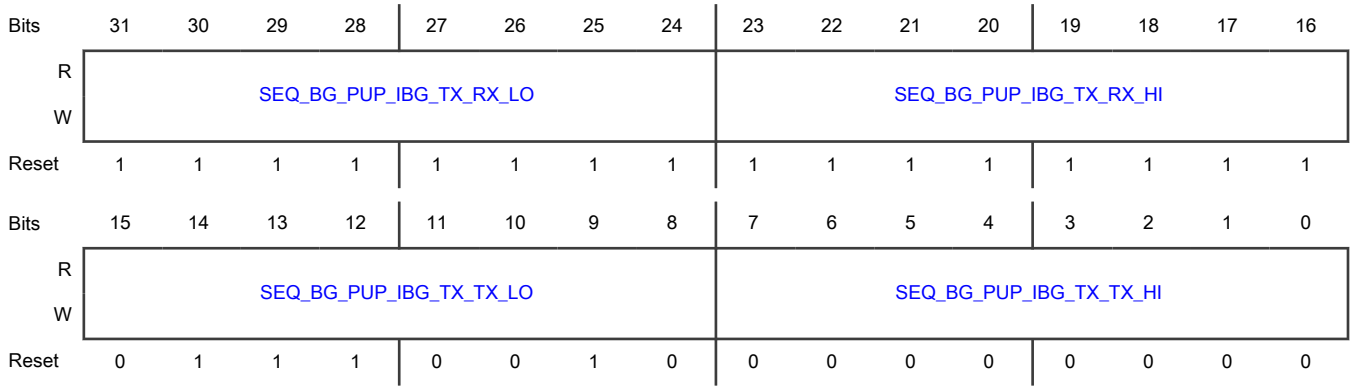
Field	Function
31-24 SEQ_BG_PUP_IBG_XO_DIST_RX_LO	De-assertion time setting for SEQ_BG_PUP_IBG_XO_DIST (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_XO_DIST signal or group will transition from HI to LO.
23-16 SEQ_BG_PUP_IBG_XO_DIST_RX_HI	Assertion time setting for SEQ_BG_PUP_IBG_XO_DIST (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_XO_DIST signal or group will transition from LO to HI.
15-8 SEQ_BG_PUP_IBG_XO_DIST_TX_LO	De-assertion time setting for SEQ_BG_PUP_IBG_XO_DIST (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_XO_DIST signal or group will transition from HI to LO.
7-0 SEQ_BG_PUP_IBG_XO_DIST_TX_HI	Assertion time setting for SEQ_BG_PUP_IBG_XO_DIST (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_XO_DIST signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.39 TSM_TIMING29 (TIMING29)

Offset

Register	Offset
TIMING29	94h

Diagram



Fields

Field	Function
31-24 SEQ_BG_PUP_IBG_TX_RX_LO	De-assertion time setting for SEQ_BG_PUP_IBG_TX (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_TX signal or group will transition from HI to LO.
23-16 SEQ_BG_PUP_IBG_TX_RX_HI	Assertion time setting for SEQ_BG_PUP_IBG_TX (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_TX signal or group will transition from LO to HI.
15-8 SEQ_BG_PUP_IBG_TX_TX_LO	De-assertion time setting for SEQ_BG_PUP_IBG_TX (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_TX signal or group will transition from HI to LO.
7-0 SEQ_BG_PUP_IBG_TX_TX_HI	Assertion time setting for SEQ_BG_PUP_IBG_TX (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_TX signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.40 TSM_TIMING30 (TIMING30)

Offset

Register	Offset
TIMING30	98h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_BG_PUP_IBG_RX_RX_LO								SEQ_BG_PUP_IBG_RX_RX_HI							
Reset	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_BG_PUP_IBG_RX_TX_LO								SEQ_BG_PUP_IBG_RX_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 SEQ_BG_PUP_IBG_RX_RX_LO	De-assertion time setting for SEQ_BG_PUP_IBG_RX (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_RX signal or group will transition from HI to LO.
23-16 SEQ_BG_PUP_IBG_RX_RX_HI	Assertion time setting for SEQ_BG_PUP_IBG_RX (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_RX signal or group will transition from LO to HI.
15-8 SEQ_BG_PUP_IBG_RX_TX_LO	De-assertion time setting for SEQ_BG_PUP_IBG_RX (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_RX signal or group will transition from HI to LO. **NOTE** This signal can be asserted in most of the time except for IP RX2TX.
7-0 SEQ_BG_PUP_IBG_RX_TX_HI	Assertion time setting for SEQ_BG_PUP_IBG_RX (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_BG_PUP_IBG_RX signal or group will transition from LO to HI. **NOTE** This signal can be asserted in most of the time except for IP RX2TX.

52.4.4.2.2.4.3.1.41 TSM_TIMING31 (TIMING31)

Offset

Register	Offset
TIMING31	9Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_TSM_ISO_B_2P4GHZ_RX_LO								SEQ_TSM_ISO_B_2P4GHZ_RX_HI							
Reset	0	1	0	1	1	0	1	1	0	0	0	0	1	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_TSM_ISO_B_2P4GHZ_TX_LO								SEQ_TSM_ISO_B_2P4GHZ_TX_HI							
Reset	0	1	1	1	0	0	0	1	0	0	0	0	1	0	0	0

Fields

Field	Function
31-24 SEQ_TSM_ISO_B_2P4GHZ_RX_LO	De-assertion time setting for SEQ_TSM_ISO_B_2P4GHZ (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_TSM_ISO_B_2P4GHZ signal or group will transition from HI to LO.
23-16 SEQ_TSM_ISO_B_2P4GHZ_RX_HI	Assertion time setting for SEQ_TSM_ISO_B_2P4GHZ (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_TSM_ISO_B_2P4GHZ signal or group will transition from LO to HI.
15-8 SEQ_TSM_ISO_B_2P4GHZ_TX_LO	De-assertion time setting for SEQ_TSM_ISO_B_2P4GHZ (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_TSM_ISO_B_2P4GHZ signal or group will transition from HI to LO.
7-0 SEQ_TSM_ISO_B_2P4GHZ_TX_HI	Assertion time setting for SEQ_TSM_ISO_B_2P4GHZ (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_TSM_ISO_B_2P4GHZ signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.42 TSM_TIMING32 (TIMING32)

Offset

Register	Offset
TIMING32	A0h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_RCCAL_PUP_RX_LO								SEQ_RCCAL_PUP_RX_HI							
Reset	0	0	0	1	1	0	0	1	0	0	0	1	0	0	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_RCCAL_PUP_TX_LO								SEQ_RCCAL_PUP_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 SEQ_RCCAL_PUP_RX_LO	De-assertion time setting for SEQ_RCCAL_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_RCCAL_PUP signal or group will transition from HI to LO.
23-16 SEQ_RCCAL_PUP_RX_HI	Assertion time setting for SEQ_RCCAL_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_RCCAL_PUP signal or group will transition from LO to HI.
15-8 SEQ_RCCAL_PUP_TX_LO	De-assertion time setting for SEQ_RCCAL_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0]value) at which the SEQ_RCCAL_PUP signal or group will transition from HI toLO. **NOTE** This signal can be asserted only during WU or FC transtions.
7-0 SEQ_RCCAL_PUP_TX_HI	Assertion time setting for SEQ_RCCAL_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0]value) at which the SEQ_RCCAL_PUP signal or group will transition from LO toHI. **NOTE** This signal can be asserted only during WU or FC transtions.

52.4.4.2.2.4.3.1.43 TSM_TIMING33 (TIMING33)

Offset

Register	Offset
TIMING33	A4h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_PD_EN_FCAL_BIAS_RX_LO								SEQ_PD_EN_FCAL_BIAS_RX_HI							
Reset	0	0	1	0	0	0	1	1	0	0	0	1	0	0	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_PD_EN_FCAL_BIAS_TX_LO								SEQ_PD_EN_FCAL_BIAS_TX_HI							
Reset	0	1	0	1	1	0	1	0	0	0	0	1	0	0	0	1

Fields

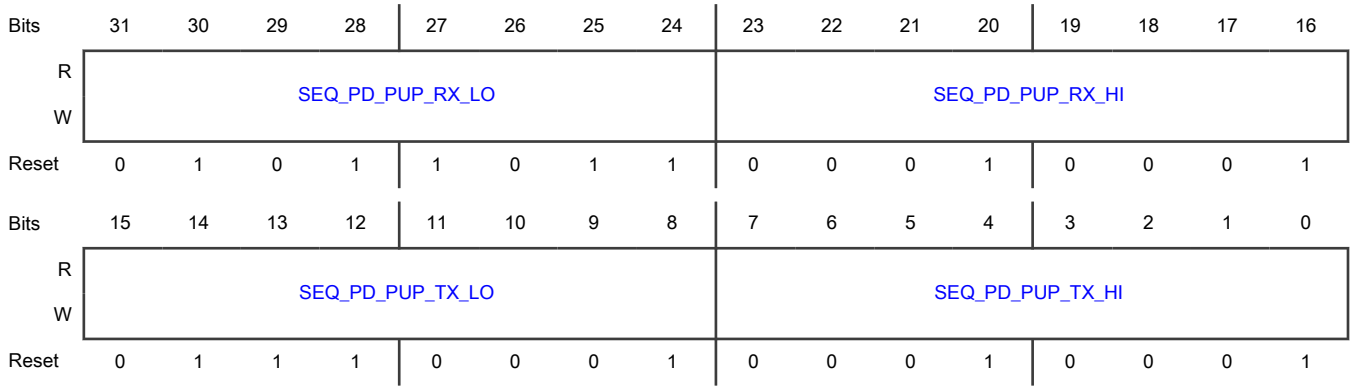
Field	Function
31-24 SEQ_PD_EN_FCAL_BIAS_RX_LO	De-assertion time setting for SEQ_PD_EN_FCAL_BIAS (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PD_EN_FCAL_BIAS signal or group will transition from HI to LO.
23-16 SEQ_PD_EN_FCAL_BIAS_RX_HI	Assertion time setting for SEQ_PD_EN_FCAL_BIAS (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PD_EN_FCAL_BIAS signal or group will transition from LO to HI.
15-8 SEQ_PD_EN_FCAL_BIAS_TX_LO	De-assertion time setting for SEQ_PD_EN_FCAL_BIAS (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PD_EN_FCAL_BIAS signal or group will transition from HI to LO.
7-0 SEQ_PD_EN_FCAL_BIAS_TX_HI	Assertion time setting for SEQ_PD_EN_FCAL_BIAS (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PD_EN_FCAL_BIAS signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.44 TSM_TIMING34 (TIMING34)

Offset

Register	Offset
TIMING34	A8h

Diagram



Fields

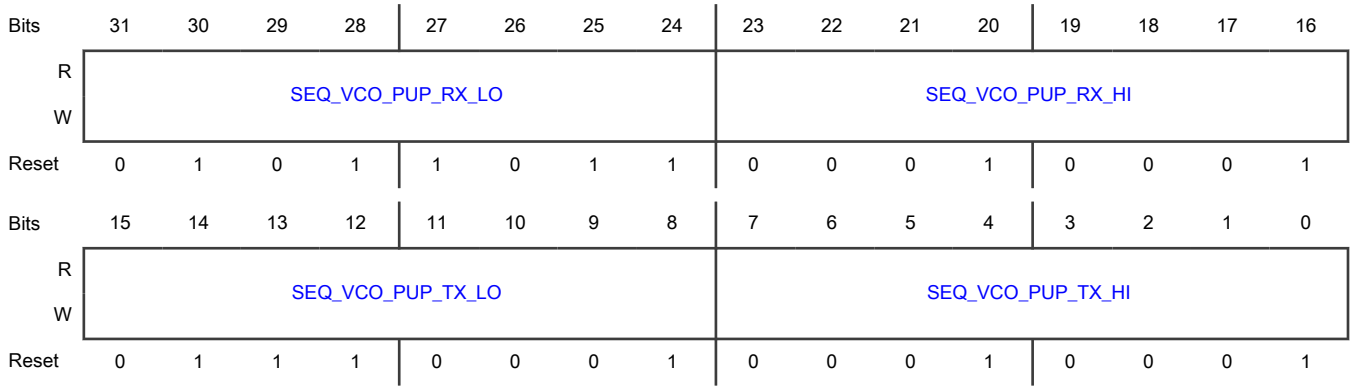
Field	Function
31-24 SEQ_PD_PUP_RX_LO	De-assertion time setting for SEQ_PD_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PD_PUP signal or group will transition from HI to LO.
23-16 SEQ_PD_PUP_RX_HI	Assertion time setting for SEQ_PD_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PD_PUP signal or group will transition from LO to HI.
15-8 SEQ_PD_PUP_TX_LO	De-assertion time setting for SEQ_PD_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PD_PUP signal or group will transition from HI to LO.
7-0 SEQ_PD_PUP_TX_HI	Assertion time setting for SEQ_PD_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PD_PUP signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.45 TSM_TIMING35 (TIMING35)

Offset

Register	Offset
TIMING35	ACh

Diagram



Fields

Field	Function
31-24 SEQ_VCO_PUP_RX_LO	De-assertion time setting for SEQ_VCO_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_VCO_PUP signal or group will transition from HI to LO.
23-16 SEQ_VCO_PUP_RX_HI	Assertion time setting for SEQ_VCO_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_VCO_PUP signal or group will transition from LO to HI.
15-8 SEQ_VCO_PUP_TX_LO	De-assertion time setting for SEQ_VCO_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_VCO_PUP signal or group will transition from HI to LO.
7-0 SEQ_VCO_PUP_TX_HI	Assertion time setting for SEQ_VCO_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_VCO_PUP signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.46 TSM_TIMING36 (TIMING36)

Offset

Register	Offset
TIMING36	B0h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_XO_DIST_EN_RX_LO								SEQ_XO_DIST_EN_RX_HI							
Reset	0	1	0	1	1	0	1	1	0	0	0	1	0	0	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_XO_DIST_EN_TX_LO								SEQ_XO_DIST_EN_TX_HI							
Reset	0	1	1	1	0	0	0	1	0	0	0	1	0	0	0	1

Fields

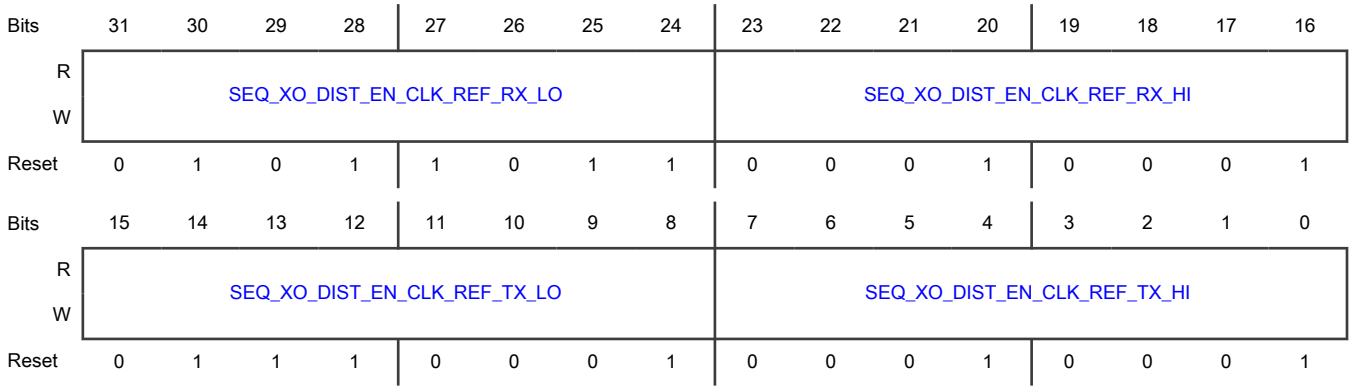
Field	Function
31-24 SEQ_XO_DIST_EN_RX_LO	De-assertion time setting for SEQ_XO_DIST_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_XO_DIST_EN signal or group will transition from HI to LO.
23-16 SEQ_XO_DIST_EN_RX_HI	Assertion time setting for SEQ_XO_DIST_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_XO_DIST_EN signal or group will transition from LO to HI.
15-8 SEQ_XO_DIST_EN_TX_LO	De-assertion time setting for SEQ_XO_DIST_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_XO_DIST_EN signal or group will transition from HI to LO.
7-0 SEQ_XO_DIST_EN_TX_HI	Assertion time setting for SEQ_XO_DIST_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_XO_DIST_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.47 TSM_TIMING37 (TIMING37)

Offset

Register	Offset
TIMING37	B4h

Diagram



Fields

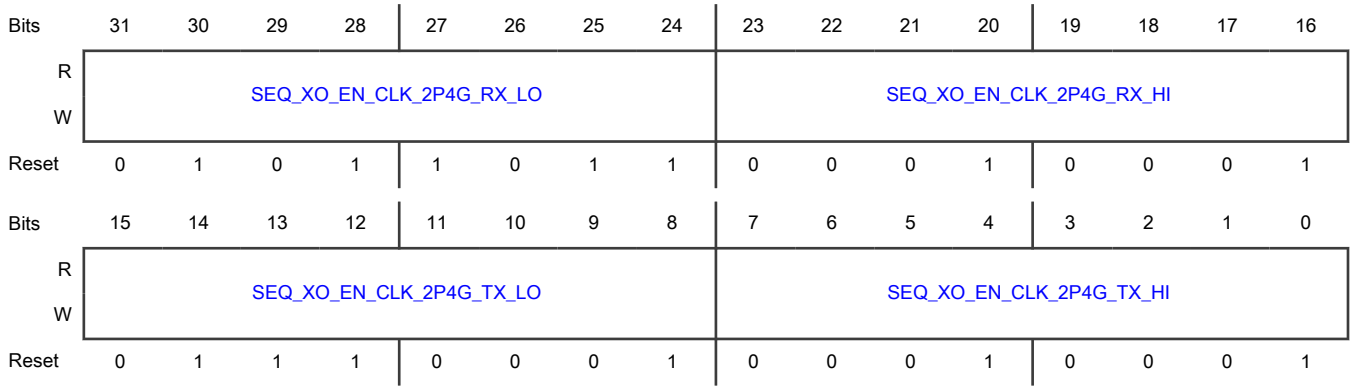
Field	Function
31-24 SEQ_XO_DIST_EN_CLK_REF_RX_LO	De-assertion time setting for SEQ_XO_DIST_EN_CLK_REF (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_XO_DIST_EN_CLK_REF signal or group will transition from HI to LO.
23-16 SEQ_XO_DIST_EN_CLK_REF_RX_HI	Assertion time setting for SEQ_XO_DIST_EN_CLK_REF (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_XO_DIST_EN_CLK_REF signal or group will transition from LO to HI.
15-8 SEQ_XO_DIST_EN_CLK_REF_TX_LO	De-assertion time setting for SEQ_XO_DIST_EN_CLK_REF (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_XO_DIST_EN_CLK_REF signal or group will transition from HI to LO.
7-0 SEQ_XO_DIST_EN_CLK_REF_TX_HI	Assertion time setting for SEQ_XO_DIST_EN_CLK_REF (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_XO_DIST_EN_CLK_REF signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.48 TSM_TIMING38 (TIMING38)

Offset

Register	Offset
TIMING38	B8h

Diagram



Fields

Field	Function
31-24 SEQ_XO_EN_CLK_2P4G_RX_LO	De-assertion time setting for SEQ_XO_EN_CLK_2P4G (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_XO_EN_CLK_2P4G signal or group will transition from HI to LO.
23-16 SEQ_XO_EN_CLK_2P4G_RX_HI	Assertion time setting for SEQ_XO_EN_CLK_2P4G (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_XO_EN_CLK_2P4G signal or group will transition from LO to HI.
15-8 SEQ_XO_EN_CLK_2P4G_TX_LO	De-assertion time setting for SEQ_XO_EN_CLK_2P4G (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_XO_EN_CLK_2P4G signal or group will transition from HI to LO.
7-0 SEQ_XO_EN_CLK_2P4G_TX_HI	Assertion time setting for SEQ_XO_EN_CLK_2P4G (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_XO_EN_CLK_2P4G signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.49 TSM_TIMING39 (TIMING39)

Offset

Register	Offset
TIMING39	BCh

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_XO_DIST_EN_CLK_ADCDAC_RX_LO								SEQ_XO_DIST_EN_CLK_ADCDAC_RX_HI							
Reset	0	1	0	1	1	0	1	1	0	0	1	0	1	0	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_XO_DIST_EN_CLK_ADCDAC_TX_LO								SEQ_XO_DIST_EN_CLK_ADCDAC_TX_HI							
Reset	0	1	1	1	0	0	0	1	0	0	0	1	0	0	0	1

Fields

Field	Function
31-24 SEQ_XO_DIST_EN_CLK_ADCDAC_RX_LO	De-assertion time setting for SEQ_XO_DIST_EN_CLK_ADCDAC (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_XO_DIST_EN_CLK_ADCDAC signal or group will transition from HI to LO.
23-16 SEQ_XO_DIST_EN_CLK_ADCDAC_RX_HI	Assertion time setting for SEQ_XO_DIST_EN_CLK_ADCDAC (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_XO_DIST_EN_CLK_ADCDAC signal or group will transition from LO to HI.
15-8 SEQ_XO_DIST_EN_CLK_ADCDAC_TX_LO	De-assertion time setting for SEQ_XO_DIST_EN_CLK_ADCDAC (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_XO_DIST_EN_CLK_ADCDAC signal or group will transition from HI to LO.
7-0 SEQ_XO_DIST_EN_CLK_ADCDAC_TX_HI	Assertion time setting for SEQ_XO_DIST_EN_CLK_ADCDAC (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_XO_DIST_EN_CLK_ADCDAC signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.50 TSM_TIMING40 (TIMING40)

Offset

Register	Offset
TIMING40	C0h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_DAC_PUP_RX_LO								SEQ_DAC_PUP_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_DAC_PUP_TX_LO								SEQ_DAC_PUP_TX_HI							
Reset	0	1	1	1	0	0	0	1	0	0	0	1	0	0	0	1

Fields

Field	Function
31-24 SEQ_DAC_PUP_RX_LO	De-assertion time setting for SEQ_DAC_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_DAC_PUP signal or group will transition from HI to LO.
23-16 SEQ_DAC_PUP_RX_HI	Assertion time setting for SEQ_DAC_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_DAC_PUP signal or group will transition from LO to HI.
15-8 SEQ_DAC_PUP_TX_LO	De-assertion time setting for SEQ_DAC_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_DAC_PUP signal or group will transition from HI to LO.
7-0 SEQ_DAC_PUP_TX_HI	Assertion time setting for SEQ_DAC_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_DAC_PUP signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.51 TSM_TIMING41 (TIMING41)

Offset

Register	Offset
TIMING41	C4h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_VCO_EN_HPM_RX_LO								SEQ_VCO_EN_HPM_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_VCO_EN_HPM_TX_LO								SEQ_VCO_EN_HPM_TX_HI							
Reset	0	1	1	1	0	0	0	1	0	0	0	1	0	0	0	1

Fields

Field	Function
31-24 SEQ_VCO_EN_HPM_RX_LO	De-assertion time setting for SEQ_VCO_EN_HPM (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_VCO_EN_HPM signal or group will transition from HI to LO.
23-16 SEQ_VCO_EN_HPM_RX_HI	Assertion time setting for SEQ_VCO_EN_HPM (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_VCO_EN_HPM signal or group will transition from LO to HI.
15-8 SEQ_VCO_EN_HPM_TX_LO	De-assertion time setting for SEQ_VCO_EN_HPM (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_VCO_EN_HPM signal or group will transition from HI to LO.
7-0 SEQ_VCO_EN_HPM_TX_HI	Assertion time setting for SEQ_VCO_EN_HPM (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_VCO_EN_HPM signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.52 TSM_TIMING42 (TIMING42)

Offset

Register	Offset
TIMING42	C8h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_LO_PUP_VLO_FBK_RX_LO								SEQ_LO_PUP_VLO_FBK_RX_HI							
Reset	0	1	0	1	1	0	1	1	0	0	0	1	0	0	1	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_LO_PUP_VLO_FBK_TX_LO								SEQ_LO_PUP_VLO_FBK_TX_HI							
Reset	0	1	1	1	0	0	0	1	0	0	0	1	0	0	1	0

Fields

Field	Function
31-24 SEQ_LO_PUP_VLO_FBK_RX_LO	De-assertion time setting for SEQ_LO_PUP_VLO_FBK (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_FBK signal or group will transition from HI to LO.
23-16 SEQ_LO_PUP_VLO_FBK_RX_HI	Assertion time setting for SEQ_LO_PUP_VLO_FBK (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_FBK signal or group will transition from LO to HI.
15-8 SEQ_LO_PUP_VLO_FBK_TX_LO	De-assertion time setting for SEQ_LO_PUP_VLO_FBK (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_FBK signal or group will transition from HI to LO.
7-0 SEQ_LO_PUP_VLO_FBK_TX_HI	Assertion time setting for SEQ_LO_PUP_VLO_FBK (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_FBK signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.53 TSM_TIMING43 (TIMING43)

Offset

Register	Offset
TIMING43	CCh

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_LO_PUP_VLO_RX_RX_LO								SEQ_LO_PUP_VLO_RX_RX_HI							
Reset	0	1	0	1	1	0	1	1	0	0	0	1	0	0	1	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_LO_PUP_VLO_RX_TX_LO								SEQ_LO_PUP_VLO_RX_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

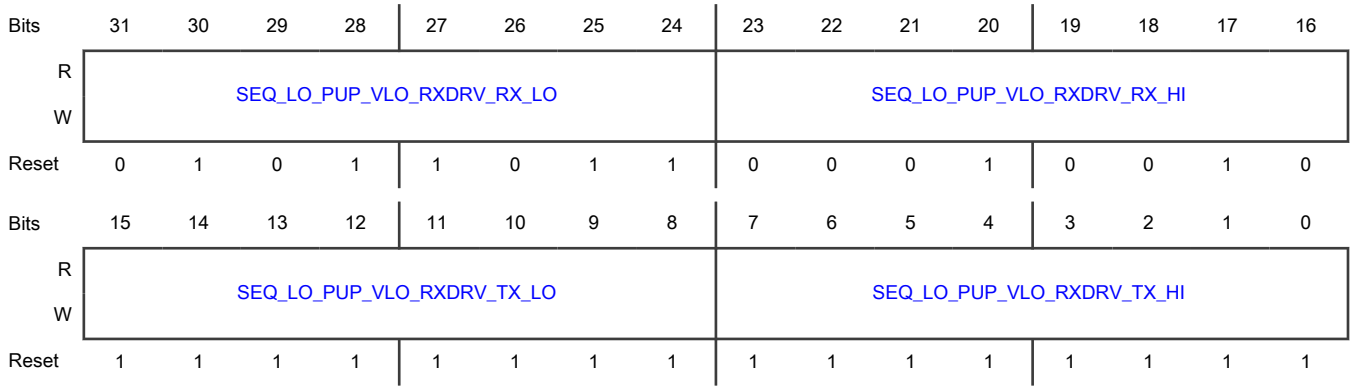
Field	Function
31-24 SEQ_LO_PUP_VLO_RX_RX_LO	De-assertion time setting for SEQ_LO_PUP_VLO_RX (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_RX signal or group will transition from HI to LO.
23-16 SEQ_LO_PUP_VLO_RX_RX_HI	Assertion time setting for SEQ_LO_PUP_VLO_RX (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_RX signal or group will transition from LO to HI.
15-8 SEQ_LO_PUP_VLO_RX_TX_LO	De-assertion time setting for SEQ_LO_PUP_VLO_RX (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_RX signal or group will transition from HI to LO.
7-0 SEQ_LO_PUP_VLO_RX_TX_HI	Assertion time setting for SEQ_LO_PUP_VLO_RX (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_RX signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.54 TSM_TIMING44 (TIMING44)

Offset

Register	Offset
TIMING44	D0h

Diagram



Fields

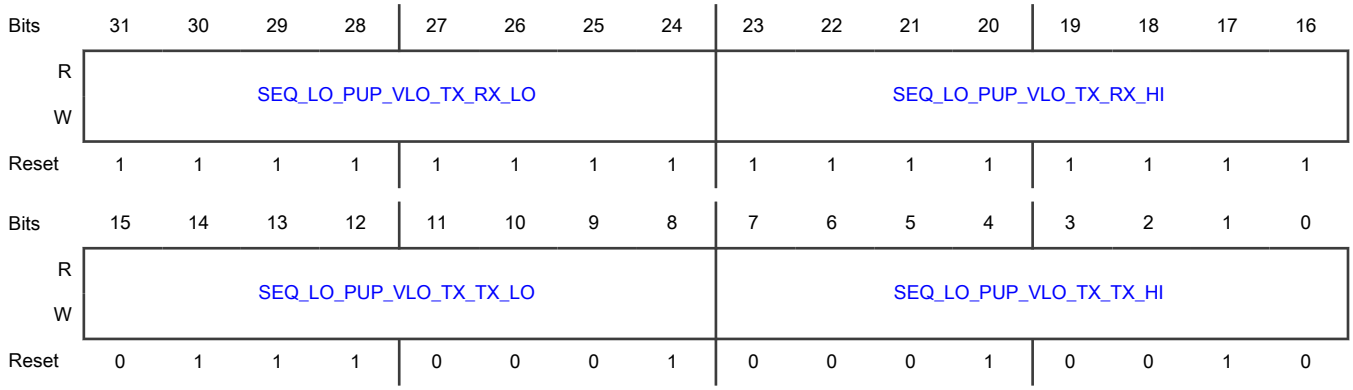
Field	Function
31-24 SEQ_LO_PUP_VLO_RXDRV_RX_LO	De-assertion time setting for SEQ_LO_PUP_VLO_RXDRV (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_RXDRV signal or group will transition from HI to LO.
23-16 SEQ_LO_PUP_VLO_RXDRV_RX_HI	Assertion time setting for SEQ_LO_PUP_VLO_RXDRV (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_RXDRV signal or group will transition from LO to HI.
15-8 SEQ_LO_PUP_VLO_RXDRV_TX_LO	De-assertion time setting for SEQ_LO_PUP_VLO_RXDRV (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_RXDRV signal or group will transition from HI to LO.
7-0 SEQ_LO_PUP_VLO_RXDRV_TX_HI	Assertion time setting for SEQ_LO_PUP_VLO_RXDRV (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_RXDRV signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.55 TSM_TIMING45 (TIMING45)

Offset

Register	Offset
TIMING45	D4h

Diagram



Fields

Field	Function
31-24 SEQ_LO_PUP_VLO_TX_RX_LO	De-assertion time setting for SEQ_LO_PUP_VLO_TX (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_TX signal or group will transition from HI to LO.
23-16 SEQ_LO_PUP_VLO_TX_RX_HI	Assertion time setting for SEQ_LO_PUP_VLO_TX (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_TX signal or group will transition from LO to HI.
15-8 SEQ_LO_PUP_VLO_TX_TX_LO	De-assertion time setting for SEQ_LO_PUP_VLO_TX (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_TX signal or group will transition from HI to LO.
7-0 SEQ_LO_PUP_VLO_TX_TX_HI	Assertion time setting for SEQ_LO_PUP_VLO_TX (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_TX signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.56 TSM_TIMING46 (TIMING46)

Offset

Register	Offset
TIMING46	D8h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_LO_PUP_VLO_TXDRV_RX_LO								SEQ_LO_PUP_VLO_TXDRV_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_LO_PUP_VLO_TXDRV_TX_LO								SEQ_LO_PUP_VLO_TXDRV_TX_HI							
Reset	0	1	1	1	0	0	0	1	0	0	0	1	0	0	1	0

Fields

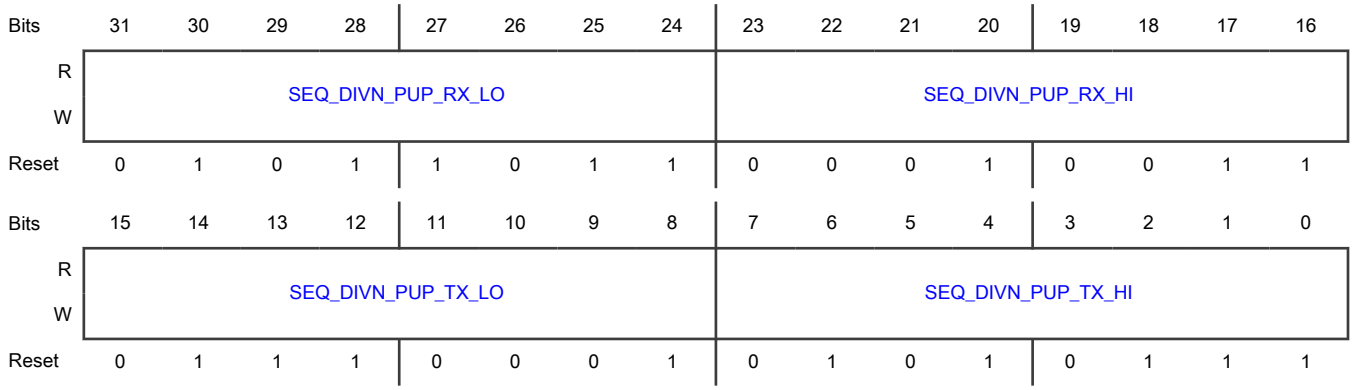
Field	Function
31-24 SEQ_LO_PUP_VLO_TXDRV_RX_LO	De-assertion time setting for SEQ_LO_PUP_VLO_TXDRV (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_TXDRV signal or group will transition from HI to LO.
23-16 SEQ_LO_PUP_VLO_TXDRV_RX_HI	Assertion time setting for SEQ_LO_PUP_VLO_TXDRV (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_TXDRV signal or group will transition from LO to HI.
15-8 SEQ_LO_PUP_VLO_TXDRV_TX_LO	De-assertion time setting for SEQ_LO_PUP_VLO_TXDRV (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_TXDRV signal or group will transition from HI to LO.
7-0 SEQ_LO_PUP_VLO_TXDRV_TX_HI	Assertion time setting for SEQ_LO_PUP_VLO_TXDRV (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LO_PUP_VLO_TXDRV signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.57 TSM_TIMING47 (TIMING47)

Offset

Register	Offset
TIMING47	DCh

Diagram



Fields

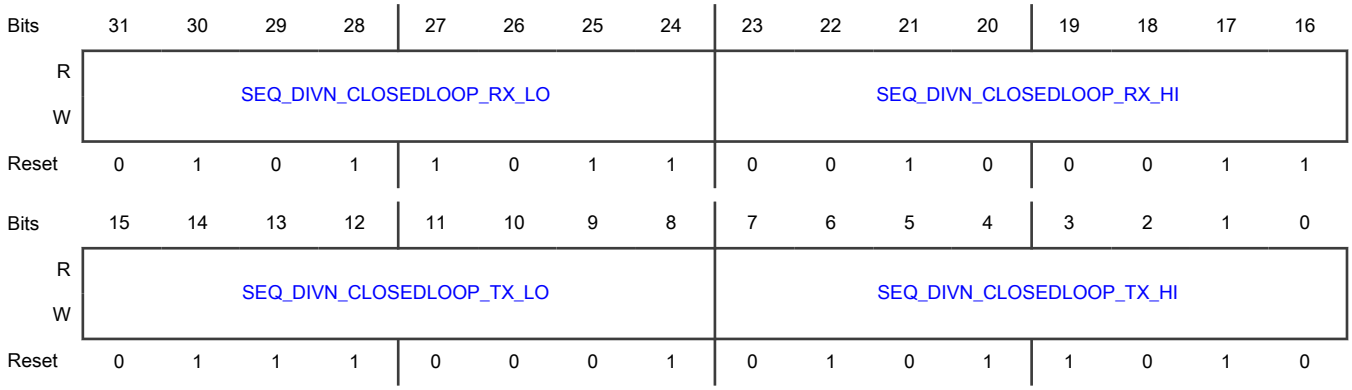
Field	Function
31-24 SEQ_DIVN_PUP_RX_LO	De-assertion time setting for SEQ_DIVN_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_DIVN_PUP signal or group will transition from HI to LO.
23-16 SEQ_DIVN_PUP_RX_HI	Assertion time setting for SEQ_DIVN_PUP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_DIVN_PUP signal or group will transition from LO to HI.
15-8 SEQ_DIVN_PUP_TX_LO	De-assertion time setting for SEQ_DIVN_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_DIVN_PUP signal or group will transition from HI to LO.
7-0 SEQ_DIVN_PUP_TX_HI	Assertion time setting for SEQ_DIVN_PUP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_DIVN_PUP signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.58 TSM_TIMING48 (TIMING48)

Offset

Register	Offset
TIMING48	E0h

Diagram



Fields

Field	Function
31-24 SEQ_DIVN_CLOSEDLOOP_RX_LO	De-assertion time setting for SEQ_DIVN_CLOSEDLOOP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_DIVN_CLOSEDLOOP signal or group will transition from HI to LO.
23-16 SEQ_DIVN_CLOSEDLOOP_RX_HI	Assertion time setting for SEQ_DIVN_CLOSEDLOOP (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_DIVN_CLOSEDLOOP signal or group will transition from LO to HI.
15-8 SEQ_DIVN_CLOSEDLOOP_TX_LO	De-assertion time setting for SEQ_DIVN_CLOSEDLOOP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_DIVN_CLOSEDLOOP signal or group will transition from HI to LO.
7-0 SEQ_DIVN_CLOSEDLOOP_TX_HI	Assertion time setting for SEQ_DIVN_CLOSEDLOOP (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_DIVN_CLOSEDLOOP signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.59 TSM_TIMING49 (TIMING49)

Offset

Register	Offset
TIMING49	E4h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_PD_EN_PD_DRV_RX_LO								SEQ_PD_EN_PD_DRV_RX_HI							
Reset	0	1	0	1	1	0	1	1	0	0	1	0	0	0	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_PD_EN_PD_DRV_TX_LO								SEQ_PD_EN_PD_DRV_TX_HI							
Reset	0	1	1	1	0	0	0	1	0	1	0	1	1	0	1	0

Fields

Field	Function
31-24 SEQ_PD_EN_PD_DRV_RX_LO	De-assertion time setting for SEQ_PD_EN_PD_DRV (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PD_EN_PD_DRV signal or group will transition from HI to LO.
23-16 SEQ_PD_EN_PD_DRV_RX_HI	Assertion time setting for SEQ_PD_EN_PD_DRV (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PD_EN_PD_DRV signal or group will transition from LO to HI.
15-8 SEQ_PD_EN_PD_DRV_TX_LO	De-assertion time setting for SEQ_PD_EN_PD_DRV (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PD_EN_PD_DRV signal or group will transition from HI to LO.
7-0 SEQ_PD_EN_PD_DRV_TX_HI	Assertion time setting for SEQ_PD_EN_PD_DRV (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PD_EN_PD_DRV signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.60 TSM_TIMING50 (TIMING50)

Offset

Register	Offset
TIMING50	E8h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_CBPF_EN_DCOC_RX_LO								SEQ_CBPF_EN_DCOC_RX_HI							
Reset	0	1	0	1	1	0	1	1	0	0	1	0	1	0	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_CBPF_EN_DCOC_TX_LO								SEQ_CBPF_EN_DCOC_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 SEQ_CBPF_EN_DCOC_RX_LO	De-assertion time setting for SEQ_CBPF_EN_DCOC (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_CBPF_EN_DCOC signal or group will transition from HI to LO.
23-16 SEQ_CBPF_EN_DCOC_RX_HI	Assertion time setting for SEQ_CBPF_EN_DCOC (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_CBPF_EN_DCOC signal or group will transition from LO to HI.
15-8 SEQ_CBPF_EN_DCOC_TX_LO	De-assertion time setting for SEQ_CBPF_EN_DCOC (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_CBPF_EN_DCOC signal or group will transition from HI to LO. **NOTE** This signal can be asserted in most of the time except for IP RX2TX.
7-0 SEQ_CBPF_EN_DCOC_TX_HI	Assertion time setting for SEQ_CBPF_EN_DCOC (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_CBPF_EN_DCOC signal or group will transition from LO to HI. **NOTE** This signal can be asserted in most of the time except for IP RX2TX.

52.4.4.2.2.4.3.1.61 TSM_TIMING51 (TIMING51)

Offset

Register	Offset
TIMING51	ECh

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_RX_GANG_PUP_RX_LO								SEQ_RX_GANG_PUP_RX_HI							
Reset	0	1	0	1	1	0	1	1	0	0	1	0	1	0	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_RX_GANG_PUP_TX_LO								SEQ_RX_GANG_PUP_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

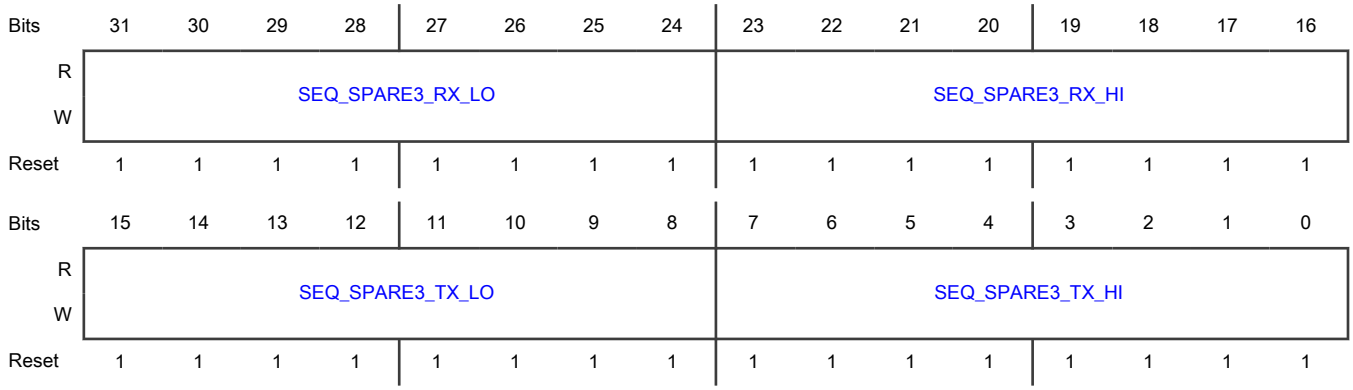
Field	Function
31-24 SEQ_RX_GANG_PUP_RX_LO	De-assertion time setting for SEQ_(RX_LAN/RX_MIX/CBPF/ADC_PUP) and SEQ_SPARE1 (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_(RX_LAN/RX_MIX/CBPF/ADC_PUP) and SEQ_SPARE1 signal or group will transition from HI to LO.
23-16 SEQ_RX_GANG_PUP_RX_HI	Assertion time setting for SEQ_(RX_LAN/RX_MIX/CBPF/ADC_PUP) and SEQ_SPARE1 (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_(RX_LAN/RX_MIX/CBPF/ADC_PUP) and SEQ_SPARE1 signal or group will transition from LO to HI.
15-8 SEQ_RX_GANG_PUP_TX_LO	De-assertion time setting for SEQ_(RX_LAN/RX_MIX/CBPF/ADC_PUP) and SEQ_SPARE1 (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_(RX_LAN/RX_MIX/CBPF/ADC_PUP) and SEQ_SPARE1 signal or group will transition from HI to LO. **NOTE** This signal can be asserted in most of the time except for IP RX2TX.
7-0 SEQ_RX_GANG_PUP_TX_HI	Assertion time setting for SEQ_(RX_LAN/RX_MIX/CBPF/ADC_PUP) and SEQ_SPARE1 (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_(RX_LAN/RX_MIX/CBPF/ADC_PUP) and SEQ_SPARE1 signal or group will transition from LO to HI. **NOTE** This signal can be asserted in most of the time except for IP RX2TX.

52.4.4.2.2.4.3.1.62 TSM_TIMING52 (TIMING52)

Offset

Register	Offset
TIMING52	F0h

Diagram



Fields

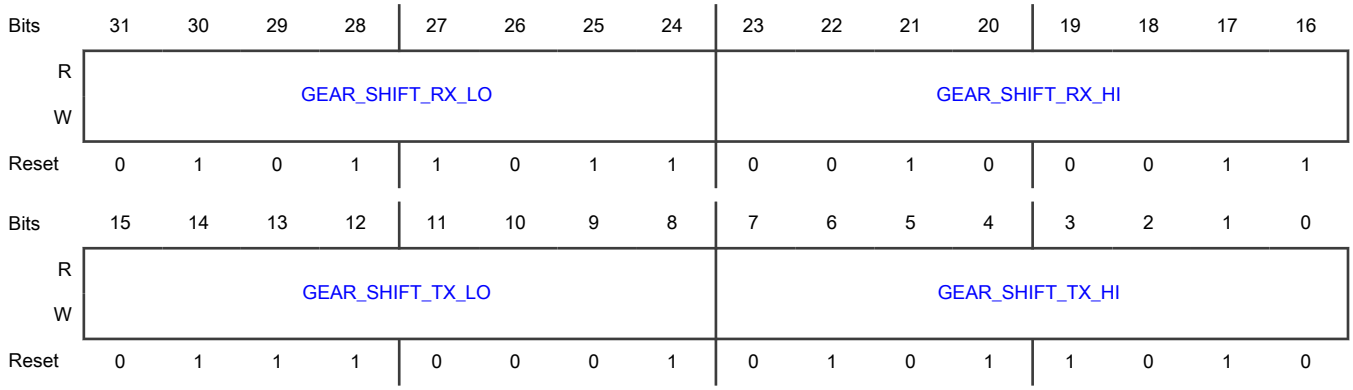
Field	Function
31-24 SEQ_SPARE3_RX_LO	De-assertion time setting for SEQ_SPARE3 (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_SPARE3 signal or group will transition from HI to LO.
23-16 SEQ_SPARE3_RX_HI	Assertion time setting for SEQ_SPARE3 (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_SPARE3 signal or group will transition from LO to HI.
15-8 SEQ_SPARE3_TX_LO	De-assertion time setting for SEQ_SPARE3 (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_SPARE3 signal or group will transition from HI to LO.
7-0 SEQ_SPARE3_TX_HI	Assertion time setting for SEQ_SPARE3 (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_SPARE3 signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.63 TSM TIMING_53 (TIMING53)

Offset

Register	Offset
TIMING53	F4h

Diagram



Fields

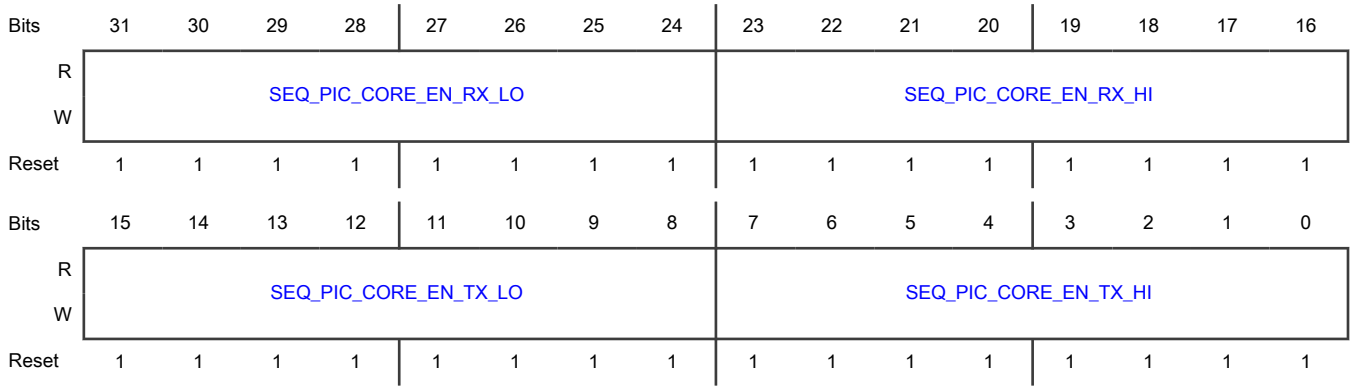
Field	Function
31-24 GEAR_SHIFT_RX_LO	De-assertion time setting for GEAR_SHIFT (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the GEAR_SHIFT signal or group will transition from HI to LO.
23-16 GEAR_SHIFT_RX_HI	Assertion time setting for GEAR_SHIFT (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the GEAR_SHIFT signal or group will transition from LO to HI.
15-8 GEAR_SHIFT_TX_LO	De-assertion time setting for GEAR_SHIFT (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the GEAR_SHIFT signal or group will transition from HI to LO.
7-0 GEAR_SHIFT_TX_HI	Assertion time setting for GEAR_SHIFT (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the GEAR_SHIFT signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.64 TSM TIMING_54 (TIMING54)

Offset

Register	Offset
TIMING54	F8h

Diagram



Fields

Field	Function
31-24 SEQ_PIC_CORE_EN_RX_LO	De-assertion time setting for SEQ_PIC_CORE_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_CORE_EN signal or group will transition from HI to LO.
23-16 SEQ_PIC_CORE_EN_RX_HI	Assertion time setting for SEQ_PIC_CORE_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_CORE_EN signal or group will transition from LO to HI.
15-8 SEQ_PIC_CORE_EN_TX_LO	De-assertion time setting for SEQ_PIC_CORE_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_CORE_EN signal or group will transition from HI to LO.
7-0 SEQ_PIC_CORE_EN_TX_HI	Assertion time setting for SEQ_PIC_CORE_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_CORE_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.65 TSM TIMING_55 (TIMING55)

Offset

Register	Offset
TIMING55	FCh

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_PIC_SHORT_CINT_SHORT_EN_RX_LO								SEQ_PIC_SHORT_CINT_SHORT_EN_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_PIC_SHORT_CINT_SHORT_EN_TX_LO								SEQ_PIC_SHORT_CINT_SHORT_EN_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 SEQ_PIC_SHORT_CINT_SHORT_EN_RX_LO	De-assertion time setting for SEQ_PIC_SHORT_CINT_SHORT_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_SHORT_CINT_SHORT_EN signal or group will transition from HI to LO.
23-16 SEQ_PIC_SHORT_CINT_SHORT_EN_RX_HI	Assertion time setting for SEQ_PIC_SHORT_CINT_SHORT_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_SHORT_CINT_SHORT_EN signal or group will transition from LO to HI.
15-8 SEQ_PIC_SHORT_CINT_SHORT_EN_TX_LO	De-assertion time setting for SEQ_PIC_SHORT_CINT_SHORT_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_SHORT_CINT_SHORT_EN signal or group will transition from HI to LO.
7-0 SEQ_PIC_SHORT_CINT_SHORT_EN_TX_HI	Assertion time setting for SEQ_PIC_SHORT_CINT_SHORT_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_SHORT_CINT_SHORT_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.66 TSM TIMING_56 (TIMING56)

Offset

Register	Offset
TIMING56	100h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_PIC_FILTER_LOW_BW_SM_EN_RX_LO								SEQ_PIC_FILTER_LOW_BW_SM_EN_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_PIC_FILTER_LOW_BW_SM_EN_TX_LO								SEQ_PIC_FILTER_LOW_BW_SM_EN_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 SEQ_PIC_FILTER_LOW_BW_SM_EN_RX_LO	De-assertion time setting for SEQ_PIC_FILTER_LOW_BW_SM_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_FILTER_LOW_BW_SM_EN signal or group will transition from HI to LO.
23-16 SEQ_PIC_FILTER_LOW_BW_SM_EN_RX_HI	Assertion time setting for SEQ_PIC_FILTER_LOW_BW_SM_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_FILTER_LOW_BW_SM_EN signal or group will transition from LO to HI.
15-8 SEQ_PIC_FILTER_LOW_BW_SM_EN_TX_LO	De-assertion time setting for SEQ_PIC_FILTER_LOW_BW_SM_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_FILTER_LOW_BW_SM_EN signal or group will transition from HI to LO.
7-0 SEQ_PIC_FILTER_LOW_BW_SM_EN_TX_HI	Assertion time setting for SEQ_PIC_FILTER_LOW_BW_SM_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_FILTER_LOW_BW_SM_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.67 TSM TIMING_57 (TIMING57)

Offset

Register	Offset
TIMING57	104h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_PIC_RFB_OPEN_SM_EN_RX_LO								SEQ_PIC_RFB_OPEN_SM_EN_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_PIC_RFB_OPEN_SM_EN_TX_LO								SEQ_PIC_RFB_OPEN_SM_EN_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 SEQ_PIC_RFB_OPEN_SM_EN_RX_LO	De-assertion time setting for SEQ_PIC_RFB_OPEN_SM_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_RFB_OPEN_SM_EN signal or group will transition from HI to LO.
23-16 SEQ_PIC_RFB_OPEN_SM_EN_RX_HI	Assertion time setting for SEQ_PIC_RFB_OPEN_SM_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_RFB_OPEN_SM_EN signal or group will transition from LO to HI.
15-8 SEQ_PIC_RFB_OPEN_SM_EN_TX_LO	De-assertion time setting for SEQ_PIC_RFB_OPEN_SM_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_RFB_OPEN_SM_EN signal or group will transition from HI to LO.
7-0 SEQ_PIC_RFB_OPEN_SM_EN_TX_HI	Assertion time setting for SEQ_PIC_RFB_OPEN_SM_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_RFB_OPEN_SM_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.68 TSM TIMING_58 (TIMING58)

Offset

Register	Offset
TIMING58	108h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_PIC_RINT2_SHORT_FM_EN_RX_LO								SEQ_PIC_RINT2_SHORT_FM_EN_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_PIC_RINT2_SHORT_FM_EN_TX_LO								SEQ_PIC_RINT2_SHORT_FM_EN_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 SEQ_PIC_RINT2_SHORT_FM_EN_RX_LO	De-assertion time setting for SEQ_PIC_RINT2_SHORT_FM_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_RINT2_SHORT_FM_EN signal or group will transition from HI to LO.
23-16 SEQ_PIC_RINT2_SHORT_FM_EN_RX_HI	Assertion time setting for SEQ_PIC_RINT2_SHORT_FM_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_RINT2_SHORT_FM_EN signal or group will transition from LO to HI.
15-8 SEQ_PIC_RINT2_SHORT_FM_EN_TX_LO	De-assertion time setting for SEQ_PIC_RINT2_SHORT_FM_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_RINT2_SHORT_FM_EN signal or group will transition from HI to LO.
7-0 SEQ_PIC_RINT2_SHORT_FM_EN_TX_HI	Assertion time setting for SEQ_PIC_RINT2_SHORT_FM_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_PIC_RINT2_SHORT_FM_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.69 TSM TIMING_59 (TIMING59)

Offset

Register	Offset
TIMING59	10Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_LODIV_SYNC_RESET_EN_RX_LO								SEQ_LODIV_SYNC_RESET_EN_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_LODIV_SYNC_RESET_EN_TX_LO								SEQ_LODIV_SYNC_RESET_EN_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

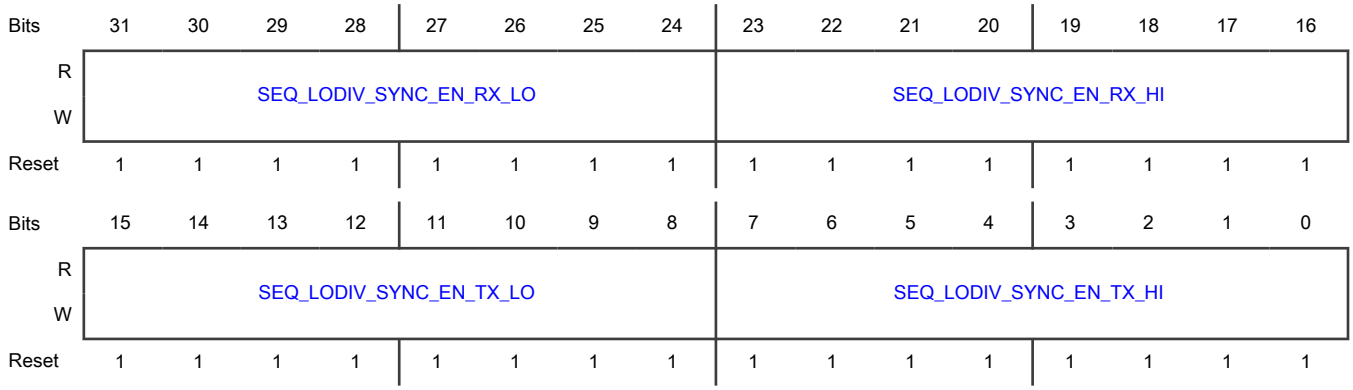
Field	Function
31-24 SEQ_LODIV_SYNC_RESET_EN_RX_LO	De-assertion time setting for SEQ_LODIV_SYNC_RESET_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LODIV_SYNC_RESET_EN signal or group will transition from HI to LO.
23-16 SEQ_LODIV_SYNC_RESET_EN_RX_HI	Assertion time setting for SEQ_LODIV_SYNC_RESET_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LODIV_SYNC_RESET_EN signal or group will transition from LO to HI.
15-8 SEQ_LODIV_SYNC_RESET_EN_TX_LO	De-assertion time setting for SEQ_LODIV_SYNC_RESET_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LODIV_SYNC_RESET_EN signal or group will transition from HI to LO.
7-0 SEQ_LODIV_SYNC_RESET_EN_TX_HI	Assertion time setting for SEQ_LODIV_SYNC_RESET_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LODIV_SYNC_RESET_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.70 TSM TIMING_60 (TIMING60)

Offset

Register	Offset
TIMING60	110h

Diagram



Fields

Field	Function
31-24 SEQ_LODIV_SYNC_EN_RX_LO	De-assertion time setting for SEQ_LODIV_SYNC_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LODIV_SYNC_EN signal or group will transition from HI to LO.
23-16 SEQ_LODIV_SYNC_EN_RX_HI	Assertion time setting for SEQ_LODIV_SYNC_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LODIV_SYNC_EN signal or group will transition from LO to HI.
15-8 SEQ_LODIV_SYNC_EN_TX_LO	De-assertion time setting for SEQ_LODIV_SYNC_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LODIV_SYNC_EN signal or group will transition from HI to LO.
7-0 SEQ_LODIV_SYNC_EN_TX_HI	Assertion time setting for SEQ_LODIV_SYNC_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LODIV_SYNC_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.71 TSM TIMING_61 (TIMING61)

Offset

Register	Offset
TIMING61	114h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_LODIV_SYNC_SPARE_EN_RX_LO								SEQ_LODIV_SYNC_SPARE_EN_RX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_LODIV_SYNC_SPARE_EN_TX_LO								SEQ_LODIV_SYNC_SPARE_EN_TX_HI							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fields

Field	Function
31-24 SEQ_LODIV_SYNC_SPARE_EN_RX_LO	De-assertion time setting for SEQ_LODIV_SYNC_SPARE_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LODIV_SYNC_SPARE_EN signal or group will transition from HI to LO.
23-16 SEQ_LODIV_SYNC_SPARE_EN_RX_HI	Assertion time setting for SEQ_LODIV_SYNC_SPARE_EN (RX) This field sets the point during a TSM RX sequence (the tsm_count[7:0] value) at which the SEQ_LODIV_SYNC_SPARE_EN signal or group will transition from LO to HI.
15-8 SEQ_LODIV_SYNC_SPARE_EN_TX_LO	De-assertion time setting for SEQ_LODIV_SYNC_SPARE_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LODIV_SYNC_SPARE_EN signal or group will transition from HI to LO.
7-0 SEQ_LODIV_SYNC_SPARE_EN_TX_HI	Assertion time setting for SEQ_LODIV_SYNC_SPARE_EN (TX) This field sets the point during a TSM TX sequence (the tsm_count[7:0] value) at which the SEQ_LODIV_SYNC_SPARE_EN signal or group will transition from LO to HI.

52.4.4.2.2.4.3.1.72 TSM OVERRIDE REGISTER 0 (OVRD0)

Offset

Register	Offset
OVRD0	118h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	SEQ_BG_...	SEQ_BG_...	RX_PHY_...	RX_PHY_...	RX_DIG_...	RX_DIG_...	RX_INIT...	RX_INIT...	FREQ_TA...	FREQ_TA...	TX_DIG_...	TX_DIG_...	DCOC_CA...	DCOC_CA...	SIGMA_D...	SIGMA_D...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	PLL_DIG...	PLL_DIG...	LDO_CAL...	LDO_CAL...	DCOC_GA...	DCOC_GA...	TSM_IRQ...	TSM_IRQ...	TSM_IRQ...	TSM_IRQ...	TSM_RF_...	TSM_RF_...	TSM_RF_...	TSM_RF_...	TSM_RF_...	TSM_RF_...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 SEQ_BG_PUP_IBG_CAL_OVRD	Override value for SEQ_BG_PUP_IBG_CAL When SEQ_BG_PUP_IBG_CAL_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_bg_pup_ibg_cal". This bit is ignored when SEQ_BG_PUP_IBG_CAL_OVRD_EN==0.
30 SEQ_BG_PUP_IBG_CAL_OVRD_EN	Override control for SEQ_BG_PUP_IBG_CAL 0b - Normal operation. 1b - Use the state of SEQ_BG_PUP_IBG_CAL_OVRD to override the signal "seq_bg_pup_ibg_cal".
29 RX_PHY_EN_OVRD	Override value for RX_PHY_EN When RX_PHY_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "rx_phy_en". This bit is ignored when RX_PHY_EN_OVRD_EN==0.
28 RX_PHY_EN_OVRD_EN	Override control for RX_PHY_EN 0b - Normal operation. 1b - Use the state of RX_PHY_EN_OVRD to override the signal "rx_phy_en".
27 RX_DIG_EN_OVRD	Override value for RX_DIG_EN When RX_DIG_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "rx_dig_en". This bit is ignored when RX_DIG_EN_OVRD_EN==0.
26 RX_DIG_EN_OVRD_EN	Override control for RX_DIG_EN 0b - Normal operation. 1b - Use the state of RX_DIG_EN_OVRD to override the signal "rx_dig_en".
25 RX_INIT_EN_OVRD	Override value for RX_INIT_EN When RX_INIT_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "rx_init_en". This bit is ignored when RX_INIT_EN_OVRD_EN==0.

Table continues on the next page...

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Field	Function
24 RX_INIT_EN_OVRD_EN	Override control for RX_INIT_EN 0b - Normal operation. 1b - Use the state of RX_INIT_EN_OVRD to override the signal "rx_init_en".
23 FREQ_TARG_LD_EN_OVRD	Override value for FREQ_TARG_LD_EN When FREQ_TARG_LD_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "freq_targ_ld_en". This bit is ignored when FREQ_TARG_LD_EN_OVRD_EN==0.
22 FREQ_TARG_LD_EN_OVRD_EN	Override control for FREQ_TARG_LD_EN 0b - Normal operation. 1b - Use the state of FREQ_TARG_LD_EN_OVRD to override the signal "freq_targ_ld_en".
21 TX_DIG_EN_OVRD	Override value for TX_DIG_EN When TX_DIG_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "tx_dig_en". This bit is ignored when TX_DIG_EN_OVRD_EN==0.
20 TX_DIG_EN_OVRD_EN	Override control for TX_DIG_EN 0b - Normal operation. 1b - Use the state of TX_DIG_EN_OVRD to override the signal "tx_dig_en".
19 DCOC_CAL_EN_OVRD	Override value for DCOC_CAL_EN When DCOC_CAL_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "dcoc_cal_en". This bit is ignored when DCOC_CAL_EN_OVRD_EN==0.
18 DCOC_CAL_EN_OVRD_EN	Override control for DCOC_CAL_EN 0b - Normal operation. 1b - Use the state of DCOC_CAL_EN_OVRD to override the signal "dcoc_cal_en".
17 SIGMA_DELTA_EN_OVRD	Override value for SIGMA_DELTA_EN When SIGMA_DELTA_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "sigma_delta_en". This bit is ignored when SIGMA_DELTA_EN_OVRD_EN==0.
16 SIGMA_DELTA_EN_OVRD_EN	Override control for SIGMA_DELTA_EN 0b - Normal operation. 1b - Use the state of SIGMA_DELTA_EN_OVRD to override the signal "sigma_delta_en".
15 PLL_DIG_EN_OVRD	Override value for PLL_DIG_EN When PLL_DIG_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "pll_dig_en". This bit is ignored when PLL_DIG_EN_OVRD_EN==0.
14	Override control for PLL_DIG_EN 0b - Normal operation.

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Field	Function
PLL_DIG_EN_OVRD_EN	1b - Use the state of PLL_DIG_EN_OVRD to override the signal "pll_dig_en".
13 LDO_CAL_EN_OVRD	Override value for LDO_CAL_EN When LDO_CAL_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "ldo_cal_en". This bit is ignored when LDO_CAL_EN_OVRD_EN==0.
12 LDO_CAL_EN_OVRD_EN	Override control for LDO_CAL_EN 0b - Normal operation. 1b - Use the state of LDO_CAL_EN_OVRD to override the signal "ldo_cal_en".
11 DCOC_GAIN_CFG_EN_OVRD	Override value for DCOC_GAIN_CFG_EN When DCOC_GAIN_CFG_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "dcoc_gain_cfg_en". This bit is ignored when DCOC_GAIN_CFG_EN_OVRD_EN==0.
10 DCOC_GAIN_CFG_EN_OVRD_EN	Override control for DCOC_GAIN_CFG_EN 0b - Normal operation. 1b - Use the state of DCOC_GAIN_CFG_EN_OVRD to override the signal "dcoc_gain_cfg_en".
9 TSM_IRQ1_STOP_TRIG_OVRD	Override value for TSM_IRQ1_STOP_TRIG When TSM_IRQ1_STOP_TRIG_OVRD_EN=1, this value overrides the mission mode state of the signal "tsm_irq1_stop_trig". This bit is ignored when TSM_IRQ1_STOP_TRIG_OVRD_EN==0.
8 TSM_IRQ1_STOP_TRIG_OVRD_EN	Override control for TSM_IRQ1_STOP_TRIG 0b - Normal operation. 1b - Use the state of TSM_IRQ1_STOP_TRIG_OVRD to override the signal "tsm_irq1_stop_trig".
7 TSM_IRQ0_START_TRIG_OVRD	Override value for TSM_IRQ0_START_TRIG When TSM_IRQ0_START_TRIG_OVRD=1, this value overrides the mission mode state of the signal "tsm_irq0_start_trig". This bit is ignored when TSM_IRQ0_START_TRIG_OVRD==0.
6 TSM_IRQ0_START_TRIG_OVRD_EN	Override control for TSM_IRQ0_START_TRIG 0b - Normal operation. 1b - Use the state of TSM_IRQ0_START_TRIG_OVRD to override the signal "tsm_irq0_start_trig".
5 TSM_RF_PRIORITY_OVRD	Override value for TSM_RF_PRIORITY When TSM_RF_PRIORITY_OVRD_EN=1, this value overrides the mission mode state of the signal "tsm_rf_priority". This bit is ignored when TSM_RF_PRIORITY_OVRD_EN==0.
4	Override control for TSM_RF_PRIORITY

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Field	Function
TSM_RF_PRIORITY_OVRD_EN	0b - Normal operation. 1b - Use the state of TSM_RF_PRIORITY_OVRD to override the signal "tsm_rf_priority".
3 TSM_RF_STATUS_OVRD	Override value for TSM_RF_STATUS When TSM_RF_STATUS_OVRD_EN=1, this value overrides the mission mode state of the signal "tsm_rf_status". This bit is ignored when TSM_RF_STATUS_OVRD_EN==0.
2 TSM_RF_STATUS_OVRD_EN	Override control for TSM_RF_STATUS 0b - Normal operation. 1b - Use the state of TSM_RF_STATUS_OVRD to override the signal "tsm_rf_status".
1 TSM_RF_ACTIVE_OVRD	Override value for TSM_RF_ACTIVE When TSM_RF_ACTIVE_OVRD_EN=1, this value overrides the mission mode state of the signal "tsm_rf_active". This bit is ignored when TSM_RF_ACTIVE_OVRD_EN==0.
0 TSM_RF_ACTIVE_OVRD_EN	Override control for TSM_RF_ACTIVE 0b - Normal operation. 1b - Use the state of TSM_RF_ACTIVE_OVRD to override the signal "tsm_rf_active".

52.4.4.2.2.4.3.1.73 TSM OVERRIDE REGISTER 1 (OVRD1)

Offset

Register	Offset
OVRD1	11Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_BG_...	SEQ_BG_...	SEQ_BG_...	SEQ_BG_...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_BG_...	SEQ_BG_...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...	SEQ_LDO...
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 SEQ_BG_PUP_IBG_ANT_OVRD	Override value for SEQ_BG_PUP_IBG_ANT When SEQ_BG_PUP_IBG_ANT_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_bg_pup_ibg_ant". This bit is ignored when SEQ_BG_PUP_IBG_ANT_OVRD_EN==0.
30 SEQ_BG_PUP_IBG_ANT_OVRD_EN	Override control for SEQ_BG_PUP_IBG_ANT 0b - Normal operation. 1b - Use the state of SEQ_BG_PUP_IBG_ANT_OVRD to override the signal "seq_bg_pup_ibg_ant".
29 SEQ_BG_PUP_OVRD	Override value for SEQ_BG_PUP When SEQ_BG_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_bg_pup". This bit is ignored when SEQ_BG_PUP_OVRD_EN==0.
28 SEQ_BG_PUP_OVRD_EN	Override control for SEQ_BG_PUP 0b - Normal operation. 1b - Use the state of SEQ_BG_PUP_OVRD to override the signal "seq_bg_pup".
27 SEQ_LDO_LV_PUP_OVRD	Override value for SEQ_LDO_LV_PUP When SEQ_LDO_LV_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_ldo_lv_pup". This bit is ignored when SEQ_LDO_LV_PUP_OVRD_EN==0.
26 SEQ_LDO_LV_PUP_OVRD_EN	Override control for SEQ_LDO_LV_PUP 0b - Normal operation. 1b - Use the state of SEQ_LDO_LV_PUP_OVRD to override the signal "seq_ldo_lv_pup".
25 SEQ_LDO_RXTXLF_PUP_OVRD	Override value for SEQ_LDO_RXTXLF_PUP When SEQ_LDO_RXTXLF_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_ldo_rxtxlf_pup". This bit is ignored when SEQ_LDO_RXTXLF_PUP_OVRD_EN==0.
24 SEQ_LDO_RXTXLF_PUP_OVRD_EN	Override control for SEQ_LDO_RXTXLF_PUP 0b - Normal operation. 1b - Use the state of SEQ_LDO_RXTXLF_PUP_OVRD to override the signal "seq_ldo_rxtxlf_pup".
23 SEQ_LDO_RXTXHF_PUP_OVRD	Override value for SEQ_LDO_RXTXHF_PUP When SEQ_LDO_RXTXHF_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_ldo_rxtxhf_pup". This bit is ignored when SEQ_LDO_RXTXHF_PUP_OVRD_EN==0.
22	Override control for SEQ_LDO_RXTXHF_PUP

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Field	Function
SEQ_LDO_RXTXHF_PUP_OVRD_EN	0b - Normal operation. 1b - Use the state of SEQ_LDO_RXTXHF_PUP_OVRD to override the signal "seq_ldo_rxtxhf_pup".
21 SEQ_LDO_XO_DIST_PUP_OVRD	Override value for SEQ_LDO_XO_DIST_PUP When SEQ_LDO_XO_DIST_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_ldo_xo_dist_pup". This bit is ignored when SEQ_LDO_XO_DIST_PUP_OVRD_EN==0.
20 SEQ_LDO_XO_DIST_PUP_OVRD_EN	Override control for SEQ_LDO_XO_DIST_PUP 0b - Normal operation. 1b - Use the state of SEQ_LDO_XO_DIST_PUP_OVRD to override the signal "seq_ldo_xo_dist_pup".
19 SEQ_LDO_VCO_PUP_OVRD	Override value for SEQ_LDO_VCO_PUP When SEQ_LDO_VCO_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_ldo_vco_pup". This bit is ignored when SEQ_LDO_VCO_PUP_OVRD_EN==0.
18 SEQ_LDO_VCO_PUP_OVRD_EN	Override control for SEQ_LDO_VCO_PUP 0b - Normal operation. 1b - Use the state of SEQ_LDO_VCO_PUP_OVRD to override the signal "seq_ldo_vco_pup".
17 SEQ_LDO_PLL_PUP_OVRD	Override value for SEQ_LDO_PLL_PUP When SEQ_LDO_PLL_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_ldo_pll_pup". This bit is ignored when SEQ_LDO_PLL_PUP_OVRD_EN==0.
16 SEQ_LDO_PLL_PUP_OVRD_EN	Override control for SEQ_LDO_PLL_PUP 0b - Normal operation. 1b - Use the state of SEQ_LDO_PLL_PUP_OVRD to override the signal "seq_ldo_pll_pup".
15 SEQ_LDO_ANT_PUP_OVRD	Override value for SEQ_LDO_ANT_PUP When SEQ_LDO_ANT_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_ldo_ant_pup". This bit is ignored when SEQ_LDO_ANT_PUP_OVRD_EN==0.
14 SEQ_LDO_ANT_PUP_OVRD_EN	Override control for SEQ_LDO_ANT_PUP 0b - Normal operation. 1b - Use the state of SEQ_LDO_ANT_PUP_OVRD to override the signal "seq_ldo_ant_pup".
13 SEQ_LDO_RXTXLF_FC_OVRD	Override value for SEQ_LDO_RXTXLF_FC When SEQ_LDO_RXTXLF_FC_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_ldo_rxtxlf_fc". This bit is ignored when SEQ_LDO_RXTXLF_FC_OVRD_EN==0.

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Field	Function
12 SEQ_LDO_RXTXLF_FC_OVRD_EN	Override control for SEQ_LDO_RXTXLF_FC 0b - Normal operation. 1b - Use the state of SEQ_LDO_RXTXLF_FC_OVRD to override the signal "seq_ldo_rxtxlf_fc".
11 SEQ_LDO_RXTXHF_FC_OVRD	Override value for SEQ_LDO_RXTXHF_FC When SEQ_LDO_RXTXHF_FC_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_ldo_rxtxhf_fc". This bit is ignored when SEQ_LDO_RXTXHF_FC_OVRD_EN==0.
10 SEQ_LDO_RXTXHF_FC_OVRD_EN	Override control for SEQ_LDO_RXTXHF_FC 0b - Normal operation. 1b - Use the state of SEQ_LDO_RXTXHF_FC_OVRD to override the signal "seq_ldo_rxtxhf_fc".
9 SEQ_LDO_VCO_FC_OVRD	Override value for SEQ_LDO_VCO_FC When SEQ_LDO_VCO_FC_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_ldo_vco_fc". This bit is ignored when SEQ_LDO_VCO_FC_OVRD_EN==0.
8 SEQ_LDO_VCO_FC_OVRD_EN	Override control for SEQ_LDO_VCO_FC 0b - Normal operation. 1b - Use the state of SEQ_LDO_VCO_FC_OVRD to override the signal "seq_ldo_vco_fc".
7 SEQ_LDO_PLL_FC_OVRD	Override value for SEQ_LDO_PLL_FC When SEQ_LDO_PLL_FC_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_ldo_pll_fc". This bit is ignored when SEQ_LDO_PLL_FC_OVRD_EN==0.
6 SEQ_LDO_PLL_FC_OVRD_EN	Override control for SEQ_LDO_PLL_FC 0b - Normal operation. 1b - Use the state of SEQ_LDO_PLL_FC_OVRD to override the signal "seq_ldo_pll_fc".
5 SEQ_BG_FC_OVRD	Override value for SEQ_BG_FC When SEQ_BG_FC_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_bg_fc". This bit is ignored when SEQ_BG_FC_OVRD_EN==0.
4 SEQ_BG_FC_OVRD_EN	Override control for SEQ_BG_FC 0b - Normal operation. 1b - Use the state of SEQ_BG_FC_OVRD to override the signal "seq_bg_fc".
3 SEQ_LDO_CAL_PUP_OVRD	Override value for SEQ_LDO_CAL_PUP When SEQ_LDO_CAL_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_ldo_cal_pup". This bit is ignored when SEQ_LDO_CAL_PUP_OVRD_EN==0.
2	Override control for SEQ_LDO_CAL_PUP

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Field	Function
SEQ_LDO_CAL_PUP_OVRD_EN	0b - Normal operation. 1b - Use the state of SEQ_LDO_CAL_PUP_OVRD to override the signal "seq_ldo_cal_pup".
1 SEQ_LDOTRIM_PUP_OVRD	Override value for SEQ_LDOTRIM_PUP When SEQ_LDOTRIM_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_ldotrim_pup". This bit is ignored when SEQ_LDOTRIM_PUP_OVRD_EN==0.
0 SEQ_LDOTRIM_PUP_OVRD_EN	Override control for SEQ_LDOTRIM_PUP 0b - Normal operation. 1b - Use the state of SEQ_LDOTRIM_PUP_OVRD to override the signal "seq_ldotrim_pup".

52.4.4.2.2.4.3.1.74 TSM OVERRIDE REGISTER 2 (OVRD2)

Offset

Register	Offset
OVRD2	120h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	SEQ_LO_...	SEQ_LO_...	SEQ_LO_...	SEQ_LO_...	SEQ_VCO...	SEQ_VCO...	SEQ_DAC...	SEQ_DAC...	SEQ_XO_...	SEQ_XO_...	SEQ_XO_...	SEQ_XO_...	SEQ_XO_...	SEQ_XO_...	SEQ_XO_...	SEQ_XO_...
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_VCO...	SEQ_VCO...	SEQ_PD_...	SEQ_PD_...	SEQ_PD_...	SEQ_PD_...	SEQ_RCC...	SEQ_RCC...	SEQ_TSM...	SEQ_TSM...	SEQ_BG_...	SEQ_BG_...	SEQ_BG_...	SEQ_BG_...	SEQ_BG_...	SEQ_BG_...
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 SEQ_LO_PUP_VLO_RXDRV_OVRD	Override value for SEQ_LO_PUP_VLO_RXDRV When SEQ_LO_PUP_VLO_RXDRV_OVRD=1, this value overrides the mission mode state of the signal "seq_lo_pup_vlo_rxdrv". This bit is ignored when SEQ_LO_PUP_VLO_RXDRV_OVRD==0.
30	Override control for SEQ_LO_PUP_VLO_RXDRV

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Field	Function
SEQ_LO_PUP_VLO_RXDRV_OVRD_EN	0b - Normal operation. 1b - Use the state of SEQ_LO_PUP_VLO_RXDRV_OVRD to override the signal "seq_lo_pup_vlo_rxdrv".
29 SEQ_LO_PUP_VLO_FBK_OVRD	Override value for SEQ_LO_PUP_VLO_FBK When SEQ_LO_PUP_VLO_FBK_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_lo_pup_vlo_fbk". This bit is ignored when SEQ_LO_PUP_VLO_FBK_OVRD_EN==0.
28 SEQ_LO_PUP_VLO_FBK_OVRD_EN	Override control for SEQ_LO_PUP_VLO_FBK 0b - Normal operation. 1b - Use the state of SEQ_LO_PUP_VLO_FBK_OVRD to override the signal "seq_lo_pup_vlo_fbk".
27 SEQ_VCO_EN_HPM_OVRD	Override value for SEQ_VCO_EN_HPM When SEQ_VCO_EN_HPM_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_vco_en_hpm". This bit is ignored when SEQ_VCO_EN_HPM_OVRD_EN==0.
26 SEQ_VCO_EN_HPM_OVRD_EN	Override control for SEQ_VCO_EN_HPM 0b - Normal operation. 1b - Use the state of SEQ_VCO_EN_HPM_OVRD to override the signal "seq_vco_en_hpm".
25 SEQ_DAC_PUP_OVRD	Override value for SEQ_DAC_PUP When SEQ_DAC_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_dac_pup". This bit is ignored when SEQ_DAC_PUP_OVRD_EN==0.
24 SEQ_DAC_PUP_OVRD_EN	Override control for SEQ_DAC_PUP 0b - Normal operation. 1b - Use the state of SEQ_DAC_PUP_OVRD to override the signal "seq_dac_pup".
23 SEQ_XO_DIST_EN_CLK_ADCDAC_OVRD	Override value for SEQ_XO_DIST_EN_CLK_ADCDAC When SEQ_XO_DIST_EN_CLK_ADCDAC_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_xo_dist_en_clk_adcdac". This bit is ignored when SEQ_XO_DIST_EN_CLK_ADCDAC_OVRD_EN==0.
22 SEQ_XO_DIST_EN_CLK_ADCDAC_OVRD_EN	Override control for SEQ_XO_DIST_EN_CLK_ADCDAC 0b - Normal operation. 1b - Use the state of SEQ_XO_DIST_EN_CLK_ADCDAC_OVRD_EN to override the signal "seq_xo_dist_en_clk_adcdac".
21	Override value for SEQ_XO_EN_CLK_2P4G

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Field	Function
SEQ_XO_EN_CLK_2P4G_OVRD	When SEQ_XO_EN_CLK_2P4G_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_xo_en_clk_2p4g". This bit is ignored when SEQ_XO_EN_CLK_2P4G_OVRD_EN==0.
20 SEQ_XO_EN_CLK_2P4G_OVRD_EN	Override control for SEQ_XO_EN_CLK_2P4G 0b - Normal operation. 1b - Use the state of SEQ_XO_EN_CLK_2P4G_OVRD to override the signal "seq_xo_en_clk_2p4g".
19 SEQ_XO_DIST_EN_CLK_REF_OVRD	Override value for SEQ_XO_DIST_EN_CLK_REF When SEQ_XO_DIST_EN_CLK_REF_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_xo_dist_en_clk_ref". This bit is ignored when SEQ_XO_DIST_EN_CLK_REF_OVRD_EN==0.
18 SEQ_XO_DIST_EN_CLK_REF_OVRD_EN	Override control for SEQ_XO_DIST_EN_CLK_REF 0b - Normal operation. 1b - Use the state of SEQ_XO_DIST_EN_CLK_REF_OVRD to override the signal "seq_xo_dist_en_clk_ref".
17 SEQ_XO_DIST_EN_OVRD	Override value for SEQ_XO_DIST_EN When SEQ_XO_DIST_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_xo_dist_en". This bit is ignored when SEQ_XO_DIST_EN_OVRD_EN==0.
16 SEQ_XO_DIST_EN_OVRD_EN	Override control for SEQ_XO_DIST_EN 0b - Normal operation. 1b - Use the state of SEQ_XO_DIST_EN_OVRD to override the signal "seq_xo_dist_en".
15 SEQ_VCO_PUP_OVRD	Override value for SEQ_VCO_PUP When SEQ_VCO_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_vco_pup". This bit is ignored when SEQ_VCO_PUP_OVRD_EN==0.
14 SEQ_VCO_PUP_OVRD_EN	Override control for SEQ_VCO_PUP 0b - Normal operation. 1b - Use the state of SEQ_VCO_PUP_OVRD to override the signal "seq_vco_pup".
13 SEQ_PD_PUP_OVRD	Override value for SEQ_PD_PUP When SEQ_PD_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_pd_pup". This bit is ignored when SEQ_PD_PUP_OVRD_EN==0.
12 SEQ_PD_PUP_OVRD_EN	Override control for SEQ_PD_PUP 0b - Normal operation. 1b - Use the state of SEQ_PD_PUP_OVRD to override the signal "seq_pd_pup".
11	Override value for SEQ_PD_EN_FCAL_BIAS

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Field	Function
SEQ_PD_EN_FCAL_BIAS_OVRD	When SEQ_PD_EN_FCAL_BIAS_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_pd_en_fcal_bias". This bit is ignored when SEQ_PD_EN_FCAL_BIAS_OVRD_EN==0.
10 SEQ_PD_EN_FCAL_BIAS_OVRD_EN	Override control for SEQ_PD_EN_FCAL_BIAS 0b - Normal operation. 1b - Use the state of SEQ_PD_EN_FCAL_BIAS_OVRD to override the signal "seq_pd_en_fcal_bias".
9 SEQ_RCCAL_PUP_OVRD	Override value for SEQ_RCCAL_PUP When SEQ_RCCAL_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "rx_rccal_pup". This bit is ignored when SEQ_RCCAL_PUP_OVRD_EN==0.
8 SEQ_RCCAL_PUP_OVRD_EN	Override control for SEQ_RCCAL_PUP 0b - Normal operation. 1b - Use the state of SEQ_RCCAL_PUP_OVRD to override the signal "rx_rccal_pup".
7 SEQ_TSM_ISO_B_2P4GHZ_OVRD	Override value for SEQ_TSM_ISO_B_2P4GHZ When SEQ_TSM_ISO_B_2P4GHZ_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_tsm_iso_b_2p4ghz". This bit is ignored when SEQ_TSM_ISO_B_2P4GHZ_OVRD_EN==0.
6 SEQ_TSM_ISO_B_2P4GHZ_OVRD_EN	Override control for SEQ_TSM_ISO_B_2P4GHZ 0b - Normal operation. 1b - Use the state of SEQ_TSM_ISO_B_2P4GHZ_OVRD to override the signal "seq_tsm_iso_b_2p4ghz".
5 SEQ_BG_PUP_IBG_RX_OVRD	Override value for SEQ_BG_PUP_IBG_RX When SEQ_BG_PUP_IBG_RX_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_bg_pup_ibg_rx". This bit is ignored when SEQ_BG_PUP_IBG_RX_OVRD_EN==0.
4 SEQ_BG_PUP_IBG_RX_OVRD_EN	Override control for SEQ_BG_PUP_IBG_RX 0b - Normal operation. 1b - Use the state of SEQ_BG_PUP_IBG_RX_OVRD to override the signal "seq_bg_pup_ibg_rx".
3 SEQ_BG_PUP_IBG_TX_OVRD	Override value for SEQ_BG_PUP_IBG_TX When SEQ_BG_PUP_IBG_TX_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_bg_pup_ibg_tx". This bit is ignored when SEQ_BG_PUP_IBG_TX_OVRD_EN==0.
2 SEQ_BG_PUP_IBG_TX_OVRD_EN	Override control for SEQ_BG_PUP_IBG_TX 0b - Normal operation. 1b - Use the state of SEQ_BG_PUP_IBG_TX_OVRD to override the signal "seq_bg_pup_ibg_tx".

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Field	Function
1 SEQ_BG_PUP_IBG_XO_DIST_OVRD	Override value for SEQ_BG_PUP_IBG_XO_DIST When SEQ_BG_PUP_IBG_XO_DIST_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_bg_pup_ibg_xo_dist". This bit is ignored when SEQ_BG_PUP_IBG_XO_DIST_OVRD_EN==0.
0 SEQ_BG_PUP_IBG_XO_DIST_OVRD_EN	Override control for SEQ_BG_PUP_IBG_XO_DIST 0b - Normal operation. 1b - Use the state of SEQ_BG_PUP_IBG_XO_DIST_OVRD to override the signal "seq_bg_pup_ibg_xo_dist".

52.4.4.2.2.4.3.1.75 TSM OVERRIDE REGISTER 3 (OVRD3)

Offset

Register	Offset
OVRD3	124h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	GEAR_SH...	GEAR_SH...	RX_MODE...	RX_MODE...	TX_MODE...	TX_MODE...	SEQ_SPA...	SEQ_SPA...	SEQ_SPA...	SEQ_SPA...	SEQ_RX_...	SEQ_RX_...	SEQ_CBP...	SEQ_CBP...	SEQ_ADC...	SEQ_ADC...
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SEQ_RX_...	SEQ_RX_...	SEQ_CBP...	SEQ_CBP...	SEQ_PD_...	SEQ_PD_...	SEQ_DIV...	SEQ_DIV...	SEQ_DIV...	SEQ_DIV...	SEQ_LO_...	SEQ_LO_...	SEQ_LO_...	SEQ_LO_...	SEQ_LO_...	SEQ_LO_...
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 GEAR_SHIFT_OVRD	Override value for GEAR_SHIFT When GEAR_SHIFT_OVRD_EN=1, this value overrides the mission mode state of the signal "gear_shift". This bit is ignored when GEAR_SHIFT_OVRD_EN==0.
30 GEAR_SHIFT_OVRD_EN	Override control for GEAR_SHIFT 0b - Normal operation. 1b - Use the state of GEAR_SHIFT_OVRD to override the signal "gear_shift".

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Field	Function
29 RX_MODE_OVRD	Override value for RX_MODE When RX_MODE_OVRD_EN=1, this value overrides the mission mode state of the signal "rx_mode". This bit is ignored when RX_MODE_OVRD_EN==0.
28 RX_MODE_OVRD_EN	Override control for RX_MODE 0b - Normal operation. 1b - Use the state of RX_MODE_OVRD to override the signal "rx_mode".
27 TX_MODE_OVRD	Override value for TX_MODE When TX_MODE_OVRD_EN=1, this value overrides the mission mode state of the signal "tx_mode". This bit is ignored when TX_MODE_OVRD_EN==0.
26 TX_MODE_OVRD_EN	Override control for TX_MODE 0b - Normal operation. 1b - Use the state of TX_MODE_OVRD to override the signal "tx_mode".
25 SEQ_SPARE3_OVRD	Override value for SEQ_SPARE3 When SEQ_SPARE3_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_spare3". This bit is ignored when SEQ_SPARE3_OVRD_EN==0.
24 SEQ_SPARE3_OVRD_EN	Override control for SEQ_SPARE3 0b - Normal operation. 1b - Use the state of SEQ_SPARE3_OVRD to override the signal "seq_spare3".
23 SEQ_SPARE1_OVRD	Override value for SEQ_SPARE1 When SEQ_SPARE1_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_spare1". This bit is ignored when SEQ_SPARE1_OVRD_EN==0.
22 SEQ_SPARE1_OVRD_EN	Override control for SEQ_SPARE1 0b - Normal operation. 1b - Use the state of SEQ_SPARE1_OVRD to override the signal "seq_spare1".
21 SEQ_RX_MIX_PUP_OVRD	Override control for SEQ_RX_MIX_PUP 0b - Normal operation. 1b - Use the state of SEQ_RX_MIX_PUP_OVRD to override the signal "seq_rx_mix_pup".
20 SEQ_RX_MIX_PUP_OVRD_EN	Override control for SEQ_RX_MIX_PUP 0b - Normal operation. 1b - Use the state of SEQ_RX_MIX_PUP_OVRD to override the signal "seq_rx_mix_pup".
19	Override value for SEQ_CBPF_PUP

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Field	Function
SEQ_CBPF_PUP_OVRD	When SEQ_CBPF_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_cbpf_pup". This bit is ignored when SEQ_CBPF_PUP_OVRD_EN==0.
18 SEQ_CBPF_PUP_OVRD_EN	Override control for SEQ_CBPF_PUP 0b - Normal operation. 1b - Use the state of SEQ_CBPF_PUP_OVRD to override the signal "seq_cbpf_pup".
17 SEQ_ADC_PUP_OVRD	Override value for SEQ_ADC_PUP When SEQ_ADC_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_adc_pup". This bit is ignored when SEQ_ADC_PUP_OVRD_EN==0.
16 SEQ_ADC_PUP_OVRD_EN	Override control for SEQ_ADC_PUP 0b - Normal operation. 1b - Use the state of SEQ_ADC_PUP_OVRD to override the signal "seq_adc_pup".
15 SEQ_RX_LNA_PUP_OVRD	Override value for SEQ_RX_LNA_PUP When SEQ_RX_LNA_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_rx_lna_pup". This bit is ignored when SEQ_RX_LNA_PUP_OVRD_EN==0.
14 SEQ_RX_LNA_PUP_OVRD_EN	Override control for SEQ_RX_LNA_PUP 0b - Normal operation. 1b - Use the state of SEQ_RX_LNA_PUP_OVRD to override the signal "seq_rx_lna_pup".
13 SEQ_CBPF_EN_DCOC_OVRD	Override value for SEQ_CBPF_EN_DCOC When SEQ_CBPF_EN_DCOC_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_cbpf_en_dcoc". This bit is ignored when SEQ_CBPF_EN_DCOC_OVRD_EN==0.
12 SEQ_CBPF_EN_DCOC_OVRD_EN	Override control for SEQ_CBPF_EN_DCOC 0b - Normal operation. 1b - Use the state of SEQ_CBPF_EN_DCOC_OVRD to override the signal "seq_cbpf_en_dcoc".
11 SEQ_PD_EN_PD_DRV_OVRD	Override value for SEQ_PD_EN_PD_DRV When SEQ_PD_EN_PD_DRV_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_pd_en_pd_drv". This bit is ignored when SEQ_PD_EN_PD_DRV_OVRD_EN==0.
10 SEQ_PD_EN_PD_DRV_OVRD_EN	Override control for SEQ_PD_EN_PD_DRV 0b - Normal operation. 1b - Use the state of SEQ_PD_EN_PD_DRV_OVRD to override the signal "seq_pd_en_pd_drv".
9	Override value for SEQ_DIVN_OPENLOOP

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Field	Function
SEQ_DIVN_OPENLOOP_OVRD	When SEQ_DIVN_OPENLOOP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_divn_openloop". This bit is ignored when SEQ_DIVN_OPENLOOP_OVRD_EN==0.
8 SEQ_DIVN_OPENLOOP_OVRD_EN	Override control for SEQ_DIVN_OPENLOOP 0b - Normal operation. 1b - Use the state of SEQ_DIVN_OPENLOOP_OVRD to override the signal "seq_divn_openloop".
7 SEQ_DIVN_PUP_OVRD	Override value for SEQ_DIVN_PUP When SEQ_DIVN_PUP_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_divn_pup". This bit is ignored when SEQ_DIVN_PUP_OVRD_EN==0.
6 SEQ_DIVN_PUP_OVRD_EN	Override control for SEQ_DIVN_PUP 0b - Normal operation. 1b - Use the state of SEQ_DIVN_PUP_OVRD to override the signal "seq_divn_pup".
5 SEQ_LO_PUP_VLO_TXDRV_OVRD	Override value for SEQ_LO_PUP_VLO_TXDRV When SEQ_LO_PUP_VLO_TXDRV_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_lo_pup_vlo_txdrv". This bit is ignored when SEQ_LO_PUP_VLO_TXDRV_OVRD_EN==0.
4 SEQ_LO_PUP_VLO_TXDRV_OVRD_EN	Override control for SEQ_LO_PUP_VLO_TXDRV 0b - Normal operation. 1b - Use the state of SEQ_LO_PUP_VLO_TXDRV_OVRD to override the signal "seq_lo_pup_vlo_txdrv".
3 SEQ_LO_PUP_VLO_TX_OVRD	Override value for SEQ_LO_PUP_VLO_TX When SEQ_LO_PUP_VLO_TX_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_lo_pup_vlo_tx". This bit is ignored when SEQ_LO_PUP_VLO_TX_OVRD_EN==0.
2 SEQ_LO_PUP_VLO_TX_OVRD_EN	Override control for SEQ_LO_PUP_VLO_TX 0b - Normal operation. 1b - Use the state of SEQ_LO_PUP_VLO_TX_OVRD to override the signal "seq_lo_pup_vlo_tx".
1 SEQ_LO_PUP_VLO_RX_OVRD	Override value for SEQ_LO_PUP_VLO_RX When SEQ_LO_PUP_VLO_RX_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_lo_pup_vlo_rx". This bit is ignored when SEQ_LO_PUP_VLO_RX_OVRD_EN==0.
0	Override control for SEQ_LO_PUP_VLO_RX 0b - Normal operation. 1b - Use the state of SEQ_LO_PUP_VLO_RX_OVRD to override the signal "seq_lo_pup_vlo_rx".

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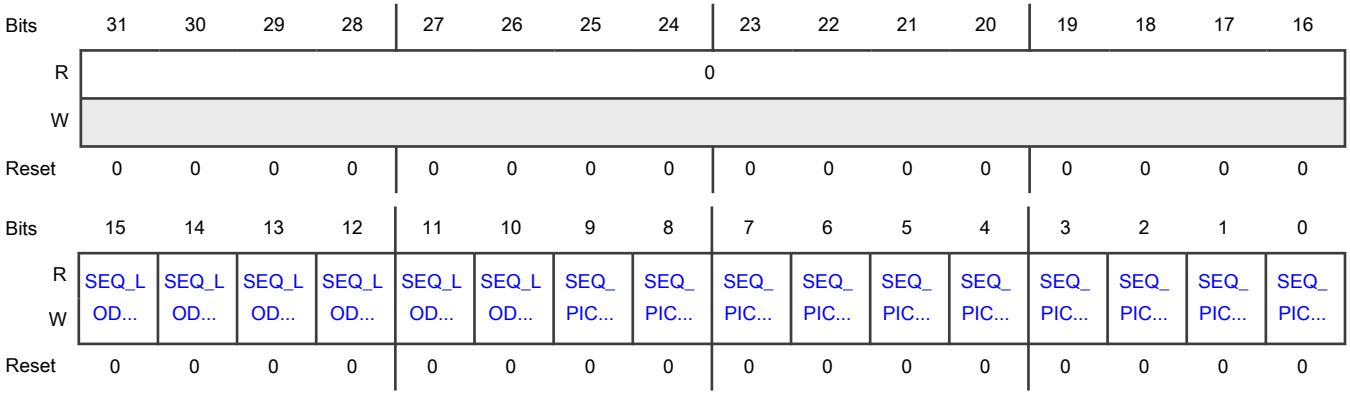
Field	Function
SEQ_LO_PUP_VLO_RX_OVRD_EN	

52.4.4.2.2.4.3.1.76 TSM OVERRIDE REGISTER 4 (OVRD4)

Offset

Register	Offset
OVRD4	128h

Diagram



Fields

Field	Function
31-16 —	Reserved
15 SEQ_LODIV_SYNC_SPARE_EN_OVRD	Override value for SEQ_LODIV_SYNC_SPARE_EN When SEQ_LODIV_SYNC_SPARE_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_lodiv_sync_spare_en". This bit is ignored when SEQ_LODIV_SYNC_SPARE_EN_OVRD_EN==0.
14 SEQ_LODIV_SYNC_SPARE_EN_OVRD_EN	Override control for SEQ_LODIV_SYNC_SPARE_EN 0b - Normal operation. 1b - Use the state of SEQ_LODIV_SYNC_SPARE_EN_OVRD to override the signal "seq_lodiv_sync_spare_en".
13	Override value for SEQ_LODIV_SYNC_EN

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Field	Function
SEQ_LODIV_SYNC_EN_OVRD	When SEQ_LODIV_SYNC_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_lodiv_sync_en". This bit is ignored when SEQ_LODIV_SYNC_EN_OVRD_EN==0.
12 SEQ_LODIV_SYNC_EN_OVRD_EN	Override control for SEQ_LODIV_SYNC_EN 0b - Normal operation. 1b - Use the state of SEQ_LODIV_SYNC_EN_OVRD to override the signal "seq_lodiv_sync_en".
11 SEQ_LODIV_SYNC_RESET_EN_OVRD	Override value for SEQ_LODIV_SYNC_RESET_EN When SEQ_LODIV_SYNC_RESET_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_lodiv_sync_reset_en". This bit is ignored when SEQ_LODIV_SYNC_RESET_EN_OVRD_EN==0.
10 SEQ_LODIV_SYNC_RESET_EN_OVRD_EN	Override control for SEQ_LODIV_SYNC_RESET_EN 0b - Normal operation. 1b - Use the state of SEQ_LODIV_SYNC_RESET_EN_OVRD to override the signal "seq_lodiv_sync_reset_en".
9 SEQ_PIC_RINT2_SHORT_FM_EN_OVRD	Override value for SEQ_PIC_RINT2_SHORT_FM_EN When SEQ_PIC_RINT2_SHORT_FM_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_pic_rint2_short_fm_en". This bit is ignored when SEQ_PIC_RINT2_SHORT_FM_EN_OVRD_EN==0.
8 SEQ_PIC_RINT2_SHORT_FM_EN_OVRD_EN	Override control for SEQ_PIC_RINT2_SHORT_FM_EN 0b - Normal operation. 1b - Use the state of SEQ_PIC_RINT2_SHORT_FM_EN_OVRD to override the signal "seq_pic_rint2_short_fm_en".
7 SEQ_PIC_RFB_OPEN_SM_EN_OVRD	Override value for SEQ_PIC_RFB_OPEN_SM_EN When SEQ_PIC_RFB_OPEN_SM_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_pic_rfb_open_sm_en". This bit is ignored when SEQ_PIC_RFB_OPEN_SM_EN_OVRD_EN==0.
6 SEQ_PIC_RFB_OPEN_SM_EN_OVRD_EN	Override control for SEQ_PIC_RFB_OPEN_SM_EN 0b - Normal operation. 1b - Use the state of SEQ_PIC_RFB_OPEN_SM_EN_OVRD to override the signal "seq_pic_rfb_open_sm_en".
5 SEQ_PIC_FILTER_LOW_BW_SM_EN_OVRD	Override value for SEQ_PIC_FILTER_LOW_BW_SM_EN When SEQ_PIC_FILTER_LOW_BW_SM_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_pic_filter_low_bw_sm_en". This bit is ignored when SEQ_PIC_FILTER_LOW_BW_SM_EN_OVRD_EN==0.
4	Override control for SEQ_PIC_FILTER_LOW_BW_SM_EN

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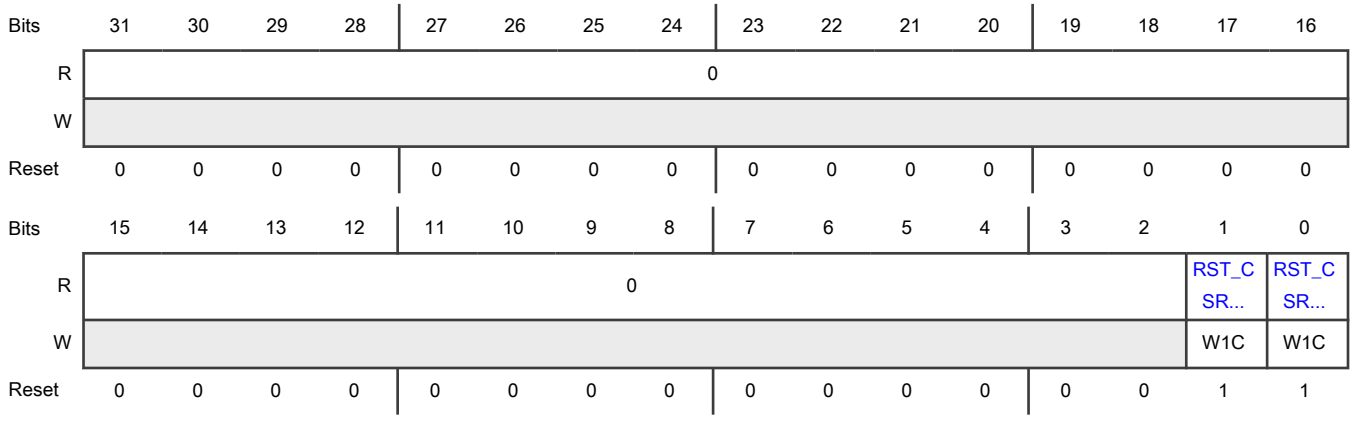
Field	Function
SEQ_PIC_FILTER_LOW_BW_SM_EN_OVRD_EN	0b - Normal operation. 1b - Use the state of SEQ_PIC_FILTER_LOW_BW_SM_EN_OVRD to override the signal "seq_pic_filter_low_bw_sm_en".
3 SEQ_PIC_SHORT_CINT_SHORT_EN_OVRD	Override value for SEQ_PIC_SHORT_CINT_SHORT_EN When SEQ_PIC_SHORT_CINT_SHORT_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_pic_short_cint_short_en". This bit is ignored when SEQ_PIC_SHORT_CINT_SHORT_EN_OVRD_EN==0.
2 SEQ_PIC_SHORT_CINT_SHORT_EN_OVRD_EN	Override control for SEQ_PIC_SHORT_CINT_SHORT_EN 0b - Normal operation. 1b - Use the state of SEQ_PIC_SHORT_CINT_SHORT_EN_OVRD to override the signal "seq_pic_short_cint_short_en".
1 SEQ_PIC_CORE_EN_OVRD	Override value for SEQ_PIC_CORE_EN When SEQ_PIC_CORE_EN_OVRD_EN=1, this value overrides the mission mode state of the signal "seq_pic_core_en". This bit is ignored when SEQ_PIC_CORE_EN_OVRD_EN==0.
0 SEQ_PIC_CORE_EN_OVRD_EN	Override control for SEQ_PIC_CORE_EN 0b - Normal operation. 1b - Use the state of SEQ_PIC_CORE_EN_OVRD to override the signal "seq_pic_core_en".

52.4.4.2.2.4.3.1.77 TSM CONTROL 2 (CTRL2)

Offset

Register	Offset
CTRL2	12Ch

Diagram



Fields

Field	Function
31-2 —	Reserved
1 RST_CSR_SW2_EN	Reset CSR Timing Values By SW 2 This field is to have reset values for RSM , it has been filled with nominal values to avoid reprogramming all TSM registers when switching from Bluetooth LE to channel sounding. To enable it , it must be written to 1 then must be read again to exit the reset and activate the default reset value. It is a write one to clear register. 0b - Reset Enabled 1b - Reset Disabled
0 RST_CSR_SW_EN	Reset CSR Timing Values By SW 1 This field is to have reset values for BLE, it has been filled with nominal values to avoid reprogramming all TSM registers when switching from channel sounding to Bluetooth LE. To enable it , it must be written to 1 then must be read again to exit the reset and activate the default reset value. It is a write one to clear register. 0b - Reset Enabled 1b - Reset Disabled

52.4.4.2.2.5 Ranging Sequence Manager (RSM)

52.4.4.2.2.5.1 Introduction

The Ranging Sequence Manager (RSM) automates RX and TX operations across a set of frequencies in order to allow two devices to capture samples and other data for distance measurement calculations performed by software. To perform this task, the RSM acts like a small link layer, directing the transceiver to perform RX and TX as needed. The figure and list below shows the modules to which the RSM interfaces:

- To control the RSM's behavior in each frequency step, the RSM reads information stored in the configuration buffer located in the Packet RAM.
  - This configuration data consists of the desired CS mode, frequency, tone extension information, antenna permutation pattern, unidirectional mode, CFO setting, frequency calibration information (ext_ctune and ext_hpm_cal_factor in the figure) and phase adjustment used by the PLL.
  - If some packet exchange is expected in the step, RSM reads also Access Address and Payload for the two parts of the step in the Packet RAM.
- To store the result in each frequency step, RSM writes some statuses during the step processing in result buffer located in the Packet RAM. This information consists on the step number, the size of the step result, the AGC index, the Access Address detection flag, If the ext_ctune info is not used and the PLL performs ctune calibration, then on each frequency change the ctune_best_diff value is saved to Packet RAM by the RSM.
- The RSM provides control signals to the TSM to start receive or transmit operations, to switch between receive and transmit operations, and to end receive and transmit operations.
- For transmit, the RSM uses the tx_mod_disable signal to tell the TXDIG whether to modulate data (packet transmit) or not (tone transmit). For packet transmit, the RSM provides data included Access Address and payload informations to transmit to the TXDIG. Note that the RSM does not control the transmit power; that should be programmed in the TXDIG

- When receiving packets, the RSM reads packet configuration information from the Packet RAM which is used by the PHY as the access address (AA) and is also provided as "RTT bits" to the PHY. Depending on RTT type, RSM provides also expected payload to RX_DIG. It also directs the RTT (round trip time) results from the PHY, the NADM results from RX_DIG, AA_matched status, the TPM and CFO_EST values to the Packet RAM.
- When receiving tones, the RSM provides a dma_trigger and a dma_mask output for use by the Transceiver DMA module. The dma_trigger asserts whenever RSM's RX_EN or TX_EN bitfields are set. The dma_mask asserts at a programmable delay (DMA_DLY or DMA_DLY0 bitfields) from the start of receive, and remains asserted for a programmable duration (DMA_DUR or DMA_DUR0 bitfields). The delay is programmed to allow the receiver analog and digital time to settle, and the duration programmed for the desired sample capture duration. The RSM also sends a signal to the PLL (ext_rx_lpm_mod_dis in the figure) which indicates that for tone reception the PLL should disable low port modulation and instead use a constant value (programmed in PLL) for high port modulation. RSM directs the PCT computation from RX_DIG to the Packet RAM.
- For ranging operations which use antenna switching, the RSM provides triggers to the Localization Control module; lcl_rx_trigger is used in PM_RX states and lcl_tx_trigger is used in PM_TX states. Since the PM duration can take four different values (T_PM0-3), the RSM also outputs a signal (lcl_alt_reg_sel[1:0]) to the Localization Control module to indicate which T_PM duration is currently being used. Note that if the Localization Control module is used in conjunction with RSM, in PM_RX states the Localization Control module will provide the DMA mask control to the Transceiver DMA and the RSM's DMA mask feature should be disabled. Refer to Antenna Control Used With RSM for more information on LCL_CTRL usage with RSM.
- The RSM "active" output is used by RXDIG and TXDIG in order to keep the Rx/Tx clocks running while the RSM is active. This is required for timestamping continuity for RTT (i.e., the relationship of fine time-stamp to the corresponding integer reference clock timestamp is maintained) as well as tone exchange (i.e., digital down mixing of the IF frequency & CIC clocking randomness do not contribute additional phase jitter). This doesn't require any software configuration except for the RXDIG control bit CIC_CNTR_FREE_RUN_EN which resets to 1, and should remain set to ensure the clocks remain running.

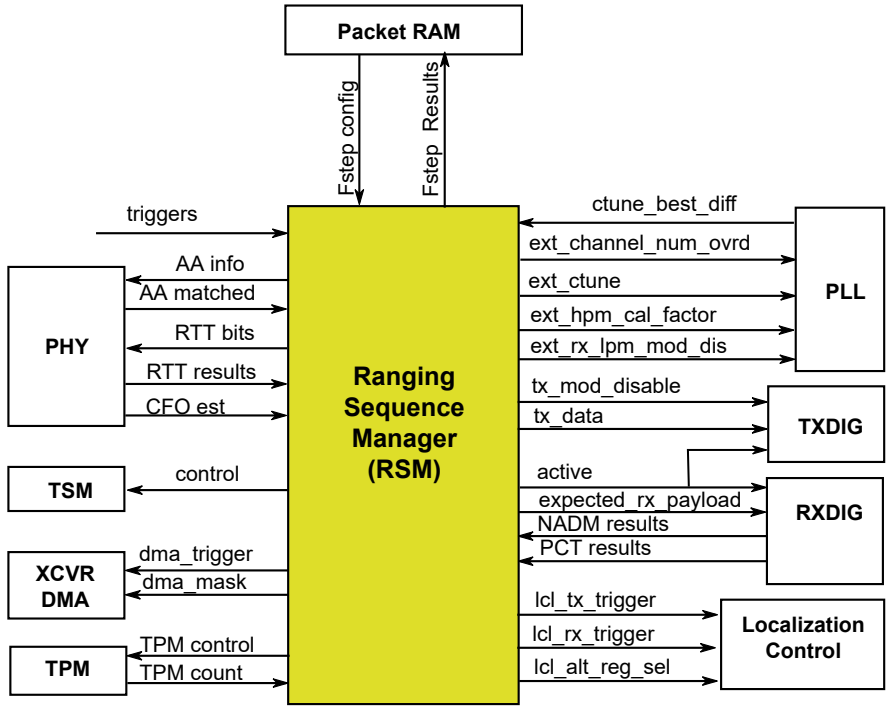


Figure 322. RSM Interfaces

The RSM supports two modes of operation: SQTE (Secure Quick Tone Exchange) and PDE (Phase-based Distance Estimation). These modes, which are described in detail in the following sections, have a good deal in common, including the following:

- The RSM can be configured to begin with a transmit operation (TX_EN bitfield programmed to 1) or receive operation (RX_EN bitfield programmed to 1). These correspond to the Initiator and Reflector roles for SQTE, and to Measuring Device (MD) and Reflector Device (RD) roles for PDE, respectively.

- The number of frequency steps is configurable in RSM_CTRL0[RSM_STEPS] register.
- The durations of the states associated with receive, transmit, frequency change transition and role swap transition (RX to TX or TX to RX) are configurable in RSM_CTRL1 and RSM_CTRL2 registers (T_PM, T_FC, and T_IP2 bitfields), though SQTE has additional configurability (T_IP1 and T_S bitfields).
- We will have possibility to manage T_IP1 independent of T_IP2 . The TSM is now aligned with RSM functionality and the TSM is updated automatically with jump_forward mechanism in link with T_IP1 and T_IP2 values . This is transparent for the software. This mechanism is only compatible with generic TSM and not classic mode which is not used anymore.
- The format used for each frequency step is configurable, though for PDE this only includes tone exchanges, while for SQTE this includes tone and/or packet exchanges.

52.4.4.2.2.5.2 Secure Quick Tone Exchage (SQTE) Mode

The MODE=0 setting is for SQTE, which is shown in the figure below from the Bluetooth LE standards body. In this mode, two devices (one assuming the role of "Initiator" and the other the role of "Reflector") take turns exchanging packets and/or tones. The first set of exchanges are referred to as the Frequency Compensation Step (FCS), which consists of a bidirectional packet exchange and a unidirectional Frequency Measurement (FM) step which is a tone transfer from Reflector to Initiator. The main purpose of FCS is to allow the Initiator to determine the frequency offset of the Reflector with respect to the frequency of the Initiator.

There are a programmable number of SQTE Steps, each of which are individually configured to take one of four formats, as shown in the figure: the FCS step, a Pk-Pk step which only has packet exchange; a Tn-Tn step which only has tone exchange; or a Pk-Tn-Tn-Pk which has both packet and tone exchanges. Usually, the FCS is only used in the first step, but the RSM can be programmed so that it is also used in other steps. Note that T_RD defined in the Channel Sounding standard is not shown in this figure but it is already included in T_FC , T_IP1 and T_IP2.

Data is collected during packet reception and tone reception for each "SQTE Step" by both Initiator and Reflector for later post-processing by software. Note that the packets exchanged during SQTE are not normal Bluetooth LE packet; they are comprised of an 8bit (or 16bit for 2Mbps operation) preamble, a 32bit Access Address sequence, a 4bit trailer and followed by a potential 32-bit/64-bit/96-bit/128-bit payload which is known a priori by both Initiator and Reflector

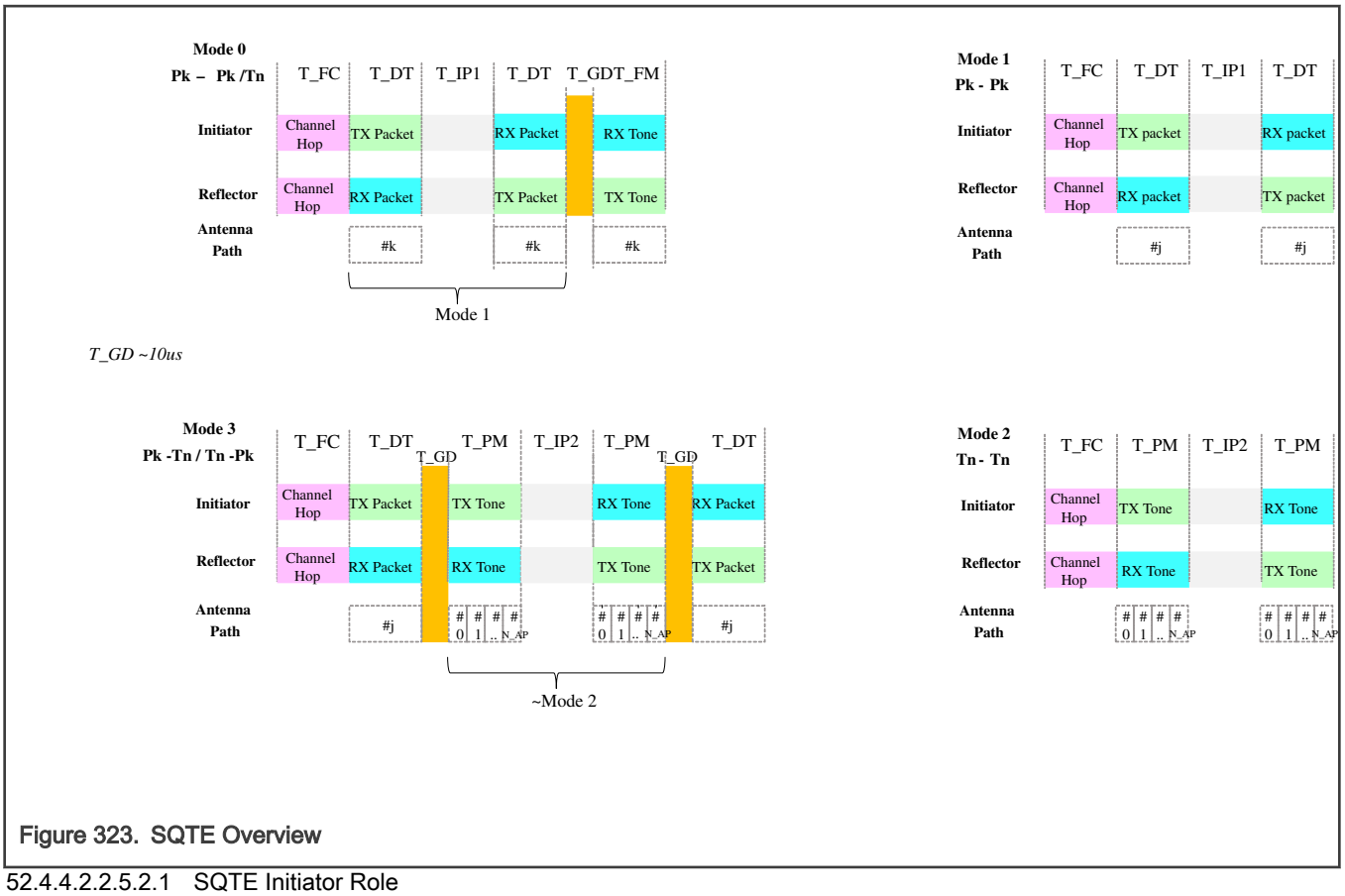


Figure 323. SQTE Overview

52.4.4.2.2.5.2.1 SQTE Initiator Role

The RSM state diagram below illustrates the RSM states used for SQTE in the Initiator role (TX_EN=1). Some of the states are duplicated in the figure to more clearly show the state transition sequence for the four different step format types (FCS, Pk-Pk, Tn-Tn, and PkTn-Tn-Pk). The states are described as follows:

- IDLE. This is the state the RSM is in after a reset and after a sequence has completed (or been aborted).
- DELAY. If a trigger delay is used, after the selected trigger is recognized, the RSM will stay in the DELAY state for TRIG_DLY microseconds.
- WU (Warmup). The RSM asserts its tx_en output to the TSM and then waits for the TSM's wu_complete signal before leaving this state. The figure shows that WU always transitions to the DT_TX state of the FCS step format but this assumes that the FCS step format is selected for the first frequency step (which is the expected behavior).
- FC_RX2TX (Frequency Change RX-to-TX transition). In this state the RSM directs the TSM to switch from RX to TX mode, change the radio frequency, and start a new step. The nominal duration of this state is T_FC
- DT_TX (Packet Transmit). In this state the RSM directs the transceiver to transmit a "packet" with a preamble, an Access Address, a trailer and a potential payload. The duration of this state depends on the RATE and RTT_TYPE bitfields.
- DT_RX (Packet Receive). In this state the RSM directs the transceiver to receive a "packet" with a preamble, an Access Address data, a trailer and a potential payload. The nominal duration of this state depends on the RATE and RTT_TYPE bitfields.
- FM_RX (Tone Receive for FCS). In this state, the RSM directs the transceiver to receive a "tone". The nominal duration of this state is the value defined in RSM_CTRL5[RSM_T_FM] register.
- PM_RX (Tone Transmit). In this state the TSM directs the transceiver to receive a "tone". The nominal duration of this state is T_PM0, T_PM1 depending on the t_pm_sel bitfield in the configuration step data stored in Packet RAM
- PM_TX (Tone Transmit). In this state the TSM directs the transceiver to transmit a tone. The duration of this state is T_PM0, T_PM1 depending on the t_pm_sel bitfield in the configuration step data stored in Packet RAM

- IP1_TX2RX (Role swap TX-to-RX transition). In this state, the RSM directs the TSM to switch from TX to RX mode. The nominal duration of this state is T_IP1
- IP2_TX2RX (Role swap TX-to-RX transition). In this state, the RSM directs the TSM to switch from TX to RX mode. The nominal duration of this state is T_IP2
- S_TX2TX (Short TX-to-TX transition). In this state, the RSM transitions between packet and tone transmit. The duration of this state is T_S
- S_RX2RX (Short RX-to-RX transition). In this state, the RSM transitions between packet and tone receive. The nominal duration of this state is T_S
- WD (Warmdown). The RSM de-asserts its rx_en or tx_en (depending on what state it was in prior to warmdown) directing the TSM to warm down the transceiver

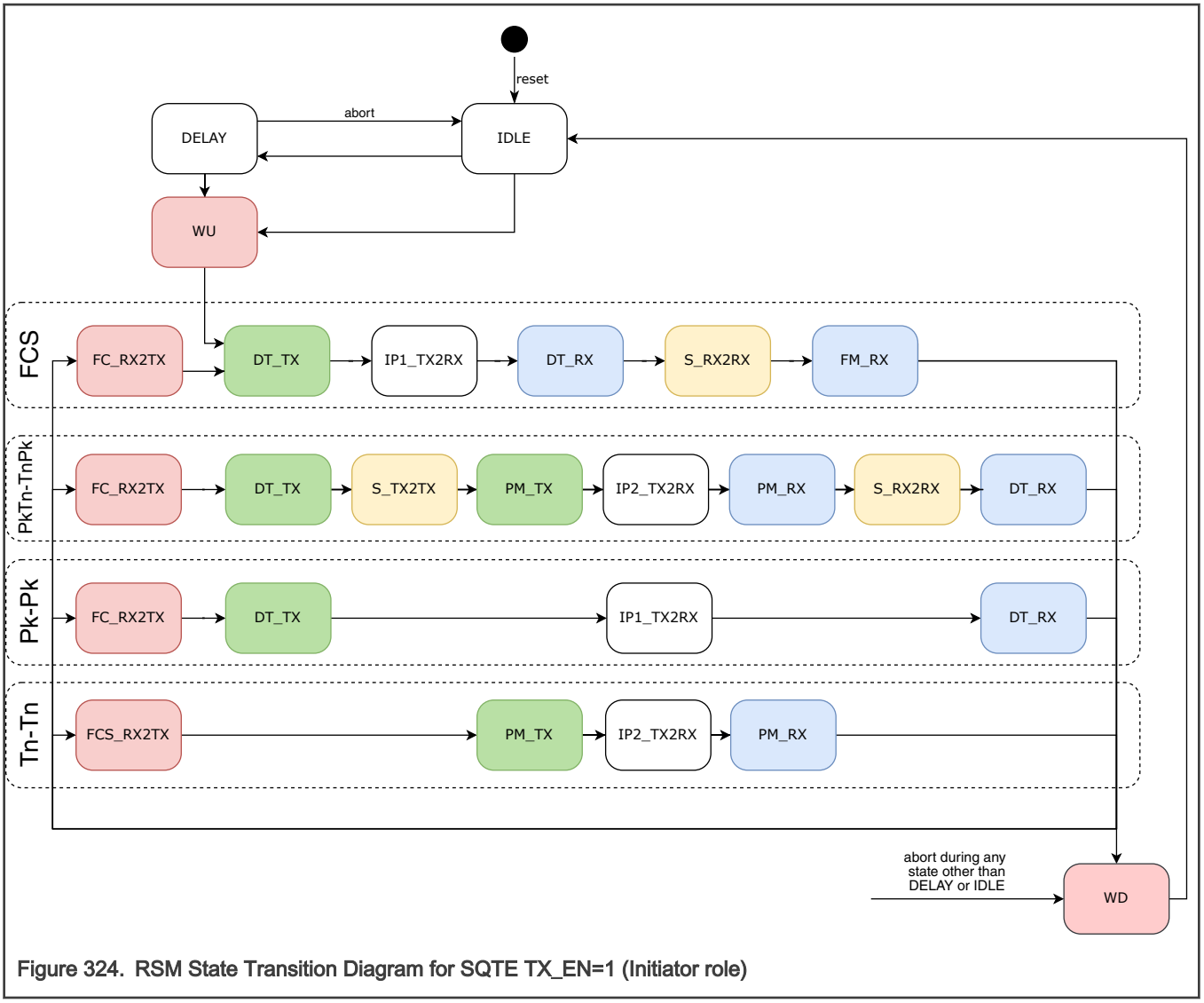


Figure 324. RSM State Transition Diagram for SQTE TX_EN=1 (Initiator role)

Any one of three methods can be used to start RSM operation when the module is configured for SQTE in the Initiator role (TX_EN=1).

1. The RSM is initiated by a hardware trigger (TRIG_SEL>0) which asserts during a previous RX or TX operation controlled by the Bluetooth or Generic LL
2. The RSM is initiated by a software trigger (TRIG_SEL=0)

3. The RSM is initiated immediately (TRIG_DLY=0) by a hardware trigger (TRIG_SEL=seq_spare3) which asserts during a dummy TX operation controlled by the Bluetooth or Generic LL

The figure below shows the timing corresponding to method #1 above. During a previous RX or TX operation controlled by the Bluetooth or Generic LL, a trigger to the is RSM asserted, and then the LL completes it RX or TX operation as usual. Meanwhile, upon recognizing the trigger, the RSM's trigger delay counter starts. After a programmable TRIG_DLY, the RSM will direct the TSM to start a transmit operation with a fast warmup if FAST_FC_TX_WU is set or a normal warmup if not. The state transitions associated with the four frequency step formats when TX_EN=1 are as described in the previous state transition diagram figure; note that the timing figure below only shows the Frequency Compensation Step and Pk-Tn-Tn-Pk step formats.

After the last frequency step, the RSM transitions to the WD state where the TSM is warmed down, and then to the IDLE state.

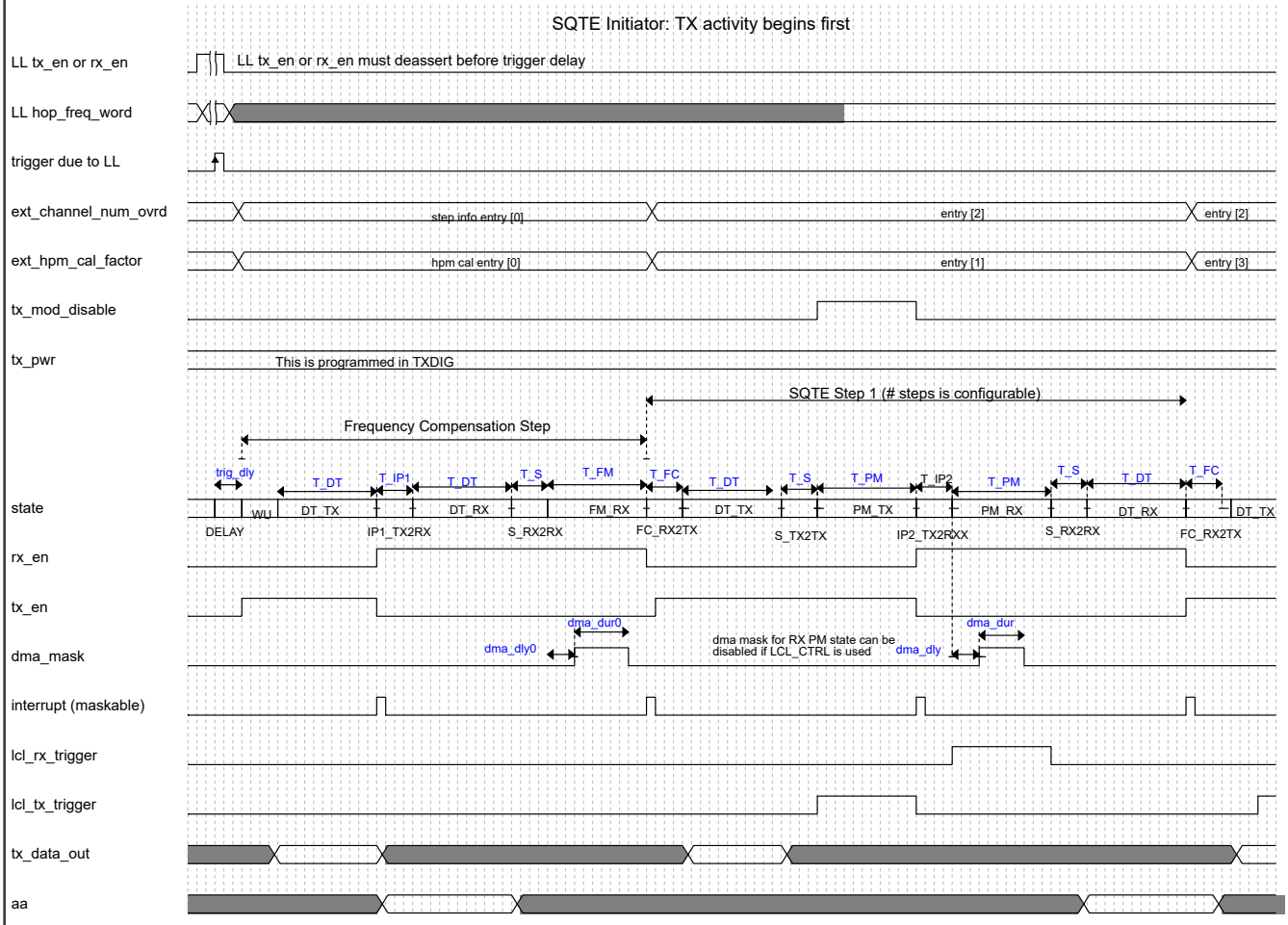


Figure 325. SQTE Mode Timing with TX_EN=1 (Initiator role)

The timing for method #2 (software trigger) is similar to above, but no link layer operation is required. Instead, if TRIG_SEL=0, then the TRIG_DLY counter begins as soon as RSM's TX_EN is programmed to 1.

The timing for method #3 (hardware trigger with dummy LL event) is also similar to above, but differs in the link layer and trigger operation. In this case, the link layer begins a "dummy" TX operation which is only used to trigger the RSM. The RSM trigger for seq_spare3 should be used and the RSM's TRIG_DLY programmed to 0. The TSM should be programmed so that seq_spare3 asserts at time 0. (Seq_spare3 can be programmed to de-assert at any time after 0.) The link layer only needs to assert its "tx_en" signal to the TSM long enough to generate the seq_spare3 trigger to the RSM; after that the link layer can "abort" its TX operation. (Any duration for link layer tx_en from 4us to ~40us should be okay.) The trigger timing for method #2 is shown in the figure below.

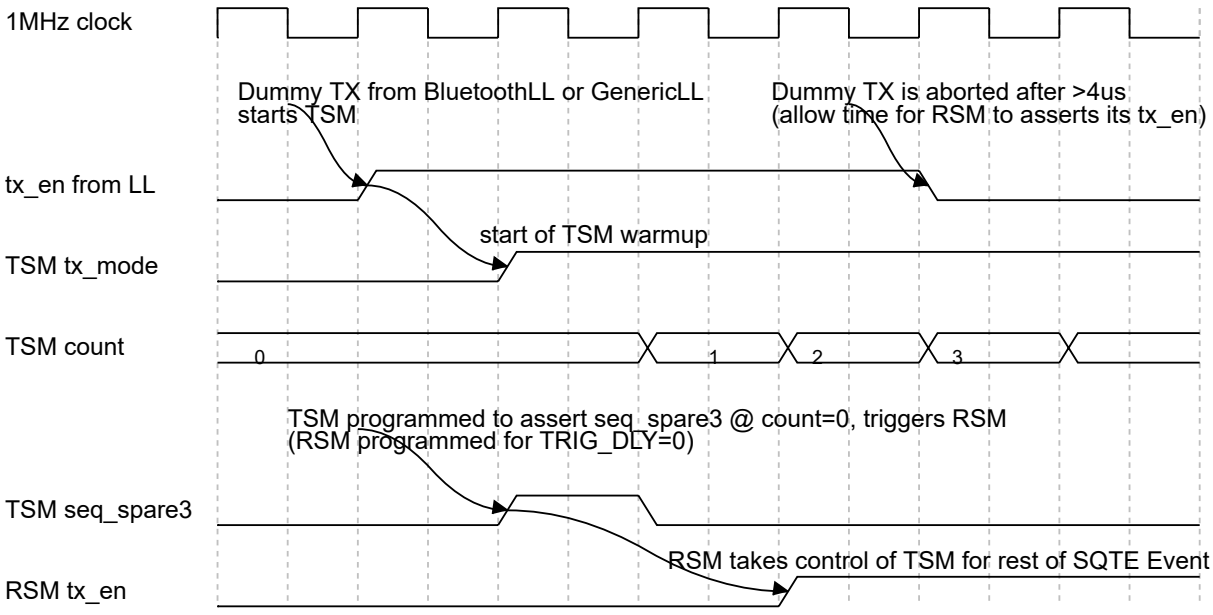


Figure 326. SQTE TX trigger method #3: Dummy LL TX Event for TX_EN=1 (Initiator role)

52.4.4.2.2.5.2.2 SQTE Reflector Role

The RSM state diagram below illustrates the RSM states used for SQTE in the Reflector role (RX_EN=1). Some of the states are duplicated in the figure to more clearly show the state transition sequence for the four different step format types (FCS, Pk-Pk, Tn-Tn, and PkTn-Tn-Pk). The states are described as follows:

- IDLE. This is the state the RSM is in after a reset and after a sequence has completed (or been aborted).
- DELAY. If a trigger delay is used, after the selected trigger is recognized, the RSM will stay in the DELAY state for TRIG_DLY microseconds.
- WU (Warmup). The RSM asserts its rx_en output to the TSM and then waits for the TSM's wu_complete signal before leaving this state. The figure shows that WU always transitions to the DT_RX state of the FCS step format but this assumes that the FCS step format is selected for the first frequency step (which is the expected behavior).
- FC_TX2RX (Frequency Change TX-to-RX transition). In this state the RSM directs the TSM to switch from TX to RX mode, change the radio frequency, and start a new step. The nominal duration of this state is T_FC
- DT_TX (Packet Transmit). In this state the RSM directs the transceiver to transmit a "packet" with a preamble, an Access Address, a trailer and a potential payload. The duration of this state depends on the RATE and RTT_TYPE bitfields.
- DT_RX (Packet Receive). In this state the RSM directs the transceiver to receive a "packet" with a preamble, an Access Address, a trailer and a potential payload. The nominal duration of this state depends on the RATE and RTT_TYPE bitfields.
- FM_TX (Tone Transmit for FCS). In this state, the RSM directs the transceiver to transmit a "tone". The duration of this state is the value defined in RSM_CTRL5[RSM_T_FM] register.
- PM_RX (Tone Transmit). In this state the TSM directs the transceiver to receive a "tone". The nominal duration of this state is T_PM0, T_PM1 depending on the t_pm_sel bitfield in the configuration step data stored in Packet RAM
- PM_TX (Tone Transmit). In this state the TSM directs the transceiver to transmit a tone. The duration of this state is T_PM0, T_PM1dependening on the t_pm_sel bitfield in the configuration step data stored in Packet RAM
- IP1_RX2TX (Role swap RX-to-TX transition). In this state, the RSM directs the TSM to switch from RX to TX mode. The nominal duration of this state is T_IP1

- IP2_RX2TX (Role swap RX-to-TX transition). In this state, the RSM directs the TSM to switch from RX to TX mode. The nominal duration of this state is T_IP2
- S_TX2TX (Short TX-to-TX transition). In this state, the RSM transitions between packet and tone transmit. The duration of this state is T_S
- S_RX2RX (Short RX-to-RX transition). In this state, the RSM transitions between packet and tone receive. The nominal duration of this state is T_S
- WD (Warmdown). The RSM de-asserts its rx_en or tx_en (depending on what state it was in prior to warmdown) directing the TSM to warm down the transceiver

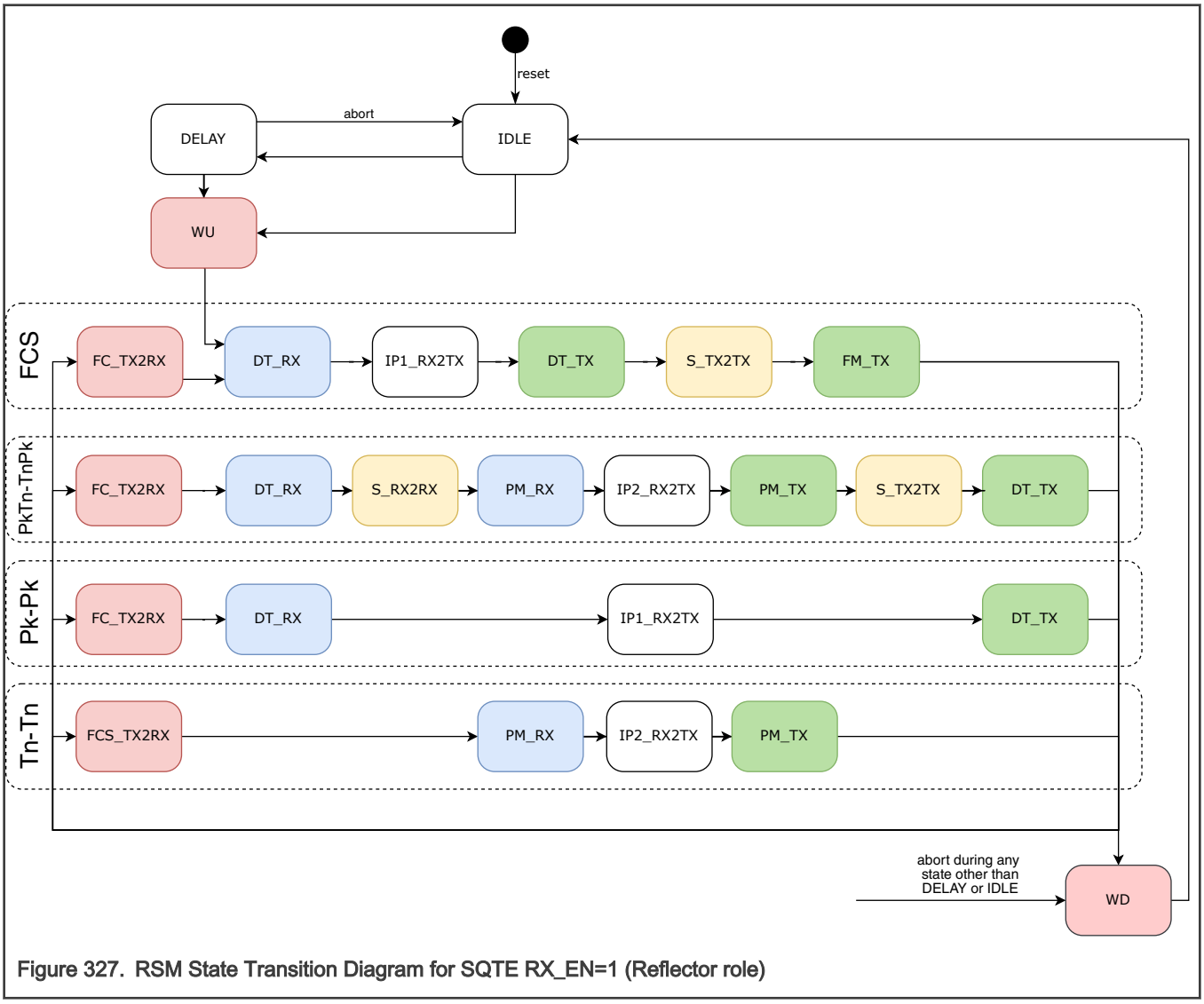


Figure 327. RSM State Transition Diagram for SQTE RX_EN=1 (Reflector role)

Any one of three methods can be used to start RSM operation when the module is configured for SQTE in the Reflector role (RX_EN=1).

1. The RSM is initiated by a hardware trigger (TRIG_SEL>0) which asserts during a previous RX or TX operation controlled by the Bluetooth or Generic LL
2. The RSM is initiated by a software trigger (TRIG_SEL=0)
3. The RSM is initiated immediately (TRIG_DLY=0) by a hardware trigger (TRIG_SEL=seq_spare3) which asserts during a dummy RX operation controlled by the Bluetooth or Generic LL

The figure below shows the timing corresponding to method #1 above. During a previous RX or TX operation controlled by the Bluetooth or Generic LL, a trigger to the is RSM asserted, and then the LL completes it RX or TX operation as usual. Meanwhile, upon recognizing the trigger, the RSM's trigger delay counter starts. After a programmable TRIG_DLY, the RSM will direct the TSM to start a receive operation with a fast warmup if FAST_FC_RX_WU is set or a normal warmup if not. Unless the DT_RX_SYNC_DIS bit is set, then during the FCS RX packet, the RSM will sync the timing using the AA matched signal from the PHY. When SQTE begins with receive, the RSM also utilizes the DMA_DLY0 and DMA_DUR0 to define when and how long dma_mask asserts during the Frequency Error Measurement (T_FM) Step. The state transitions associated with the four frequency step formats when RX_EN=1 are as described in the previous state transition diagram figure; note that the timing figure below only shows the Frequency Compensation Step and Pk-Tn-Tn-Pk step formats.

After the last frequency step, the RSM transitions to the WD state where the TSM is warmed down, and then to the IDLE state.

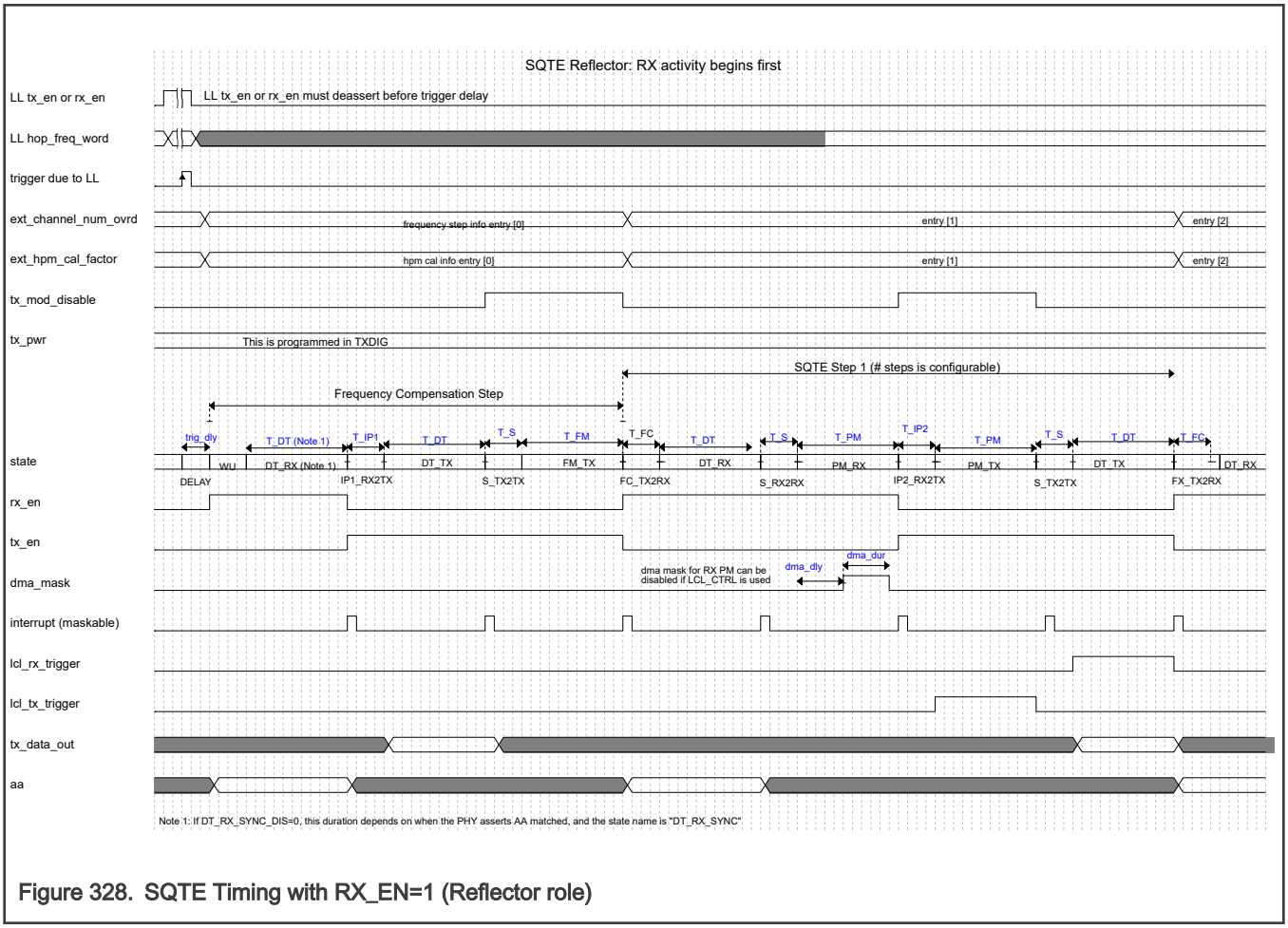


Figure 328. SQTE Timing with RX_EN=1 (Reflector role)

The timing for method #2 (software trigger) is similar to above, but no link layer operation is required. Instead, if TRIG_SEL=0, then the TRIG_DLY counter begins as soon as RSM's RX_EN is programmed to 1.

The timing for method #3 (hardware trigger with dummy LL event) is also similar to above, but differs in the link layer and trigger operation. In this case, the link layer begins a "dummy" RX operation which is only used to trigger the RSM. The RSM trigger for seq_spare3 should be used and the RSM's TRIG_DLY programmed to 0. The TSM should be programmed so that seq_spare3 asserts at time 0. (Seq_spare3 can be programmed to de-assert at any time after 0.) The link layer only needs to assert its "rx_en" signal to the TSM long enough to generate the seq_spare3 trigger to the RSM; after that the link layer can "abort" its RX operation. (Any duration for link layer rx_en from 4us to ~40us should be okay.) The trigger timing for method #2 is shown in the figure below.

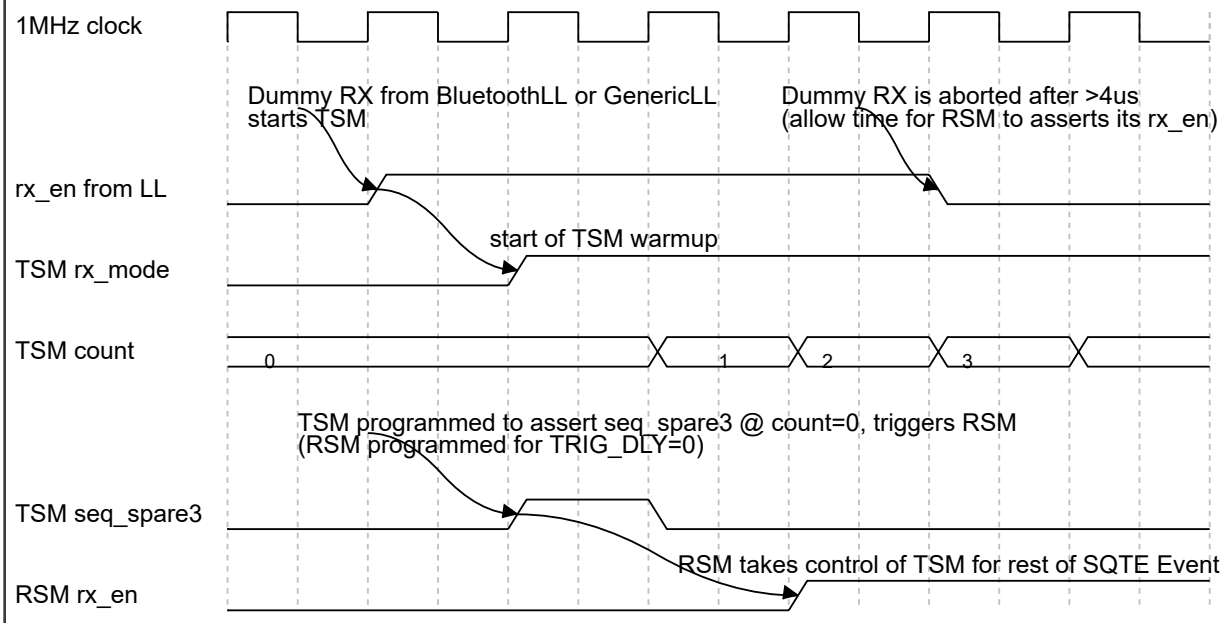


Figure 329. SQTE RX trigger method #3: Dummy LL RX Event for RX_EN=1 (Reflector role)

52.4.4.2.2.5.2.3 SQTE Tone extension

To support the standard wit h tone extension management , an interaction between LCL and RSM is managed to take into account the tone extension.

Modes 2 and 3 will need to manage antenna switching in an order defined in the standard, the permutation will be done according to configuration information in packet ram STEP_CFG[ANT_PERMUT[4:0]].

For packets and mode 0, we will use the configuration packet_ram STEP_CFG[[ANT_CS_SYNC[1:0]].

Then, in mode 3 we have a mixed between packets and tone , that means that ant_cs_sync pktram field will manage antenna number for packets and ant_permut pktram field will manage antenna number during tones.

The tone extension parameter will come from packet ram configuration STEP_CFG[TONE_EXT[1:0]]. The bit 0 will indicate if we have a tone extension during the Initiator transmission (the first part of the transfer between t_fc and t_ip) and the bit 1 will indicate if tone extension is present or not during the Reflector transmission (after t_ip). In the device in reception, the measurement will be available whatever the tone extension (to be able to detect attacks by checking if power is present or not without tone extension) .

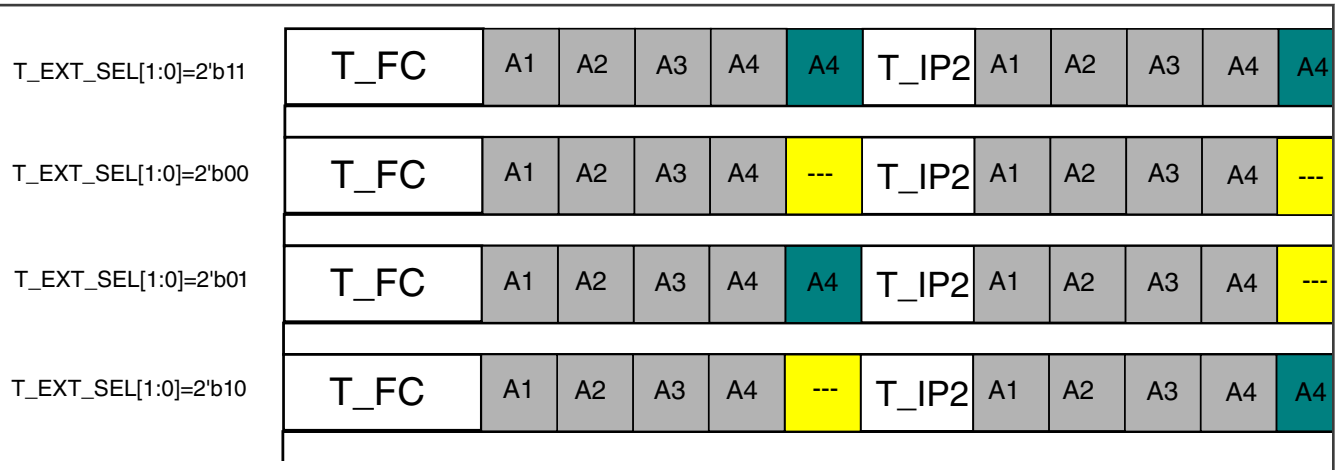


Figure 330. Tone extension mode 2 (example 4 antennas)

Concerning mode 3 , we have asymmetric management after t_ip2, this can lead to empty slot at the end of the step after the packet, as we can show below:

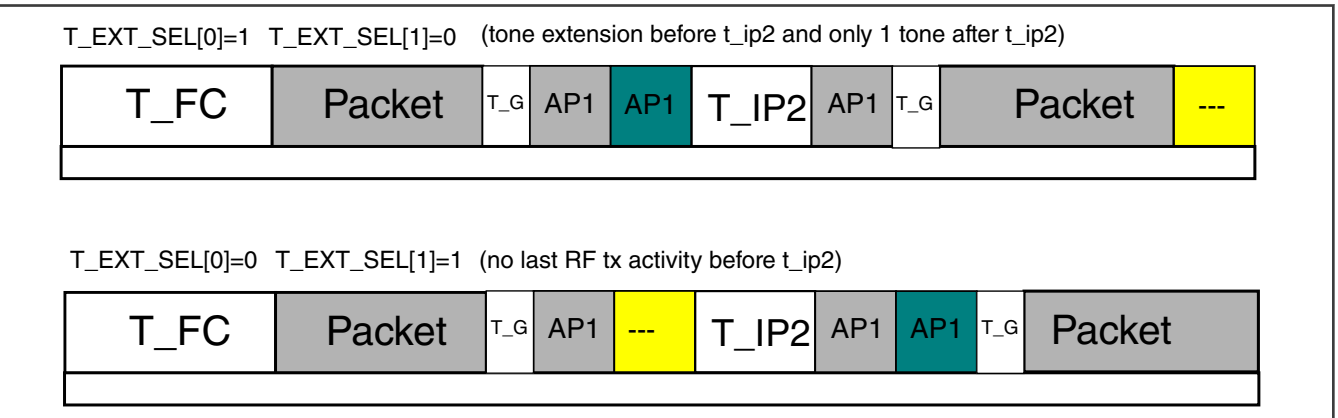


Figure 331. Tone extension mode 3 (example 1 antenna)

For tone extension part, the TX must be switched OFF when t_ext_sel from pktram is set to 0 , for modes 2 and 3. Therefore, a rx measurement will still occur and could be also used for security as we should not detect any activity during this period.

The antenna order will be managed by antenna permutation during tones described in LCL chapter, the order will be defined depending on the number of antenna , defined in the Bluetooth Low Energy Channel Sounding standard.

The tone_ext[1:0] from the Packet Ram configuration buffer allows more possibilities than the current standard definition. So, some restrictions on tone_ext[1:0] field have to be taken into account during the programmation of this field to be aligned with the Channel Sounding standard and the fact that a device in RX mode has always to check the presence or not of the tone extension.

```
If (mode==2) begin
   if (device==reflector)
       tone_ext={tone_ext_part2, 1'b1};
   else if (device==initiator)
       tone_ext={1'b1, tone_ext_part1};
   else if (device==sniffer)
       tone_ext={2'b11};
end
else if (mode==3) begin
   if (device==reflector)
       tone_ext={tone_ext_part2, 1'b1};
   else if (device==initiator)
       tone_ext={tone_ext_part2, tone_ext_part1};
   else if (device==sniffer)
       tone_ext={tone_ext_part2, 1'b1};
end
```

52.4.4.2.2.5.3 Phase-based Distance Estimation (PDE) Mode

The MODE=1 setting is for PDE mode. In this mode the transceiver is not warmed down from the LL receive or transmit operation prior to the RSM taking control. Instead, the RSM is allowed to extend the receive or transmit operation initiated by the LL. For this to work correctly, the frequency used by the LL must match the frequency information in the first set of frequency step information read by the RSM from the Packet RAM (seeConfiguration Stored in Packet RAM).

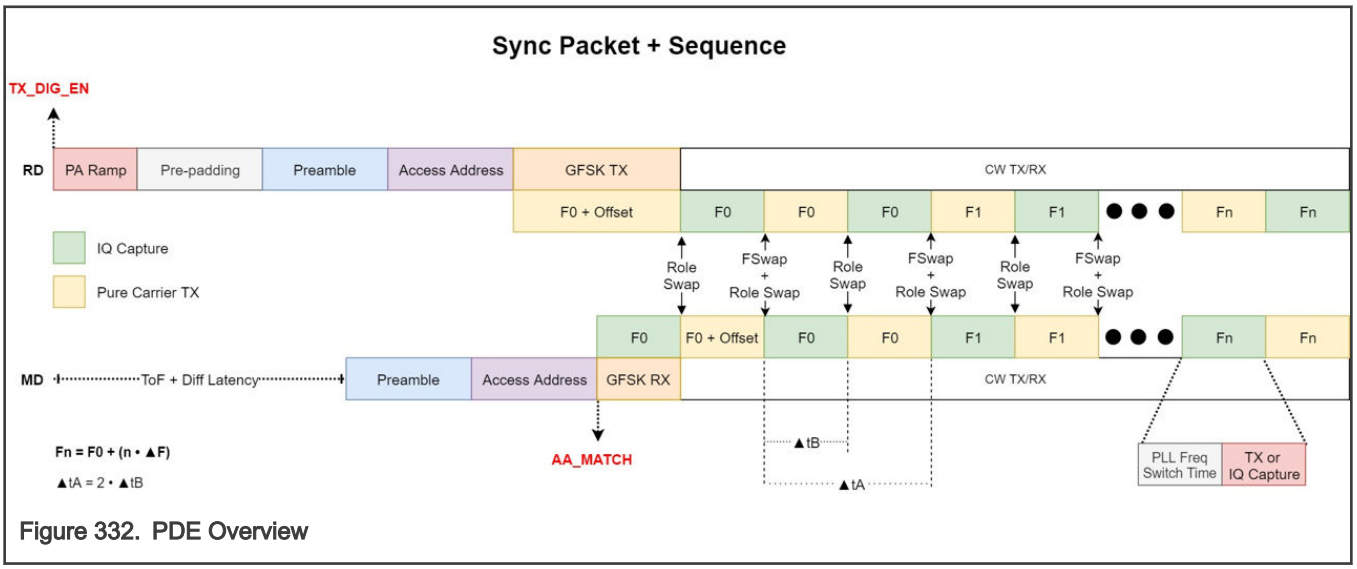


Figure 332. PDE Overview

52.4.4.2.2.5.3.1 PDE TX_EN=1 (RD Role)

The RSM state diagram below illustrates the RSM states used for PDE with TX_EN=1 (RD Role). Note that unlike SQTE, only one step format (Tn-Tn) is used, so the state diagram is greatly simplified. The states are described as follows:

- IDLE. This is the state the RSM is in after a reset and after a sequence has completed (or been aborted).
- EXT_TX. After the trigger is recognized, the RSM will enter and stay in this state for TRIG_DLY microseconds. During this state, the RSM will assert its tx_en output to the TSM. The link layer continues to control the transceiver at entry to this state, but is expected to de-assert its tx_en output by the time the TRIG_DLY timer expires.

- FC_RX2TX (Frequency Change RX-to-TX transition). In this state the RSM directs the TSM to switch from RX to TX mode, change the radio frequency, and start a new step. The nominal duration of this state is T_FC
- PM_RX (Tone Transmit). In this state the TSM directs the transceiver to receive a "tone". The nominal duration of this state is T_PM0, T_PM1, T_PM2, or T_PM3 depending on the t_p_sel[1:0] bitfield in the frequency step data stored in Packet RAM
- PM_TX (Tone Transmit). In this state the TSM directs the transceiver to transmit a tone. The duration of this state is T_PM0, T_PM1, T_PM2, or T_PM3 depending on the t_p_sel[1:0] bitfield in the frequency step data stored in Packet RAM
- IP2_TX2RX (Role swap TX-to-RX transition). In this state, the RSM directs the TSM to switch from TX to RX mode. The nominal duration of this state is T_IP2
- WD (Warmdown). The RSM de-asserts its rx_en or tx_en (depending on what state it was in prior to warmdown) directing the TSM to warm down the transceiver

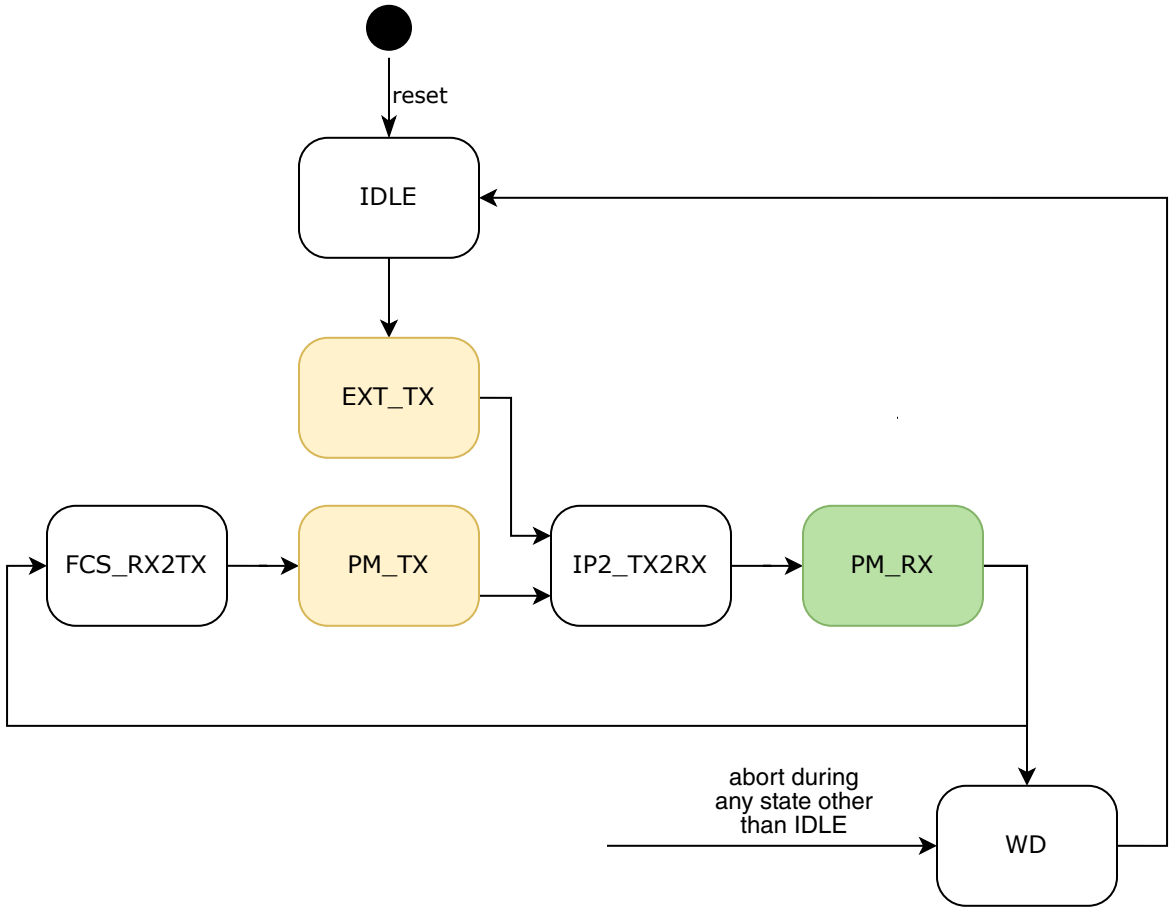


Figure 333. RSM State Transition Diagram for PDE TX_EN=1 (RD role)

The figure below shows PDE operation when the RSM is configured to begin with transmit operation. On assertion of the trigger (for example, TX_DIG_EN from the TSM), the RSM will assert its tx_en signal to keep the transmit operation active until TRIG_DLY expires. By that time, the LL's tx_en should be de-asserted so that the RSM can take full control of the transceiver. When the RSM is configured to begin with transmit, frequency steps occur on RX2TX transitions. Role swaps without frequency changes occur on TX2RX transitions.

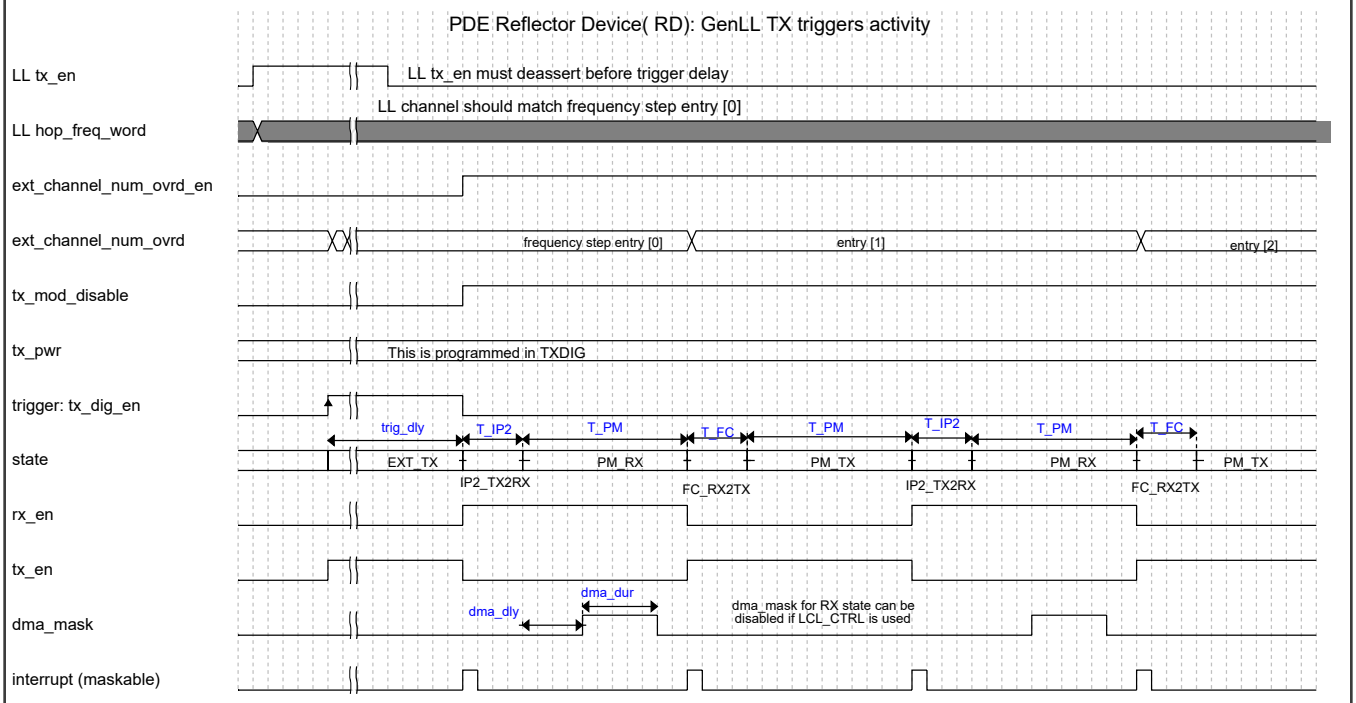


Figure 334. PDE Timing with TX_EN=1 (RD Role)

52.4.4.2.2.5.3.2 PDE RX_EN=1 (MD Role)

The RSM state diagram below illustrates the RSM states used for PDE with RX_EN=1 (MD Role). Note that unlike SQTE, only one step format (Tn-Tn) is used, so the state diagram is greatly simplified. The states are described as follows:

- IDLE. This is the state the RSM is in after a reset and after a sequence has completed (or been aborted).
- EXT_RX. After the trigger is recognized, the RSM will enter and stay in this state for TRIG_DLY microseconds. During this state, the RSM will assert its rx_en output to the TSM. The link layer continues to control the transceiver at entry to this state, but is expected to de-assert its rx_en output by the time the TRIG_DLY timer expires.
- FC_TX2RX (Frequency Change TX-to-RX transition). In this state the RSM directs the TSM to switch from TX to RX mode, change the radio frequency, and start a new step. The nominal duration of this state is T_FC
- PM_RX (Tone Transmit). In this state the TSM directs the transceiver to receive a "tone". The nominal duration of this state is T_PM0, T_PM1, T_PM2, or T_PM3 depending on the t_p_sel[1:0] bitfield in the frequency step data stored in Packet RAM
- PM_TX (Tone Transmit). In this state the TSM directs the transceiver to transmit a tone. The duration of this state is T_PM0, T_PM1, T_PM2, or T_PM3 depending on the t_p_sel[1:0] bitfield in the frequency step data stored in Packet RAM
- IP2_RX2TX (Role swap RX-to-TX transition). In this state, the RSM directs the TSM to switch from RX to TX mode. The nominal duration of this state is T_IP2
- WD (Warmdown). The RSM de-asserts its rx_en or tx_en (depending on what state it was in prior to warmdown) directing the TSM to warm down the transceiver

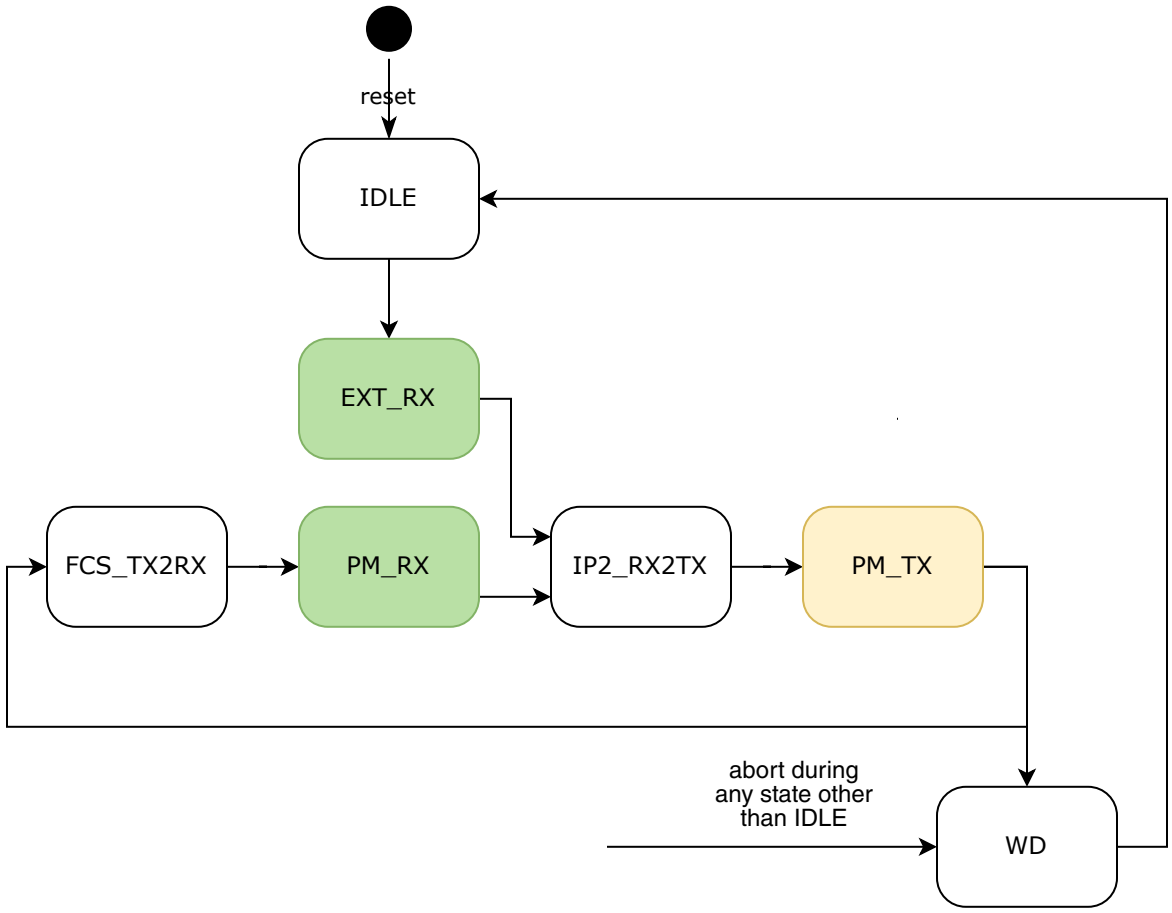


Figure 335. RSM State Transition Diagram for PDE RX_EN=1 (MD role)

The figure below show PDE operation when the RSM is configured to begin with receive operation. On assertion of the trigger (for example, crc_valid), the RSM will assert its rx_en signal to keep the receive operation active until TRIG_DLY expires. By that time, the LL's rx_en should be de-asserted so that the RSM can take full control of the transceiver. When the RSM is configured to begin with receive, frequency steps occur on TX2RX transitions; role swaps without frequency changes occur on RX2TX transitions. When PDE begins with receive, the trigger is also a timing reference for DMA_DLY0 and DMA_DUR0, which define when and how long the dma_mask will be asserted for the initial receive operation.

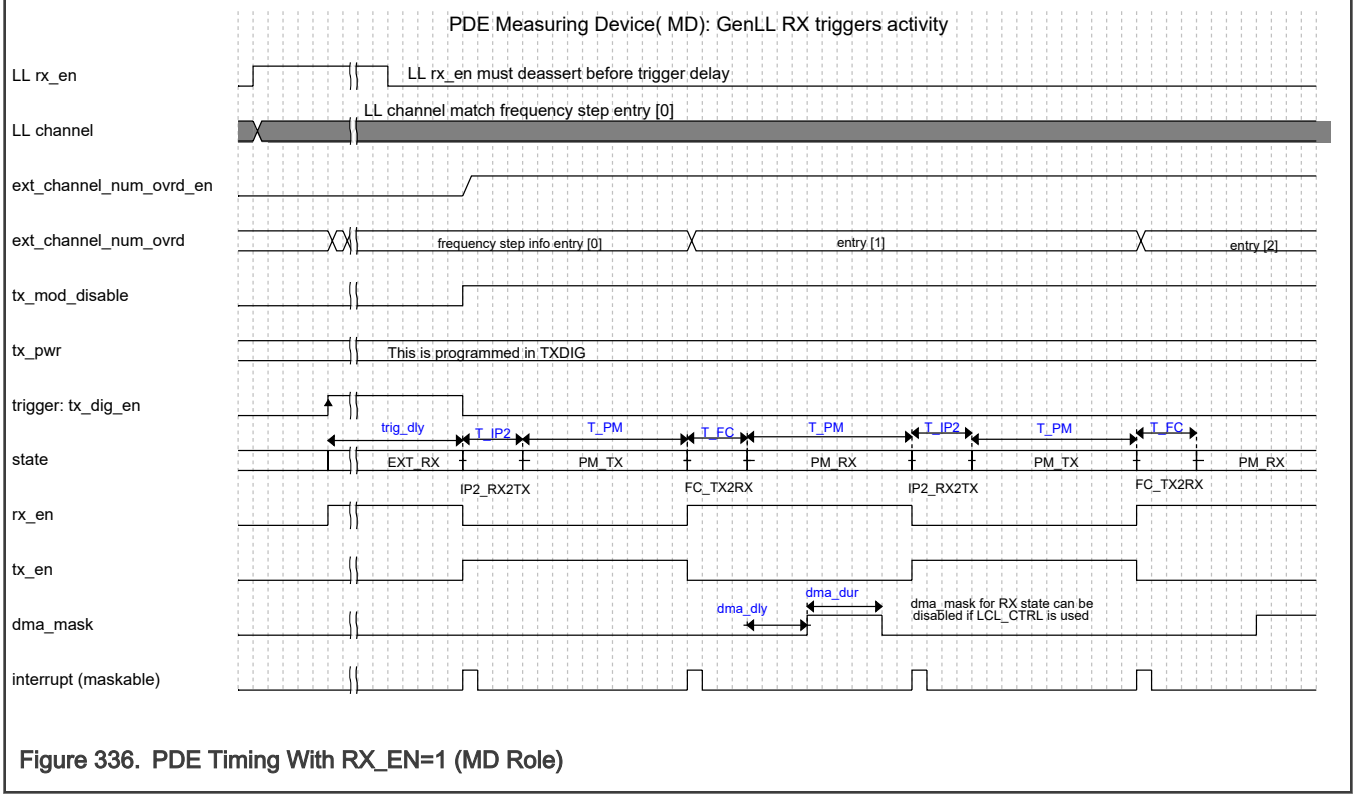


Figure 336. PDE Timing With RX_EN=1 (MD Role)

52.4.4.2.2.5.4 Payload demodulation (Sounding/Random sequence)

52.4.4.2.2.5.4.1 Overview

The Channel Sounding standard defines two optional sequences which extends the packet length by adding payload after Access Address and the trailer bits in order to improve the time of arrival estimation as well as to detect potential MITM attacks.

- The optional sounding sequence is a sequence of bit alternating between 0 and 1 bits, The first bit of the sounding sequence is always 0 and the last bit of the sounding sequence is always a 1. For each packet, one or more 4-bit marker signal shall be added at a random location with a random polarity which is unknown to an attacker. The position and the polarity of these markers are determined cryptographically by the two devices through a lock-step symmetric key mechanism.
- The optional random sequence payload is a sequence of randomized bits for each packet. This random bit sequence is completely unknown to an attacker as it is determined cryptographically by the two devices through a lock-step symmetric key mechanism.

Enabling the demodulation mechanism allows FW to detect an attack through the error detection by comparing demodulated bits with expected bits of the sounding sequence.

The payload demodulation can also be activated during random sequence to improve the attack detection by using a higher-sensitivity symbol demodulator.

52.4.4.2.2.5.4.2 GEN4_PHY programming

In order to provide the received payload of the sounding or random sequences to FW, radio shall support the payload demodulation of RTT packets with a random bit sequence payload (32, 64, 96 or 128 bit) . This packet demodulation can be applied in mode 1 or mode 3 in case of non-null payload length.

If register bitfield RTT_CTRL[RTT_SEQ_SEQ_LEN] is set then demodulation is started at the same time as RTT computation otherwise payload is not demodulated and only RTT computation is performed.

Some registers have to be programmed in GEN4_PHY in order to demodulate payload

- GEN4_PHY_DMD_CTRL2[WAIT_DMD_CLKEN_ADJ] = 0x7 : valid value to ensure correct demodulation of the fist payload bit
- GEN4_PHY_DMD_CTRL1[TTRK_INT_RANGE] = 0x2 : valid value to ensure correct demodulation of the fist payload bit
- GEN4_PHY_RTT_CTRL[RTT_SEQ_LEN] = 0x1 : enables Payload demodulation during RTT computation. In order to ensure the correct demodulator behavior, RTT_SEQ_LEN bitfield must be set only after Mode0 if rtt_type /=0. It should be written in the same time as the AGC_GAIN_ IDX_OVRD bi

52.4.4.2.2.5.4.3 RX PAYLOAD

Payload can be stored in memory by GenFSK.

Rx payload stored by GENFSK

If the demodulated packet demodulation mode is enabled then GENFSK link Layer has to be programmed during CS initialization to store the demodulated payload in Rx Packet RAM by setting the register bitfield MULT_PKT_CTRL[MULT_PKT_EN] which enables the feature “Send and Receive multiple packets” in GENFSK link Layer.

In this configuration, the first packet received is stored in the Segment 0. The second packet is stored in Segment 1, and so on. Register MULT_PKT_CTRL[PKT_INDEX] is initially 0 and is automatically increased by 1 after successfully received a packet. So MULT_PKT_CTRL[PKT_INDEX] has two meanings: the number of packet received and the segment number to store the next coming packet. FW can check PKT_INDEX to identify the location of the latest received payload in RX Packet RAM.

FW has also to write MULT_PKT_CTRL[RESET_PKT_IDX] to clear the PKT_INDEX to 0 before starting a CS sub-event with payload demodulation mode.

Since the maximum payload size is 128 bits, FW has also to set the RAM Segment Size for each packet to the minimum segment size which is 32bytes (MULT_PKT_CTRL[SEG_SZ]=0). This setting optimizes the memory space in Rx Packet RAM for RTT packet reception.

If the payload demodulation is enabled with GenFSK then it’s preferable to put circular config and result RSM buffers in Tx packet RAM to avoid that GenFSK Link layer overrides the content of these buffers when it stores payload in the different segments of the Rx packet RAM.

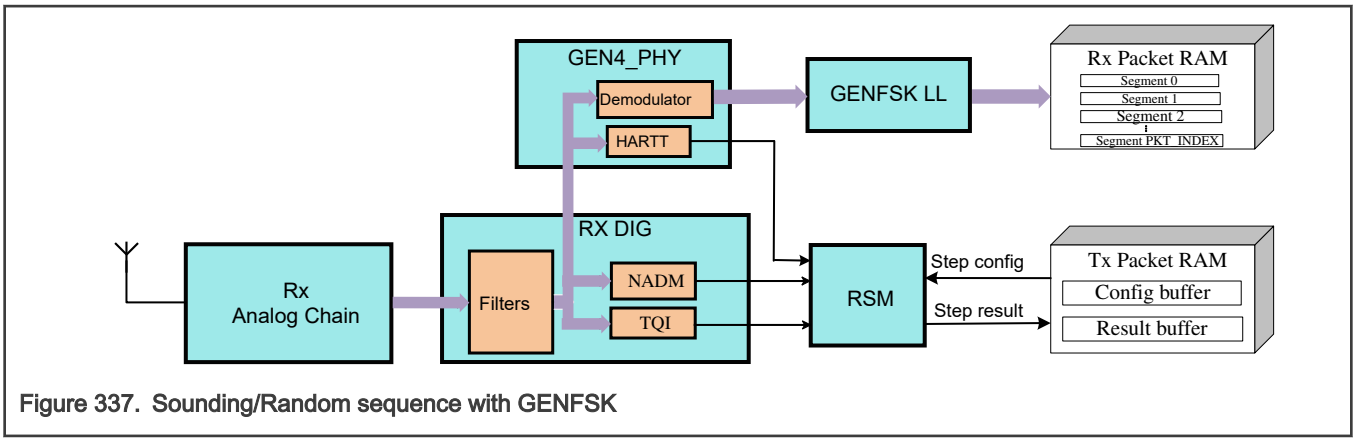


Figure 337. Sounding/Random sequence with GENFSK

Some additional registers have also to be programmed in order that GenFSK Link Layer stores correctly payload in Rx Packet RAM during channel sounding sub-events. An example of programming is described below:

- XCVR_TSM_CTRL[TSM_LL_INHIBIT]=x8 : disables GenFSK LL command at TSM level.
- GENFSK_ENH_FEATURE[STAY_IN_RX]=1 : forces GenFSK LL to stay in Rx state after a correct RX packet
- GENFSK_PACKET_CFG[LENGTH_SZ]=0 : indicates there is no length field in Header
- GENFSK_PACKET_CFG[H0_SZ]=0 : indicates there is no H0 field in Header

- GENFSK_PACKET_CFG[H1_SZ]=0 : indicates there is no H1 field in Header
- RBME_CRCW_CFG3[CRC_SZ]=0 : indicates there is no CRC field in Packet
- GENFSK_PACKET_CFG[AA_PLAYBACK_CNT]=1 : indicates that AA is playback to Link Layer.
- GENFSK_PACKET_CFG[SYNC_ADDR_SZ]=0 : reduces AA size to 1 byte
- GENFSK_LENGTH_ADJ = Payload length -1 (in bytes) depends on RSM_CTRL2[RSM_RTT_TYPE] value
- GENFSK_MULT_PKT_CTRL[MULT_PKT_EN] =1 : enables feature “Send and Receive multiple packets” in GENFSK link Layer
- GENFSK_MULT_PKT_CTRL[SEG_SZ]=0 : reduces the Segment depth to 32 bytes
- GENFSK_XCVR_CTRL[SEQCMD] = 0x5 : puts GenFSK LL in Rx mode
- GEN4_PHY_DMD_CTRL2[WAIT_DMD_CLKEN_ADJ] = 0x7 : valid value to ensure correct demodulation of the fist payload bit
- GEN4_PHY_DMD_CTRL1[TTRK_INT_RANGE] = 0x2 : valid value to ensure correct demodulation of the fist payload bit
- GEN4_PHY_RTT_CTRL[RTT_SEQ_LEN] = 0x1 : enables Payload demodulation during RTT computation. In order to ensure the correct demodulator behavior, RTT_SEQ_LEN bitfield must be set only after Mode0 if rtt_type /=0. It should be written in the same time as the AGC_GAIN_ IDX_OVRD bitfield.

52.4.4.2.2.5.5 Timestamp Packet Module

52.4.4.2.2.5.5.1 Overview

The TPM block is basically a counter that allows to get the packet detection time. Having this feature embedded in the radio allows to add the TPM collected information to the packet ram results, as part of the CS information, collected by the hardware at each step and needed for RTT.

52.4.4.2.2.5.5.2 Functional Description

The TPM counter is a 32-bits counter clocking by transceiver clock that measures the ToD-ToA and ToA-ToD time. The start/stop conditions depend on the initiator or reflector role:

52.4.4.2.2.5.5.2.1 Initiator mode

The behavior of the TPM counter in Initiator mode is the same whatever the step number or the modes 0, 1, or 3.

The Initiator needs to report ToA-ToD, the counter is therefore :

- reset on rsm_tx_on assertion which corresponds to the beginning of data transfer from RSM to TX_DIG.
- counts from the DT_TX state of first half part of the step until next access address detection in the DT_RX state of the second half part of the CS step .

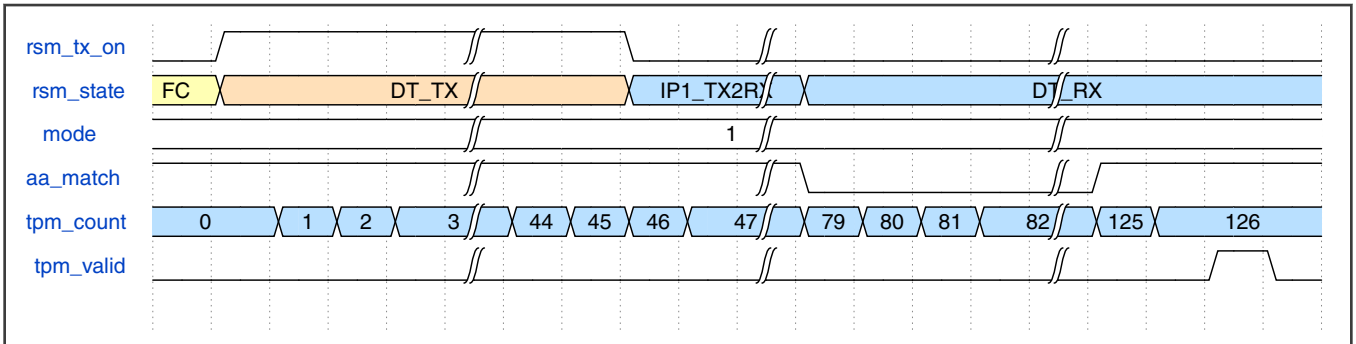


Figure 338. TPM behavior in Initiator mode

52.4.4.2.2.5.5.2.2 Reflector mode

The behavior of the TPM counter in Reflector mode differs for the first CS step than the others steps.

- For the first step, the TPM starts counting from the beginning of the warm-up sequence until the access address detection in the DT_RX state of the first half part of the CS step.

  This specific TPM value is used by FW to compute the timestamp of the beginning of the reflector sub-event .

  Note that in case of mode0 timeout configuration, TPM counter is still counting until the first Access Address detection which can occur after several FCS steps instead of the first FCS Step.

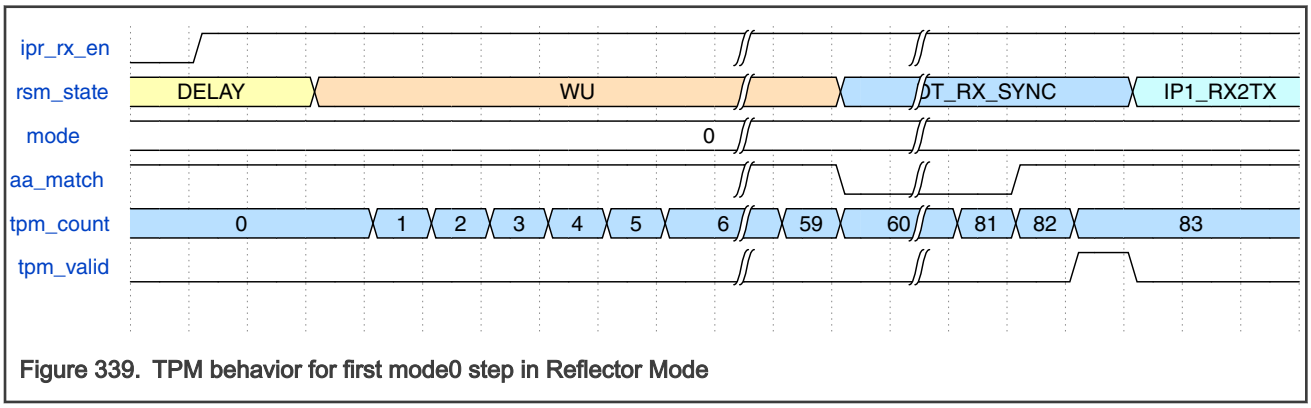


Figure 339. TPM behavior for first mode0 step in Reflector Mode

- For the others steps, the Reflector needs to report ToD-ToA, so the counter is therefore :
  - reset on rsm_tx_on assertion which corresponds to the beginning of data transfer from RSM to TX_DIG.
  - counts from the access address detection in DT_RX state of first half part of the step until the beginning of data transfer from RSM to TX_DIG in the second half part of the CS step .

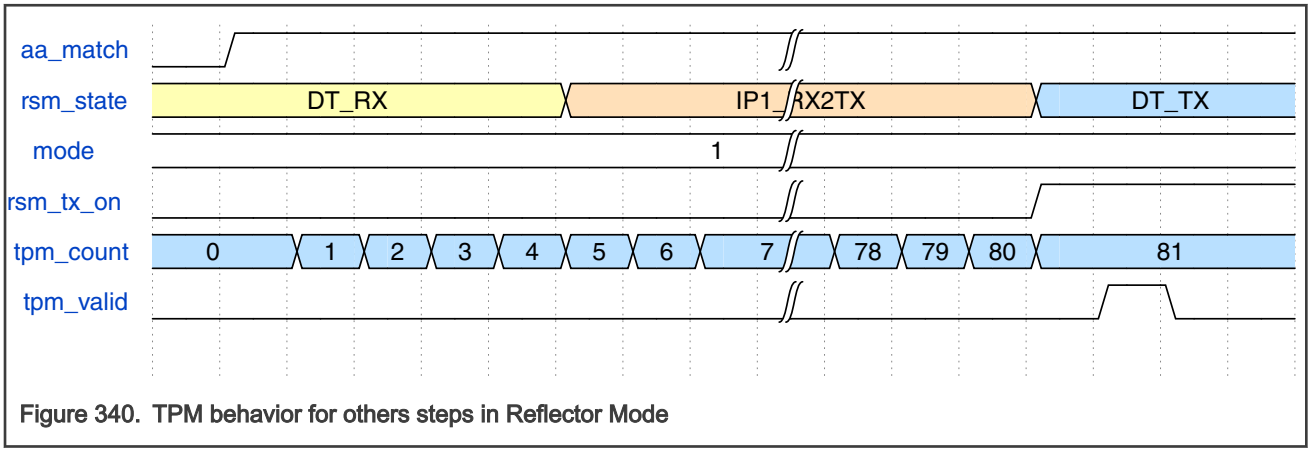


Figure 340. TPM behavior for others steps in Reflector Mode

52.4.4.2.2.5.6 Sniffer Capability

52.4.4.2.2.5.6.1 Overview

The RSM block has been updated to support the sniffer capability. When set to sniffer mode, the RSM basically works in rx mode only, and collects data from both the initiator and the reflector:

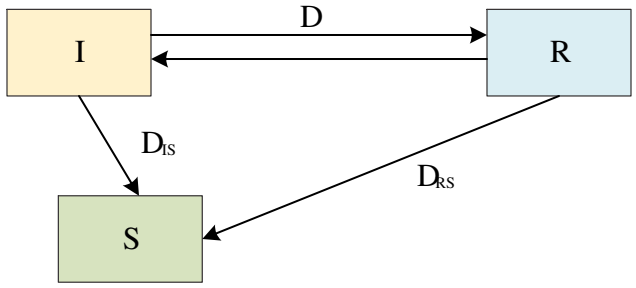


Figure 341. Sniffer Role

52.4.4.2.2.5.6.2 Functional Description

The sniffer mode is enabled by the RSM_SN_EN bitfield of RSM_CTRL0 register.

The RSM state machine has been updated in order to support the features required by the sniffer mode. For mode 0, the synchronization mechanism is the same as a reflector . The sniffer will mainly replace tx_mode with rx_mode for all modes. Next picture gives an overview of the sniffer behavior for all modes

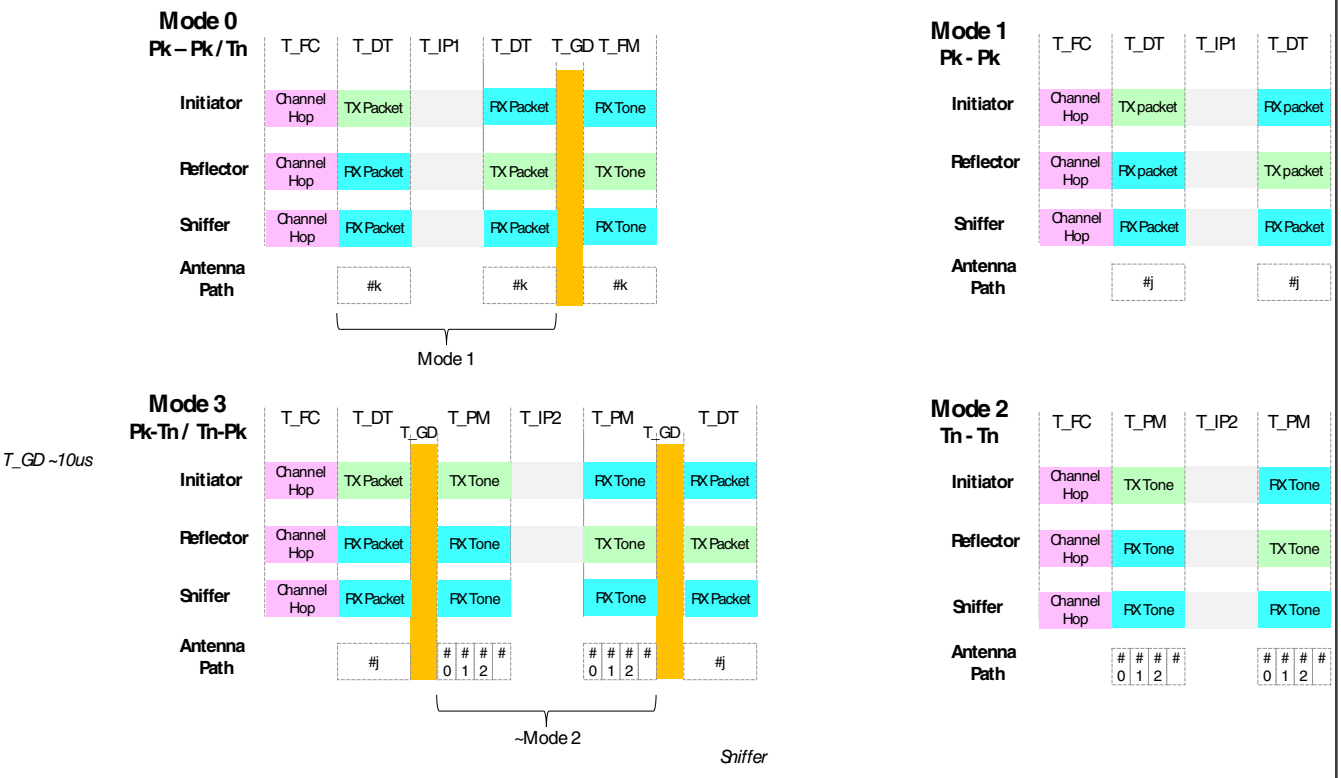


Figure 342. Overview of Sniffer Role for all modes

The details about the RSM states and evolution, for all the modes, when Sniffer role is active, is shown just below:

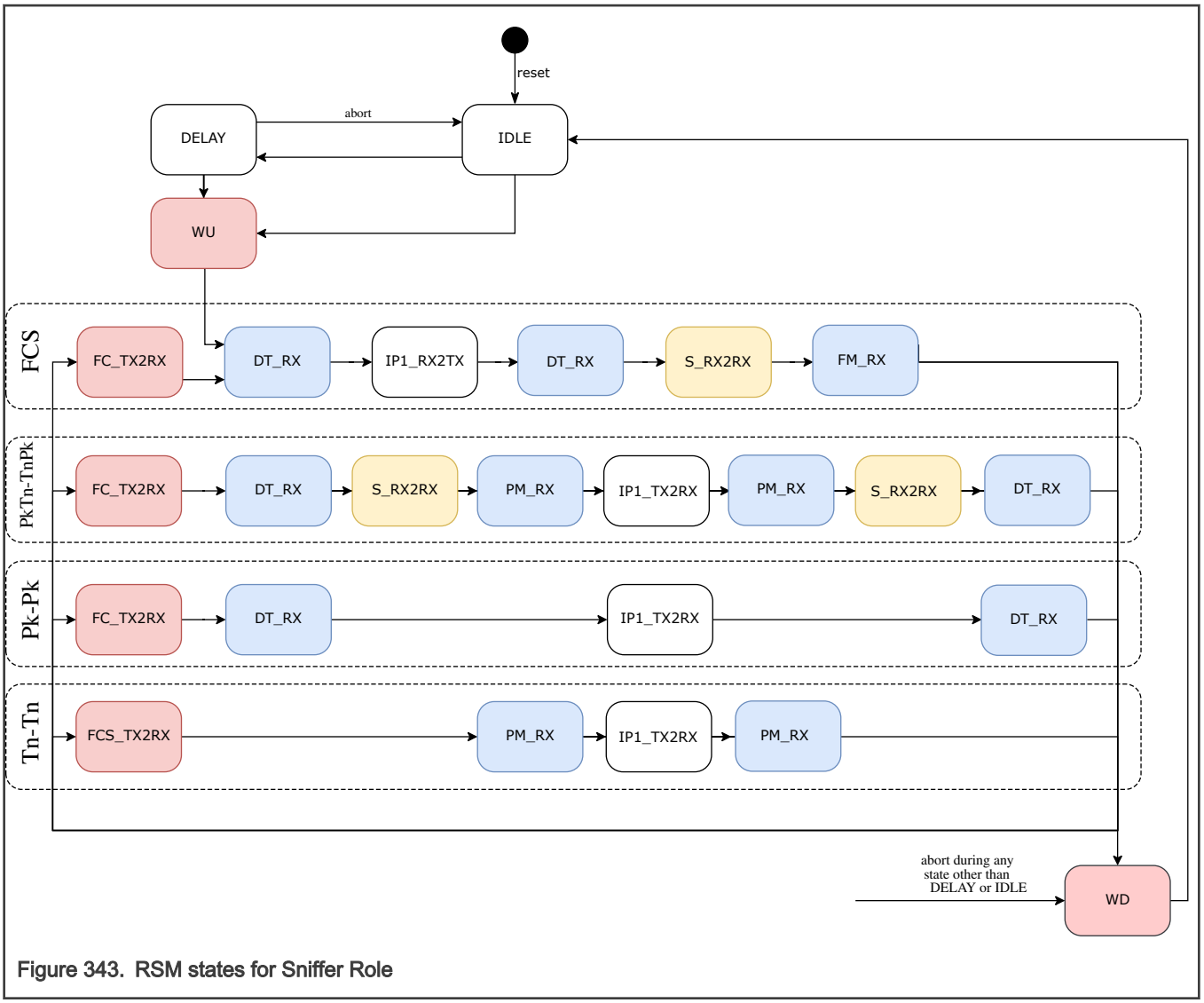


Figure 343. RSM states for Sniffer Role

The sniffer must collect data from both the initiator and the reflector, thus it needs to manage two different receptions and AGC gains. In Mode 0 the sniffer computes both the initiator and reflector gain. After mode 0, the gain to apply to the Reflector transmission part of the step is stored in the SN_AGC_INIT_IDX2 bitfield of the RXDIG CTRL2 register.

52.4.4.2.2.5.7 Unidirectional Mode

52.4.4.2.2.5.7.1 Overview

The MCXW72 Radio supports a custom unidirectional ranging mode, also called "one way". The RSM state machine fully supports this feature, independently if it acts as Initiator, Reflector or Sniffer.

52.4.4.2.2.5.7.2 Functional Description

The unidirectional mode is activated by a new field (step_one_way) in the configuration buffer of the Packet RAM.

Note that unidirectional mode is not supported in mode 3, as shown by the following picture:

Following, an overview of the different modes for Initiator, Reflector and Sniffer, when unidirectional mode is active. The Mode 0 does not change with respect to the bidirectional mode, because the device needs to sync, in any case.

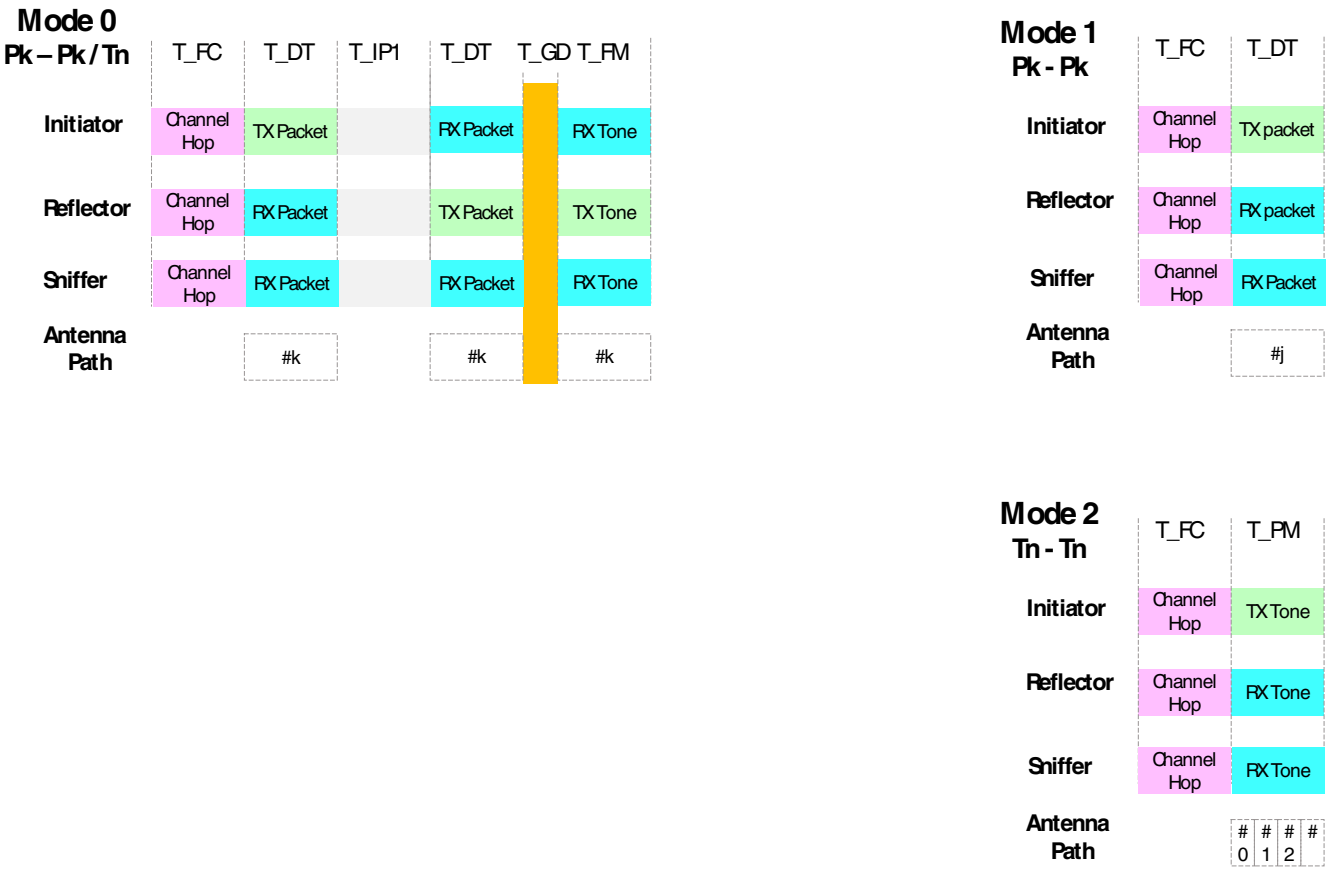


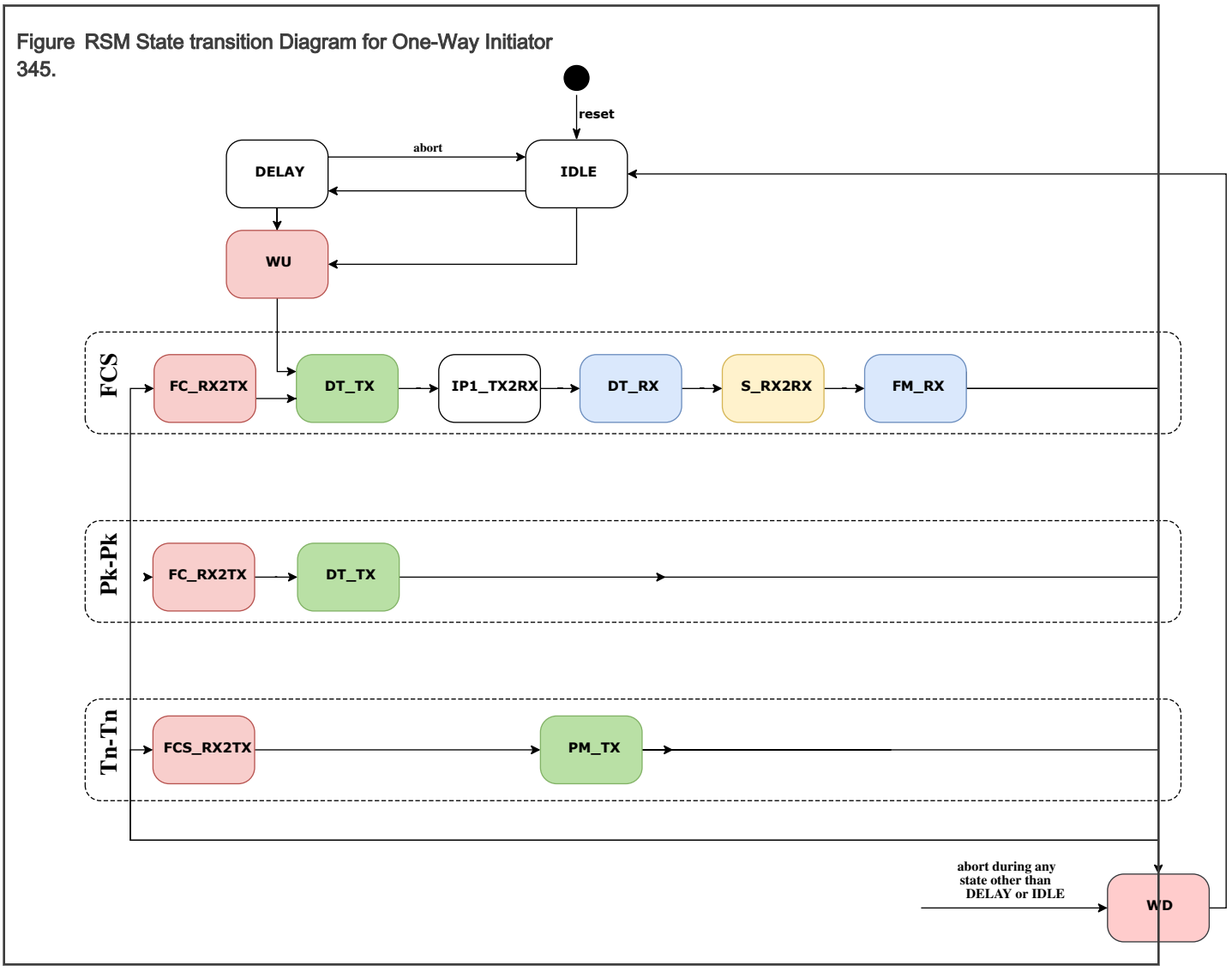
Figure 344. Overview of undirectional mode

SQTE Unidirectional Initiator Role

The RSM state diagram below illustrates the RSM states used for SQTE in the Initiator role (TX_EN=1) when the one-way mode is activated. Some of the states are duplicated in the figure to more clearly show the state transition sequence for the supported step format types (FCS, Pk-Pk and Tn-Tn).

The description of each state can be found in the SQTE mode related chapter

Figure RSM State transition Diagram for One-Way Initiator 345.



SQTE Unidirectional Reflector Role

The RSM state diagram below illustrates the RSM states used for SQTE in the Reflector role (RX_EN=1) when the one-way mode is activated. Some of the states are duplicated in the figure to more clearly show the state transition sequence for the supported step format types (FCS, Pk-Pk and Tn-Tn). The description of each state can be found in the SQTE mode related chapter.

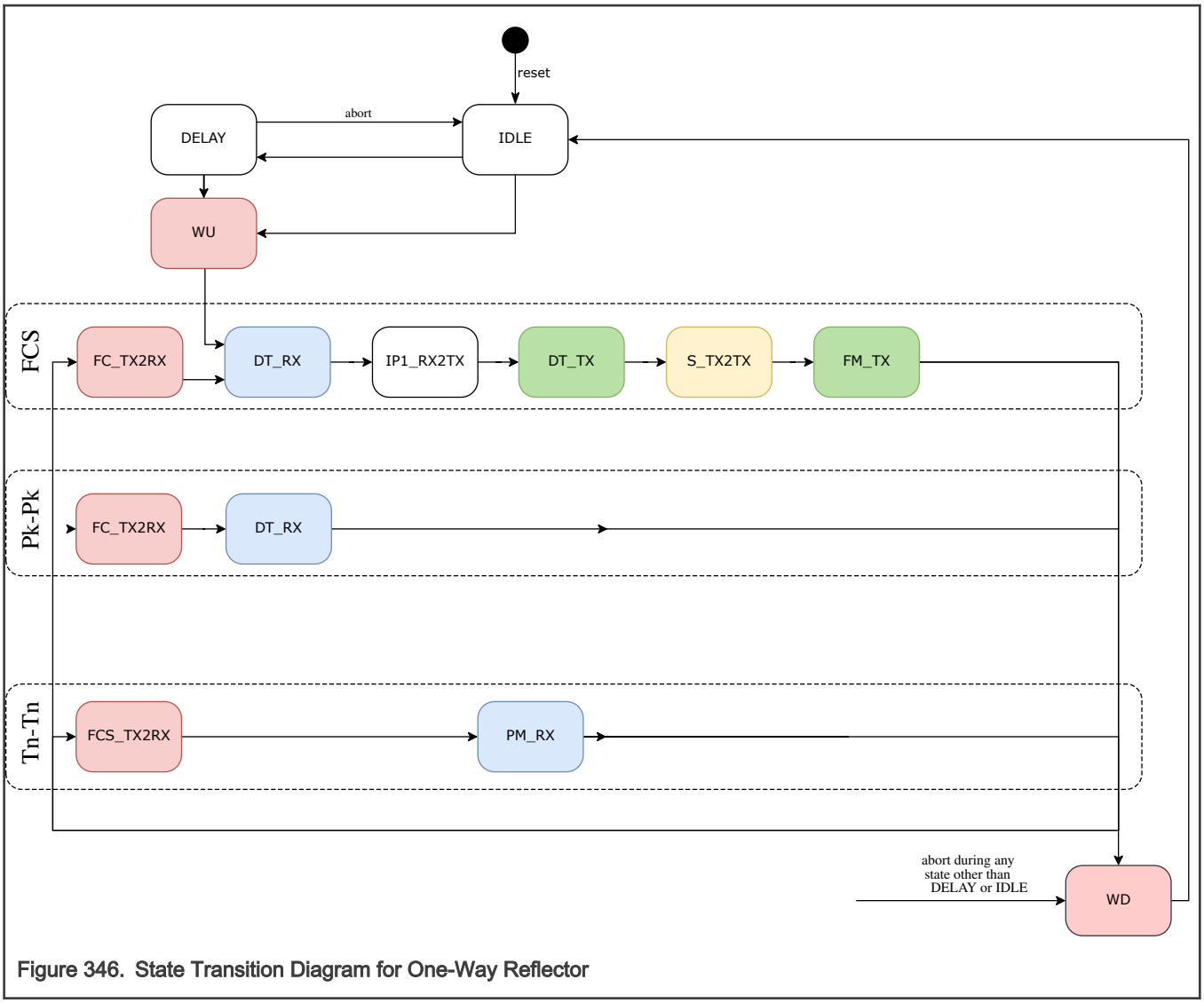


Figure 346. State Transition Diagram for One-Way Reflector

SQTE Unidirectional Sniffer Role

The RSM state diagram below illustrates the RSM states used for SQTE in the Sniffer role (RX_EN=1) when the one-way mode is activated. Some of the states are duplicated in the figure to more clearly show the state transition sequence for the supported step format types (FCS, Pk-Pk and Tn-Tn). The description of each state can be found in the SQTE mode related chapter.

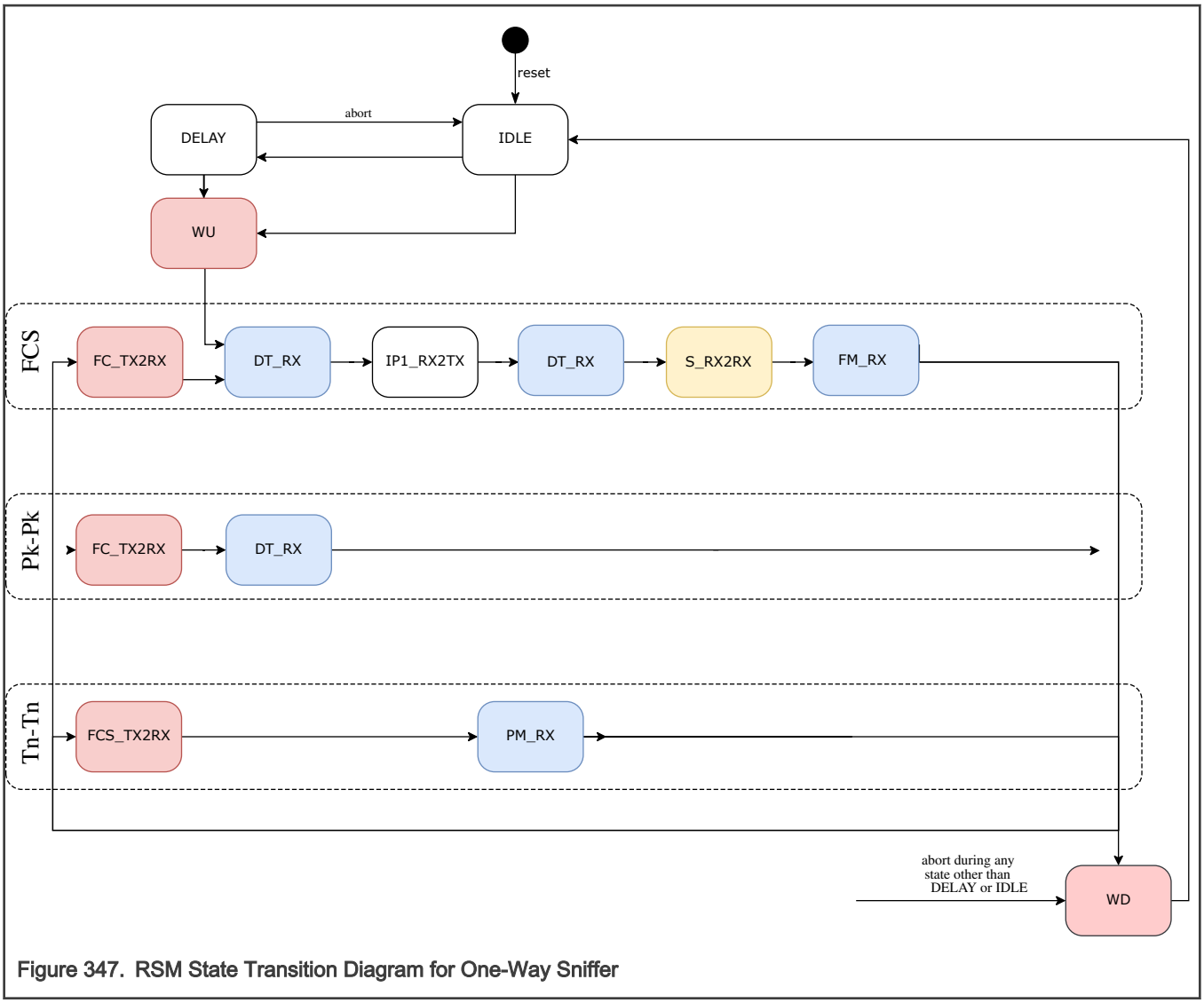


Figure 347. RSM State Transition Diagram for One-Way Sniffer

52.4.4.2.2.5.8 Role Swap and Frequency Change Transitions

This section provides information on the role swap (changing from receive to transmit or vice versa, from receive packet to receive tone or vice versa, or from transmit packet to transmit tone or vice versa) and frequency change transitions (with or without role swap) and their timings in more detail. These transitions are all intended to be handled by the RSM logic without software involvement; however, as a fallback, it is also possible to trigger interrupts at the beginning of different states so that software can perform any additional tasks. Note that fewer transitions are supported for PDE than for SQTE, and that the transitions used depends also on the role (whether RX_EN or TX_EN bit is set).

52.4.4.2.2.5.8.1 TSM Features Utilized

The RSM utilizes several TSM features to control these transitions and to minimize the transition durations: fast RX2TX and fast TX2RX; recycle events; and fast RX and TX warmups. RSM usage of these features is described in the next three paragraphs.

First, for role swap the RSM always directs the Transceiver Sequence Manager (TSM) to perform fast RX2TX and fast TX2RX transitions. In these transitions, the TSM jumps from a recieve (transmit) sequence already warmed up to a programmable starting point in the transmit (receive) sequence. The starting points are programmed in the TSM: FAST_TX2RX_START for IP1_TX2RX or IP2_TX2RX, FAST_TX2RX_START_FC for FC_TX2RX, FAST_RX2TX_START for IP1_RX2TX or IP2_RX2TX, and FAST_RX2TX_START_FC for FC_RX2TX. For the FC_RX2TX and FC_TX2RX, the start value is expected to be programmed such that the TSM's pll_dig_en is de-asserted for 1us and then re-asserted, coincident with new frequency information provided

to the PLL from the RSM; for the other transitions a frequency change is not performed, so the start time value should be such that the TSM's pll_dig_en does not de-assert.

Second, for S_RX2RX transitions (which are only used in SQTE), the RSM can direct the TSM using a "recycle0" event. In these transitions, the TSM jumps from a receive sequence already warmed up to a programmable starting point in the receive sequence. The starting count is programmed in the TSM's RECYCLE_COUNT0 bitfield such that rx_dig_en cycles and rx_init pulses to reset the receiver. (Note that S_TX2TX does not require a recycle event; the transmitter is not reset during this transition)

Third, to further minimize the duration of the RX2TX and TX2RX transitions, the RSM can direct the TSM to perform a fast TX or fast RX warmup. Fast RX or TX warmups allow the TSM to skip some TSM counts in the middle of the TSM warmup sequence (after the RX2TX and TX2RX start times described above). For example, during a fast RX warmup the DCOC calibration time can be skipped. The skip times are programmed in the TSM: FAST_TX_START and FAST_TX_DEST for transmit, and FAST_RX_START and FAST_RX_DEST for receive. The use of fast RX or TX warmups during RSM transitions is an optional feature. It is enabled through the RSM's FAST_IP_TX_WU (for IP1_RX2TX and IP2_RX2TX transitions), FAST_IP_RX_WU (for IP1_TX2RX and IP2_TX2RX transitions), FAST_FC_RX_WU (for FC_TX2RX transitions), and FAST_FC_TX_WU (for FC_RX2TX transitions) bitfields.

In below discussion of the transition timings, the following assumptions are made concerning the configuration of the TXDIG ramp:

- TXDIG is programmed for 1us ramp (PA_RAMP_SEL=2'b01).

NOTE

The 1us ramp setting is a requirement for proper operation of the RSM with the TXDIG

- For PA ramp-up: PAD_DLY (delay from tx_dig_en to PA enable) is assumed to be programmed to 0

The RX2TX transition states (IP1_RX2TX, IP2_RX2TX, and FC_RX2TX) are described as follows:

- The RSM signals to the TSM to initiate a fast RX2TX transition. In response the TSM will change from rx_mode to tx_mode and change its count to FAST_RX2TX_START (IP1_RX2TX, IP2_RX2TX) or FAST_RX2TX_START_FC (FC_RX2TX). FAST_RX2TX_START and FAST_RX2TX_START_FC are programmed in the TSM
- If RSM's FAST_IP_TX_WU bit is set (IP1_RX2TX, IP2_RX2TX) or FAST_FC_TX_WU bit is set (FC_RX2TX), the RSM will also signal to the TSM to perform a fast warmup during the TX warmup. As the TSM count increments it will skip from FAST_TX_START to FAST_TX_DEST (which are programmed in the TSM)
- The TSM reaches the end of warmup when its count reaches END_OF_TX_WU and after the TXDIG has asserted the pa_wu_complete signal.

The time needed for the RX2TX transitions are shown in the table below, where the term "pa_ru" accounts for any additional time after END_OF_TX_WU before the PA ramp-up completes:

- if (RAMP_UP_DLY + 2us >= END_OF_TX_WU - TX_DIG_EN_TX_HI) pa_ru = (RAMP_UP_DLY + 2us) - (END_OF_TX_WU - TX_DIG_EN_TX_HI)
- else pa_ru = 0us

Transition	Time needed for transition	Roles
IP1_RX2TX	(END_OF_TX_WU - FAST_RX2TX_START) - (FAST_DEST_TX - FAST_START_TX)*FAST_IP_TX_WU + pa_ru	SQTE Reflector
IP2_RX2TX	(END_OF_TX_WU - FAST_RX2TX_START) - (FAST_DEST_TX - FAST_START_TX)*FAST_IP_TX_WU + pa_ru	SQTE Reflector, PDE MD
FC_RX2TX	(END_OF_TX_WU - FAST_RX2TX_START_FC) - (FAST_DEST_TX - FAST_START_TX_FC)*FAST_FC_TX_WU + pa_ru	SQTE Initiator, PDE RD

The TX2RX transition states (IP1_TX2RX, IP2_TX2RX, and FC_TX2RX) are described as follows:

- The RSM directs the TXDIG to ramp-down the PA

- The RSM signals to the TSM to initiate a fast TX2RX transition. In response the TSM will change from tx_mode to rx_mode and change its count to FAST_TX2RX_START (IP1_TX2RX, IP2_TX2RX) or FAST_TX2RX_START_FC (FC_TX2RX). FAST_TX2RX_START and FAST_TX2RX_START_FC are programmed in the TSM
- If RSM's FAST_IP_RX_WU bit is set (IP1_TX2RX, IP2_TX2RX) or FAST_FC_RX_WU bit is set (FC_TX2RX), the RSM will also signal to the TSM to perform a fast warmup during the RX warmup. As the TSM count increments it will skip from FAST_RX_START to FAST_RX_DEST (which are programmed in the TSM)
- The TSM reaches the end of warmup when its count reaches END_OF_RX_WU.

The time needed for the TX2RX transitions are shown below. The 2us + TX_DATA_FLUSH_DLY is related to PA ramp-down at the beginning of the transition .

Transition	Time needed for transition	Roles
IP1_TX2RX	(END_OF_RX_WU - FAST_TX2RX_START) - (FAST_DEST_RX - FAST_START_RX)*FAST_IP_RX_WU + 2us + TX_DATA_FLUSH_DLY	SQTE Initiator
IP2_TX2RX	(END_OF_RX_WU - FAST_TX2RX_START) - (FAST_DEST_RX - FAST_START_RX)*FAST_IP_RX_WU + 2us + TX_DATA_FLUSH_DLY	SQTE Inititator, PDE RD
FC_TX2RX	(END_OF_RX_WU - FAST_TX2RX_START_FC) - (FAST_DEST_RX - FAST_START_RX)*FAST_FC_RX_WU + 2us + TX_DATA_FLUSH_DLY	SQTE Reflector, PDE MD

The RX2RX transition state (S_RX2RX) is described as follows.

- The RSM signals to the TSM using recycle0. In response the TSM will change its count to RECYCLE_COUNT0
- The TSM reaches the end of warmup when its count reaches END_OF_RX_WU.

The TX2TX transition state (S_TX2TX), doesn't require a recycle event; the TX_DATA_FLUSH_DLY accounts for the flushing delay in the transition. The time needed for the RX2RX and TX2TX transitions are shown below.

Transition	Time needed for transition	Roles
S_RX2RX	(END_OF_RX_WU - RECYCLE_COUNT0)	SQTE Initiator, SQTE Reflector
S_TX2TX	TX_DATA_FLUSH_DLY	SQTE Initiator, SQTE Reflector

For SQTE, the RSM has to warmup the transceiver from the TSM IDLE state. For SQTE Initiator role, if RSM's FAST_FC_TX_WU bit is set, the RSM will signal to the TSM to perform a fast warmup during the TX warmup. For SQTE Reflector role, if RSM's FAST_FC_RX_WU bit is set, the RSM will signal to the TSM to perform a fast warmup during the RX warmup.

Transition	Time needed for transition	Roles
WU	END_OF_TX_WU - (FAST_DEST_TX - FAST_START_TX)*FAST_FC_TX_WU + pa_ru + 3us	SQTE Initiator (TX warmup)
WU	END_OF_RX_WU - (FAST_DEST_RX - FAST_START_RX)*FAST_FC_RX_WU + 1us	SQTE Reflector (RX warmup)

52.4.4.2.2.5.8.2 RX and TX Latency Handling

When transmitting, in order to be "on air" beginning at the desired time, it is necessary to account for the latency through the TXDIG and PLL. To account for this, the RSM uses the TXDIG programmable value TX_DATA_FLUSH_DLY which is specified in terms of microseconds. The RSM will shift TX states (DT_TX, FM_TX, PM_TX) to begin earlier in time by TX_DATA_FLUSH_DLY to ensure that transmit information is "on air" at the correct time.

When receiving is it necessary to account for latency through the receiver and PHY. The RSM uses the TSM programmable value RX_SETTLING_LATENCY (which is specified in terms of microseconds) for this. The RSM will extend RX states (DT_RX, FM_RX, PM_RX) by RX_SETTLING_LATENCY to ensure that the last "on air" information during T_DT, T_FM, or T_PM can be processed by the receiver. Please note that RSM_RXLAT_DIG has no impact on RSM states duration, but it maintains active some radio processing modules (for instance HARTT computation) after the end of PM_STATE or RX_DT_STATE, even if RSM state has changed. Note that the RX_SYNC_DLY value depends on RX_SETTLING_LATENCY and they both must be changed in order to properly align reflector timings.

These concepts are illustrated in the example figure below for a SQTE step of type Pk-Tn-Tn-Pk. In both Initator and Reflector roles, the TX (DT_TX, FM_TX, and PM_TX) states are shifted early by TX_DATA_FLUSH_DLY with respect to the "nominal time", while the RX (DT_RX, FM_RX, and PM_RX) states are extended by RX_SETTLING_LATENCY.

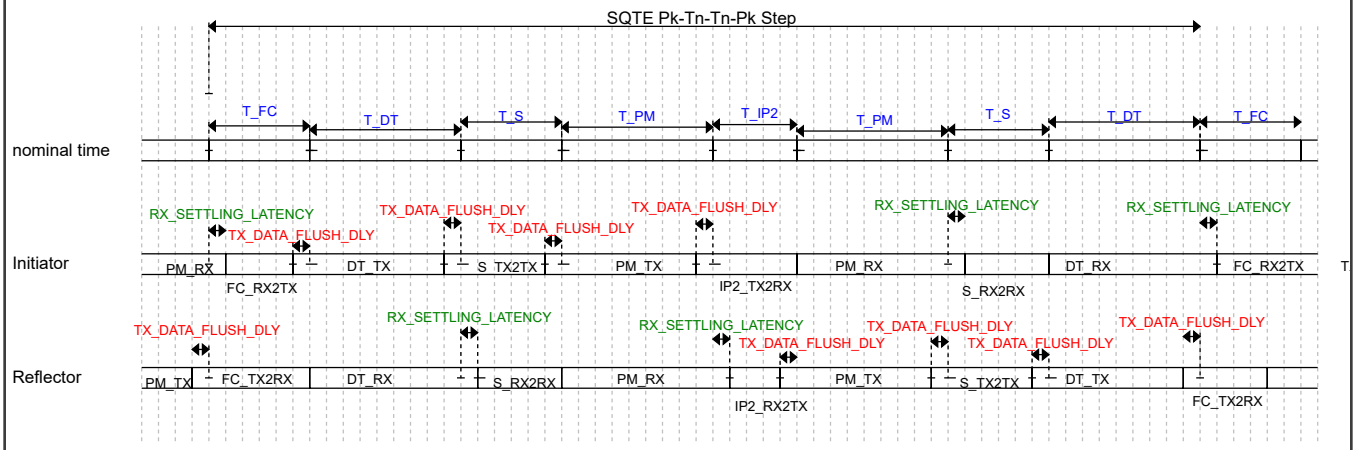


Figure 348. RX and TX Latency

As shown in the timing figure above, after taking into account the RX and TX latencies some of RSM state's durations are different than the "nominal" durations. This is summarized in the table below

Table 481. RSM Actual State Durations

State	Nominal Duration	Actual Duration
FC_RX2TX	T_FC	T_FC - RX_SETTLING_LATENCY - TX_DATA_FLUSH_DLY
IP1_RX2TX	T_IP1	T_IP1 - RX_SETTLING_LATENCY - TX_DATA_FLUSH_DLY
IP2_RX2TX	T_IP2	T_IP2 - RX_SETTLING_LATENCY - TX_DATA_FLUSH_DLY
FC_TX2RX	T_FC	T_FC + TX_DATA_FLUSH_DLY
IP1_TX2RX	T_IP1	T_IP1 + TX_DATA_FLUSH_DLY
IP2_TX2RX	T_IP2	T_IP2 + TX_DATA_FLUSH_DLY
S_RX2RX	T_S	T_S - RX_SETTLING_LATENCY
S_TX2TX	T_S	
PM_RX	T_PM[1]	T_PM[1] + RX_SETTLING_LATENCY
FM_RX	T_FM[2]	T_FM[2] + RX_SETTLING_LATENCY

Table continues on the next page...

Table 481. RSM Actual State Durations (continued)

State	Nominal Duration	Actual Duration
DT_RX	T_DT[3]	T_DT[3] + RX_SETTLING_LATENCY
PM_TX	T_PM[1]	
FM_TX	T_FM[2]	
DT_TX	T_DT[3]	

1. T_PM0, T_PM1, T_PM2, or T_PM3 depending on T_PM_SEL[1:0] for the current step format
2. T_FM0 or T_FM1 depending on T_PM_SEL[0] for the current step format
3. T_DT is a function of RATE and RTT_TYPE programmable bitfields.
   - 1Mbps rate, RTT_TYPE=0 : 8bit preamble + 32bit data + 4bit trailer = 44us
   - 1Mbps rate, RTT_TYPE=1 or 3 : 8bit preamble + 32bit data + 4bit trailer + 32bit payload = 76us
   - 1Mbps rate, RTT_TYPE=4 : 8bit preamble + 32bit data + 4bit trailer + 64bit payload = 108us
   - 1Mbps rate, RTT_TYPE=2 or 5: 8bit preamble + 32bit data + 4bit trailer + 96bit payload = 140us
   - 1Mbps rate, RTT_TYPE=6: 8bit preamble + 32bit data + 4bit trailer +128bit payload = 172us
   - 2Mbps rate, RTT_TYPE=0: 16bit preamble + 32bit data + 4bit trailer = 26us
   - 2Mbps rate, RTT_TYPE=1 or 3 : 16bit preamble + 32bit data + 4bit trailer + 32bit payload= 42us
   - 2Mbps rate, RTT_TYPE=4 : 16bit preamble + 32bit data + 4bit trailer + 64bit payload= 58us
   - 2Mbps rate, RTT_TYPE=2,5 : 16bit preamble + 32bit data + 4bit trailer + 96bit payload= 74us
   - 2Mbps rate, RTT_TYPE=6 : 16bit preamble + 32bit data + 4bit trailer + 128bit payload= 90us

52.4.4.2.2.5.8.3 Transition Time Summary

The following tables show the transition duration requirements, taking into account the TSM and PA ramp timing, and the TX and RX latency, for different SQTE and PDE roles.

Table 482. SQTE Initiator

Transition Time	Must be programmed to a value no less than
WU[1]	END_OF_TX_WU - (FAST_DEST_TX - FAST_START_TX)*FAST_FC_TX_WU + pa_ru + 3us
T_IP1	IP1_TX2RX - TX_DATA_FLUSH_DLY = (END_OF_RX_WU - FAST_TX2RX_START) - (FAST_DEST_RX - FAST_START_RX)*FAST_IP_RX_WU + 2us
T_S	Maximum of .. S_RX2RX + RX_SETTLING_LATENCY = (END_OF_RX_WU - RECYCLE_COUNT0) + RX_SETTLING_LATENCY S_TX2TX = TX_DATA_FLUSH_DLY
T_IP2	IP2_TX2RX - TX_DATA_FLUSH_DLY = (END_OF_RX_WU - FAST_TX2RX_START) - (FAST_DEST_RX - FAST_START_RX)*FAST_IP_RX_WU + 2us
T_FC	FC_RX2TX + RX_SETTLING_LATENCY + TX_DATA_FLUSH_DLY = (END_OF_TX_WU - FAST_RX2TX_START_FC) - (FAST_DEST_TX - FAST_START_TX)*FAST_FC_TX_WU + pa_ru + RX_SETTLING_LATENCY + TX_DATA_FLUSH_DLY

1. The Warmup transition time is shown here for reference, but there is no programmable "WU" bitfield for this in the RSM programming model

Table 483. SQTE Reflector

Transition Time	Must be programmed to a value no less than
WU[1]	END_OF_RX_WU - (FAST_DEST_RX - FAST_START_RX)*FAST_FC_RX_WU + 1us
T_IP1	IP1_RX2TX + RX_SETTLING_LATENCY + TX_DATA_FLUSH_DLY = (END_OF_TX_WU - FAST_RX2TX_START) - (FAST_DEST_TX - FAST_START_TX)*FAST_IP_TX_WU + pa_ru + RX_SETTLING_LATENCY + TX_DATA_FLUSH_DLY
T_S	Maximum of .. S_RX2RX + RX_SETTLING_LATENCY = (END_OF_RX_WU - RECYCLE_COUNT0) + RX_SETTLING_LATENCY S_TX2TX = TX_DATA_FLUSH_DLY
T_IP2	IP2_RX2TX + RX_SETTLING_LATENCY + TX_DATA_FLUSH_DLY = (END_OF_TX_WU - FAST_RX2TX_START) - (FAST_DEST_TX - FAST_START_TX)*FAST_IP_TX_WU + pa_ru + RX_SETTLING_LATENCY + TX_DATA_FLUSH_DLY
T_FC	FC_TX2RX - TX_DATA_FLUSH_DLY = (END_OF_RX_WU - FAST_TX2RX_START_FC) - (FAST_DEST_RX - FAST_START_RX)*FAST_FC_RX_WU + 2us

1. The Warmup transition time is shown here for reference, but there is no programmable "WU" bitfield for this in the RSM programming model

Table 484. PDE MD

Transition Time	Must be programmed to a value no less than
T_IP1	(Not used)
T_S	(Not used)
T_IP2	IP2_RX2TX + RX_SETTLING_LATENCY = (END_OF_TX_WU - FAST_RX2TX_START) - (FAST_DEST_TX - FAST_START_TX)*FAST_IP_TX_WU + pa_ru + RX_SETTLING_LATENCY
T_FC	FC_TX2RX - TX_DATA_FLUSH_DLY = (END_OF_RX_WU - FAST_TX2RX_START_FC) - (FAST_DEST_RX - FAST_START_RX)*FAST_FC_RX_WU + 2us

Table 485. PDE RD

Transition Time	Must be programmed to a value no less than
T_IP1	(Not used)

Table continues on the next page...

Table 485. PDE RD (continued)

Transition Time	Must be programmed to a value no less than
T_S	(Not used)
T_IP2	IPS_TX2RX = (END_OF_RX_WU - FAST_TX2RX_START) - (FAST_DEST_RX - FAST_START_RX)*FAST_IP_RX_WU + 2us
T_FC	FC_RX2TX + RX_SETTLING_LATENCY + TX_DATA_FLUSH_DLY= (END_OF_TX_WU - FAST_RX2TX_START_FC) - (FAST_DEST_TX - FAST_START_TX)*FAST_FC_TX_WU + pa_ru + RX_SETTLING_LATENCY + TX_DATA_FLUSH_DLY

52.4.4.2.2.5.9 Timing adjustment

For ranging consideration , we have some timings constraints that need to be handled during measurement. We need to adjust timing drift and alignment to ensure correct behavior in ranging and RTT mode. The CFO compensation need also to be done over channels. A timeout will also be managed in case RX not correctly received during mode 0.

52.4.4.2.2.5.9.1 Timing drift

Timing misalignment due to Xtal cannot be fully compensated in the -50 to 50 ppm so a digital time tracking mechanism can be used in place. We need to adjust RSM drift depending on CFO, the RSM sequence counter can be advanced or delayed based upon a software scheduling. Software can determine when to advance/delay based upon the residual ppm which is left after the crystal trimming.

In KW45, there is a software approach to manage this limitation but with some drawbacks in term of accuracy and real time software.

To cover the maximum drift possible (~160 mode 3 worst case), below we can see how the time adjustment will be managed:

a) **RSM mode** : RSM_CTRL7.RSM_TIME_CORR_MODE=1 : enable drift compensation via RSM

RSM_CTRL7.RSM_TIME_CORR[16:0] : register @ 1us resolution is used to ease software to manage internal hardware timeout_counter signed and computed by software based on CFO value. This will start an internal counter in RSM from rsm_start and stops at rsm_end sequence without any reset, it will wrap when reach max val.

When timeout elapse, we will freeze or jump one value on the internal rsm_counter (used for state counting) depending on cfo sign : 0 -> freeze value, 1 -> jump value , in order to slow or speed up the rsm counter. Note that the adjustment will be done at end t_fc and not during t_pm to avoid signal alignment issues.

b) **CGM mode**: possibility is to adjust drift via CGM (RSM_CTRL7.RSM_TIME_CORR_MODE=2)

The granularity will be 250 ns granularity inside CGM and not on RSM counter. It can help for better accuracy. In this case, the adjustment will be done by modifying the 4 MHz rate time to time in hardware to adjust the rate depending on RSM_TIME_CORR value.

Below an example of programming to enable modes :

```
RSM_CTRL7[RSM_TIME_CORR_MODE] = time_drift
if (time_drift>=1) begin
  if (xtal_freq_ppm>0)       val_time_corr = 1e6/xtal_freq_ppm
  else if (xtal_freq_ppm<0) val_time_corr = -1e6/xtal_freq_ppm
  else                            val_time_corr = 0;
  if (xtal_freq_ppm>0) delta_time_corr = 1 else -1;
  RSM_CTRL7[RSM_TIME_CORR_DELTA] = delta_time_corr;
end
if (time_drift==1) //rsm  mode , 1 us granularity count adjust
  RSM_CTRL7[RSM_TIME_CORR]=val_time_corr;
else if (time_drift==2)  // cgm mode , 250 us granularity
  RSM_CTRL7[RSM_TIME_CORR] = val_time_corr/4);
```

Figure 349. Timing drift software setting example

52.4.4.2.2.5.9.2 Timing alignment

We need to reach a better accuracy than 1 us if we want to have a correct alignment between initiator and reflector whatever the CFO. Because of AA detection on 4/8 MHz grid, we will have an uncertainty on the alignment , which could be centered [-0.5 us ..0.5 us] but also shifted [0 ..1 us] or [-1 us .. 0] (this is in fact a result of all rx delay).

To adjust alignment , we use Access Adress detection method described as below:

- the first aa_detection will be compared to 1 us grid and realigned to improve alignment accuracy (RSM_CTRL7.RSM_TIME_ALIGN_MODE). We will have possibility also to program an offset for the calibration if needed (RSM_CTRL7.RSM_TIME_ALIGN_OFFSET[1:0]) . Once the alignment is done on reflector after the Rx synchro state in mode 0, we keep it until the end of subevent.

52.4.4.2.2.5.9.3 Timing compensation over channels

We need to adjust CFO depending on channel frequency. The register pll_numerator_offset[27:0] can adjust the frequency, it uses a signed value that allows for a carrier frequency offset of up to +/-100ppm be added to the PLL numerator to allow for a SW controlled static shift of PLL frequency. A mux is added on this register to take the control from RSM with a value embedded in pktram configuration for each channel (step_cfo[15:0]) . These values will be filled by software after the mode 0 (to get the cfo) and pre-computed in linear way with channel number. This functionality will avoid to post process data to compensate CFO over channels as it was done in KW45.

52.4.4.2.2.5.9.4 Timeout mode 0

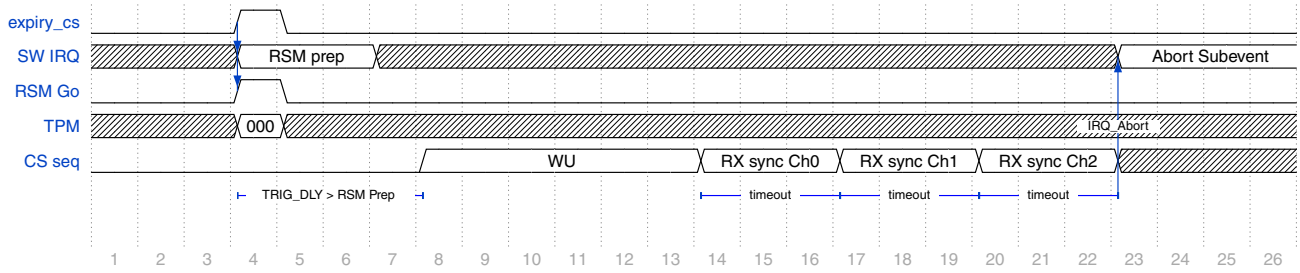
We need a timeout mechanism in the RSM in case we missed the mode 0 synchronization (first mode 0 rx_sync state). Main steps to enable the feature are detailed below :

The field RSM_CTRL6.RSM_MODE0_TIMEOUT[11:0] must be set by software to adjust the exact value for timeout; the 0 value will mean the feature is bypass and we come back to legacy mode as in KW45 (no timeout). For now the range of identified values is within 247 to 483 us, but a 12 bits register will give extra margin if needed.

An internal counter inside RSM will start from the end of WU state and a new mode 0 will be retried if we reached the mode0_timeout 0 value. This counter will be reloaded with timeout value for the next mode0.

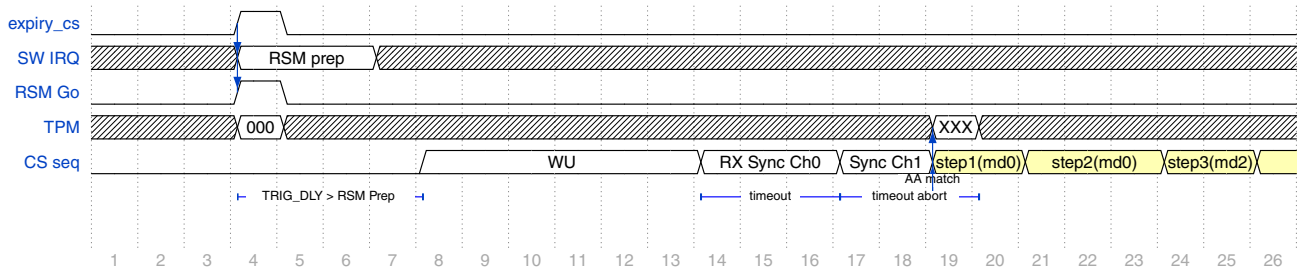
The AGC will be reseted to max gain on next mode 0 , which can be done with a rx_init reset on rx_digital part. We can achieve this by sending a recycle to the TSM from the RSM after the mode0_timeout.

In case all mode 0 are missed, an abort will occur.



CS Sync case 1: 3 mode0 steps missed, abort CS Subevent - timeout is set to mode0 duration (247 to 483 us)

Figure 350. Mode FCS timeout abort



CS Sync case 2: 1 mode0 step missed, 2nd mode0 step matched, starting CS subevent - timeout is set to mode0 duration (247 to 483 us)

Figure 351. Mode FCS timeout retry

52.4.4.2.2.5.10 RSM Configuration

52.4.4.2.2.5.10.1 Register Bitfields

The following table describes the control bits used in software configuration of the RSM for PDE and SQTE operation

Table 486. Register Bitfields

Field	Access	Description
MODE	RW	Mode of Operation- 0 - SQTE 1 - PDE
RX_EN	RW	Enables and arms the module for operation starting with Receive. This corresponds to the SQTE "Reflector" role, and the PDE "RD" role. Once set, this bit should remain set until the RSM returns to the IDLE state at the end of the sequence.
TX_EN	RW	Enables and arms the module for operation starting with Transmit. This corresponds to the SQTE "Initiator" role, and the PDE "MD" role. Once set, this bit should remain set until the RSM returns to the IDLE state at the end of the sequence.
RATE	RW	Only used for SQTE. Indicates how the transceiver is configured, and the transfer rate for packets 0 - 1Mbps 1 - 2Mbps
RTT_TYPE	RW	Only used for SQTE. Indicates the payload packet length.

Table continues on the next page...

Table 486. Register Bitfields (continued)

Field	Access	Description
		0 - no payload 1 - 32-bit payload (souding sequence) 2 - 96-bit payload (souding sequence) 3 - 32-bit payload (random sequence) 4 - 64-bit payload (random sequence) 5 - 96-bit payload (random sequence) 6 - 128-bit payload (random sequence)
STEPS[7:0]	RW	Number of frequency steps. (For SQTE this also includes the FCS.) The maximum number supported is 256, limited by RX Packet RAM used by RSM. A value of 0 should not be used
T_PM0[9:0], T_PM1[9:0]	RW	PM (phase measurement) durations, in microseconds. For SQTE, this is the T_PM*N_AP duration shown in the figures. The T_PM used (T_PM0, T_PM1) depends on t_pm_sel field. The minimum value is 10us. The programmed T_PM0/ T_PM1 value is required to be N_AP multiplied by the desired T_PM per antenna slot (see Configuration Stored in Packet RAM)
T_FM[7:0]	RW	FM (frequency measurement) duration, in microseconds. This field should be set to 80us. (see Configuration Stored in Packet RAM).
T_FC[7:0]	RW	FC (frequency change) duration, in microseconds. This field should be programmed between 40us to 150us.
T_IP1[7:0]	RW	Only applies to SQTE. IP1 (interlude period 1) duration, in microseconds. This field should be programmed between 25us to 150us.
T_S[4:0]	RW	Only applies to SQTE. S (Gard Time period) duration, in microseconds. This field should be set to 10us.
T_IP2[7:0]	RW	IP2 (interlude period 2) duration, in microseconds. This field should be programmed between 25us to 150us.
FAST_IP_RX_WU	RW	If set, forces TSM to perform a fast RX warmup during IP1_TX2RX and IP2_TX2RX transitions
FAST_IP_TX_WU	RW	If set, forces TSM to perform a fast TX warmup during IP1_RX2TX and IP2_TX2RX transitions
FAST_FC_RX_WU	RW	If set, forces TSM to perform a fast RX warmup during FC_TX2RX transitions (and for SQTE with ipr_rx_en=1 during WU state)
FAST_FC_TX_WU	RW	If set, forces TSM to perform a fast TX warmup during FC_RX2TX transitions (and for SQTE with ipr_tx_en=1 during WU state)
RX_SETTLING_LATENCY	RW	Receiver latency. (In a TSM register)
TX_DATA_FLUSH_DLY	RW	TX data flush delay / TX latency. (IN a TXDIG register)
AA_HAMM[2:0]	RW	Only applies to SQTE. Indicates the Access Address Hamming distance to be used by the PHY when RSM is active

Table continues on the next page...

Table 486. Register Bitfields (continued)

Field	Access	Description
CTUNE	RW	If set, RSM will send coarse tune values read from the Packet RAM to the PLL. If clear, the PLL will perform coarse tune.
HPM_CAL	RW	If set, RSM will send hpm calibration values read from the Packet RAM to the PLL. If clear, the PLL will perform hpm calibration.
TRIG_SEL[2:0]	RW	Selects which trigger to use. 0 - Software trigger (immediate trigger) 1- Trigger on CRC pass 2- Trigger on PHY access address found 3- Trigger on seq_spare3 (tx_dig_en from TSM) 4- Trigger on tx_done 5- Trgger on LCL pattern found 6- Trigger on NBU Start trigger
TRIG_DLY[10:0]	RW	SQTE mode: delay in microseconds from trigger to the beginning of the warm-up sequence. PDE mode: delay in microseconds from trigger to when the first RX2TX or TX2RX transition occurs, in microseconds. For PDE mode, this should be programmed to a value greater than 0.
DMA_DLY[7:0]	RW	Delay from end of RX warmup to assertion of dma_mask signal, in microseconds. Used in PM_RX state.
DMA_DLY0[7:0]	RW	Same as DMA_DLY[7:0] but used for the SQTE Frequency Measurement (FM) step (in FCS), and for PDE in the handoff from the LL.
DMA_DUR[9:0]	RW	Duration of the dma_mask signal, in microseconds. Used in the PM_RX state. NOTE: If used in conjunction with the RXDIG's window averager, to ensure that the same number of samples are captured during each time the dma_mask asserts, the duration should be a multiple of the window averager's duration.
DMA_DUR0[9:0]	RW	Same as DMA_DUR[6:0] but used for the SQTE Frequency Error Measurement Step, and for PDE in the handoff from the LL
DMA_RX_EN	RW	Enable dma_mask to assert in PM_RX State. (Note that the DMA mask is always allowed to assert in the SQTE Frequency Measurement (FM) step in FCS.) This bit is expected to be set in SQTE events where the device does not perform antenna switching (LCL_CTRL is not used).
SW_ABORT	RW	Used to gracefully shut down the module prior to a normal end of sequence. Once set, this bit should remain set until the RSM returns to the IDLE state at the end of the sequence.
DT_RX_SYNC_DIS	RW	Only applies to SQTE, and only used by the Reflector device (RX_EN=1) . Setting this bit disables the auto-sync feature for the Reflector device in the FCS RX packet
DT_RX_SYNC_DLY[3:0]	RW	Only applies to SQTE, and only used by the Reflector device (RX_EN=1) when DT_RX_SYNC_DIS=0.

Table continues on the next page...

Table 486. Register Bitfields (continued)

Field	Access	Description
		In this configuration the RSM uses the PHY's AA_MATCHED output to sync the Reflector device to the Initiator device's timing. This corresponds to the delay in microseconds from the PHY's AA_MATCHED to the end of DT_RX duration (the packet duration including preamble and trailer, plus RX_SETTLING_LATENCY).
RX_PHY_EN_MASK_DIS	RW	Only applies to SQTE. If set, the rx_phy_en_mask output is always asserted
SEQ_RCCAL_PUP_MASK_DIS	RW	If set, TSM signal seq_rccal_pup is not modified by RSM. If clear, seq_rccal_pup is masked to 0 for all RSM states except IDLE, WU, and FC
RX_SIGNALS_MASK_DIS	RW	If set, TSM signals dcoc_gain_cfg_en, dcoc_cal_en, seq_bg_pup_ibg_rx, seq_cbpf_en_dcoc, and rx_gang_pup are not modified by RSM. If clear, these signals are masked to 0 during RSM's IP1/IP2_RX2TX states
IRQ_IP1_EN	RW	If set, requests an interrupt at the beginning of the IP1_RX2TX or IP1_TX2RX state
IRQ_IP1	W1C	The bit is set on entry to IP1_RX2TX or IP1_TX2RX states. Write 1 to clear the bit[1].
IRQ_IP2_EN	RW	If set, requests an interrupt at the beginning of the IP2_RX2TX or IP2_TX2RX state
IRQ_IP2	W1C	The bit is set on entry to IP2_TX2RX or IP2_RX2TX states. Write 1 to clear the bit[1].
IRQ_FC_EN	RW	If set, requests an interrupt at the beginning of the FC_RX2TX or FC_TX2RX state
IRQ_FC	W1C	The bit is set on entry to FC_RX2TX or FC_TX2RX states. Write 1 to clear the bit[1].
IRQ_FM_RX_EN	RW	If set, requests an interrupt at the beginning of the FM_RX state
IRQ_FM_RX	W1C	The bit is set on entry to FM_RX state. Write 1 to clear the bit[1].
IRQ_FM_TX_EN	RW	If set, requests an interrupt at the beginning of the FM_TX state
IRQ_FM_TX	W1C	The bit is set on entry to FM_TX state. Write 1 to clear the bit[1].
IRQ_PM_RX_EN	RW	If set, requests an interrupt at the beginning of the PM_RX state
IRQ_PM_RX	W1C	The bit is set on entry to PM_RX state. Write 1 to clear the bit[1].
IRQ_PM_TX_EN	RW	If set, requests an interrupt at the beginning of the PM_TX state
IRQ_PM_TX	W1C	The bit is set on entry to PM_TX state. Write 1 to clear the bit[1].
IRQ_DT_RX_EN	RW	If set, requests an interrupt at the beginning of the DT_RX state
IRQ_DT_RX	W1C	The bit is set on entry to DT_RX state. Write 1 to clear the bit[1].
IRQ_DT_TX_EN	RW	If set, requests an interrupt at the beginning of the DT_TX state
IRQ_DT_TX	W1C	The bit is set on entry to DT_TX state. Write 1 to clear the bit[1].
IRQ_EOS_EN	RW	If set, requests an interrupt at the end of the sequence
IRQ_EOS	W1C	The bit is set to indicate that the sequence is complete. It sets when the RSM transitions from the WD to the IDLE state. Write 1 to clear the bit[1].
IRQ_ABORT_EN	RW	If set, requests an interrupt if the sequence is interrupted due to a PLL abort
IRQ_ABORT	W1C	The bit is set when the sequence is aborted due to pll_abort. This condition can occur during any RSM state except for the IDLE or WD states. Write 1 to clear the bit[1].

Table continues on the next page...

Table 486. Register Bitfields (continued)

Field	Access	Description
IRQ_STEP_EN	RW	If set, requests an interrupt every N steps processed by RSM
IRQ_STEP	W1C	The bit is set every N steps processed by RSM. Write 1 to clear the bit[1].
IRQ_RF_DENY_RISE_EN	RW	If set, requests an interrupt at the assertion of rf_not_allowed signal
IRQ_RF_DENY_RISE	W1C	The bit is set on the assertion of rf_not_allowed signal. Write 1 to clear the bit[1].
IRQ_RF_DENY_FALL_EN	RW	If set, requests an interrupt at the deassertion of rf_not_allowed signal
IRQ_RF_DENY_FALL	W1C	The bit is set on the deassertion of rf_not_allowed signal. Write 1 to clear the bit[1].
IRQ_RF_DENY_BTA_EN	RW	If set, requests an interrupt if a CS/BLE transfer is requested while rf_not_allowed signal is already set
IRQ_RF_DENY_BTA	W1C	The bit is set on a CS/BLE transfer request while rf_not_allowed signal is already set. Write 1 to clear the bit[1].

1. To clear RSM's W1C bits, RX_EN or TX_EN must be set. It is therefore recommended that software ensures that all the RSM W1C bits are cleared at the end of each RSM sequence prior to clearing RX_EN or TX_EN to disable the module.

52.4.4.2.2.5.10.2 Configuration Stored in Packet RAM

In addition to the configuration information stored in registers as described in the previous section, the RSM also relies on configuration information stored in the Packet RAM to control the behavior of each individual frequency step. So, there is a specific area of the Packet RAM used for this configuration information.

52.4.4.2.2.5.10.2.1 Circular Config Buffer

A channel sounding sub-event can support up to 160 steps, but RSM doesn't need all the steps at the same time. Therefore, the step configuration is stored in a circular buffer to use less memory space.

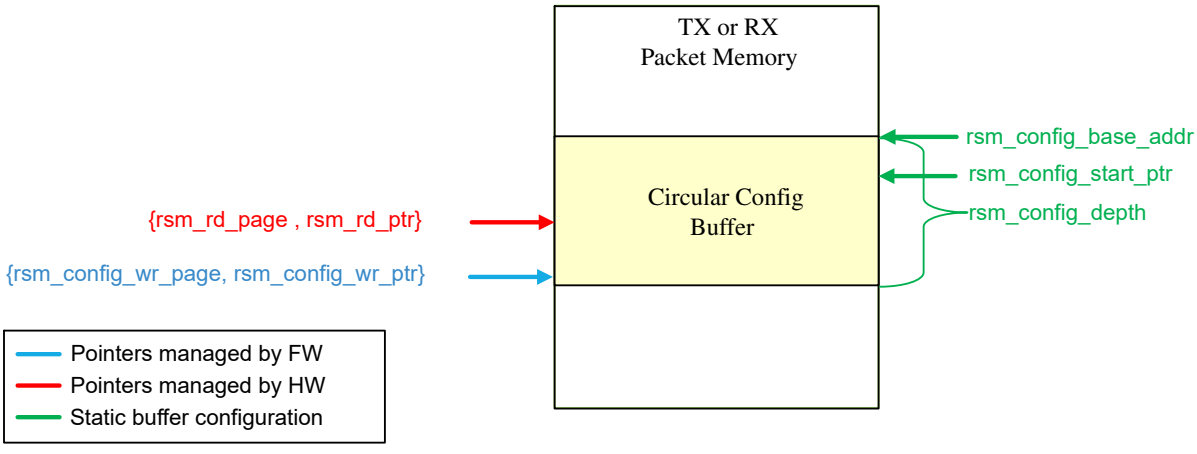


Figure 352. Circular Config Buffer

The circular config buffer is fully programmable for each sub-event to add more FW flexibility depending on memory size and applications. The RSM config buffer address, pointers and depth are word aligned in order to ease the HW implementation.

The registers below must be updated only when RSM is in IDLE and must remain unchanged until the end of a sub-event.

- RSM_CONFIG_LOC register indicates the location of the config buffer. It can be mapped in TX or RX Packet RAM.

- RSM_CONFIG_BASE_ADDR[9:0] register provides the base address of the circular config buffer to allow FW to duplicate configuration buffers or to use the same buffer but with a different start address for the next sub-events.
- RSM_CONFIG_DEPTH[8:0] register indicates the circular buffer depth to optimize the size in memory depending on FW latency
- RSM_CONFIG_START_PTR[9:0] register provides the address to read in the config buffer to get the first step configuration at the beginning of a new sub-event.

FW can used the step interrupt generated by RSM to determine when next steps configuration has to be filled in the buffer of the Packet RAM. This interrupt is generated every N steps to inform FW that N steps have been executed by RSM. The RSM_INT_NBSTEP[7:0] register indicates when this irq is set (in number of steps – value 0 is legacy mode).

An underrun error can occur during a sub-event if RSM reads a new step configuration while this information is not yet written by FW or is not anymore present in the config buffer. RSM detects easily an underrun error by comparing the current FW and HW config pointer registers and their associated config buffer wrap registers:

- CONFIG_WR_PTR [9:0] and CONFIG_RD_PTR[9:0] registers indicate respectively the current FW and HW pointers on config circular buffer. These pointers wrap to the beginning of the buffer when the space remaining at the end of the buffer is less than the maximum step size supported by the sub-event. Therefore, a step config is never split with a part at the end of the buffer and the rest at the beginning of the buffer.
- CONFIG_WR_PAGE and CONFIG_RD_PAGE registers which indicate the page number(0 or 1) are toggling each time their respective pointer is wrapping at the beginning of the circular buffer.

If an underrun error occurs, the RSM is aborted and an abort interrupt is generated and RSM_UNDR_ERR status register is set. An underrun error occurs when RSM reads config buffer when (CONFIG_WR_PAGE=CONFIG_RD_PAGE & CONFIG_WR_PTR < CONFIG_RD_PTR) or when (CONFIG_WR_PAGE!=CONFIG_RD_PAGE.& CONFIG_WR_PTR > CONFIG_RD_PTR).

The RSM always performs 32-bit read access to the config buffer, located in the TX or RX Packet RAM, to get the configuration information for the current frequency step.

Due to a specific HW management, the config buffer can not be mapped in the last 52 bytes of the TX Packet RAM. This size corresponds to the maximum configuration size of a mode3 step.

The fact that configuration buffer is circular prevents the allocation of a huge memory space and doesn't restrict the maximum STEPS number of a sub-event .

52.4.4.2.2.5.10.2.2 Step configuration

The size of configuration information can vary at each frequency step. This requires between 3 words to 13 words per frequency step depending on step mode, and RTT_TYPE mode as described in below table:

Table 487. Step Configuration Size

Step Mode	RTT Type (payload length in bit)	Step Configuration Size (in word)
0	X	5
1	0	5
	32	7
	64	9
	96	11
	128	13
2	X	3
3	0	5

Table continues on the next page...

Table 487. Step Configuration Size (continued)

Step Mode	RTT Type (payload length in bit)	Step Configuration Size (in word)
	32	7
	64	9
	96	11
	128	13

The step configuration can be split in 2 parts.

- common configuration required for every frequency steps whatever the step mode.
- packet configuration required only for frequency steps containing a packet exchange

52.4.4.2.2.5.10.2.2.1 Common configuration description

The frequency step information consists of the following mandatory fields which are present in every configuration step whatever the mode or RTT_TYPE values.

- channel_num[15:0]. This defines the frequency to be used for this step. This is decoded by the PLL using the format defined in the PLL's CHAN_MAP[HOP_TBL_CFG_OVRD] bitfield. NOTE: to ensure proper PLL operation when using the RSM, the PLL's CHAN_MAP[CHANNEL_NUM_OVRD] bitfield should be programmed to 0.
- mode[1:0]. This defines the step mode.
  - 00b - Mode 0 : Frequency Compensation Step (FCS) mode.
  - 01b - Mode 1 : Pk-Pk format.
  - 10b - Mode 2 : Tn-Tn format.
  - 11b - Mode 3 : Pk-Tn-Tn-Pk format.
- tone_ext[1:0] : This selects the tone extension mode for the TX portion of the step
  - 00b - Tone extension is not present for either role in TX.
  - 01b - Tone extension is present for initiator TX only.
  - 10b - Tone extension is present for reflector TX only.
  - 11b - Tone extension is present for both roles in TX.
- ant_permut[4:0] : This defines the antenna permutation pattern for the step
- ant_cs_sync[1:0] : This defines the Antenna CS sync value
- step_one_way: This defines if the step is in one_way or two_way mode
  - 1b : One way step
  - 0b : Two way step.
- t_pm_sel : For Tn-Tn or Pk-Tn-Tn-Pk, this selects whether T_PM0 or T_PM1 is used for the tone duration in this frequency step.
  - 1b : T_PM is associated to T_PM1.
  - 0b : T_PM is associated to T_PM0.
- step_cfo[15:0]: This define the CFO setting for the step.
- hpm_cal_factor[12:1]. This defines the 12 MSBs of the PLL high port modulation calibration factor. The LSB is assigned to 0. It is used only if RSM_HPM_CAL register is set. Note that this has the same format as PLL's HPM_CAL_FACTOR_MANUAL bitfield

- ctune_manual[8:0]. This defines the PLL coarse tune value for this frequency step. It is used only if RSM_CTUNE register is set.
- phase_add[7:0] : This allows FW to adjust phase with first antenna on a multiple antenna context.

Allowing the coarse tune value and hpm calibration factor for each step to be read from RAM reduces the T_FC duration since the PLL does not have to perform these calibration. Note that even if RSM's CTUNE and HPM_CAL bits are cleared (indicating PLL will perform these calibrations), these information are still fetched by RSM at each step.

Table 488. Frequency Step Configuration

Step Mode	Address Offset	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Mode 0/1/2/3	0	channel_num[7:0]							
	1	channel_num[15:8]							
	2	ant_permut[4:0]				tone_ext[1:0]		mode[1:0]	
	3	-			t_pm_sel	step_one_way	ant_cs_sync[1:0]		
	4	step_cfo[7:0]							
	5	step_cfo[15:8]							
	6	hpm_cal_factor[8:1]							
	7	-				hpm_cal_factor[12:9]			
	8	ctune_manual[8:0]							
	9	-							
	10	phase_add[7:0]							
	11	-							

Refer to COMMON_MODE_CONFIG_HEADER section of General description for more information.

52.4.4.2.2.5.10.2.2.2 Packet configuration description

For SQTE steps which have packet exchanges, there is additional information regarding the packet contents in the configuration of each frequency step. This information is located in the configuration buffer from step base address +12. The content depth varies from 2 words when there is no Payload to 10 words when Payload length is 128bit. Each packet exchange consists of the Initiator sending a packet to the Reflector, and the Reflector sending a packet to the Initiator. So, the first word or words stored in Packet RAM are for the Initiator-to-Reflector packet, and the next word or words are for the Reflector-to-Initiator packet.

Note that the packet format also includes a 8bit (or 16bit in the case of 2Mbps) preamble and a 4bit trailer. The bit sequence in the preamble and trailer is not read from the Packet RAM; it is determined by hardware based on the AA sequence.

The additional information provided for packet exchanges are:

- aa_init[31:0] : This corresponds to the Access Address sent by Initiator to Reflector.
- aa_refl[31:0] : This corresponds to the Access Address sent by Reflector to Initiator.
- payload_init[127:0] : This corresponds to the payload sent by Initiator to the Reflector. The field size depends on RSM_RTT_TYPE register
- payload_refl[127:0] : This corresponds to the payload sent by Reflector to Initiator. The field size depends on RSM_RTT_TYPE register

Table 489. Additional step configuration for packets depending on RSM_RTT_TYPE

Step Mode	RSM_RTT_TYPE	Address Offset (from step config base address)	bits [31:0]
Mode 0/1/3	0, 1, 2, 3, 4, 5, 6	12	aa_init[31:0] for Initiator-to-Reflector packet
		16	aa_refl[31:0] for Reflector-to-Initiator packet
Mode 1 /3	1, 3	20	payload_init[31:0] for Initiator-to-Reflector packet
		24	payload_refl[31:0] for Reflector-to-Initiator packet
	4	20	payload_init[31:0] for Initiator-to-Reflector packet
		24	payload_init[63:32] for Initiator-to-Reflector packet
		28	payload_refl[31:0] for Reflector-to-Initiator packet
		32	payload_refl[63:32] for Reflector-to-Initiator packet
	2, 5	20	payload_init[31:0] for Initiator-to-Reflector packet
		24	payload_init[63:32] for Initiator-to-Reflector packet
		28	payload_init[95:64] for Initiator-to-Reflector packet
		32	payload_refl[31:0] for Reflector-to-Initiator packet
		36	payload_refl[63:32] for Reflector-to-Initiator packet
		40	payload_refl[95:64] for Reflector-to-Initiator packet
	6	20	payload_init[31:0] for Initiator-to-Reflector packet
		24	payload_init[63:32] for Initiator-to-Reflector packet
		28	payload_init[95:64] for Initiator-to-Reflector packet
		32	payload_init[127:96] for Initiator-to-Reflector packet
		36	payload_refl[31:0] for Reflector-to-Initiator packet
		40	payload_refl[63:32] for Reflector-to-Initiator packet
		44	payload_refl[95:64] for Reflector-to-Initiator packet
		48	payload_refl[127:96] for Reflector-to-Initiator packet

Refer to COMMON_MODE_013_CONFIG_BODY section of General description for more information.

52.4.4.2.2.5.10.2.2.3 Possible configurations per Mode

52.4.4.2.2.5.10.2.2.3.1 Mode 0 Configuration

In addition of the common header configuration, the access address for Initiator and reflector packets is provided in the configuration buffer for mode 0 frequency steps.

Table 490. Mode 0 Configuration Table

Address Offset	bits [31:0]
0	00b/ t_pm_sel / step_one_way / ant_cs_sync[1:0] / ant_permut[4:0] / tone_ext[1:0] / mode[1:0] / channel_num[15:0].

Table continues on the next page...

Table 490. Mode 0 Configuration Table (continued)

Address Offset	bits [31:0]
4	00000b / hpm_cal_factor[12:1] / step_cfo[15:0]
8	0000000b/ phase_add[7:0] / 000000b/ ctune_manual[8:0].
12	aa_init[31:0] for Initiator-to-Reflector packet
16	aa_refl[31:0] for Reflector-to-Initiator packet

52.4.4.2.2.5.10.2.2.3.2 Mode 1 Configuration

In addition of the common header configuration, the access address and potential payload for Initiator and reflector packets are provided in the configuration buffer for mode 1 frequency steps.

Table 491. Mode 1 Configuration Table when RTT_TYPE=0

Address Offset	RSM_RTT_TYPE	bits [31:0]
0	0	00b/ t_pm_sel / step_one_way / ant_cs_sync[1:0] / ant_permut[4:0] / tone_ext[1:0] / mode[1:0] / channel_num[15:0].
4		00000b / hpm_cal_factor[12:1] / step_cfo[15:0]
8		0000000b/ phase_add[7:0] / 000000b/ ctune_manual[8:0].
12		aa_init[31:0] for Initiator-to-Reflector packet
16		aa_refl[31:0] for Reflector-to-Initiator packet

Table 492. Mode 1 Configuration Table when RTT_TYPE=1 or RTT_TYPE=3

Address Offset	RSM_RTT_TYPE	bits [31:0]
0	1, 3	00b/ t_pm_sel / step_one_way / ant_cs_sync[1:0] / ant_permut[4:0] / tone_ext[1:0] / mode[1:0] / channel_num[15:0].
4		00000b / hpm_cal_factor[12:1] / step_cfo[15:0]
8		0000000b/ phase_add[7:0] / 000000b/ ctune_manual[8:0].
12		aa_init[31:0] for Initiator-to-Reflector packet
16		aa_refl[31:0] for Reflector-to-Initiator packet
20		payload_init[31:0] for Initiator-to-Reflector packet
24		payload_refl[31:0] for Reflector-to-Initiator packet

Table 493. Mode 1 Configuration Table when RTT_TYPE=4

Address Offset	RSM_RTT_TYPE	bits [31:0]
0	4	00b/ t_pm_sel / step_one_way / ant_cs_sync[1:0] / ant_permut[4:0] / tone_ext[1:0] / mode[1:0] / channel_num[15:0].
4		00000b / hpm_cal_factor[12:1] / step_cfo[15:0]
8		0000000b/ phase_add[7:0] / 000000b/ ctune_manual[8:0].
12		aa_init[31:0] for Initiator-to-Reflector packet

Table continues on the next page...

Table 493. Mode 1 Configuration Table when RTT_TYPE=4 (continued)

Address Offset	RSM_RTT_TYPE	bits [31:0]
16		aa_refl[31:0] for Reflector-to-Initiator packet
20		payload_init[31:0] for Initiator-to-Reflector packet
24		payload_init[63:32] for Initiator-to-Reflector packet
28		payload_refl[0:31] for Reflector-to-Initiator packet
32		payload_refl[63:32] for Reflector-to-Initiator packet

Table 494. Mode 1 Configuration Table when RTT_TYPE=2 or RTT_TYPE=5

Address Offset	RSM_RTT_TYPE	bits [31:0]
0	2, 5	00b/ t_pm_sel / step_one_way / ant_cs_sync[1:0] / ant_permut[4:0] / tone_ext[1:0] / mode[1:0] / channel_num[15:0].
4		00000b / hpm_cal_factor[12:1] / step_cfo[15:0]
8		0000000b/ phase_add[7:0] / 000000b/ ctune_manual[8:0].
12		aa_init[31:0] for Initiator-to-Reflector packet
16		aa_refl[31:0] for Reflector-to-Initiator packet
20		payload_init[31:0] for Initiator-to-Reflector packet
24		payload_init[63:32] for Initiator-to-Reflector packet
28		payload_init[95:64] for Initiator-to-Reflector packet
32		payload_refl[31:0] for Reflector-to-Initiator packet
36		payload_refl[63:32] for Reflector-to-Initiator packet
40		payload_refl[95:64] for Reflector-to-Initiator packet

Table 495. Mode 1 Configuration Table when RTT_TYPE=6

Address Offset	RSM_RTT_TYPE	bits [31:0]
0	6	00b/ t_pm_sel / step_one_way / ant_cs_sync[1:0] / ant_permut[4:0] / tone_ext[1:0] / mode[1:0] / channel_num[15:0].
4		00000b / hpm_cal_factor[12:1] / step_cfo[15:0]
8		0000000b/ phase_add[7:0] / 000000b/ ctune_manual[8:0].
12		aa_init[31:0] for Initiator-to-Reflector packet
16		aa_refl[31:0] for Reflector-to-Initiator packet
20		payload_init[31:0] for Initiator-to-Reflector packet
24		payload_init[63:32] for Initiator-to-Reflector packet
28		payload_init[95:64] for Initiator-to-Reflector packet
32		payload_init[127:96] for Initiator-to-Reflector packet
36		payload_refl[31:0] for Reflector-to-Initiator packet

Table continues on the next page...

Table 495. Mode 1 Configuration Table when RTT_TYPE=6 (continued)

Address Offset	RSM_RTT_TYPE	bits [31:0]
40		payload_refl[63:32] for Reflector-to-Initiator packet
44		payload_refl[95:64] for Reflector-to-Initiator packet
48		payload_refl[127:96] for Reflector-to-Initiator packet

52.4.4.2.2.5.10.2.2.3.3 Mode 2 Configuration

Only the common header configuration is provided in the configuration buffer for mode 2 steps.

Table 496. Mode 2 Configuration Table

Address Offset	bits [31:0]
0	00b/ t_pm_sel / step_one_way / ant_cs_sync[1:0] / ant_permut[4:0] / tone_ext[1:0] / mode[1:0] / channel_num[15:0].
4	00000b / hpm_cal_factor[12:1] / step_cfo[15:0]
8	0000000b/ phase_add[7:0] / 000000b/ ctune_manual[8:0].

52.4.4.2.2.5.10.2.2.3.4 Mode 3 Configuration

In addition of the common header configuration, the access address and potential payload for Initiator and reflector packets are provided in the configuration buffer for mode 3 frequency steps.

Table 497. Mode 3 Configuration Table when RTT_TYPE=0

Address Offset	RSM_RTT_TYPE	bits [31:0]
0	0	00b/ t_pm_sel / step_one_way / ant_cs_sync[1:0] / ant_permut[4:0] / tone_ext[1:0] / mode[1:0] / channel_num[15:0].
4		00000b / hpm_cal_factor[12:1] / step_cfo[15:0]
8		0000000b/ phase_add[7:0] / 000000b/ ctune_manual[8:0].
12		aa_init[31:0] for Initiator-to-Reflector packet
16		aa_refl[31:0] for Reflector-to-Initiator packet

Table 498. Mode 3 Configuration Table when RTT_TYPE=1 or RTT_TYPE=3

Address Offset	RSM_RTT_TYPE	bits [31:0]
0	1, 3	00b/ t_pm_sel / step_one_way / ant_cs_sync[1:0] / ant_permut[4:0] / tone_ext[1:0] / mode[1:0] / channel_num[15:0].
4		00000b / hpm_cal_factor[12:1] / step_cfo[15:0]
8		0000000b/ phase_add[7:0] / 000000b/ ctune_manual[8:0].
12		aa_init[31:0] for Initiator-to-Reflector packet
16		aa_refl[31:0] for Reflector-to-Initiator packet
20		payload_init[31:0] for Initiator-to-Reflector packet
24		payload_refl[31:0] for Reflector-to-Initiator packet

Table 499. Mode 3 Configuration Table when RTT_TYPE=4

Address Offset	RSM_RTT_TYPE	bits [31:0]
0	4	00b/ t_pm_sel / step_one_way / ant_cs_sync[1:0] / ant_permut[4:0] / tone_ext[1:0] / mode[1:0] / channel_num[15:0].
4		00000b / hpm_cal_factor[12:1] / step_cfo[15:0]
8		0000000b/ phase_add[7:0] / 000000b/ ctune_manual[8:0].
12		aa_init[31:0] for Initiator-to-Reflector packet
16		aa_refl[31:0] for Reflector-to-Initiator packet
20		payload_init[31:0] for Initiator-to-Reflector packet
24		payload_init[63:32] for Initiator-to-Reflector packet
28		payload_refl[0:31] for Reflector-to-Initiator packet
32		payload_refl[63:32] for Reflector-to-Initiator packet

Table 500. Mode 3 Configuration Table when RTT_TYPE=2 or RTT_TYPE=5

Address Offset	RSM_RTT_TYPE	bits [31:0]
0	2, 5	00b/ t_pm_sel / step_one_way / ant_cs_sync[1:0] / ant_permut[4:0] / tone_ext[1:0] / mode[1:0] / channel_num[15:0].
4		00000b / hpm_cal_factor[12:1] / step_cfo[15:0]
8		0000000b/ phase_add[7:0] / 000000b/ ctune_manual[8:0].
12		aa_init[31:0] for Initiator-to-Reflector packet
16		aa_refl[31:0] for Reflector-to-Initiator packet
20		payload_init[31:0] for Initiator-to-Reflector packet
24		payload_init[63:32] for Initiator-to-Reflector packet
28		payload_init[95:64] for Initiator-to-Reflector packet
32		payload_refl[31:0] for Reflector-to-Initiator packet
36		payload_refl[63:32] for Reflector-to-Initiator packet
40		payload_refl[95:64] for Reflector-to-Initiator packet

Table 501. Mode 3 Configuration Table when RTT_TYPE=6

Address Offset	RSM_RTT_TYPE	bits [31:0]
0	6	00b/ t_pm_sel / step_one_way / ant_cs_sync[1:0] / ant_permut[4:0] / tone_ext[1:0] / mode[1:0] / channel_num[15:0].
4		00000b / hpm_cal_factor[12:1] / step_cfo[15:0]
8		0000000b/ phase_add[7:0] / 000000b/ ctune_manual[8:0].
12		aa_init[31:0] for Initiator-to-Reflector packet
16		aa_refl[31:0] for Reflector-to-Initiator packet

Table continues on the next page...

Table 501. Mode 3 Configuration Table when RTT_TYPE=6 (continued)

Address Offset	RSM_RTT_TYPE	bits [31:0]
20		payload_init[31:0] for Initiator-to-Reflector packet
24		payload_init[63:32] for Initiator-to-Reflector packet
28		payload_init[95:64] for Initiator-to-Reflector packet
32		payload_init[127:96] for Initiator-to-Reflector packet
36		payload_refl[31:0] for Reflector-to-Initiator packet
40		payload_refl[63:32] for Reflector-to-Initiator packet
44		payload_refl[95:64] for Reflector-to-Initiator packet
48		payload_refl[127:96] for Reflector-to-Initiator packet

52.4.4.2.2.5.11 RSM Results

During each individual frequency step, some statuses are written by RSM in Packet RAM to provide information about the computed step. So, a specific area is allocated in the Packet RAM to store the frequency step results.

52.4.4.2.2.5.11.1 Circular Result Buffer

A channel sounding sub-event can support up to 160 steps, but FW doesn't need all the step results at the same time. Therefore, the step results are stored in a circular buffer to use less memory space.

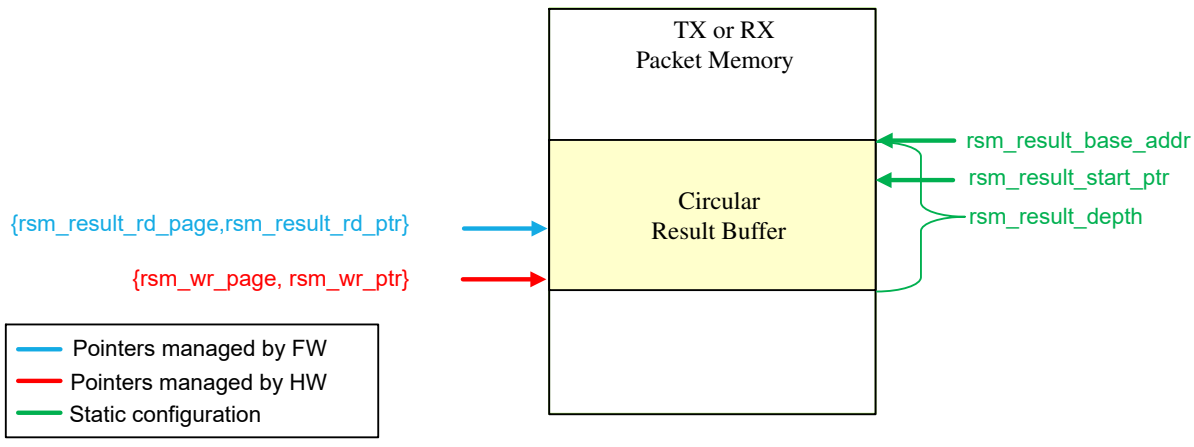


Figure 353. Circular Result Buffer

The circular result buffer is fully programmable for each sub-event to add more FW flexibility depending on memory size and applications. The RSM result buffer address, pointers and depth are word aligned in order to ease the HW implementation.

The registers below must be updated only when RSM is in IDLE and must remain unchanged until the end of a sub-event.

- RSM_RESULT_LOC register indicates the location of the result buffer. It can be mapped in TX or RX Packet RAM.
- RSM_RESULT_BASE_ADDR[9:0] register provides the base address of the circular result buffer to allow FW to duplicate result buffers or to use the same buffer but with a different start address for the next sub-events.
- RSM_RESULT_DEPTH[8:0] register indicates the circular result buffer depth to optimize the size in memory depending on FW latency

- RSM_RESULT_START_PTR[9:0] register provides the address to read in the result buffer to get the first step result at the beginning of a new sub-event.

In overflow error can occur during a sub-event if RSM writes step results while there is not anymore place in the result buffer. RSM detects easily an overflow error by comparing the current FW and HW result pointer registers and their associated result buffer wrap registers:

- RESULT_WR_PTR [9:0] and RESULT_RD_PTR[9:0] registers indicate respectively the current HW and FW pointers on result circular buffer. These pointers wrap to the beginning of the buffer when the space remaining at the end of the buffer is less than the maximum result size supported by the sub-event. Therefore, a step result is never split with a part at the end of the buffer and the rest at the beginning of the buffer.
- RESULT_WR_PAGE and RESULT_RD_PAGE registers which indicate the page number(0 or 1) are toggling each time their respective pointer is wrapping at the beginning of the circular buffer.

If an overrun error occurs, the RSM is aborted and an abort interrupt is generated and RSM_OVRD_ERR status register is set. An overflow error occurs when RSM reads config buffer when (RESULT_WR_PAGE=RESULT_RD_PAGE & RESULT_WR_PTR < RESULT_RD_PTR) or when (RESULT_WR_PAGE!=RESULT_RD_PAGE.& RESULT_WR_PTR > RESULT_RD_PTR).

The RSM performs 8/16/24/32-bit write access to the result buffer, located in the TX or RX Packet RAM, to update the status information for the current frequency step.

Due to a specific HW management, the result buffer can not be mapped in the last 80bytes of the TX Packet RAM. This size corresponds to the maximum result size of a mode3 step in sniffer role.

The fact that result buffer is circular prevents the allocation of a huge memory space and doesn't restrict the maximum STEPS number of a sub-event.

The procedure to manage the rollover of the circular result buffer is the following :

- Calculate (or look up) the Mode 3 step size (RES_SIZE) as a function of NUM_AP.
- When reading RESULT space, if the pointer (before the read) points to a location < RES_SIZE away from the end of the result buffer end, the pointer is reset to the base of the result buffer.

52.4.4.2.2.5.11.2 RSM statuses

The size of result information can vary at every frequency step. This requires between 3 words to 20 words per frequency step depending on step mode, the number of antenna paths and the ranging role as described in below table:

Table 502. Step Result Size Table

Mode	Antenna path number	Step Result Size (in word)	
		Reflector/ Initiator role	Sniffer role
Mode 0	X	5	10
Mode 1	X	5	10
Mode 2	1	3	6
	2	4	8
	3	5	10
	4	6	12
Mode 3	1	7	14
	2	8	16
	3	9	18
	4	10	20

Note that in sniffer configuration, the result size of a frequency step is duplicated since RSM stores first part and second part of the step.

The channel sounding results can be split in 3 kind of status reported by RSM.

- common status reported for every frequency steps whatever the step mode.
- packet status reported for every frequency steps containing a packet exchange
- tone status reported for every frequency steps containing a tone exchange

52.4.4.2.2.5.11.2.1 Common status

Some fields are always present in the result buffer whatever the mode in the frequency step results.

- step_id[7:0] : This indicates the frequency step number.
- result_len[3:0] : This indicates the result length in words of the frequency step.
- agc_idx[3:0] : This indicates the AGC index applied during the RX part of the frequency step.
- pcbd[8:0] / ctune[8:0] : In the configuration where the PLL performs coarse tune during the RSM operation (CTUNE=0), the RSM will capture the coarse tune best diff value or the vco ctune value depending on RSM_PCBD_CTUNE_SEL register.
- time_drift[1:0] : Indicates the timing drift delta value for this step (00b: 0us, 01b : +1 us, 11b: -1us).
- aa_det : This indicates if a packet access address has been detected during the frequency step. This field is expected to be set in mode 0/1/3 if the access address of the RX packet is correctly received, otherwise it is expected to be 0.

Table 503. Common Results Table

Step Mode	Address Offset	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Mode 0/1/2/3	0	step_id[7:0]							
	1	agc_idx[3:0]				result_len[3:0]			
	2	pcbd[7:0] / ctune[7:0]							
	3	aa_det	-	time_drift		-			pcbd[8] / ctune[8]

Refer to COMMON_MODE_RESULT_HEADER section of General description for more information.

52.4.4.2.2.5.11.2.2 Packet status

Some fields are only present in channel sounding mode 0/1/3 when packet transfer is expected during frequency step. This information is located in the status buffer from step status base address +4. In that case, additional fields are written by RSM in circular result buffer:

- rssi_nb[7:0] : This indicates the narrowband RSSI value computed during the access address reception
- raw_nadm[23:0] : This describes all the statuses computed by NADM module.
  - raw_nadm[7:0] indicates the NADM FM correlator value. This is the NADM correlation result of the received signal with a local reference signal.
  - raw_nadm[8] indicates if the NADM FM correlator value is valid.
  - raw_nadm[12:9] indicates to the NADM FM symbol error value. This is the NADM check result between the received signal payload and a reference payload.
  - raw_nadm[13] indicates if the NADM FM symbol error value is valid.
  - Raw_nadm[23:14] indicates the NADM pdelta value. It corresponds to the difference of correlations around maximum correlator instance

- rtt_data[31:0] : This describes all the RTT(round trip time) statuses computed by PHY module.
  - rtt_data[0] indicates if rtt_data[31:1] is valid.
  - rtt_value[1] indicates the ha_rtt_found value. This flag indicates that the HARTT operation is done through the Cordic algorithm.
  - rtt_value[17:2] indicates the ha_rtt_cfo[15:0]. It corresponds to the high accuracy CFO computed by the HARTT block through the Cordic algorithm.
  - rtt_value[19:18] indicates rtt_int_adj[1:0]. It corresponds to an integer adjustment of the timing which takes a value different of 0 when the early-late mechanism in the HARTT block chooses a peak different of the one chosen in the acquisition module (possible values are {-1,0,+1}).
  - rtt_value[21:20] indicates ham_rtt_dist_sat[1:0]. It corresponds to the Computed Hamming distance saturated to 2 bits.
  - rtt_value[31:22] indicates rtt_pdelta[9:0]. It corresponds to the difference between the squared correlation magnitude values, pm-pp, provided by the HARTT block.
- cfo_est[9:0] : This indicates the CFO estimate computed by the AA0 detector
- tpm[31:0] : This indicates the ToA-ToD time. The unit of this time is the Transceiver clock period (31.25ns).
  - In initiator configuration, it corresponds to the time between the beginning of Tx packet and the access address detection of the RX packet.
  - In reflector configuration,
    - at the first CS step, it corresponds to the time between the beginning of the warm-up sequence to the access address detection of the Rx packet.
    - after the first CS step, it corresponds to the time between the access address detection of the Rx packet to the beginning of TX packet.

Table 504. Packet Results

Step Mode	Address Offset	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Mode 0 (FCS) or Mode 1 (Pk-Pk) or Mode 3 (Pk-Tn-Tn-Pk)	4	rssi_nb[7:0]							
	5	raw_nadm[7:0]							
	6	raw_nadm[15:8]							
	7	raw_nadm[23:16]							
	8	rtt_data[7:0]							
	9	rtt_data[15:8]							
	10	rtt_data[23:16]							
	11	rtt_data[31:24]							
	12	cfo_est[9:0]							
	13	-							
	14	-							
	15	-							
	16	tpm[7:0]							
	17	tpm15:8]							

Table continues on the next page...

Table 504. Packet Results (continued)

Step Mode	Address Offset	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
	18	tpm[23:16]							
	19	tpm[31:24]							

Refer to COMMON_MODE_013_RESULT_BODY section of General description for more information.

52.4.4.2.2.5.11.2.3 Tone Status

Some fields are only present in channel sounding mode 2/3 when tone transfer is expected during frequency step. This information is located in the status buffer from step status base address +4 or step status base address +20 depending on step mode. In that case, additional tone statuses per antenna paths are also written by RSM in circular result buffer:

- tqi_N[1:0] : This indicates the Tone Quality indicator for Antenna path N.
- pct_i_N[11:0] : This indicates in-phase component of the PCT for Antenna path N.
- pct_q_N[11:0] : This indicates quadrature component of the PCT for Antenna path N.

The PCT results are stored in Packet RAM from the first (permuted) antenna path to last (permuted) antenna path followed by the extension field.

PCT for the Tone Extension is always computed even if Tone Extension is not expected.

Table 505. Tone Results

Step Mode	Antenna path Number	Address Offset		bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
		Mode2	Mode3								
Mode2 (Tn-Tn) or Mode 3 (Pk-Tn-Tn-Pk)	X	4	20	pct_i_1[3:0]				-		tqi_1[1:0]	
		5	21	pct_i_1[11:4]							
		6	22	pct_q_1[3:0]				-			
		7	23	pct_q_1[11:4]							
		8	24	pct_i_2[3:0]				-		tqi_2[1:0]	
		9	25	pct_i_2[11:4]							
		10	26	pct_q_2[3:0]				-			
		11	27	pct_q_2[11:4]							
	n_ap>=2	12	28	pct_i_3[3:0]				-		tqi_3[1:0]	
		13	29	pct_i_3[11:4]							
		14	30	pct_q_3[3:0]				-			
		15	31	pct_q_3[11:4]							
	n_ap>=3	16	32	pct_i_4[3:0]				-		tqi_4[1:0]	
		17	33	pct_i_4[11:4]							
		18	34	pct_q_4[3:0]				-			
		19	35	pct_q_4[11:4]							

Table continues on the next page...

Table 505. Tone Results (continued)

Step Mode	Antenna path Number	Address Offset		bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
		Mode2	Mode3								
	n_ap=4	20	36	pct_i_5[3:0]				-		tqi_5[1:0]	
		21	37	pct_i_5[11:4]							
		22	38	pct_q_5[3:0]				-			
		23	39	pct_q_5[11:4]							

Refer to IQ_RESULT_BODY section of General description for more information.

52.4.4.2.2.5.11.3 RSM results depending on CS Mode

52.4.4.2.2.5.11.3.1 Mode 0/1 Result

Table 506. Mode 0/1 Result Table

Step Mode	Address Offset	bits [31:0]
Mode 0 (FCS) or Mode 1 (Pk-Pk)	0	aa_det / 0b / time_drift[1:0] / 000b /pcbd[8:0] or ctune[8:0] / agc_idx[3:0] / result_len[3:0] / step_id[7:0]
	4	raw_nadm[23:0] / rssi_nb[7:0]
	8	rtt_data[31:0]
	12	cfo_est[9:0]
	16	tpm[31:0]

52.4.4.2.2.5.11.3.2 Mode 2 Result

Table 507. Mode 2 Result Table

Step Mode	Antenna path Number	Address Offset	bits [31:0]
Mode 2 (Tn-Tn)	X	0	aa_det / 0b / time_drift[1:0] / 000b /pcbd[8:0] or ctune[8:0] / agc_idx[3:0] / result_len[3:0] / step_id[7:0]
		4	pct_q_1[11:0] / 0000b / pct_i_1[11:0] / 00b / tqi_1[1:0]
		8	pct_q_2[11:0] / 0000b / pct_i_2[11:0] / 00b / tqi_2[1:0]
	n_ap>=2	12	pct_q_3[11:0] / 0000b / pct_i_3[11:0] / 00b / tqi_3[1:0]
	n_ap>=3	16	pct_q_4[11:0] 0000b / pct_i_4[11:0] / 00b / tqi_4[1:0]
	n_ap=4	20	pct_q_5[11:0] 0000b / pct_i_5[11:0] / 00b / tqi_5[1:0]

52.4.4.2.2.5.11.3.3 Mode 3 Result

Table 508. Mode 3 Result Table

Step Mode	Address Offset	bits [31:0]
Mode 3 (Pk-Tn-Tn-Pk)	0	aa_det / 0b / time_drift[1:0] / 000b /pcbd[8:0] or ctune[8:0] / agc_idx[3:0] / result_len[3:0] / step_id[7:0]
	4	raw_nadm[23:0] / rssi_nb[7:0]
	8	rtt_data[31:0]
	12	cfo_est[9:0]
	16	tpm[31:0]
	20	pct_q_1[11:0] / 0000b / pct_i_1[11:0] / 00b / tqi_1[1:0]
	24	pct_q_2[11:0] / 0000b / pct_i_2[11:0] / 00b / tqi_2[1:0]
	28 (if n_ap>=2)	pct_q_3[11:0] / 0000b / pct_i_3[11:0] / 00b / tqi_3[1:0]
	32 (if n_ap>=3)	pct_q_4[11:0] / 0000b / pct_i_4[11:0] / 00b / tqi_4[1:0]
	36 (if n_ap=4)	pct_q_5[11:0] / 0000b / pct_i_5[11:0] / 00b / tqi_5[1:0]

52.4.4.2.2.5.12 Packet Ram Data Structures

52.4.4.2.2.5.12.1 General description

The main point of communication between RSM and Channel Sounding Link Layer Software is the Packet RAM. The config and result buffers are built in Packet RAM for each step by using specific data structures depending on step mode, the payload size and the number of antenna paths

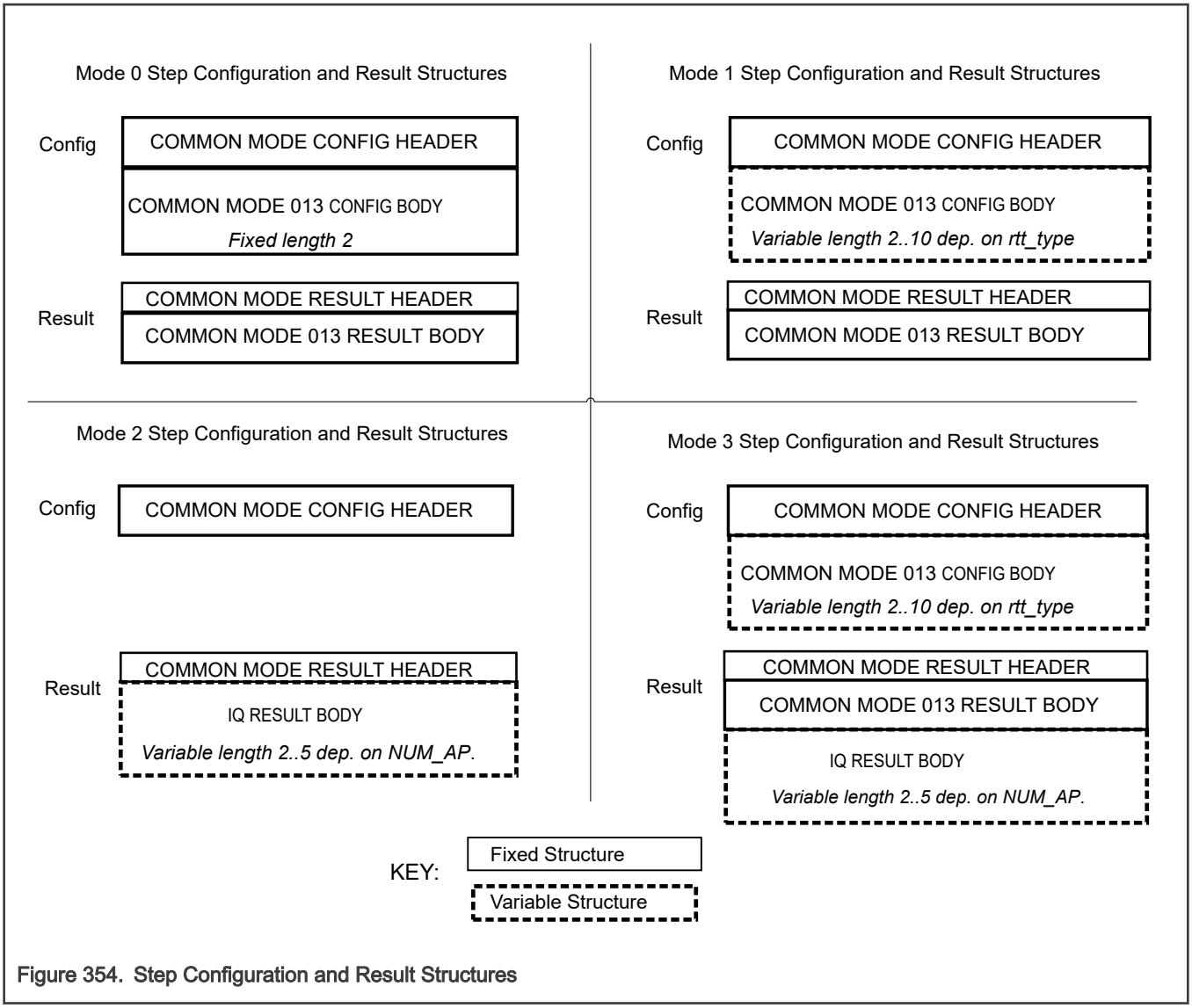


Figure 354. Step Configuration and Result Structures

52.4.4.2.2.5.12.2 COMMON MODE CONFIG HEADER

52.4.4.2.2.5.12.2.1 register descriptions

52.4.4.2.2.5.12.2.1.1 CommMode Configuration Header Indices

Data structure definition for the common header used in the configuration of all Channel Sounding Steps. Defines the format of bitfields in PKT_RAM memory for these step types. This header structure may be followed by a variable length structure representing the access address and payload contents for RTT steps.

Index	Register	Width (In bits)	Access	Reset value
0h	Channel number for the step. (CHANNEL_NUM)	16	RW	See section
2h	Configuration for the step. (STEP_CFG)	16	RW	See section
4h	CFO setting for the step (STEP_CFO)	16	RW	See section

Table continues on the next page...

Table continued from the previous page...

Index	Register	Width (In bits)	Access	Reset value
6h	HPM CAL factor to apply for the step. (HPM_CAL_FACTOR)	16	RW	See section
8h	CTUNE manual to inject for the step. (CTUNE_MANUAL)	16	RW	See section
Ah	Phase adder for the step. (PHASE_ADD)	16	RW	See section

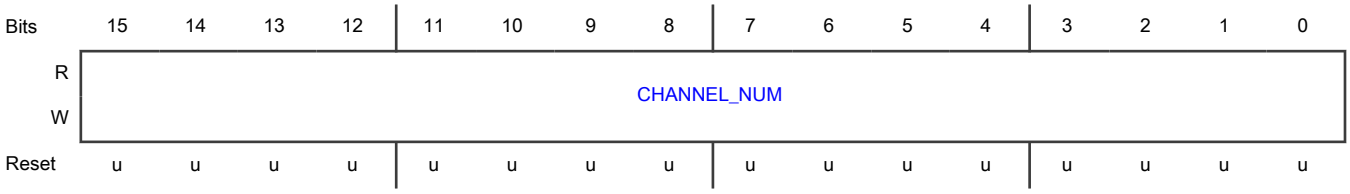
52.4.4.2.2.5.12.2.1.2 Channel number for the step. (CHANNEL_NUM)

Index

Register	Index
CHANNEL_NUM	0h

Function
Configuration fields for the Mode 2 step type.

Diagram



Fields

Field	Function
15-0 CHANNEL_NUM	Channel number for the step. This defines the frequency to be used for this step. This is decoded by the PLL using the format defined in the PLL's CHAN_MAP[HOP_TBL_CFG_OVRD] bitfield. NOTE: to ensure proper PLL operation when using the RSM, the PLL's CHAN_MAP[CHANNEL_NUM_OVRD] bitfield should be programmed to 0.

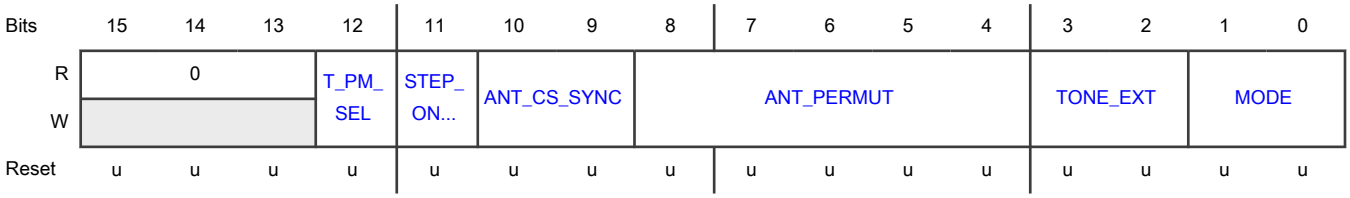
52.4.4.2.2.5.12.2.1.3 Configuration for the step. (STEP_CFG)

Index

Register	Index
STEP_CFG	2h

Function
Various configuration fields valid for the all CS modes.

Diagram



Fields

Field	Function
15-13 —	Reserved
12 T_PM_SEL	Selection of T_PM choices. For Tn-Tn and Pk-Tn-Tn-Pk formats, this selects whether T_PM0 or T_PM1 is used for the tone duration in this frequency step. 0b - T_PM0 is used 1b - T_PM1 is used
11 STEP_ONE_WAY	Unidirectional Mode When this bit is set, the Unidirectional Mode is enabled for the step. Only mode 1 and 2 support the unidirectional mode, so this bit must be always set to 0 in mode 0 and in mode 3. 0b - Unidirectional Mode is disabled 1b - Unidirectional Mode is enabled
10-9 ANT_CS_SYNC	Antenna cs Sync Selects the default antenna for modes 0,1 (and 3 for packet transmission) -> antenna 0 to antenna 3 00b - A0 01b - A1 10b - A2 11b - A3
8-4 ANT_PERMUT	Antenna permutation pattern for the step. This field is used only in mode 2 or mode 3 when LCL_CFG0[LCL_ANT_PERMUT_EN] is set. It indicates the index of antenna permutation table which is used to select the specific antenna paths position order.
3-2 TONE_EXT	Choice of tone extension for the initiator portion of the step. Used only in mode 2 or mode 3 Since the presence of the Tone Extension is always checked by the RX device then TONE_EXT[0]=0x1 for Reflector and sniffer in mode 2 and mode 3 TONE_EXT[1]=0x1 for Initiator only in mode 2 and sniffer in mode 2 and mode 3 00b - Tone extension is not present for either role TX. 01b - Tone extension is present for initiator TX only.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	10b - Tone extension is present for reflector TX only. 11b - Tone extension is present for both roles TX.
1-0 MODE	Mode for the step 00b - Frequency Compensation Step (Mode 0) 01b - Pk-Pk step (Mode 1) 10b - Tn-Tn step (Mode 2) 11b - Pk-Tn-Tn-Pk step (Mode 3)

52.4.4.2.2.5.12.2.1.4 CFO setting for the step (STEP_CFO)

Index

Register	Index
STEP_CFO	4h

Function

This field is 16 bits signed. It can be added to pll_numerator_offset to adjust the PLL frequency (0.9536 Hz/step @ 32 Mhz) during RX whatever the step mode.

Diagram

Fields

Field	Function
15-0 STEP_CFO	CFO setting for the step. This field can be added to pll_numerator_offset to adjust the PLL frequency (0.9536 Hz/step @ 32 Mhz) during RX whatever the step mode.

52.4.4.2.2.5.12.2.1.5 HPM CAL factor to apply for the step. (HPM_CAL_FACTOR)

Index

Register	Index
HPM_CAL_FACTOR	6h

Function

This defines the 12 MSBs of the PLL high port modulation calibration factor. The LSB is assigned to 0. It is used only if RSM_HPM_CAL register is set. Note that this has the same format as PLL's HPM_CAL_FACTOR_MANUAL bitfield

Diagram

Fields

Field	Function
15-12 —	Reserved
11-0 HPM_CAL_FACTOR	HPM CAL factor to apply for the step This defines the 12 MSBs of the PLL high port modulation calibration factor. The LSB is assigned to 0. Note that this has the same format as PLL's HPM_CAL_FACTOR_MANUAL bitfield

52.4.4.2.2.5.12.2.1.6 CTUNE manual to inject for the step. (CTUNE_MANUAL)

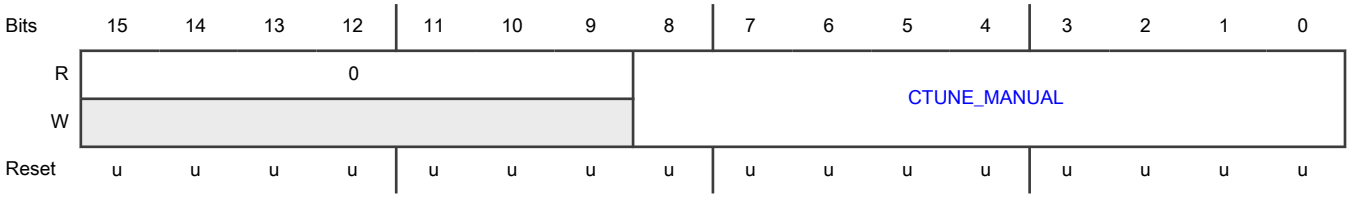
Index

Register	Index
CTUNE_MANUAL	8h

Function

This defines the PLL coarse tune value for this frequency step

Diagram



Fields

Field	Function
15-9	Reserved

Table continues on the next page...

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Field	Function
—	
8-0 CTUNE_MANUAL	CTUNE manual to inject for the step. This defines the PLL coarse tune value for this frequency step. It is used only if RSM_CTUNE register is set

52.4.4.2.2.5.12.2.1.7 Phase adder for the step. (PHASE_ADD)

Index

Register	Index
PHASE_ADD	Ah

Function

It can be added to rx_phase_return signal computed for Inline Phase Return. This offset is 8 bits signed

Diagram

Fields

Field	Function
15-8 —	Reserved
7-0 PHASE_ADD	Phase adder for the step. This allows FW to adjust phase with first antenna on a multiple antenna context

52.4.4.2.2.5.12.3 PAYLOAD CONFIG BODY

52.4.4.2.2.5.12.3.1 register descriptions

52.4.4.2.2.5.12.3.1.1 Payload Configuration Body Indices

Data structure definition for AA and payload configuration storage for Mode 1 and 3 Channel Sounding Steps. Defines the format of bitfields in PKT_RAM memory for the payload portion of these steps. This structure is intended to be used after the common_mode_config_hdr structure and may be variable length depending on the RTT payload length.

Index	Register	Width (In bits)	Access	Reset value
0h	Access address used for the Initiator transmission phase (AA_INIT)	32	RW	See section
4h	Access address used for the reflector transmission phase (AA_REF)	32	RW	See section
8h	32bit word of payload for the initiator for the step. (PAYLOAD_INIT0)	32	RW	See section
Ch	32bit word of payload for the reflector for the step. (PAYLOAD_REFL0)	32	RW	See section
10h	32bit word of payload for the initiator for the step. (PAYLOAD_INIT1)	32	RW	See section
14h	32bit word of payload for the reflector for the step. (PAYLOAD_REFL1)	32	RW	See section
18h	32bit word of payload for the initiator for the step. (PAYLOAD_INIT2)	32	RW	See section
1Ch	32bit word of payload for the reflector for the step. (PAYLOAD_REFL2)	32	RW	See section
20h	32bit word of payload for the initiator for the step. (PAYLOAD_INIT3)	32	RW	See section
24h	32bit word of payload for the reflector for the step. (PAYLOAD_REFL3)	32	RW	See section

52.4.4.2.2.5.12.3.1.2 Access address used for the Initiator transmission phase (AA_INIT)

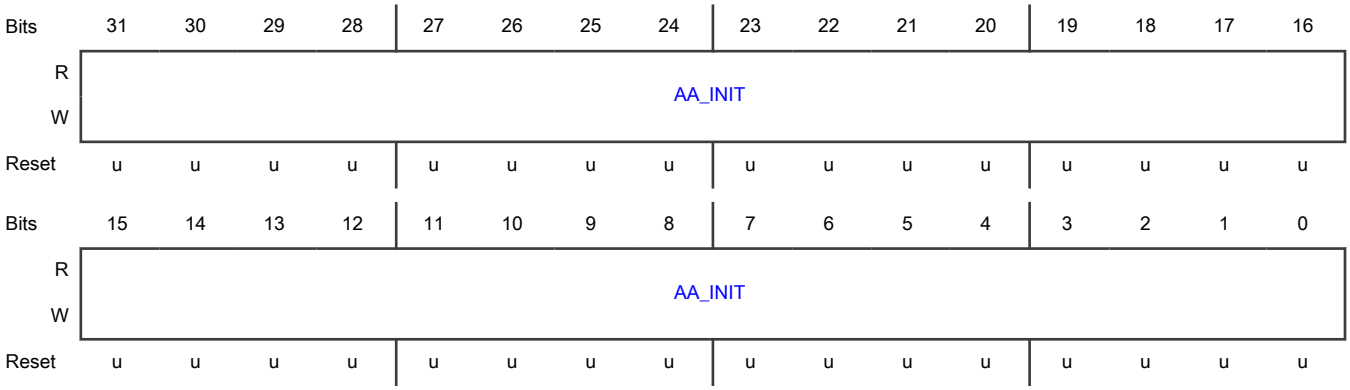
Index

Register	Index
AA_INIT	0h

Function

Access address sent during Initiator transmission phase (first half step).

Diagram



Fields

Field	Function
31-0 AA_INIT	Access address sent during Initiator transmission phase (first half step). The access address is transmitted LSB first.

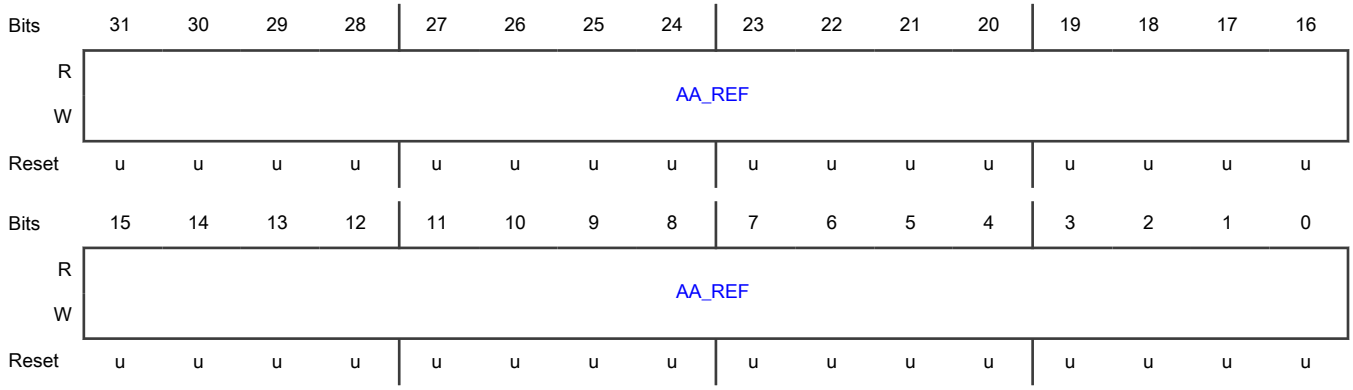
52.4.4.2.2.5.12.3.1.3 Access address used for the reflector transmission phase (AA_REF)

Index

Register	Index
AA_REF	4h

Function
Access address sent during Reflector transmission phase (first half step).

Diagram



Fields

Field	Function
31-0 AA_REF	Access address sent during Reflector transmission phase (first half step). The access address is transmitted LSB first.

52.4.4.2.2.5.12.3.1.4 32bit word of payload for the initiator for the step. (PAYLOAD_INIT0 - PAYLOAD_INIT3)

Index

Register	Index
PAYLOAD_INIT0	8h
PAYLOAD_INIT1	10h

Table continues on the next page...

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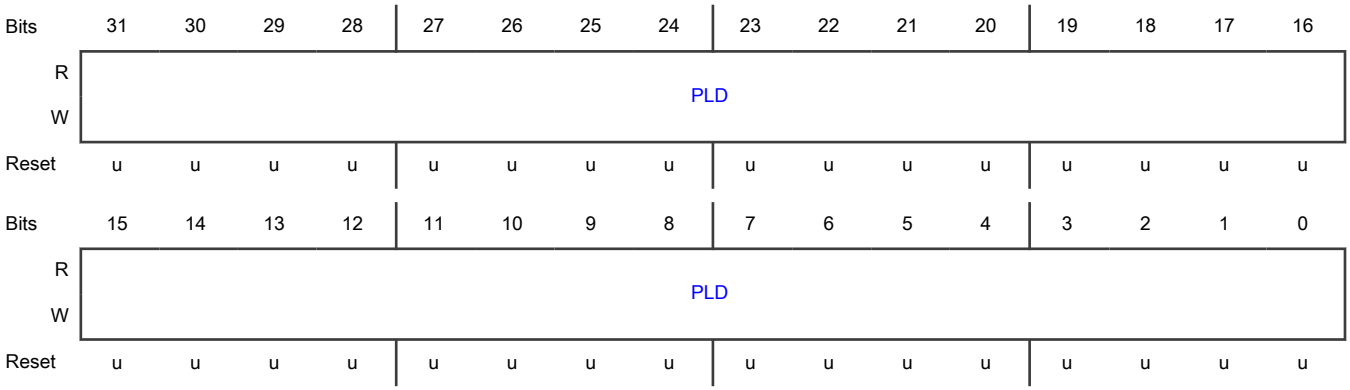
Register	Index
PAYLOAD_INIT2	18h
PAYLOAD_INIT3	20h

Function

Configuration of 1 32bit word of payload.

Diagram



Fields

Field	Function
31-0 PLD	One payload word. Corresponds to a 32-bit vector of the payload. This vector is transmited LSB bit. The size of the complete payload depends on RTT_TYPE bitfield of RSM_CTRL2 register: 000b - no payload 010b - 96-bit payload 011b - 32-bit payload 100b - 64-bit payload 101b - 96-bit payload 110b - 128-bit payload

52.4.4.2.2.5.12.3.1.5 32bit word of payload for the reflector for the step. (PAYLOAD_REFL0 - PAYLOAD_REFL3)

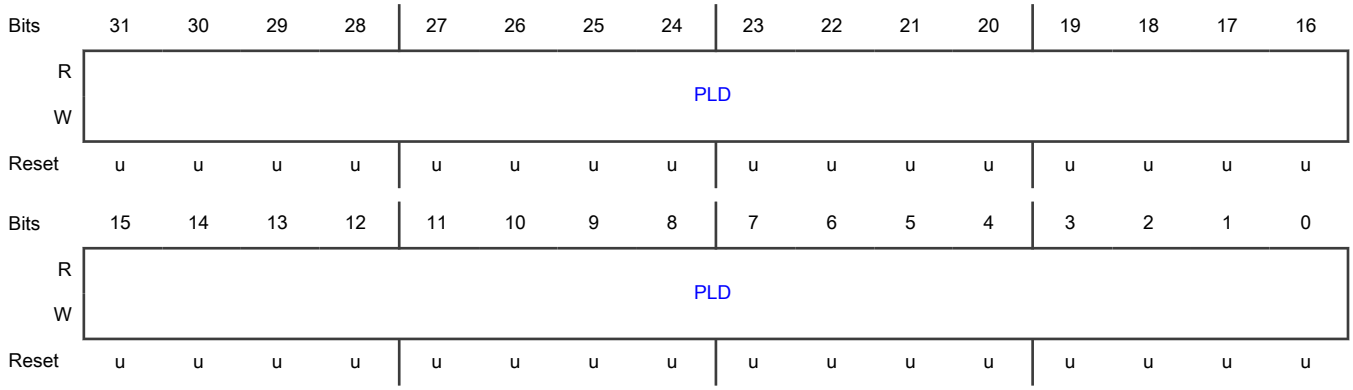
Index

Register	Index
PAYLOAD_REFL0	Ch
PAYLOAD_REFL1	14h
PAYLOAD_REFL2	1Ch
PAYLOAD_REFL3	24h

Function

Configuration of 1 32bit word of payload.

Diagram



Fields

Field	Function
31-0 PLD	One payload word. Corresponds to a 32-bit vector of the payload. This vector is transmited LSB bit. The size of the complete payload depends on RTT_TYPE bitfield of RSM_CTRL2 register: 000b - no payload 010b - 96-bit payload 011b - 32-bit payload 100b - 64-bit payload 101b - 96-bit payload 110b - 128-bit payload

52.4.4.2.2.5.12.4 COMMON MODE 013 RESULT BODY

52.4.4.2.2.5.12.4.1 register descriptions

52.4.4.2.2.5.12.4.1.1 Common Mode 0/1/3 Result Body Indices

Data structure definition for the body of a result for Mode 0/1/3 Channel Sounding step. This structure is common between all 3 result types and is intended to be combined with other structures to create the different composite result types. It is always after a common_mode_result_hdr structure.

Index	Register	Width (In bits)	Access	Reset value
0h	Raw NADM or Payload Error and RSSI for the step. (NADM_ERROR_RSSI)	32	RW	See section
4h	Results reported from the PHY RTT block for the step. (RTT_RESULT)	32	RW	See section
8h	CFO estimate for the step. (CFO_EST)	32	RW	See section
Ch	TPM module timestamp for the step. (TIMESTAMP)	32	RW	See section

52.4.4.2.2.5.12.4.1.2 Raw NADM or Payload Error and RSSI for the step. (NADM_ERROR_RSSI)

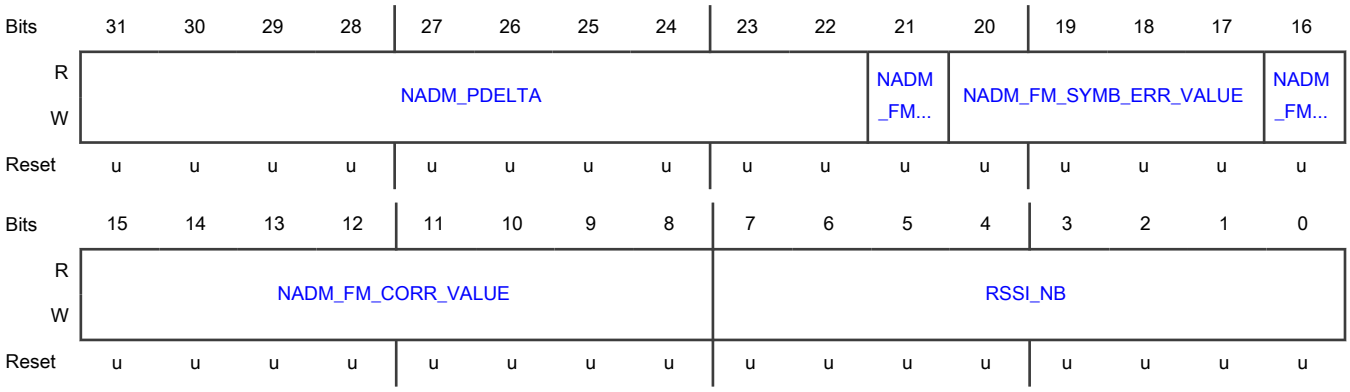
Index

Register	Index
NADM_ERROR_RSSI	0h

Function

Stores the Raw NADM result or Payload Error result for a step, depending on the step type. Stores measured RSSI for the step.

Diagram



Fields

Field	Function
31-22 NADM_PDELTA	NADM pdelta value It corresponds to the difference of correlations around maximum correlator instance
21 NADM_FM_SYMB_ERR_VALID	NADM FM symbol error valid flag Indicates if the NADM FM symbol error value is valid
20-17 NADM_FM_SYMB_ERR_VALUE	NADM FM symbol error value This is the NADM check result between the received signal payload and a reference payload.
16 NADM_FM_CORR_VALID	NADM FM correlator valid flag Indicates if the NADM FM correlator value is valid.
15-8 NADM_FM_CORR_VALUE	NADM FM correlator value This is the NADM correlation result of the received signal with a local reference signal.
7-0 RSSI_NB	Narrowband RSSI measured for the step. 8-bit signedformat.

52.4.4.2.2.5.12.4.1.3 Results reported from the PHY RTT block for the step. (RTT_RESULT)

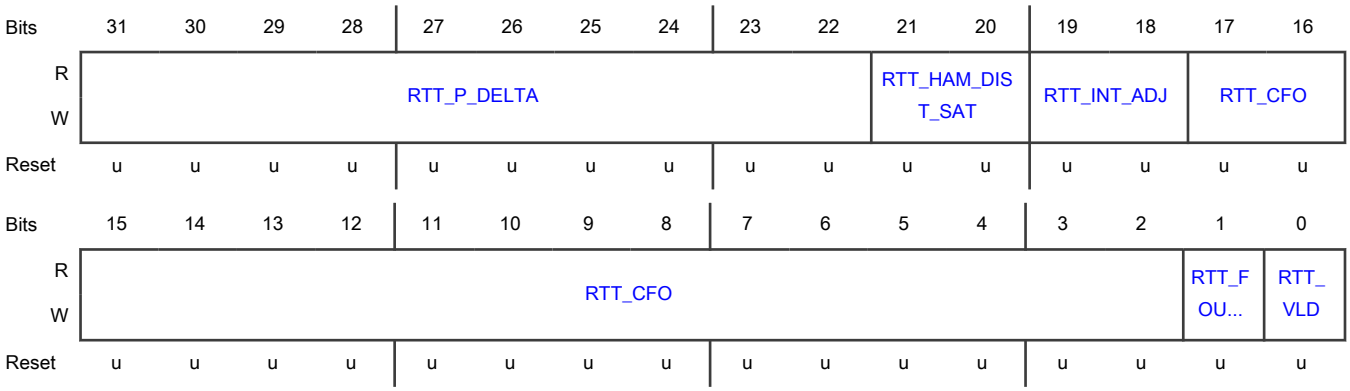
Index

Register	Index
RTT_RESULT	4h

Function

Stores the results reported from the PHY RTT block, including found/valid status, the CFO offset reported, and several fields related to the RTT timing estimation.

Diagram



Fields

Field	Function
31-22 RTT_P_DELTA	P-delta value from the RTT result. It corresponds to the difference between the squared correlation magnitude values, pm-pp, provided by the HARTT block.
21-20 RTT_HAM_DIST_SAT	Hamming Distance Saturation from the RTT result. It corresponds to the Computed Hamming distance saturated to 2 bits.
19-18 RTT_INT_ADJ	Integer adjustment reported from the RTT result. It corresponds to an integer adjustment of the timing which takes a value different of 0 when the early-late mechanism in the HARTT block chooses a peak different of the one chosen in the acquisition module (possible values are {-1,0,+1}).
17-2 RTT_CFO	RTT Carrier Frequency Offset (CFO) result. It corresponds to the high accuracy CFO computed by the HARTT block through the Cordic algorithm.
1 RTT_FOUND	RTT found status. This flag indicates that the HARTT operation is done through the Cordic algorithm.
0 RTT_VLD	RTT valid status. This bit indicates if the other fields of RTT_RESULT register are valid

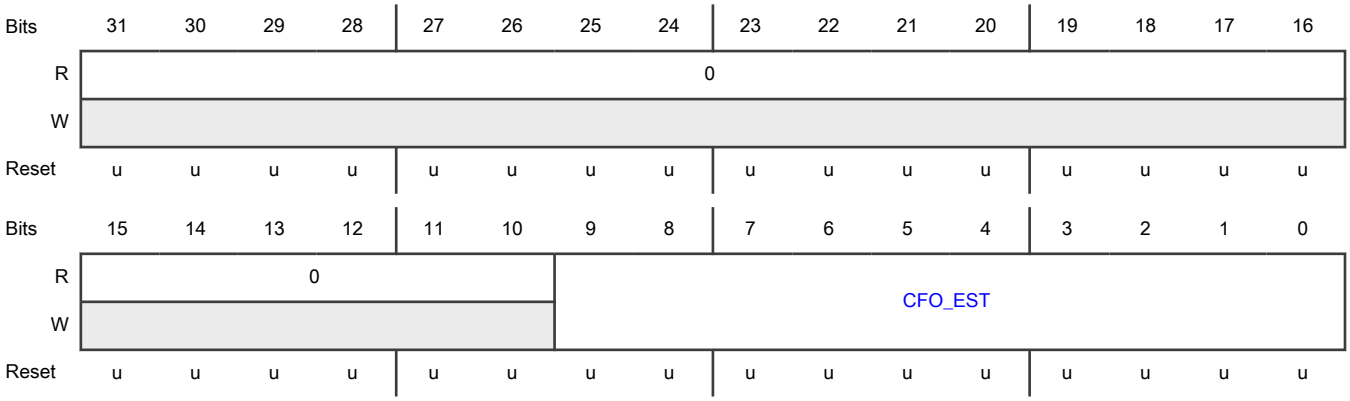
52.4.4.2.2.5.12.4.1.4 CFO estimate for the step. (CFO_EST)

Index

Register	Index
CFO_EST	8h

Function
This indicates the CFO estimate computed by the AA0 detector

Diagram



Fields

Field	Function
31-10 —	Reserved
9-0 CFO_EST	Carrier Frequency Offset estimate for the step. Signed 10-bit format. This indicates the CFO estimate computed by the AA0 detector

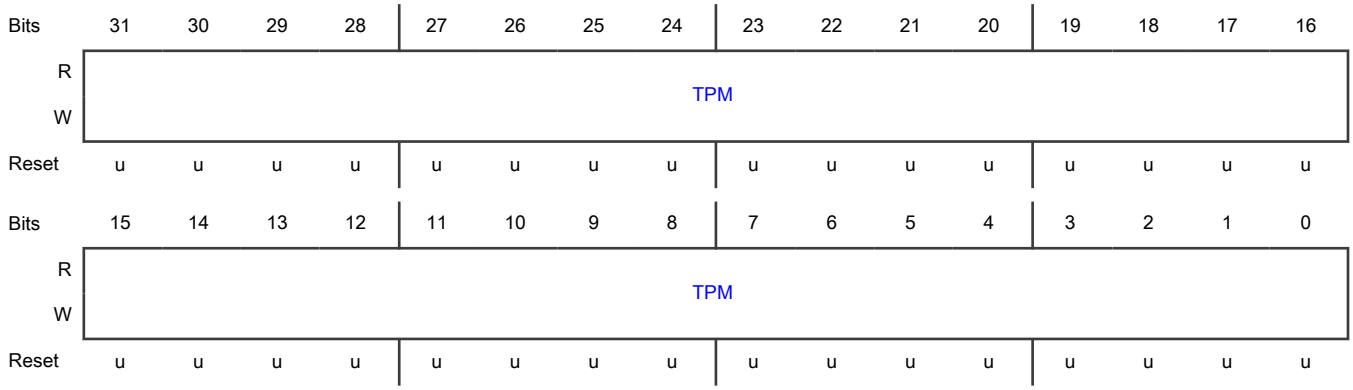
52.4.4.2.2.5.12.4.1.5 TPM module timestamp for the step. (TIMESTAMP)

Index

Register	Index
TIMESTAMP	Ch

Function
Stores the timestamp captured by the RTT step.

Diagram



Fields

Field	Function
31-0 TPM	Timestamp for the step. This indicates the ToA-ToD time. The unit of this time is the Transceiver clock period (31.25ns). In initiator configuration, it corresponds to the time between the beginning of Tx packet and the access address detection of the RX packet. In reflector configuration, - at the first CS step, it corresponds to the time between the beginning of the warm-up sequence to the access address detection of the Rx packet. - after the first CS step, it corresponds to the time between the access address detection of the Rx packet to the beginning of TX packet.

52.4.4.2.2.5.12.5 COMMON MODE RESULT HEADER

52.4.4.2.2.5.12.5.1 register descriptions

52.4.4.2.2.5.12.5.1.1 Common Mode Result Header Indices

Data structure definition for the header of a result for any Channel Sounding step. This structure is common between all 4 result types and is intended to be combined with other structures to create the different composite result types. It is always first in the results sequence.

Index	Register	Width (In bits)	Access	Reset value
0h	STEP_ID for the step. (STEP_ID)	8	RW	See section
1h	Result size and AGC index for the step. (SIZE_AGC_IDX)	8	RW	See section
2h	PBCD or CTUNE and AA detection status for the step (PBCD_CTUNE_AA_DET)	16	RW	See section

52.4.4.2.2.5.12.5.1.2 STEP_ID for the step. (STEP_ID)

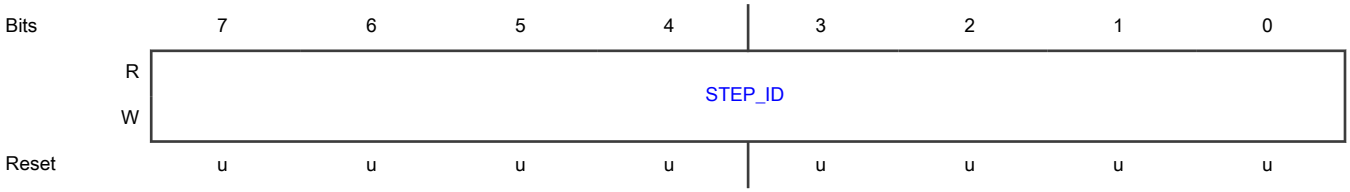
Index

Register	Index
STEP_ID	0h

Function

STEP_ID for the step. This field is incremented for every received step

Diagram



Fields

Field	Function
7-0 STEP_ID	STEP_ID for the step.

52.4.4.2.2.5.12.5.1.3 Result size and AGC index for the step. (SIZE_AGC_IDX)

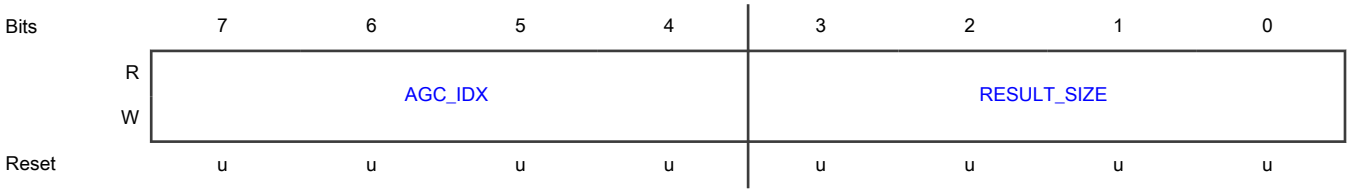
Index

Register	Index
SIZE_AGC_IDX	1h

Function

Stores the standard set of results that are common to all Channel Sounding step result reports.

Diagram



Fields

Field	Function
7-4 AGC_IDX	AGC Index reported for the step.
3-0 RESULT_SIZE	Result length for the step. This indicates the result length in words of the frequency step.

52.4.4.2.2.5.12.5.1.4 PBCD or CTUNE and AA detection status for the step (PBCD_CTUNE_AA_DET)

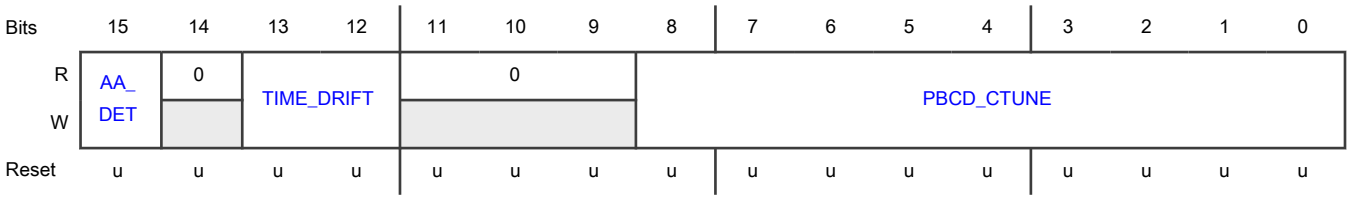
Index

Register	Index
PBCD_CTUNE_AA_DET	2h

Function

PBCD or CTUNE and AA detection status for the step.

Diagram



Fields

Field	Function
15 AA_DET	AA detection status reported for the step. This indicates if a packet access address has been detected during the frequency step. This field is expected to be set in mode 0/1/3 if the access address of the RX packet is correctly received, otherwise it is expected to be 0.
14 —	Reserved
13-12 TIME_DRIFT	TIME DRIFT delta value Indicates if a time drift delta value for this step 00b - 0 us 01b - +1us 11b - -1us
11-9 —	Reserved
8-0 PBCD_CTUNE	PBCD or CTUNE for the step. In the configuration where the PLL performs coarse tune during the RSM operation (CTUNE=0), the RSM will capture the coarse tune best diff value or the vco ctune value depending on RSM_PCBD_CTUNE_SEL register.

52.4.4.2.2.5.12.6 IQ RESULT BODY

52.4.4.2.2.5.12.6.1 register descriptions

52.4.4.2.2.5.12.6.1.1 IQ result (PCT) Body Indices

Data structure definition for IQ result storage for Mode 2 and 3 Channel Sounding Steps. Defines the format of bitfields in PKT_RAM memory for the IQ result portion of these steps. This structure is intended to be used after the

common_mode_result_hdr structure and may be variable length depending on the number of antenna paths and the tone extension state.

Index	Register	Width (In bits)	Access	Reset value
0h - 10h	IQ and TQI result for the step. (PCT_RESULT0 - PCT_RESULT4)	32	RW	See section

52.4.4.2.2.5.12.6.1.2 IQ and TQI result for the step. (PCT_RESULT0 - PCT_RESULT4)

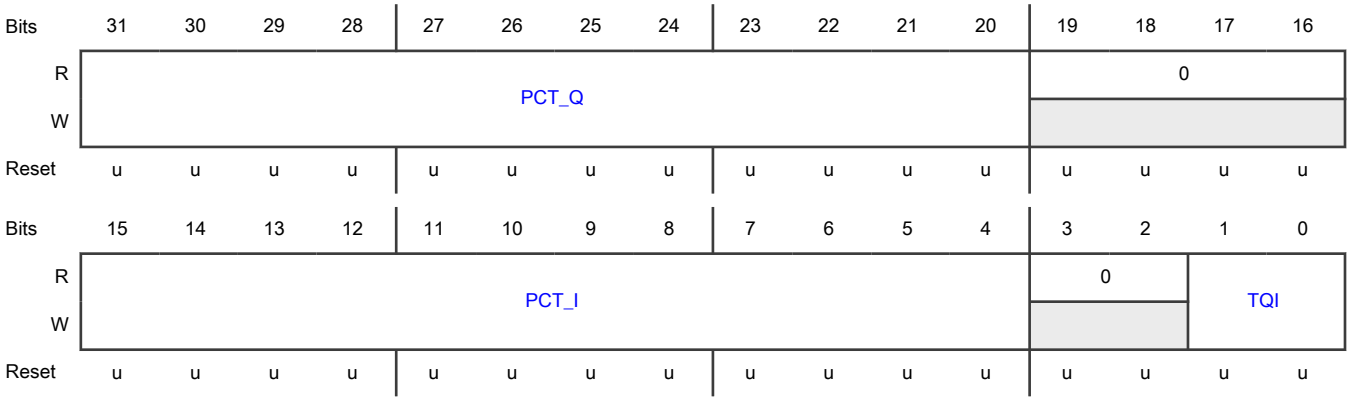
Index

Register	Index
PCT_RESULT0	0h
PCT_RESULT1	4h
PCT_RESULT2	8h
PCT_RESULT3	Ch
PCT_RESULT4	10h

Function

Stores the PCT I and Q and the Tone Quality Indication for one antenna path or tone extension slot.

Diagram



Fields

Field	Function
31-20 PCT_Q	Quadrature component of the PCT for the individual path. 12-bit signed format
19-16	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
15-4 PCT_I	In-phase component of the PCT for the individual path. 12-bit signed format
3-2 —	Reserved
1-0 TQI	Tone Quality Indication (TQI) for the individual path. Indicates the Tone Quality indicator. 00b - Good quality 01b - Medium quality 10b - Low quality 11b - Reserved

52.4.4.2.2.6 Localization Control Module (LCL)

52.4.4.2.2.6.1 Introduction

The transceiver supports two antenna control mechanisms: Fast Antenna Diversity (FAD), and Localization Control. FAD allows an optimal choice between two antennas during the PHY's preamble search. Localization Control refers to direction finding (angle of arrival / angle of departure) and ranging. Only one of these is enabled at any given time.

A high level figure illustrating the transceiver modules involved is shown below. The FAD algorithm is in the PHY, which provides an output to control the antenna through the FAD Common pin interface. The Localization control outputs "lant_lut_gpio[3:0]" (to control an external antenna switch) plus a start trigger and DMA mask signal to the XCVR DMA to facilitate capture of receiver samples. For Bluetooth LE direction finding, the Localization Control module accepts CTE control signals from the Bluetooth LE link layer. For ranging, a Ranging Sequence Manager sequences the transceiver between RX and TX operations across a set of programmable frequencies for the purpose of the capturing phase samples (when tones are transmitted) and RTT measurements (when packets are transmitted) in the receiving device, and also provides a trigger to the Localization Control module for optional antenna switching. In addition, the Localization Control module provides a trigger to the SOC (to be connected to a timer) for time-of-flight timestamping; this trigger is a mux of several signals in the transceiver as shown in the figure. The four FAD outputs and LCL_CTRL's lant_lut_gpio[3:0] outputs go to SOC pins via the RF_GPO muxes described in the Coexistence/FEM/LANT connections section of the Radio Control chapter.

The Localization Control , Ranging Sequence Manager and FAD Common Pin Interface are described in the sections below. For more info on the PHY's FAD algorithm refer to the PHY chapter.

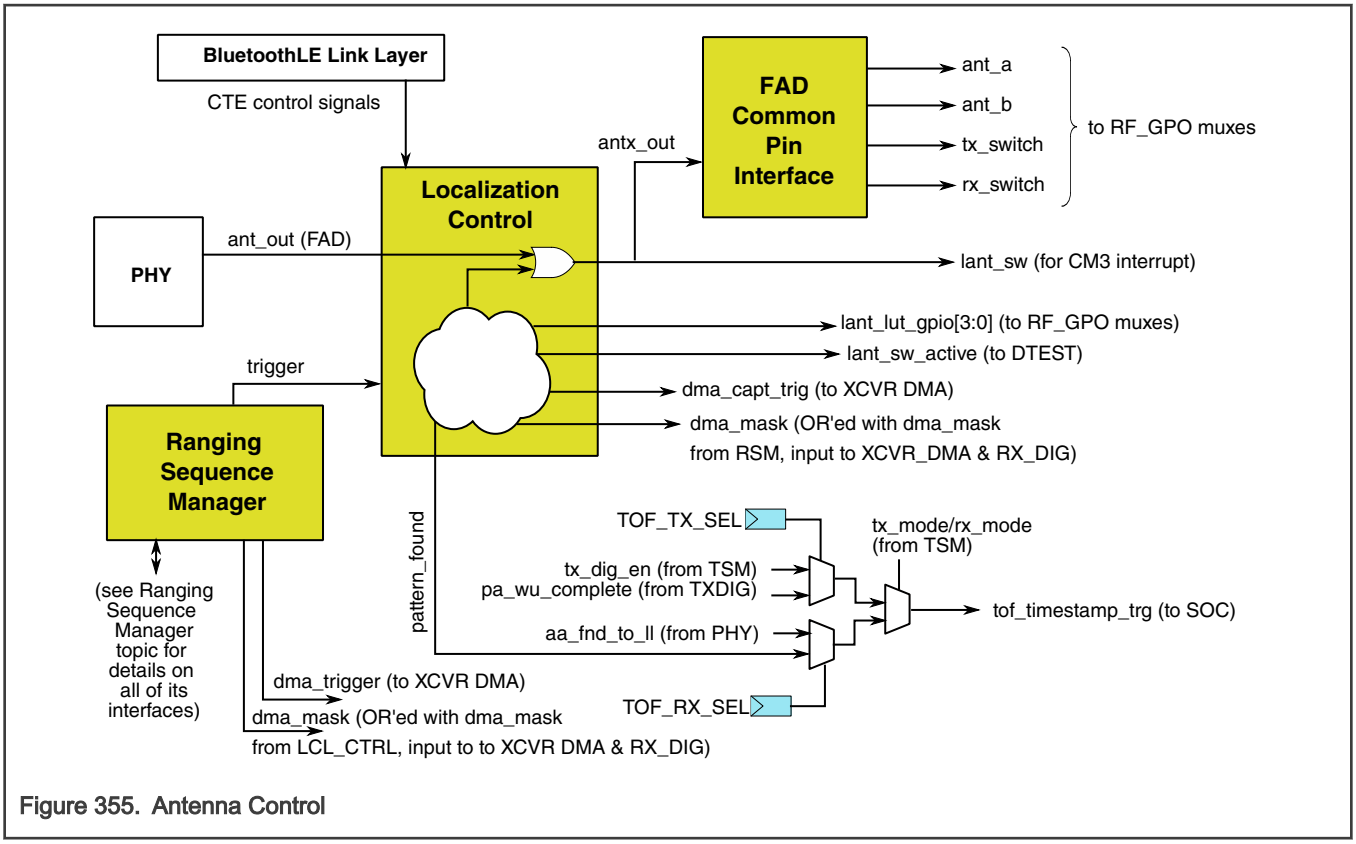


Figure 355. Antenna Control

52.4.4.2.2.6.2 Functional description

The LCL_CTRL module implements various controls intended to assist with antenna control and sample capture.

There are 3 significant functions of this module:

1. Scan the bit stream for a pattern
2. Control the switching of the antenna output (lant_lut_gpio[3:0])
3. Provide a data valid mask signal for the XCVR DMA

Within the LCL_CTRL there is pattern matching logic that will assert a pattern found signal when the incoming bit stream matches the pre-programmed pattern. The pattern can be 4, 5, 6, or 8 bytes (setting PM_NUM_BYTES). The pattern must be programmed in the LCL_PM_MSB and LCL_PM_LSB registers and pattern matching must be enabled. If COMP_EN is set, then pattern matching will operate during RX. For pattern matching in TX, both COMP_EN and COMP_TX_EN must be set. The pattern_match output asserts when a pattern match has occurred. For RX, when the pattern_match output asserts the dma_capt_trig to the XCVR_DMA also asserts.

For antenna control, the LCL_CTRL module can be configured using the MODE bit to operate with or without use of the Bluetooth LE Link Layer's Constant Tone Extension (CTE) control signals.

52.4.4.2.2.6.2.1 Antenna Control Without BLE CTE Signals

For antenna control without using the Bluetooth LE CTE control signals, various settings must be programmed prior to operation. The significant fields are:

- CTE_DUR : Duration of switching activity in doublets, where a doublet = RX/TX_HI_PER + RX/TX_LO_PER
- LANT_INV : When set to 1, the lant_sw signal is inverted
- RX/TX_LCL_EN : Enables antenna switching control in RX and/or TX
- LCL_EN : Enable for the entire LCL_CTRL module

- RX/TX_DELAY_OFF : Extra offset (in samples) to fine tune the RX/TX_DELAY
- RX/TX_DELAY : Delay, in intervals, before antenna switching is to begin
- RX/TX_LO_PER : Number of intervals for which lant_sw should be 0, when switching is active. For RX, RX_LO_PER also indicates the number of intervals that the dma_mask should be 0.
- RX/TX_HI_PER : Number of intervals for which lant_sw should be 1, when switching is active. For RX, RX_HI_PER also indicates the number of intervals that the dma_mask should be 1.
- RX/TX_ANT_TRIG_SEL : Selects the trigger to be observed to begin counting DELAY
- RX/TX_SPINT : Defines the number of samples per interval. This is realized using the sample clock associated with either RX or TX, (typically 4MHz or 8MHz).
- M_ON_DELAY/N_ON_DELAY: The rx/tx_lco_on output will de-assert M_ON_DELAY intervals + N_ON_DELAY doublets earlier than the antenna switching stops.
- LUT_0 to LUT_31: state of lant_lut_gpio[3:0] for the switching activity doublet from 0 to 31
- LUT_WRAP_PTR: Wrap point for the LUT_0 to LUT_31. If programmed to value "N", output will be LUT_0, ..., LUT_N, LUT_0, ...

When enabled, the LCL_CTRL control module begins monitoring the selected trigger source as indicated by RX/TX_ANT_TRIG_SEL. When the trigger occurs, a timer begins. When the timer reaches DELAY+DELAY_OFF, the system will align to the next available sample clock and the antenna switching begins. The switching is described by asserting as 1 for HI_PER, then de-asserting as 0 for LO_PER. One of these cycles is termed a 'doublet'. This initial process is depicted in the figure below.

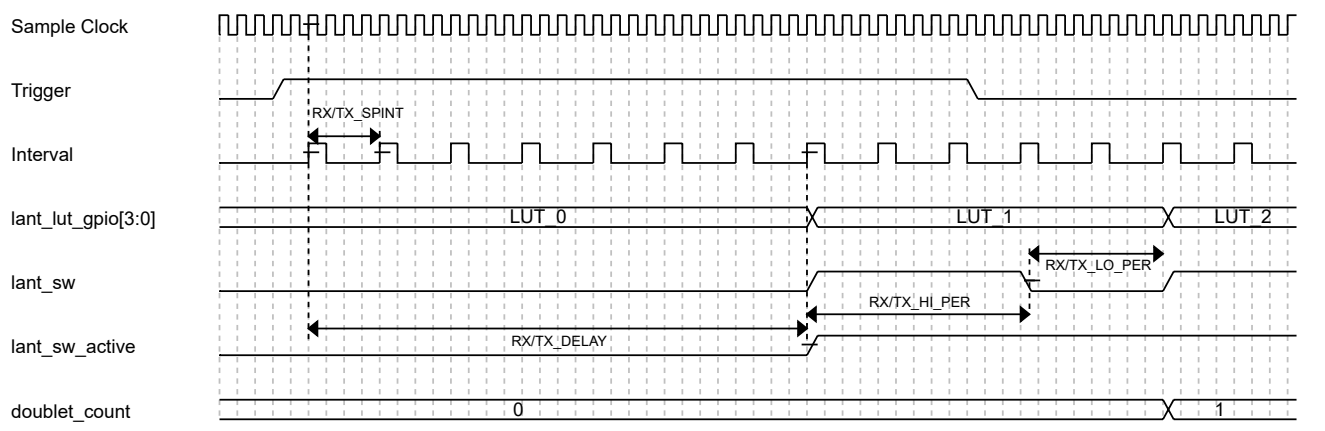


Figure 356. LCL_CTRL startup

After antenna switching has begun, another counter will count the doublets. When the CTE_DUR is reached, switching will stop as depicted in the following figure.

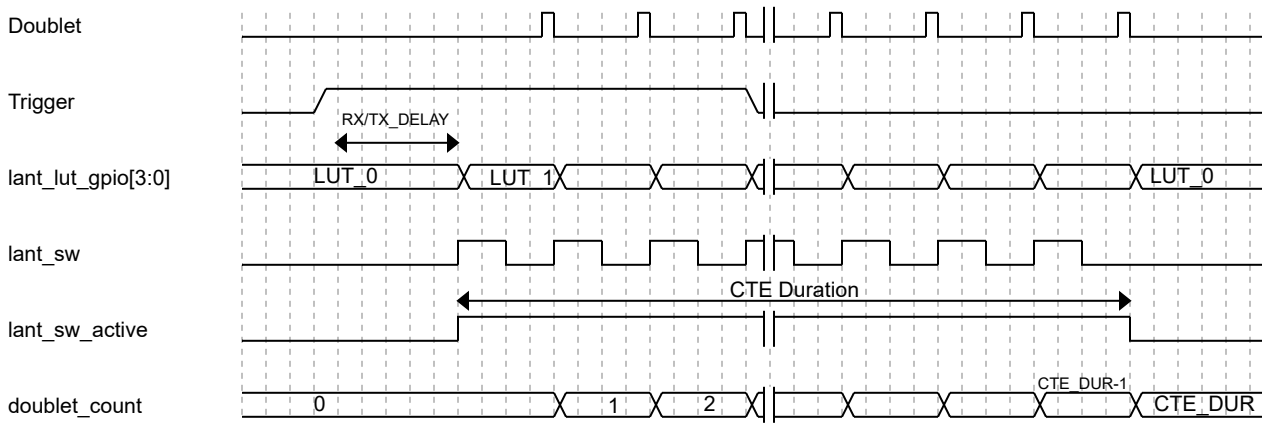


Figure 357. LCL_CTRL shutdown

The LCL_CTLR provides a data valid mask signal for the XCVR DMA so the DMA can avoid capturing unwanted data in the Guard period, and immediately after antenna is switched ("switching slots"). For this feature, there are several additional control settings:

- DMA_MASK_DELAY_OFF: Extra offset (in samples) to fine tune the DMA_MASK_DELAY
- DMA_MASK_DELAY: Delay, in intervals, from RX trigger to the time at which DMA mask asserts
- DMA_MASK_REF_PER: Duration, in intervals, of the reference period after DMA_MASK_DELAY expires during which the dma_mask remains asserted

The following figure depicts the dma_mask signal behavior in a CTE example. As can be seen, the dma_mask allows data to be captured during the reference period and sampling slots while avoid the guard period and switching slots.

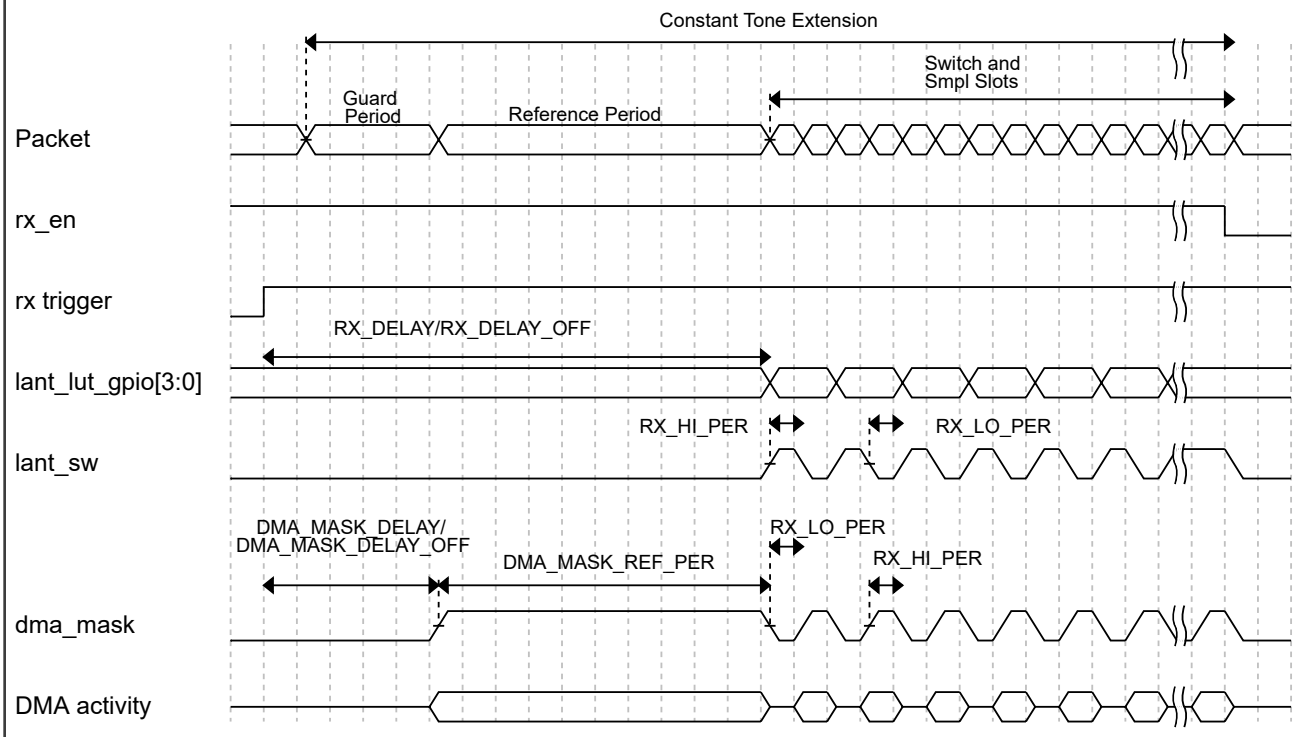


Figure 358. LCL_CTRL dma_mask

52.4.4.2.2.6.2.1.1 Antenna Control Used With RSM

Using LCL_CTRL with the RSM is considered a special case of "Antenna Control Without Bluetooth LE CTE Signals."

The RSM's rx and tx trigger output to the LCL_CTRL are expected to be used in this configuration. The RSM will trigger the LCL during it's T_PM (tone exchange) states. Since the RSM supports dynamically switching between 4 different T_PM durations while it is active, the LCL_CTRL include the following registers which are used only in conjunction with RSM:

- RX/TX_LO_PER1-3 : Alternate number of intervals for which lant_sw should be 0, when switching is active. For RX, RX_LO_PER also indicates the number of intervals that the dma_mask should be 0. These are used when RSM signals the LCL_CTRL that it is using T_PM1-3 durations instead of T_PM0 duration. (When T_PM0 duration is used, LCL_CTRL's RX/TX_LO_PER are used.) Refer to Introduction for more information on T_PM durations.
- RX/TX_HI_PER1-3 : Alternate number of intervals for which lant_sw should be 1, when switching is active. For RX, RX_HI_PER also indicates the number of intervals that the dma_mask should be 1. These are used when RSM signals the LCL_CTRL that it is using T_PM1-3 durations instead of T_PM0 duration. (When T_PM0 duration is used, LCL_CTRL's RX/TX_LO_PER are used.) Refer to Introduction for more information on T_PM durations.

The figures below illustrate the LCL_CTRL behavior when used with the RSM. Note that the delay from the trigger to the start of antenna switching is different when the RSM is used (as signalled by RSM's "active" output being high) : it includes the LO_PER and HI_PER durations in addition to DELAY/DELAY_OFF. Note that there are two figures for RX: the first one doesn't use DMA_MASK_REF_PER, and the second does.

For Figure 360, the DMA_MASK_REF_PER is not used (programmed to 0). Since the trigger asserts immediately on entry to RSM's T_PM states, the DELAY/DELAY_OFF and DMA_DELAY/DMA_DELAY_OFF values are expected to be programmed to 0 (or very small values), and the DMA mask will be asserted at the end of each LUT_x window.

For Figure 361, the samples captured during the first antenna switching period correspond to DMA_MASK_REF_PER (which would be expected to be programmed to the same value as RX_HI_PER). As compared to the other figure, the DMA mask is centered within the antenna LUT_x window. However, since there is only one DMA_MASK_REF_PER, the logic doesn't support the use of different RX_HI_PER durations / different T_PM durations.

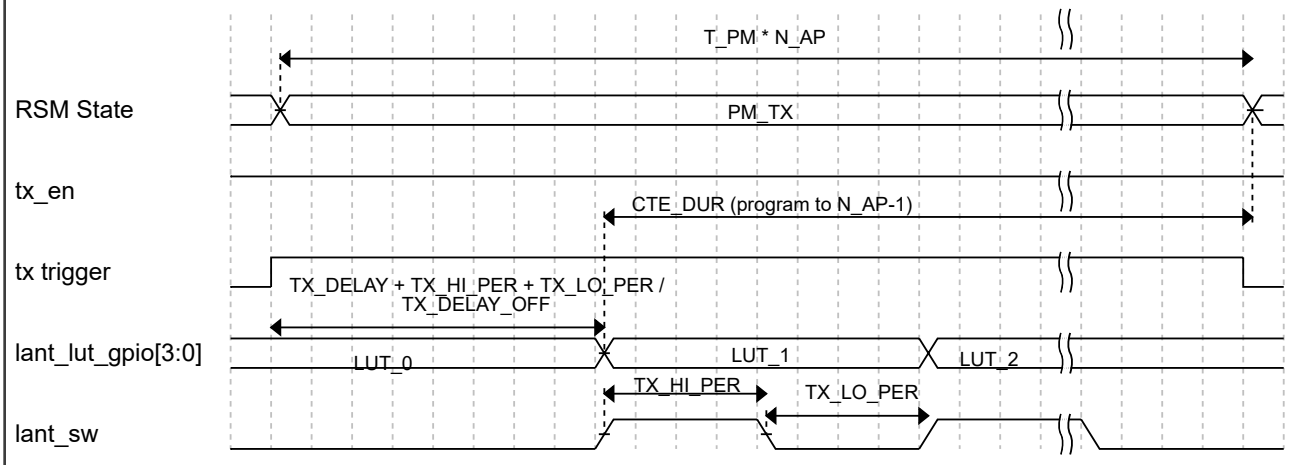


Figure 359. LCL_CTRL Operation with RSM - TX

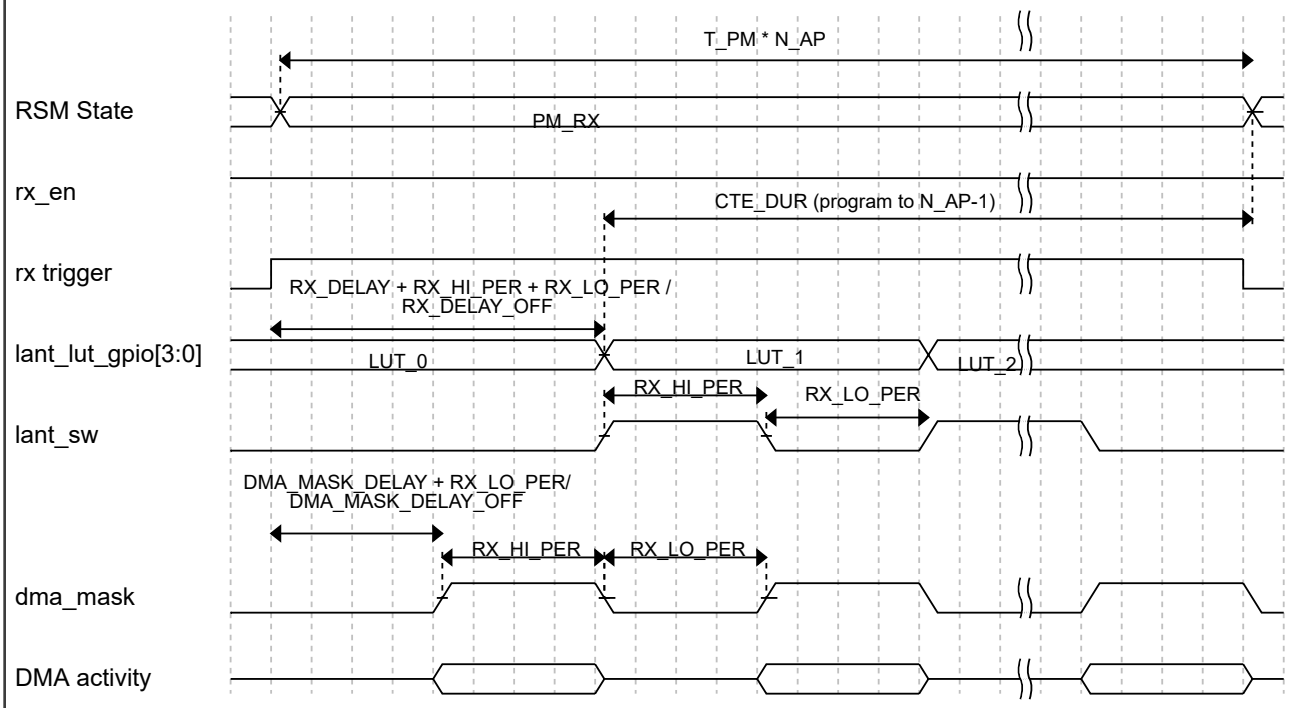


Figure 360. LCL_CTRL Operation with RSM - RX

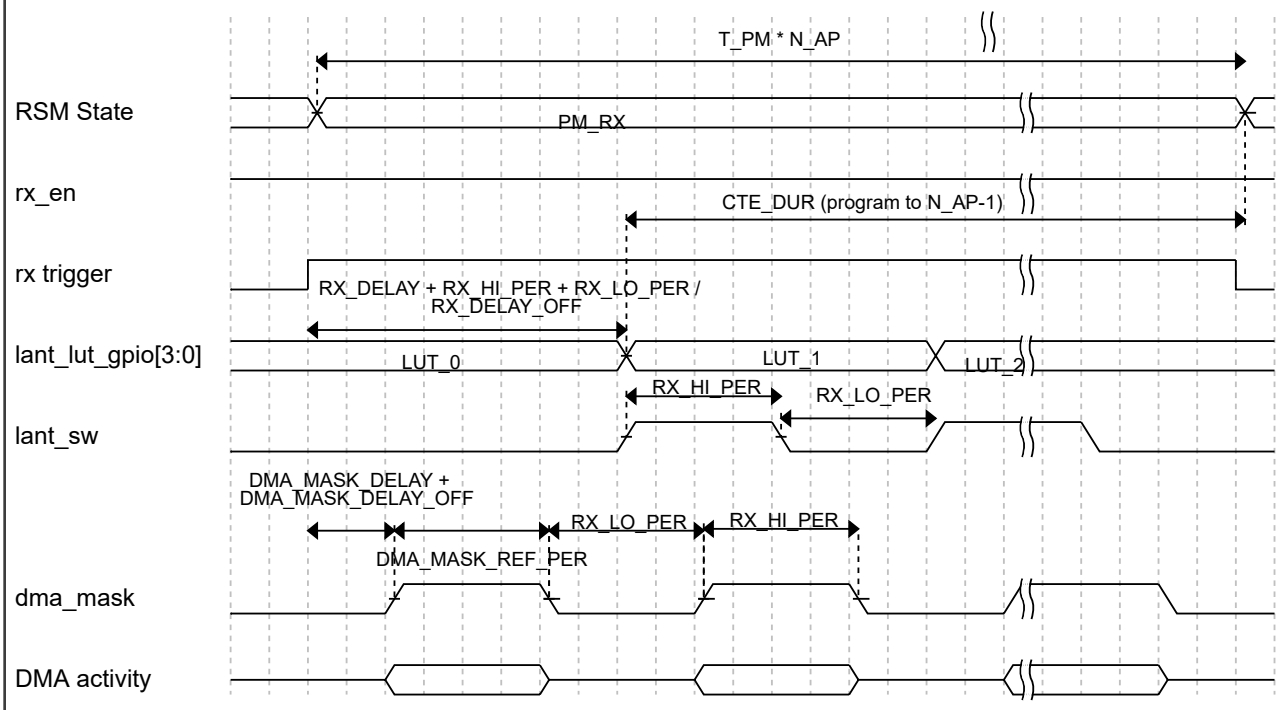


Figure 361. LCL_CTRL Operation with RSM - RX (Alternate Usage)

52.4.4.2.2.6.2.1.2 Antenna Switch Used with RSM

All fields used below for Antenna Switching are contained in LCL_TX_CFG0 and LCL_TX_CFG1 registers.

Using Antenna Switch with RSM by enabling :

- TX_SW_ACTIVE : To enable antenna switch only during T_PM.
- ANT_SW_RF : To enable switching at each gpio toggle outside T_PM.
- TX_SW_ACTIVE & ANT_SW_RF : Enable both to ensure full PA Switch feature with localization.

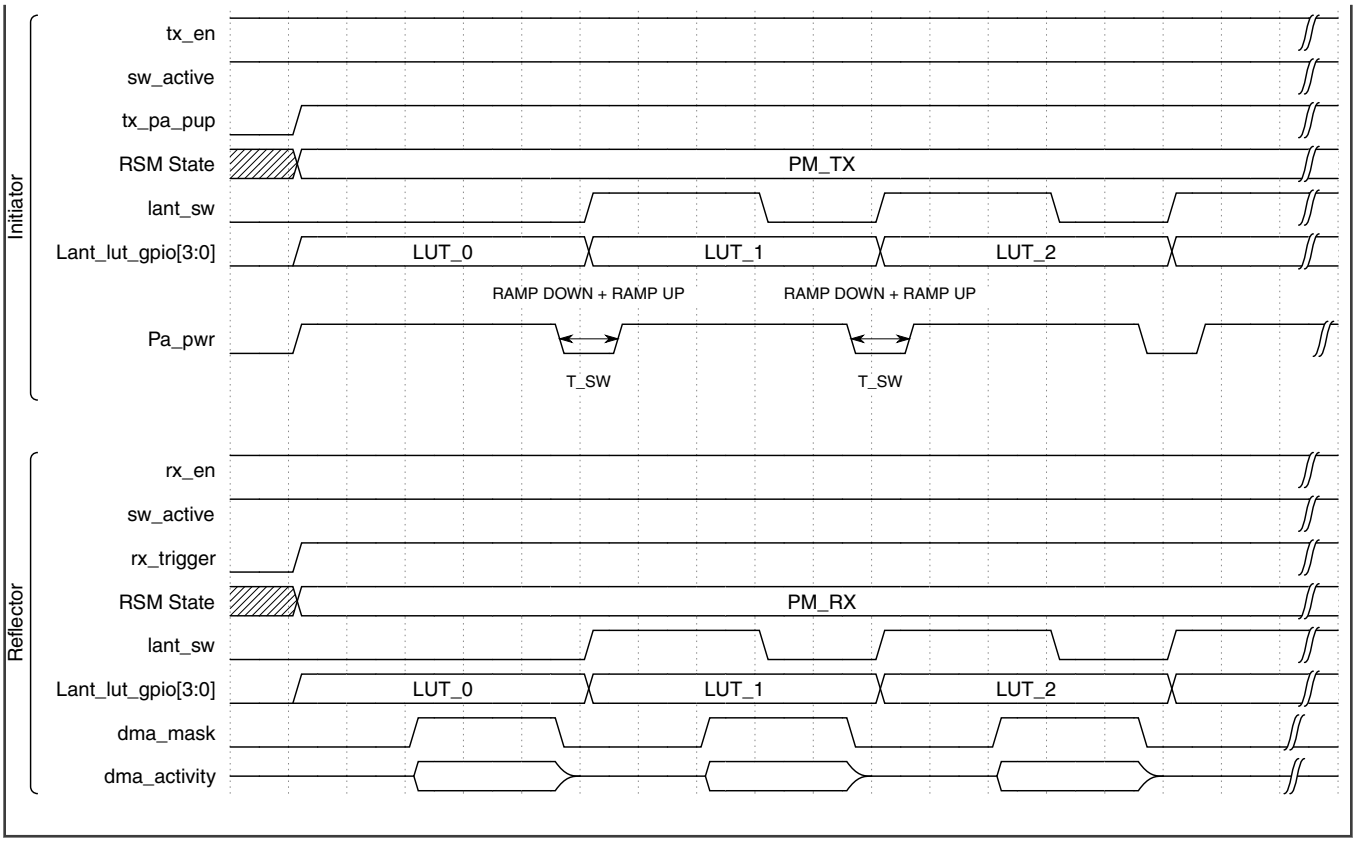
While switching antennas (between each lant_sw risings) , no high power is allowed in the antennas. This is supported by doing ramping (up and down) while switching antennas.

When switching antennas is allowed , a time of switch (T_SW) is defined : 1/2/4/10 us.

If T_SW = 1us : the ramping will cut 0.5 us from both T_PMs (previous and next one) to satisfy the T_SW timing and also the Ramping's one .

lcl_dma_mask_center[3:0] will be used to center the dma_mask (1/2/4/8/16/32/64/128 in us granularity) .This will be automatically handled by hardware (taking into account T_PM register value) to get optimum window for dma_mask without changing TX/RX_LO_PER and TX/RX_HI_PER values.

Figure 362. Antenna Switch TX-RX Sequence



While T_SW , antennas will do a proper ramp (up and down) and allow multiple configurations of the rampings and low power windows :

TX_SW_OFFSET[3:0]	A signed register that allows two cases : • ***TX_SW_OFFSET <0***: widens low power duration up to 2*8us, symmetrically to *'lant_sw'* (1us before and 1us after thus 2us granularity). • ***TX_SW_OFFSET>0***: shifts start of ramp down after *'lant_sw'*, by steps of 1us, note that maximum value depends on **PA_RAMP_SEL** and are respectively 1/2/4 (above these values, no ramp down/up is done) . • ***TX_SW_OFFSET=0***: corresponds to the end of ramp down being aligned with *'lant_sw'*.
TX_SW_ADD_OFFSET_UP[2:0]	Depending on **TX_SW_OFFSET**'s value : • ***TX_SW_OFFSET<0*** : shortens low power duration after *'lant_sw'* by steps of 1us . • ***TX_SW_OFFSET>0*** : widens low power duration after *'lant_sw'* (opposite direction as previous case). Note that there is a dependency with **PA_RAMP_SEL** (Lowest values may have no impact) .

- Alignment for antenna switch

  To have the optimum switch during t_pm , the antenna alignment needs to be in accord with t_pm value. We can play with register tx_sw* to do that , below an example of software sequence to match with different t_switch and t_ramp_sel values:

```
# general registers values :  t_sw =2/4/10 ,t_ramp_sel=1/2/3/4 ,t_flush=3/4 :

t_ramp_us = t_ramp_sel
if (t_ramp_sel==3} { t_ramp_us = 4 }
if (t_ramp_sel==4) { t_ramp_us = 3 }  # emulated 3 us (reprog pa_ramp table )

lcl_ctrl.cfg_tx_delay_off =  (t_flush+t_ramp_us)*8  #method 1, coarse
lcl_ctrl.cfg_tx_delay_off =  (t_flush_real_in_ns/125+t_ramp_us*8) #method 2 , fine

add_up  = (t_sw -2*t_ramp_us)
if (add_up==8) { add_up=7}   # limit high
if (add_up<0)   { add_up=0}   # limit low
lcl_ctrl.cfg_tx_sw_add_offset_up = add_up
```

Figure 363. LCL PA switch settings

Below the waveform concerning the PA switch during t_pm mechanism:

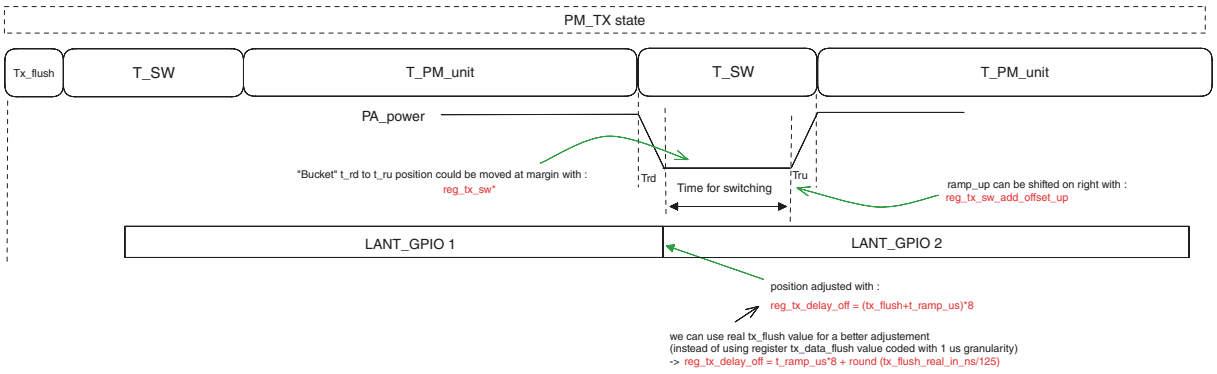


Figure 364. LCL PA switch during t_pm

- For Fine Tuning :
  - **TX_SW_FRAC_OFFSET_DN [2:0]** : adjusts low power duration before *'lant_sw'* by steps of a fraction of us .
  - **TX_SW_FRAC_OFFSET_UP [2:0]** : adjusts low power duration after *'lant_sw'* by steps of a fraction of us .

52.4.4.2.2.6.2.1.3 Antenna Shuffle Order with RSM

Antenna path permutation using rsm:

Each device may switch between up to four antenna paths within a CS step, The randomized antenna path permutation in a CS step shall be selected using the random number generation function

The number of antenna paths used within the permutation is the maximum number of N_AP antenna paths

nb_ant_perm = cfg_ap_max+1; to use nb 2 antenna path, should programme 1 (cfg start from 0) where Ap_max [1:0] , the field LCL_CFG0.AP_MAX which correspond to the bit [22: 21] in LCL_CFG0[31:0] register.

An antenna path permutation index is used to look up the specific antenna paths position order used . These lookup tables are defined based on the number of antenna paths being used as described bellow:

Table 509. Antenna path permutation according to number of antenna path (N_AP)

N_AP	Antenna Path Permutation index	Antenna Path Position After Permutation
N_AP=2	0	A1 A2
	1	A2 A1
N_AP=3	0	A1 A2 A3
	1	A2 A1 A3
	2	A1 A3 A2
	3	A3 A1 A2
	4	A3 A2 A1
	5	A2 A3 A1
N_AP=4	0	A1 A2 A3 A4
	1	A2 A1 A3 A4
	2	A1 A3 A2 A4
	3	A3 A1 A2 A4
	4	A3 A2 A1 A4
	5	A2 A3 A1 A4
	6	A1 A2 A4 A3
	7	A2 A1 A4 A3
	8	A1 A4 A2 A3
	9	A4 A1 A2 A3
	10	A4 A2 A1 A3
	11	A2 A4 A1 A3
	12	A1 A4 A3 A2
	13	A4 A1 A3 A2
	14	A1 A3 A4 A2
	15	A3 A1 A4 A2
	16	A3 A4 A1 A2
	17	A4 A3 A1 A2
	18	A4 A2 A3 A1
	19	A2 A4 A3 A1
	20	A4 A3 A2 A1
	21	A3 A4 A2 A1
	22	A3 A2 A4 A1
	23	A2 A3 A4 A1

This feature allow the possibility to manage N:M antenna , in the range 1:{1:4} , {1:4}:1, 2:2. an automatic antenna switch as defined in the standard , for mode 2, mode 3 , which should occur at each step.

The maximum index of the antenna permutation is idx_max_order((AP_MAX+1)! - 1) and it was programmed to increment from 0 to idx_max_order for a succession of tones. when transmitted or received.

The antenna permutation is valid only for tones (pm). To enable the antenna permutation feature, you should program "1" in the field "ant_permut_en" which correspond to the field LCL_CFG0.LCL_ANT_PERMUT_EN (LCL_CFG0[28] bit).

Mode 0 & 1:

if the antenna permutation is enabled, the antenna path is selected from the ant_cs_sync[1:0] of the pktram fields (bit[26:25]) as an index for the LCL_GPIO_CTRL0 [4*ant_cs_sync +: 4]. Otherwise the Antenna default num will be selected from LCL_GPIO_CTRL0 [LUT_0]

Mode 2 & 3:

The index of the antenna path permutation (ant_permut[4:0]) is figured in the pktram bit field [24:20] used at each step according the current mode (2,3) and PM transaction. After the selection of right antenna path order, the antenna path is selected from the packet ram which is configured in the register LCL_GPIO_CTRL0 [31:0] to configure the fields ; LUT_0 (3 -> 0 register bit), LUT_1 (7 -> 4 register bit), LUT_3 (11 -> 8 register bit), LUT_4 (15 -> 12 register bit) respectively to select the Antenna value (A1, A2, A3, A4) , then outputted using lant_lut_gpio[3:0] according to the antenna permutation order selected.

When ant_permut_en is disabled the antenna order is selected sequentially from lut_0 to lut_3.

The Antenna permutation is only valid for Tones (T_Pm) and not for Packets (DT) as described in the following.

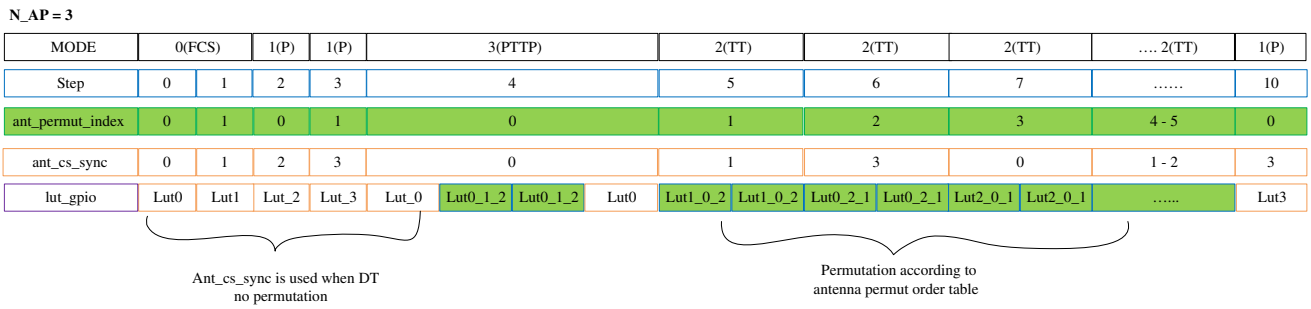


Figure 365. Example for Antenna Permutation Enabled & N_AP = 3:

52.4.4.2.2.6.2.2 Antenna Control With BLE CTE Signals

In this mode, cte_type[2:0] and cte_sample_dur[2:0] signals from the Bluetooth LE link layer are used to provide configuration of the LCL_CTRL module. The definition for cte_type[2:0] and cte_sample_dur[2:0] are shown in the table below

Table 510. CTE Signal cte_type[2:0]

cte_type[2:0]	Description
0x0	AoA Constant Tone Extension
0x1	AoD Constant Tone Extension with 1us slots
0x2	AoD Constant Tone Extension with 2us slots
0x3	Reserved

Table continues on the next page...

Table 510. CTE Signal cte_type[2:0] (continued)

cte_type[2:0]	Description
0x4	Reserved
0x5	AoD Constant Tone Extension with 4us slots
0x6	AoD Constant Tone Extension with 8us slots
0x7	Reserved

Table 511. CTE Signal cte_sample_dur[2:0]

cte_sample_dur[2:0]	Description
0x0	Reserved
0x1	For AoA receive, sampling duration is 1us
0x2	For AoA receive, sampling duration is 2us
0x3	Reserved
0x4	Reserved
0x5	For AoA receive, sampling duration is 4us
0x6	For AoA receive, sampling duration is 8us
0x7	Reserved

For antenna control using the Bluetooth LE CTE control signals, various settings must be programmed prior to operation. The significant fields are:

- LANT_INV : When set to 1, the lant_sw signal is inverted
- RX/TX_LCL_EN : Enables antenna switching control in RX and/or TX. For Bluetooth LE CTE configuration, both bits should be set.
- LCL_EN : Enable for the entire LCL_CTRL module
- RX/TX_DELAY_OFF : Extra offset (in samples) to fine tune the RX/TX_DELAY
- RX/TX_DELAY : Delay, in intervals, before antenna switching is to begin
- RX/TX_ANT_TRIG_SEL : Selects the trigger to be observed to begin counting DELAY
- RX/TX_SPINT : Defines the number of samples per interval. This is realized using the sample clock associated with either RX or TX, (typically 4MHz or 8MHz). For proper operation, RX/TX_SPINT need to be programmed so that the interval is 1us for RX and TX.
- LUT_0 to LUT_31: state of lant_lut_gpio[3:0] for the switching activity doublet from 0 to 31
- LUT_WRAP_PTR: Wrap point for the LUT_0 to LUT_31
- DMA_MASK_REF_PER: Duration, in intervals, of the reference period after DMA_MASK_DELAY expires during which the dma_mask remains asserted. For CTE the reference period is expected to be programmed for 8us.
- DMA_MASK_DELAY_OFF: Extra offset (in samples) to fine tune the DMA_MASK_DELAY
- DMA_MASK_DELAY: Delay, in intervals, from RX trigger to the time at which DMA mask asserts

Note that the following LCL_CTRL fields are not used in this configuration:

- CTE_DUR : In this configuration, the duration is controlled by the Bluetooth LE link layer
- RX/TX_LO_PER : In this configuration, the low period is determined by the CTE control signals

- RX/TX_HI_PER : In this configuration, the high period is determined by the CTE control signals
- M_ON_DELAY/N_ON_DELAY: In this configuration, switching activity stops at the end of the RX or TX burst.
- LANT_BLOCK_RX/TX: In this configuration, for RX lant output is blocked for AoD, and for TX lant output is blocked for AoA

The figures below illustrate the antenna switching operation for Bluetooth LE CTE during Transmit and Receive operations, and an addition figure illustrating the dma_mask behavior for Receive. In the Receive and Transmit figures, three examples of lant_sw / lant_lut_gpio[3:0] behavior are shown for different cte_type (and cte_sample_dur for Receive) input values. In the dma_mask figure, dma_mask and DMA activity behaviors are shown for two example cte_type and cte_sample_dur inputs. Note that these figures show example tx_trigger and rx_trigger signals which assert at the start of the guard period; the actual trigger used in the application (such as "cte_en" from the Bluetooth LE) will likely have different timing so the delays will need to be programmed accordingly.

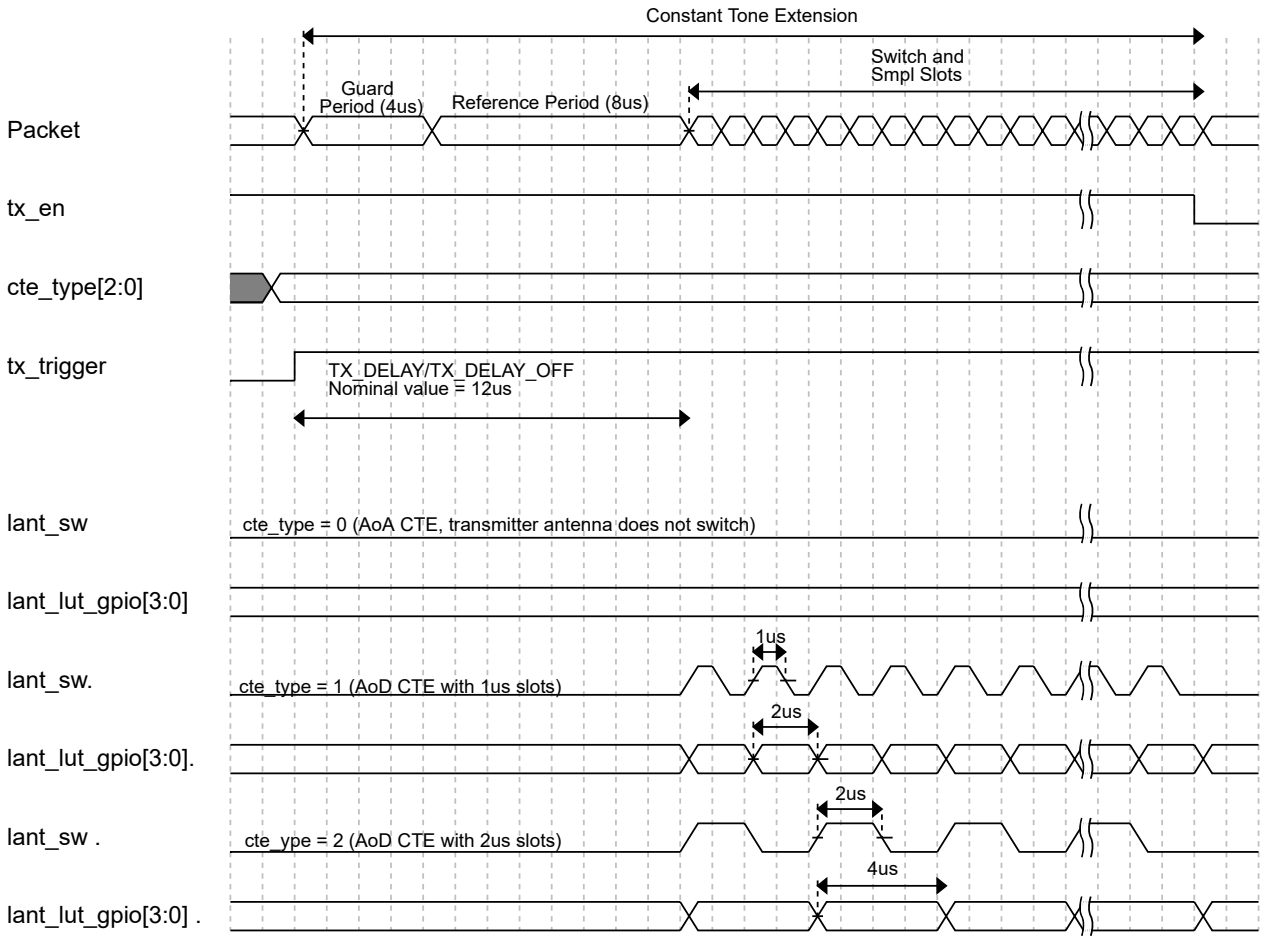


Figure 366. LCL_CTRL CTE - Transmit Antenna Switching

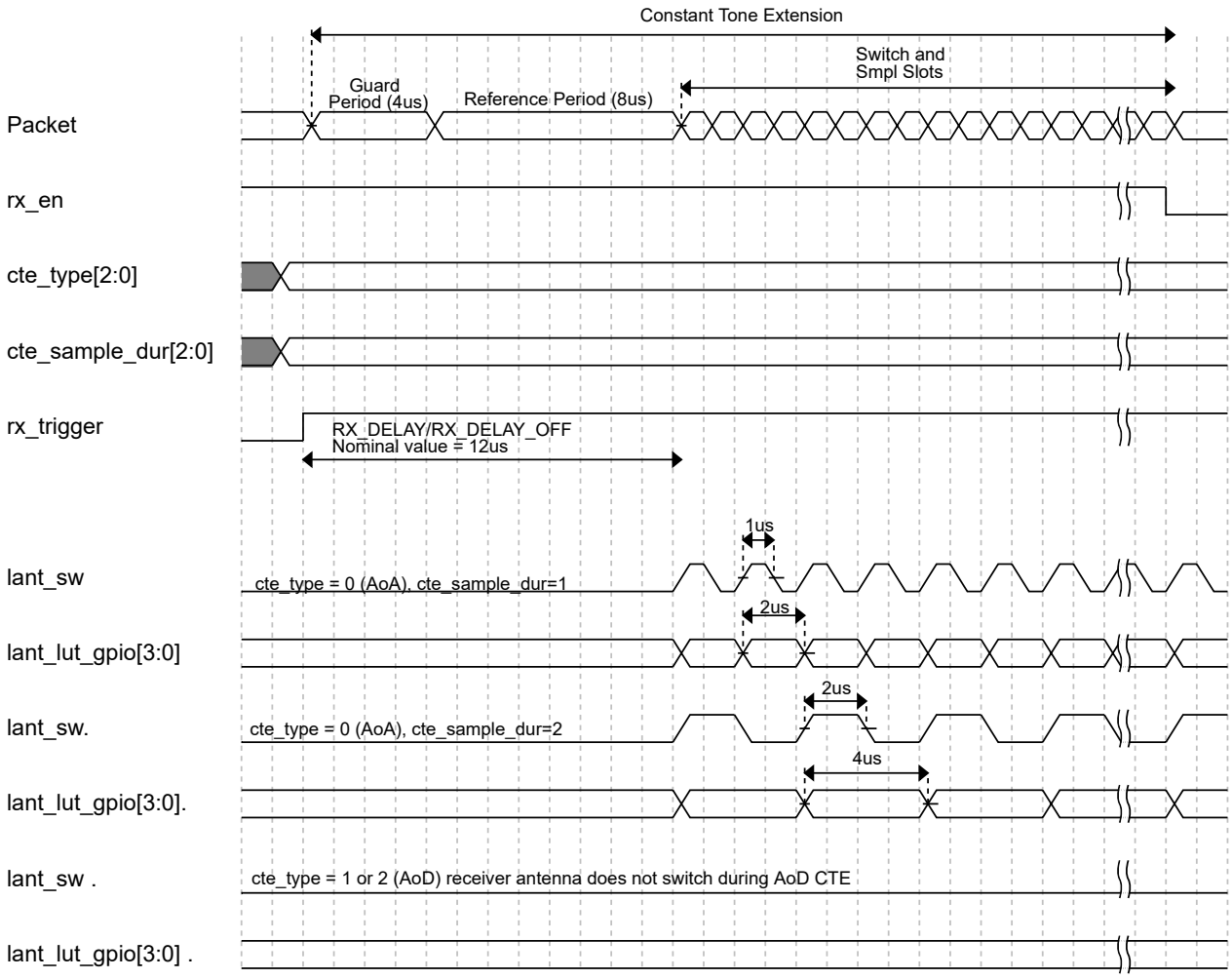


Figure 367. LCL_CTRL CTE - Receive Antenna Switching

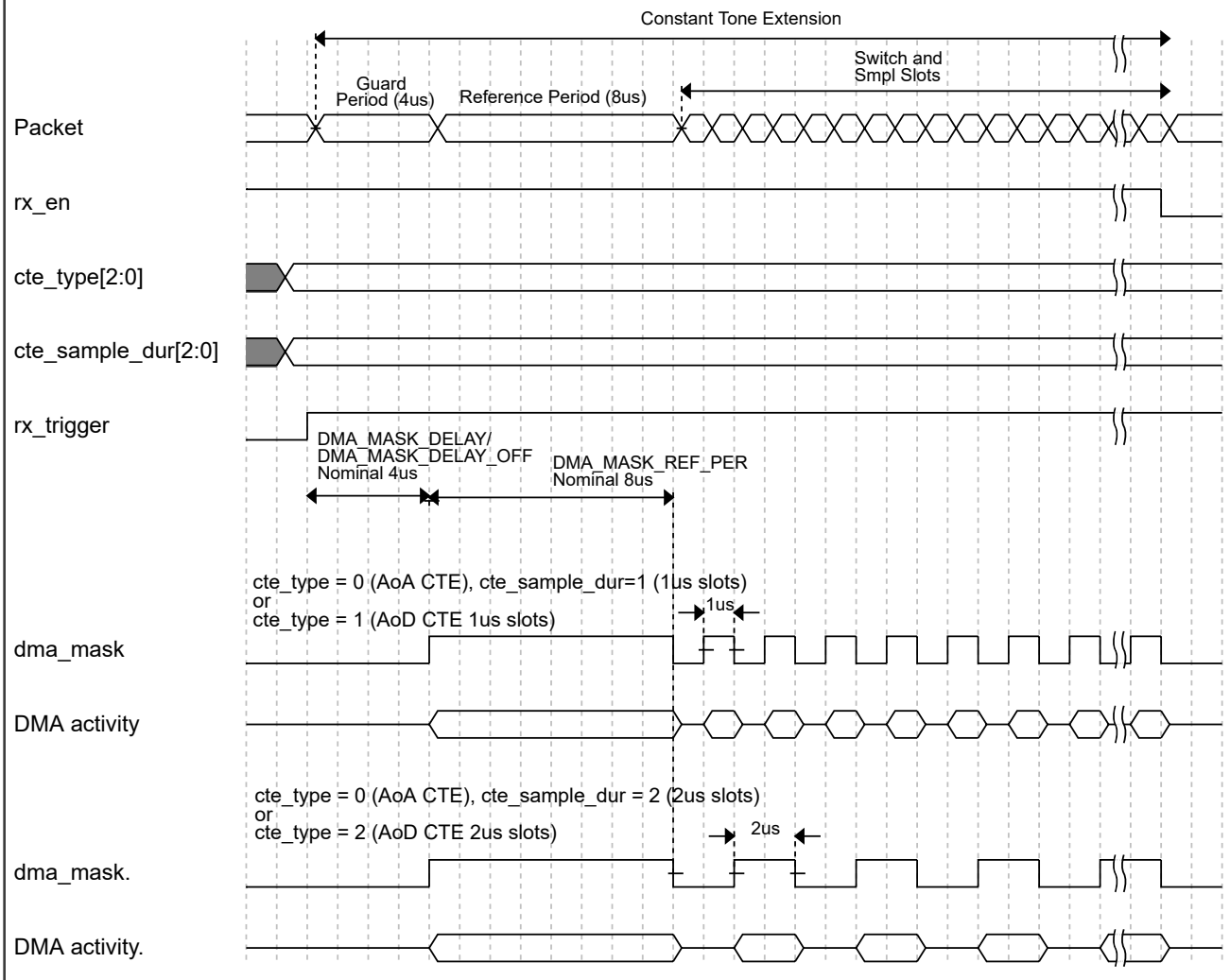


Figure 368. LCL_CTRL CTE - Receive dma_mask

52.4.4.2.2.7 Fast Antenna Diversity (FAD)

52.4.4.2.2.7.1 Introduction

The Fast Antenna Diversity (FAD) mode, when enabled, allows the optimal choice between two antennae to be selected during the PHY's preamble search. The output of the PHY's FAD algorithm is a 1-bit signal which indicates the selected antenna. This output is provided to the FAD Common Pin Interface logic. Refer to the PHY chapter(s) for more information on the FAD algorithm.

The localization control output (lant_sw) can also be used as the input to the FAD Common Pin Interface instead of the PHY signal, but the primary use case is for FAD.

52.4.4.2.2.7.2 Common Pin Interface

The FAD Common Pin Interface consists of 4 pins: ANT_A, ANT_B, TX_SWITCH, and RX_SWITCH. All pins are outputs from the device. The switch outputs convey timing information to the external module directly interfacing to the antennae, and they also can be used to control an external LNA or PA, via use of a Front End Module, or FEM. The FAD Common Pin Interface offers multiple configurations that allow for a wide range of FEM control schemes. Each of the 4 FAD-related outputs can be configured to be in FAD or TSM mode; in FAD mode, ANT_A and ANT_B are controlled by the selected FAD algorithm through signal antx_out;

in TSM mode, ANT_A and ANT_B are pure timing outputs with programmable timing configurable in the TSM. The 4-bit register FAD_CTRL[FAD_NOT_GPIO] determines whether each FAD-related output is in FAD or TSM mode:

In FAD mode (FAD_NOT_GPIO[0]=1), ANT_A is controlled by the FAD algorithm, modified by the register settings {ANTX_CTRLMODE, ANTX_EN, and ANTX_POL}.

In FAD mode (FAD_NOT_GPIO[1]=1), ANT_B is controlled by the FAD algorithm, modified by the register settings {ANTX_CTRLMODE, ANTX_EN, and ANTX_POL}.

In FAD mode (FAD_NOT_GPIO[2]=1), TX_SWITCH output is derived from TSM output **gpio2_trig_en**, modified by the register settings {ANTX_CTRLMODE, ANTX_EN, and ANTX_POL}.

In FAD mode (FAD_NOT_GPIO[3]=1), RX_SWITCH output is derived from TSM output **gpio3_trig_en**, modified by the register settings {ANTX_CTRLMODE, ANTX_EN, and ANTX_POL}.

In TSM mode, ANT_A and ANT_B become pure TSM timing-controlled outputs, similar to TX_SWITCH and RX_SWITCH, and with independently-controlled timing and capable of providing signalling in TX mode, RX mode, or both; for pins in TSM mode, the ANTX_CTRLMODE, ANTX_EN, and ANTX_POL register settings have no effect.

In TSM mode (FAD_NOT_GPIO[0]=0), ANT_A output is a pure timing signal, derived from TSM output **gpio0_trig_en**.

In TSM mode (FAD_NOT_GPIO[1]=0), ANT_B output is a pure timing signal, derived from TSM output **gpio1_trig_en**.

In TSM mode (FAD_NOT_GPIO[2]=0), TX_SWITCH output is derived from TSM output **gpio2_trig_en**.

In TSM mode (FAD_NOT_GPIO[3]=0), RX_SWITCH output is derived from TSM output **gpio3_trig_en**.

The control register XCVR_CTRL[DEMOD_SEL] determines which FAD algorithm drives the FAD Common Pin Interface: 0b10 = 802.15.4 FAD, 0b01 = FSK FAD.

The state of the antenna selection can be ascertained at any time by reading the FAD_CTRL[ANTX] bit: 0 = ANT_A, 1 = ANT_B.

Antenna selection can be placed under direct software control: Setting the FAD_CTRL[ANTX_OVRD_EN]=1 allows FAD_CTRL[ANTX_OVRD] to substitute for the algorithm-driven antenna selection; in this case, ANTX_OVRD=0 asserts ANT_A, and ANTX_OVRD=1 asserts ANT_B. Note that the algorithm-driven state of the antenna is not lost while ANTX_OVRD_EN=1. The override is temporary, for as long as the override enable is set, and control over antenna state reverts to the antx_out when ANTX_OVRD_EN is cleared to 0. The FAD_CTRL register resides in XCVR space.

The following diagram illustrates the FAD pinout, register controls, and FAD/TSM-mode multiplexing.

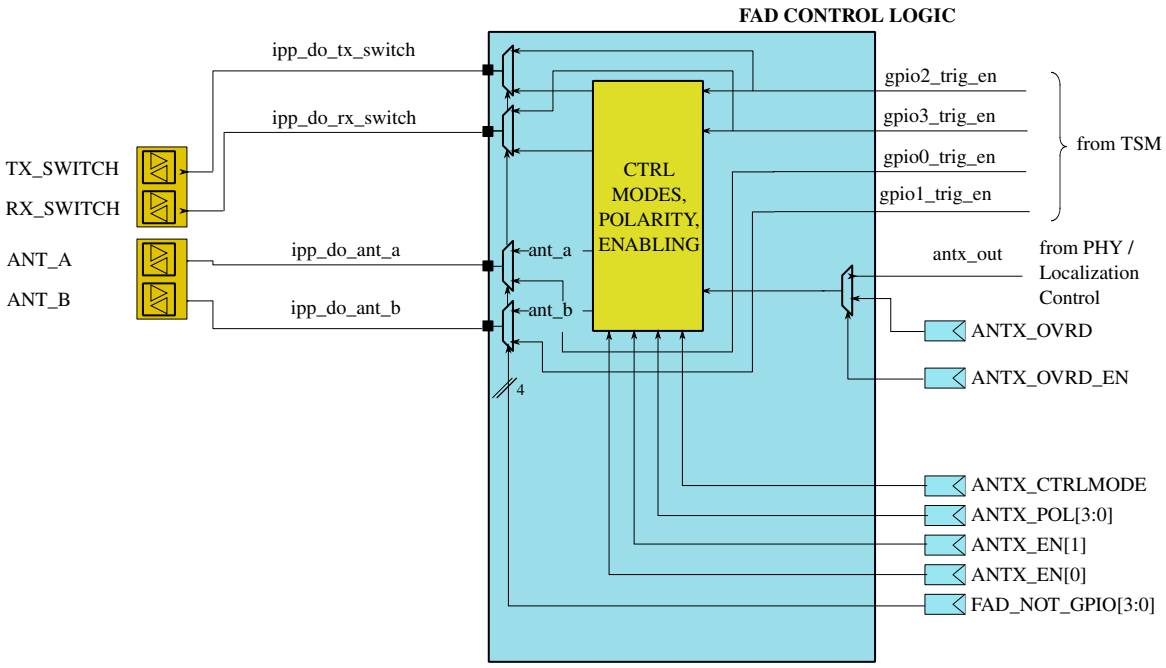


Figure 369. FAD Common Pin Interface

52.4.4.2.2.7.3 Control Bits

The following table describes the programmable registers which control FAD Common Pin Interface:

Table 512. FAD Common Pin Interface Control Bits

Field	R/W	Description
ANTX_CTRLMODE	rw	**FAD control mode-** selects the single or dual mode **0 : single mode.** ANT_A = NOT(antx) AND(gpio2_trig_en OR gpio3_trig_en) TXSWITCH = gpio2_trig_en RXSWITCH= (gpio2_trig_en OR gpio3_trig_en) **1:dual mode:** ANT_A = NOT(antx) AND(gpio2_trig_en OR gpio3_trig_en) ANT_B = antx AND(gpio2_trig_en OR gpio3_trig_en) TX_SWITCH = gpio2_trig_en RX_SWITCH = gpio3_trig_en
ANTX_EN[1:0]	rw	**FAD Pin Enable-** 00: all disabled

Table continues on the next page...

Table 512. FAD Common Pin Interface Control Bits (continued)

Field	R/W	Description
		01:only RX_SWITCH/TX_SWITCH enabled 10:only ANT_A/ANT_B enabled 11: all enabled
ANTX_POL[3:0]	rw	**Antenna controls mode-** Control the polarity of the FAD pins: ANTX_pol<0>=1 : invert the ANT_A output ANTX_pol<1>=1 : invert the ANT_B output ANTX_pol<2>=1 : invert the TX_SWITCH output ANTX_pol<3>=1 : invert the RX_SWITCH output
FAD_NOT_GPIO[3:0]	rw	**xxx1**: The ANT_A pad is controlled by the antenna-selection algorithm, modified by the register settings above {ANTX_CTRLMODE, ANTX_EN, ANTX_POL} **xxx0**: The ANT_A pad is controlled directly by the TSM output gpio0_trig_en **xx1x**: The ANT_B pad is controlled by the antenna-selection algorithm, modified by the register settings above {ANTX_CTRLMODE, ANTX_EN, ANTX_POL} **xx0x**: The ANT_B pad is controlled directly by the TSM output gpio1_trig_en **x1xx**: The TX_SWITCH pad is controlled by the antenna-selection algorithm, modified by the register settings above {ANTX_CTRLMODE, ANTX_EN, ANTX_POL} **x0xx**: The TX_SWITCH pad is controlled directly by the TSM output gpio2_trig_en **1xxx**: The RX_SWITCH pad is controlled by the antenna-selection algorithm, modified by the register settings above {ANTX_CTRLMODE, ANTX_EN, ANTX_POL} **0xxx**: The RX_SWITCH pad is controlled directly by the TSM output gpio3_trig_en
ANTX	ro	**Antenna Selection State-** The ANTX bit reflects the state of the antx_out signal.
DEMOD_SEL[1:0]	rw	**These bits select the demodulator used during reception. Also select which FAD engine is used to select the antenna-** • 0b00: No demodulator selected

Table continues on the next page...

Table 512. FAD Common Pin Interface Control Bits (continued)

Field	R/W	Description
		• 0b01: Use NXP Multi-standard PHY demodulator, and its FAD engine • 0b10: Use Legacy 802.15.4 demodulator, and the 802.15.4 FAD engine • 0b11: Reserved
ANTX_OVRD_EN	rw	**FAD ANTX Override Enable-** • 0: antx_out controls the antenna selection (mission mode) • 1: ANTX_OVRD controls the antenna selection. 0 = ANT_A, 1 = ANT_B.
ANTX_OVRD	rw	**FAD ANTX Override -** If ANTX_OVRD_EN=1, this bit is used instead of antx_out

52.4.4.2.2.7.4 FEM Example Use Cases

In 2.4GHz systems, the Radio Frequency (RF) Front-End Module is one of the most critical parts. Acting as an interface between the antenna and RF transceiver, the RF front-end module, or FEM, includes sensitive components such as an antenna Low Noise Amplifier (LNA) , power amplifiers (PA), antenna tuning switches, and a power management unit.

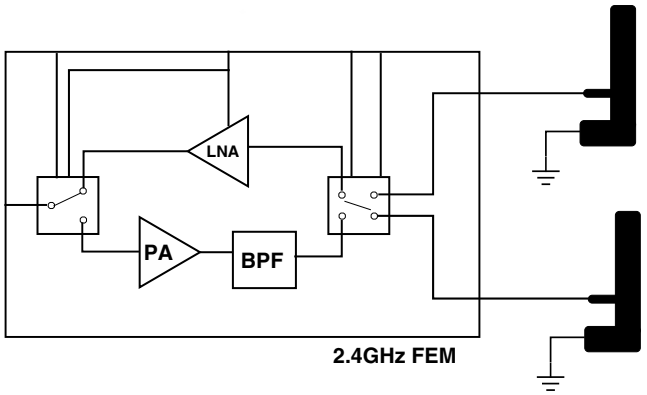


Figure 370. FEM Block Diagram

To accommodate multiple FEM interfaces and control schemes, Fast Antenna Diversity incorporates 2 Antenna Pin Control Modes, which are governed by the register control bit ANTX_CTRLMODE

Some FEM devices use a single input pin to switch the antenna selection. This is called single-mode operation. Operate Fast Antenna Diversity in this mode by programming ANTX_CTRLMODE=0. A timing diagram of single-mode operation is shown below (note: FAD output ANT_B is not used). In this example, one packet is received on Antenna A, followed by another packet received on Antenna B. Both packets require an auto-Acknowledge packet to be transmitted immediately following reception.

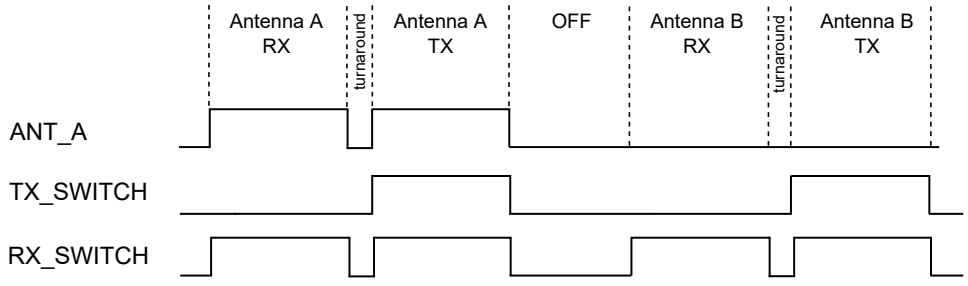


Figure 371. FAD Single Mode Timing

An example FEM Interface diagram, with FAD operated in single mode, is shown below.

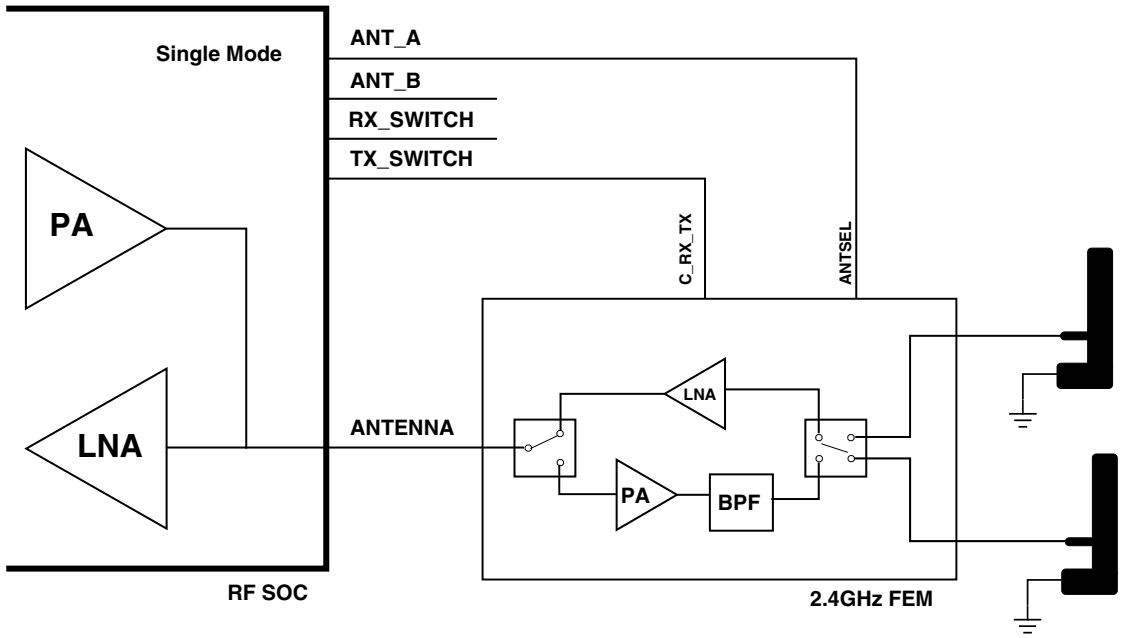


Figure 372. FEM Interface Single Mode

Other FEM devices use 2 input pins to switch the antenna selection. This is called dual-mode operation. Operate Fast Antenna Diversity in this mode by programming ANTX_CTRLMODE=1. A timing diagram of dual-mode operation is shown below. In this example, one packet is received on Antenna A, followed by another packet received on Antenna B. Both packets require an auto-Acknowledge packet to be transmitted immediately following reception.

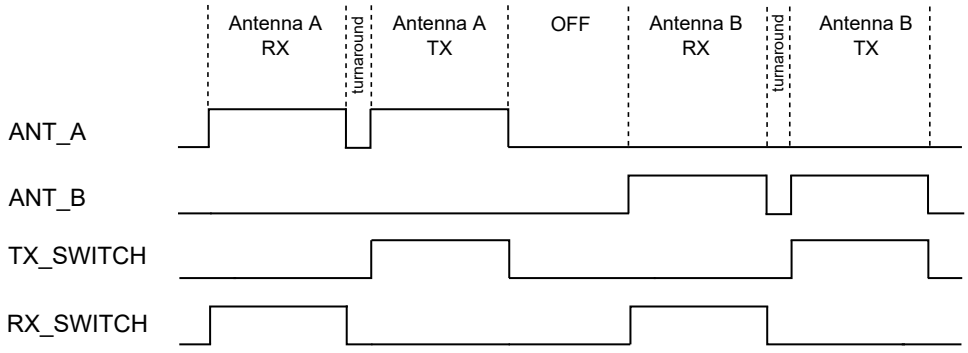


Figure 373. FAD Dual Mode Timing

An example FEM Interface diagram, with FAD operated in dual mode, is shown below.

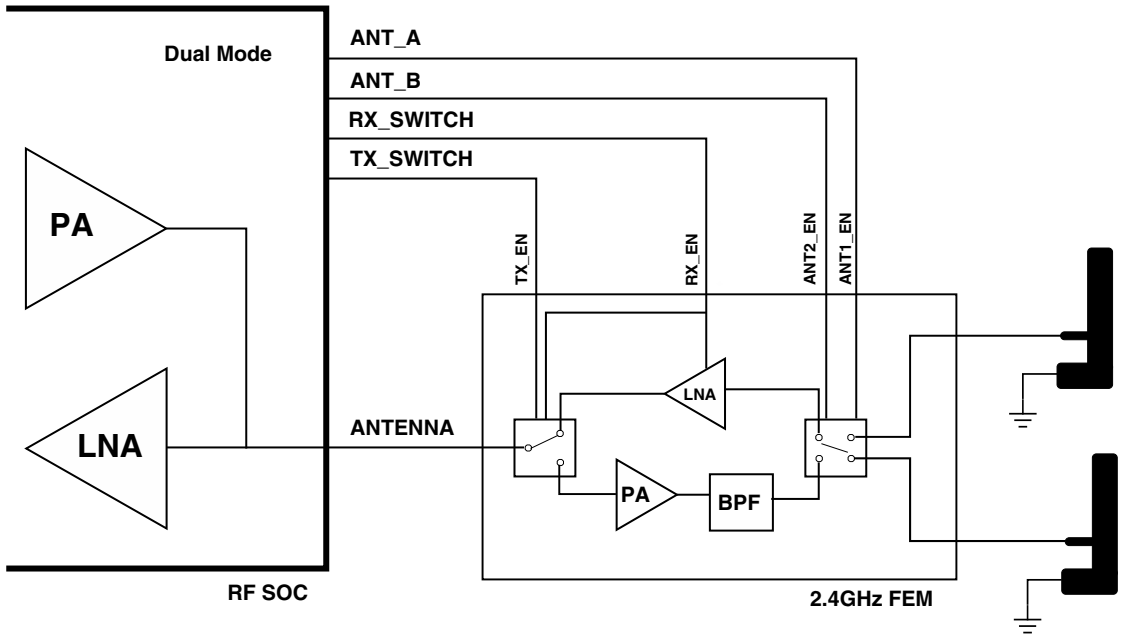


Figure 374. FEM Interface Dual Mode

Other FEM use cases, include external PA only, external LNA only, or external PA plus LNA. In such cases, ANT_A and ANT_B are not required, FAD can be disabled, and TX_SWITCH and RX_SWITCH pins can be operated in TSM mode (pure timing signals). This is called Single Antenna configuration. An example FEM interface diagram illustrating such a use case, is shown below.

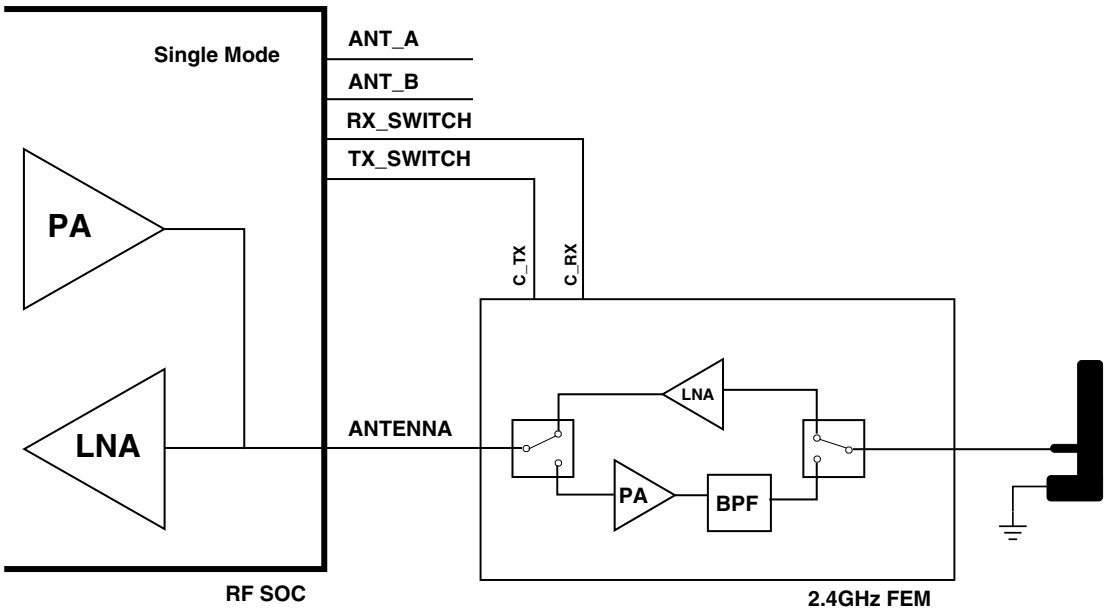


Figure 375. FEM Interface Single Antenna Configuration

52.4.4.2.2.8 Fast Overwrite Module (FOM)

The IPS_FOM module provides the capability to pre-store several address/data pairs that are quickly applied when RX or TX operation begins. Each entry consists of 3 parts:

- Address and config: The ADDR field contains the address to be written, and the ENTRY_TX/RX bits denote if the entry is to be used in TX, RX, or both modes.
- DRS0_DATA: Contains the full 32-bit word that will be written to ADDR as RX/TX begins and the data rate select is 0.
- DRS1_DATA: Contains the full 32-bit word that will be written to ADDR as RX/TX begins and the data rate select is 1.

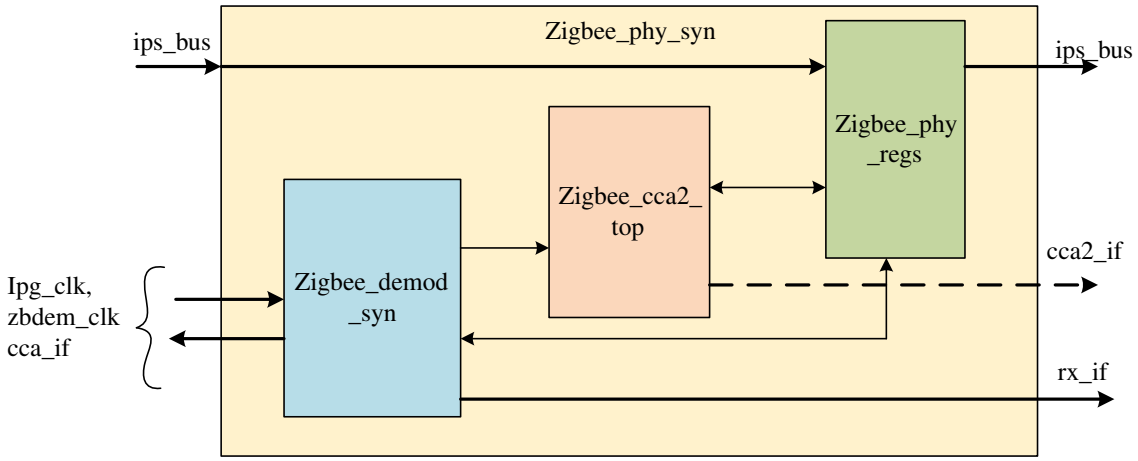
52.4.4.2.2.9 Zigbee PHY

52.4.4.2.2.9.1 Overview

This chapter is about the Zigbee Phy. This layer performs the task of modulation as well as demodulation of various transmitted and received signals,

52.4.4.2.2.9.1.1 Block Diagram

This block guide has the details for the Zigbee Demodulator function feature registers, which include multi CTRL registers.



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The PHY data service enables the transmission and reception of PHY protocol data units (PPDUs) across the physical radio channel. The features of the PHY are activation and deactivation of the radio transceiver, energy detection (ED), link quality indication (LQI), channel selection, clear channel assessment (CCA) and transmitting as well as receiving packets across the physical medium.

52.4.4.2.2.9.1.2 Feature

The PHY data service enables the transmission and reception of PHY protocol data units (PPDUs) across the physical radio channel.

The features of the PHY are :

- Activation and deactivation of the radio transceiver.
- Energy detection (ED).
- Link quality indication (LQI).
- Channel selection.
- Clear channel assessment (CCA) and transmitting as well as receiving packets across the physical medium.

52.4.4.2.2.9.2 Functional Description

52.4.4.2.2.9.2.1 Zigbee Demodulator

This section describes the zigbee demodulator sub-blocks.

52.4.4.2.2.9.2.1.1 The receiver energy detection (ED):

The receiver energy detection (ED) measurement is intended for use by a network layer as part of channel selection algorithm. It is an estimate of the received signal power within the bandwidth of an IEEE 802.15.4 channel. No attempt is made to identify or decode signals on the channel. The ED time should be equal to 8 symbol periods.

The ED result shall be reported as an 8-bit integer ranging from 0x00 to 0xff. The minimum ED value (0) shall indicate received power less than 10dB above the specified receiver sensitivity. The range of received power spanned by the ED values shall be at least 40dB. Within this range, the mapping from the received power in decibels to ED values shall be linear with an accuracy of + - 6dB.

52.4.4.2.2.9.2.1.2 Link Quality Indication (LQI):

Upon reception of a packet, the PHY sends the PSDU length, PSDU itself and link quality (LQ) in the PD-DATA.indication primitive. The LQI measurement is a characterization of the strength and/or quality of a received packet. The measurement may be implemented using receiver ED, a signal-to-noise estimation or a combination of these methods. The use of LQI result is up to the network or application layers.

The LQI result should be reported as an integer ranging from 0x00 to 0xff. The minimum and maximum LQI values should be associated with the lowest and highest quality IEEE 802.15.4 signals detectable by the receiver and LQ values should be uniformly distributed between these two limits.

52.4.4.2.2.9.2.1.3 Clear Channel Assessment (CCA):

The clear channel assessment (CCA) is performed according to at least one of the following three methods:

- Energy above threshold. CCA shall report a busy medium upon detecting any energy above the ED threshold.
- Carrier sense only. CCA shall report a busy medium only upon the detection of a signal with the modulation and spreading characteristics of IEEE 802.15.4. This signal may be above or below the ED threshold.
- Carrier sense with energy above threshold. CCA shall report a busy medium only upon the detection of a signal with the modulation and spreading characteristics of IEEE 802.15.4 with energy above the ED threshold.

52.4.4.2.2.9.2.2 Clear channel assessment (CCA2 TOP)

Provide a control sub module for the clear channel assessment mode 2 (CCA2).

52.4.4.2.2.9.2.3 Operation

Defines the physical operation of the Zigbee device including receive sensitivity, channel rejection, output power, number of channels, chip modulation, and transmission rate specifications. Most Zigbee applications operate on the 2.4 GHz ISM band at a 250 kb/s data rate. See the IEEE 802.15.4 specification for details.

52.4.4.2.2.9.2.4 Mode

There are three CCA modes, and an IEEE 802.15.4-compliant PHY must be able to operate in any one of them:

CCA mode 1:

In this mode, only the ED result is taken into account. If the energy level is above the ED threshold, the channel is considered busy. The ED threshold level can be set by the manufacturer

CCA mode 2:

Mode 2 uses only the CS result, and the channel is considered busy only if the occupying signal is compliant with the PHY of the device that is performing the CCA.

CCA mode 3:

This mode is a logical combination (AND/OR) of mode 1 and mode 2. In other words, in mode 3, the PHY can use one the following as an indication of a busy channel:

- The detected energy level is above the threshold and a compliant carrier is sensed.
- The detected energy level is above the threshold or a compliant carrier is sensed.

52.4.4.2.2.9.2.5 Clocking

Table 513. table of clock signals

Signal name	Direction	Description
ck	input	Clock, nominally 32MHz
rx_gck	input	RX-only gated clock
ipg_clk_zbdem_cca	input	CCA/ED/LQI-only gated clock
ipg_clk_cca2_2m	input	2MHz for CCA2_TOP
input ipg_clk_cca2_32m	input	32MHz for CCA2_TOP
cg4m_en	input	Enable strobe 4MHz (ck)
cg1m_en	input	Enable strobe 1MHz (ck)

52.4.4.2.2.9.2.6 Reset

Table 514. table of reset signals

Signal name	Direction	Description
ipg_hard_async_reset_b	input	Hardware async reset for registers
soft_reset	input	soft reset

52.4.4.2.2.9.2.7 Interrupts

This Module has no interrupts.

The interrupts are handled with the transceiver IRQ and Zigbee_syn levels, look at the transceiver interrupts section.

52.4.4.2.2.9.2.8 DMA

This module has no DMA.

52.4.4.2.2.9.2.9 Module Signals

Here the table of the module's signal interface:

Signal name	direction	Description
ck	input	Clock, nominally 32MHz
rx_gck	input	RX-only gated clock
ipg_clk_zbdem_cca	input	CCA/ED/LQI-only gated clock
pg_clk_cca2_2m	input	2MHz for CCA2_TOP
ipg_clk_cca2_32m	input	32MHz for CCA2_TOP
cg4m_en	input	Enable strobe 4MHz (ck)
cg1m_en	input	Enable strobe 1MHz (ck)
ipg_hard_async_reset_b	input	Async chip reset
soft_reset	input	soft chip reset

Table continues on the next page...

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Signal name	direction	Description
ips_clk	input	Bus clock for IPS Register Interface
ips_module_en	input	IPS access enable
ips_byte_en	input [3:0]	IPS byte enable for write bits
ips_addr	input [11:0]	IPS Register Address
ips_rwb	input	IPS read/write enable
ips_wdata	input [31:0]	IPS interface write data.
ips_rdata	output [31:0]	IPS Interface read data.
ips_xfr_err	output	IPS Wait state.
ips_xfr_wait	output	This is unused in the PLL.
rxin_ph	input [4:0]	RX in phase
tsm_rx_init	input	Initialize Tsm Rx
fad_on	input	Came from RSM before.
lpps_on	input	Came from RSM before.
rx_data_ready	output	RX Symbol Ready Indicator
rx_data_out	output [3:0]	RX Symbol to RAM
zb_cca1_channel_state	input	Zigbee cca1 channel state
cca1_en	input	CCA1 Mode Enable Decodes from CCA[1:0]
cca1_done	output	Output to DTM
cca1_ed_fnl	output [7:0]	CCA1/ED final value to reg
cca1_thresh	input[7:0]	Programmable threshold reg to detect CCA1
rssi_cca_avg_value	output[7:0]	rssi cca average value outputed
cca2_en	input	CCA2 Mode Enable Decodes from CCA[1:0]
cca2_min_num_corr_th	input [2:0]	Reg input for corr thresh during CCA2
cca2_corr_thresh	input [7:0]	Reg input for corr thresh during CCA2
cca2_done	output	Output to DTM
cca2_num_corr_peaks	output [3:0]	Output to reg to indicate num of peaks
cca3_en	input	CCA3 Mode Enable Decodes from CCA[1:0]
cca3_and_not_or	input	Input reg for type of CCA3
use_demod_cca2	output	from xcvr_regs
ed_en	input	Energy Detect sequence enable
ed_done	output	Output to DTM
lqi_offset_comp	input [7:0]	Lqi offset

Table continues on the next page...

Table continued from the previous page...

Signal name	direction	Description
lqi_value	output [7:0]	Locked (64usec after pre_det) LQI value to reg
pn_type	output	PN Chip Code Type (ZigBee pn_type=1)
pn_lsb	output [15:0]	PN SEED (Zigbee pn_lsb=16'hc39b)
pn_msb	output [15:0]	PN SEED (Zigbee pn_lsb=16'h744a)
rx_el_result	output [1:0]	Tracking Mode Early/Late Result
rx_sfd_phy_hdr	output [7:0]	PHY Header Byte
rssi	input [7:0]	RSSI Level to registers. Used to be output
fad_en	input	Fad Block enable
antx_in	input	ANTX from registers
antx_out	output	ANTX to registers / Antenna sel o/p
demod_sel	input	Demode select signal
rx_phy_en	input	Rx Phy enable
rx_mode	input	RX mode active or not
capt_en	output	I/Q sample capture enable
s0_det	output	s0 detected
fad_corr_en	output	FAD Correlation Enable
curr_freq	output[4:0]	current freq estimate
fad_pn_rot	output	FAD PN Code Rotate enable
fad_confirm	output	FAD s0 confirm
count63	output	Symbol Strobe
lqi_done	output	Lqi done signal
cca1_fnl	output[7:0]	Cca1 final value output
afc_out	output[4:0]	Afc output
ed_fnl	output	Energie detection output
lpps_lp_en	output	Lpps low power enable
zbdem_clk_on	output	Zigbee demodulator clock on
tx_inv	output	tx inversion
zbdem_cca_clk_on	output	Zigbee cca clock on
lqi_from_rx_dig	output	Lqi from rx dig IP
cca1_from_rx_dig	output	cca1 from rx dig IP
rx_max_corr	output	Rx maximum correlation
cca2_cnt_max	output	Cca2 max counter

Table continues on the next page...

Table continued from the previous page...

Signal name	direction	Description
cca2_cnt_sym	output	Cca2 sym counter
cca2_cnt_sym_below_thresh	output	Cca2 sym counter below threshold
cca2_channel_state	output	Cca2 channel state
cca2_complete	output	Cca2 complete status

52.4.4.2.2.9.3 External Signals

This Module has no external signals.

52.4.4.2.2.9.4 Initialization

To initialize the Zigbee phy : Configure the xcvr for zigbee and program_tsm_for_zigbee.

The initialization is done with the configuration required by the active link layer before performing any transmit or receive operations.

52.4.4.2.2.9.5 Application information

The physical layer is responsible for transmitting and receiving data over the airwaves

The procedures to use this module are described in the 802.15.4 link layer documentations.

52.4.4.2.2.9.6 Register Descriptions

The Zigbee Demodulator module memory map and detailed descriptions of all its registers are as follows.

52.4.4.2.2.9.6.1 XCVR_ZBDEMOD register descriptions

52.4.4.2.2.9.6.1.1 XCVR_ZBDEMOD_ADDR memory map

RADIO.XCVR_ZBDEMOD base address: 48A0_7500h

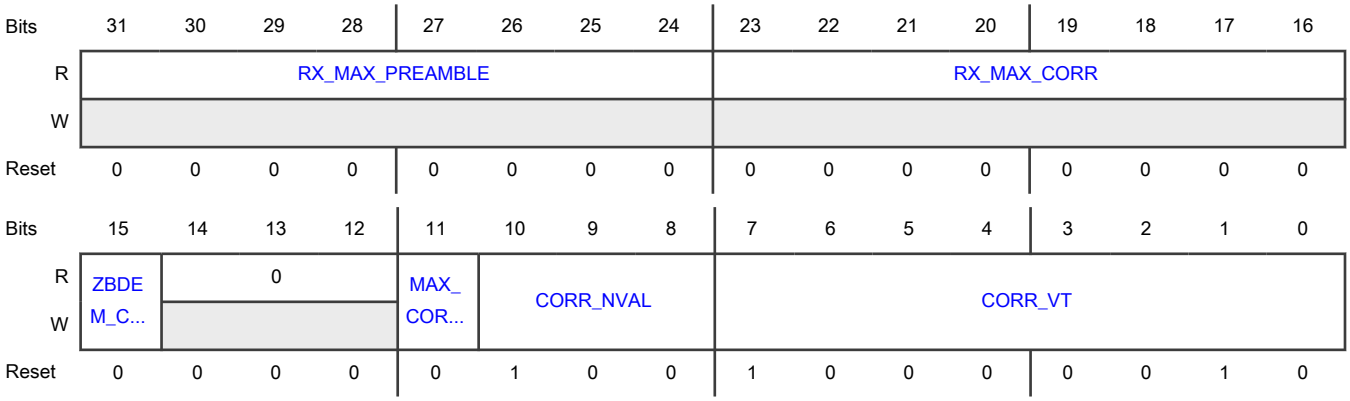
Offset	Register	Width (In bits)	Access	Reset value
0h	802.15.4 DEMOD CORRELATOR CONTROL (CORR_CTRL)	32	RW	0000_0482h
4h	802.15.4 DEMOD PN TYPE (PN_TYPE)	32	RW	0000_0001h
8h	802.15.4 DEMOD PN CODE (PN_CODE)	32	RW	744A_C39Bh
Ch	802.15.4 DEMOD SYMBOL SYNC CONTROL (SYNC_CTRL)	32	RW	0000_0008h
10h	802.15.4 CCA/LQI SOURCE (CCA_LQI_SRC)	32	RW	0000_000Ch
14h	FAD CORRELATOR THRESHOLD (FAD_LPPS_THR)	32	RW	6060_6082h
18h	802.15.4 AFC STATUS (ZBDEM_AFC)	32	RW	0000_0001h
1Ch	CCA MODE 2 CONTROL REGISTER (CCA2_CTRL)	32	RW	0000_FF05h
20h	CCA MODE 2 CONTROL REGISTER (CCA2_THRESH)	32	RW	0040_0080h
24h	CCA MODE 2 STATUS REGISTER (CCA2_STATUS)	32	R	0000_0000h
28h	802.15.4 DEMOD CORRELATOR CONTROL2 (CORR_CTRL2)	32	RW	0000_00FFh

52.4.4.2.2.9.6.1.2 802.15.4 DEMOD CORRELATOR CONTROL (CORR_CTRL)

Offset

Register	Offset
CORR_CTRL	0h

Diagram



Fields

Field	Function
31-24 RX_MAX_PREAMBLE	RX_MAX_PREAMBLE Max correlator during preamble-- max correlator value found during the preamble.
23-16 RX_MAX_CORR	RX_MAX_CORR Max correlator after preamble-- max correlator value found in packet after the preamble (refreshed every symbol rate if MAX_CORR_EN=1).
15 ZBDEM_CLK_ON	Force 802.15.4 Demodulator Clock On 0b - Normal Operation 1b - Force 802.15.4 Demodulator Clock On (debug purposes only)
14-12 —	Reserved
11 MAX_CORR_EN	MAX_CORR_EN Max correlator after preamble enable-- Enable the refresh of the max corr register.
10-8 CORR_NVAL	CORR_NVAL Number of consecutively detected zero-symbols required to declare a preamble detected.

Table continues on the next page...

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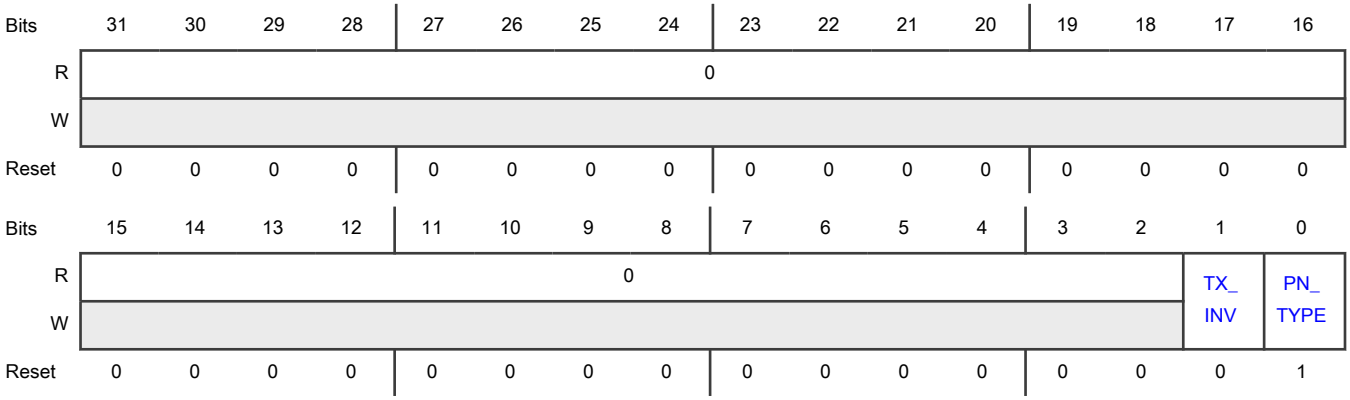
Field	Function
7-0 CORR_VT	CORR_VT Correlator threshold, defines the sensitivity of demod during the preamble search state.

52.4.4.2.2.9.6.1.3 802.15.4 DEMOD PN TYPE (PN_TYPE)

Offset

Register	Offset
PN_TYPE	4h

Diagram



Fields

Field	Function
31-2 —	Reserved
1 TX_INV	TX_INV test mode to invert the transmission
0 PN_TYPE	PN_TYPE PN Type - Pseudo Noise Chip Code Type (for 802.15.4 = 1)

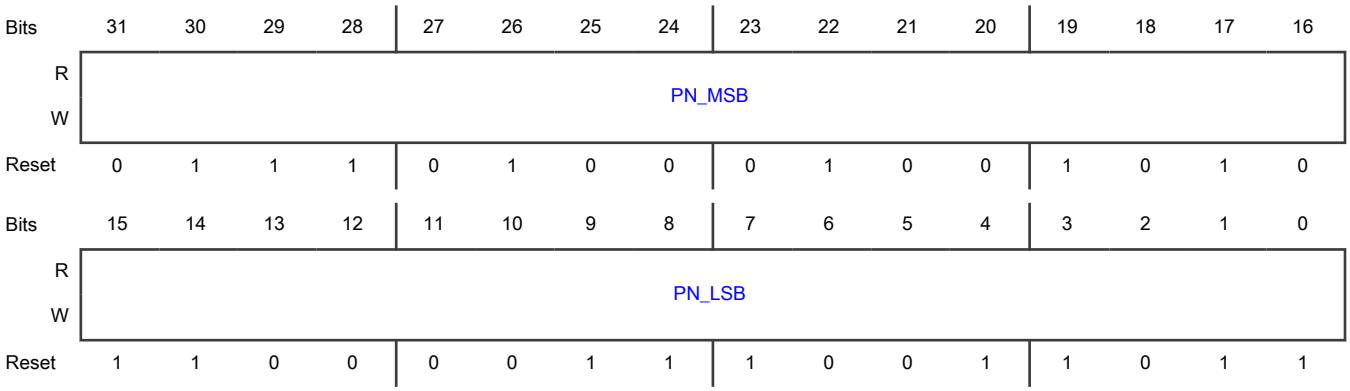
52.4.4.2.2.9.6.1.4 802.15.4 DEMOD PN CODE (PN_CODE)

Offset

Register	Offset
PN_CODE	8h

Function
Pseudo Noise Chip Code Seed Value

Diagram



Fields

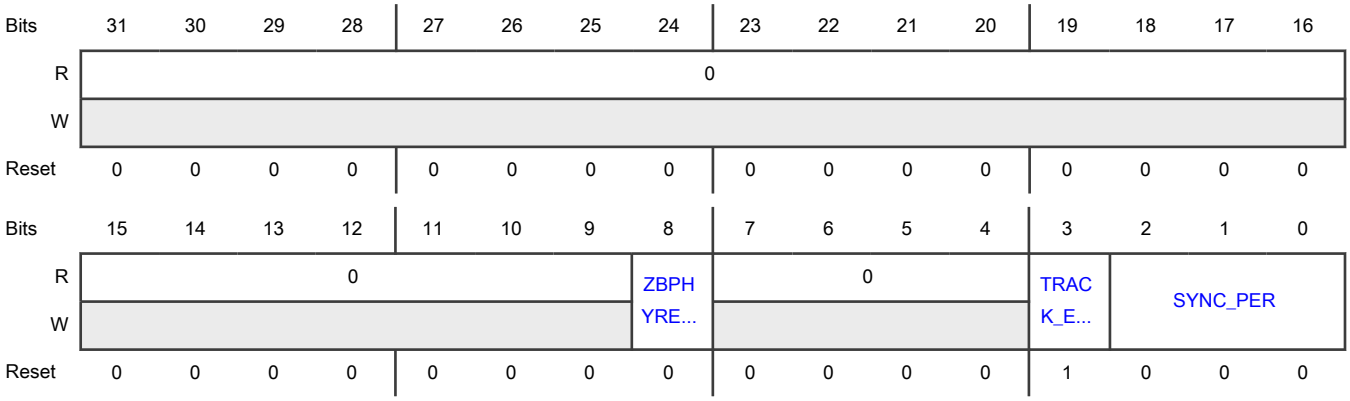
Field	Function
31-16 PN_MSB	PN_MSB PN_CODE MS half
15-0 PN_LSB	PN_LSB PN_CODE LS half

52.4.4.2.2.9.6.1.5 802.15.4 DEMOD SYMBOL SYNC CONTROL (SYNC_CTRL)

Offset

Register	Offset
SYNC_CTRL	Ch

Diagram



Fields

Field	Function
31-9 —	Reserved
8 ZBPHYREG_CKEN_FW_OV	Register clock SW override AHB clock (hclk) enable override (default = 0) If set 1'b1, the AHB hclk is always enabled
7-4 —	Reserved
3 TRACK_ENABLE	TRACK_ENABLE 0b - symbol timing synchronization tracking disabled in Rx frontend 1b - symbol timing synchronization tracking enabled in Rx frontend (default)
2-0 SYNC_PER	Symbol Sync Tracking Period determines update rate for symbol timing, per equation. An early/late measurement is made every 2^SYNC_PER[2:0] symbols. Valid range of SYNC_PER[2:0] is 0 to 4.

52.4.4.2.2.9.6.1.6 802.15.4 CCA/LQI SOURCE (CCA_LQI_SRC)

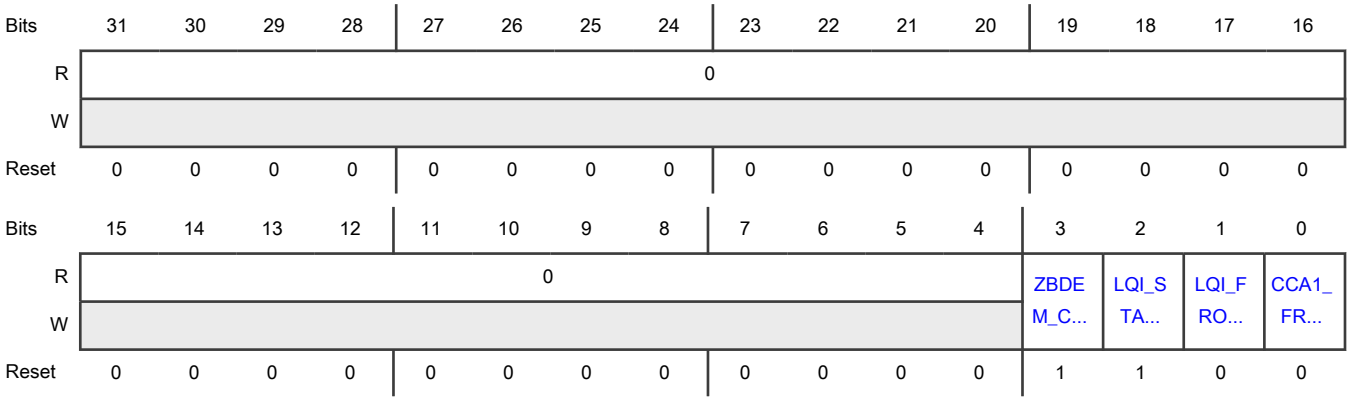
Offset

Register	Offset
CCA_LQI_SRC	10h

Function

Selects the Source of CCA and LQI Information Provided to the 802.15.4 Link Layer

Diagram



Fields

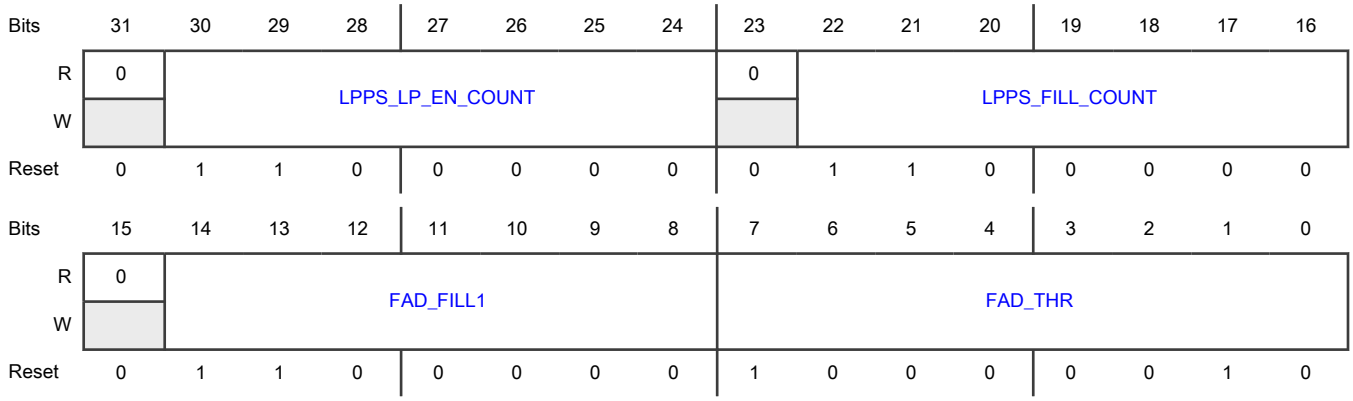
Field	Function
31-4 —	Reserved
3 ZBDEM_CCA_CLK_ON	802.15.4 Demodulator CCA Clock Enable 802.15.4 Demodulator CCA Clock Enable. This bit should be left in its default state (1) if any CCA Mode (Modes 1, 2, and 3), Energy Detect, or LQI uses the 802.15.4 Demodulator to compute its value. If 802.15.4 Demodulator is not used to compute any of these, this bit can be cleared to save power.
2 LQI_START_AT_SFD	Select Start Point for LQI Computation 0b - Start LQI computation at Preamble Detection (similar to previous NXP 802.15.4 products) 1b - Start LQI computation at SFD (Start of Frame Delimiter) Detection
1 LQI_FROM_RX_DIG	Selects the Source of LQI (Link Quality Indicator) Information Provided to the 802.15.4 Link Layer 0b - Use the LQI information computed internally in the 802.15.4 Demod 1b - Use the LQI information computed by the RX Digital
0 CCA1_FROM_RX_DIG	Selects the Source of CCA1 (Clear Channel Assessment Mode 1) Information Provided to the 802.15.4 Link Layer 0b - Use the CCA1 information computed internally in the 802.15.4 Demod 1b - Use the CCA1 information computed by the RX Digital

52.4.4.2.2.9.6.1.7 FAD CORRELATOR THRESHOLD (FAD_LPPS_THR)

Offset

Register	Offset
FAD_LPPS_THR	14h

Diagram



Fields

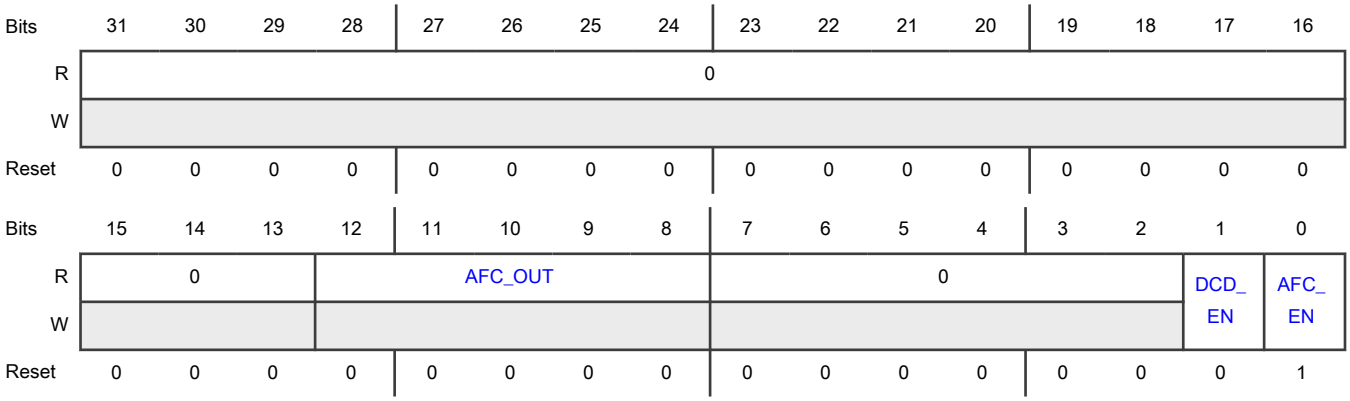
Field	Function
31 —	Reserved
30-24 LPPS_LP_EN_COUNT	LPPS_LP_EN high time Parameter used to configure the duration of time lpps_lp_enable is in high state
23 —	Reserved
22-16 LPPS_FILL_COUNT	Wait duration after lpps_lp_enable is de-asserted Parameter used to configure the wait duration used for valid samples acquisition after *lpps_lp_enable* is de-asserted. The overall wait duration expressed in base-band samples is determined using formula: *lpps_fill_duration=lpps_fill_count+lpps_tsm_warmup_duration* where *lpps_tsm_warmup_duration* is the duration of the fast TSM warmup, used for the LPPS mode, expressed in samples.
15 —	Reserved
14-8 FAD_FILL1	Pre-detection buffer filling duration Interval used to wait for valid samples acquisition after an antenna switch command has been issued.
7-0 FAD_THR	FAD_THR Correlator threshold at which the FAD will select the antenna.

52.4.4.2.2.9.6.1.8 802.15.4 AFC STATUS (ZBDEM_AFC)

Offset

Register	Offset
ZBDEM_AFC	18h

Diagram



Fields

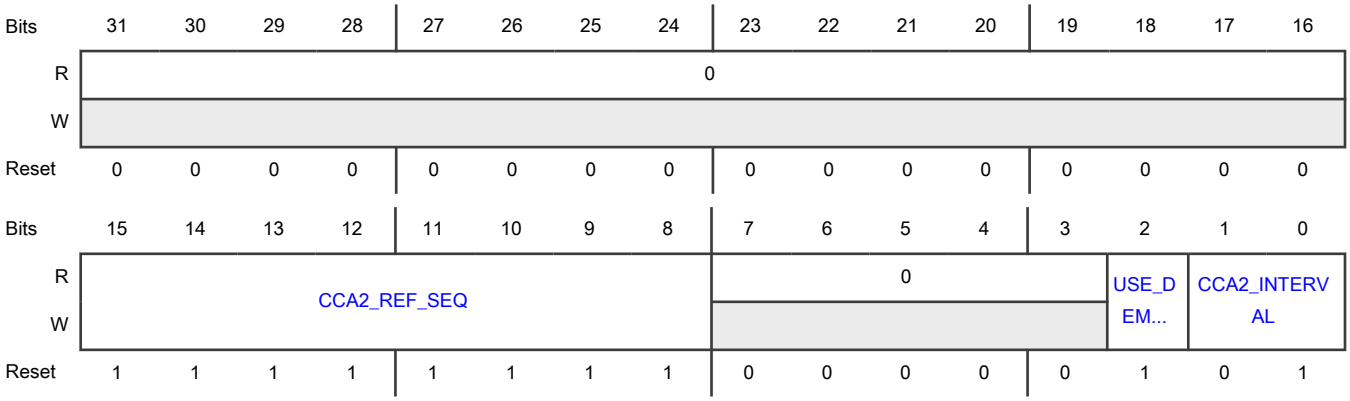
Field	Function
31-13 —	Reserved
12-8 AFC_OUT	AFC_OUT AFC Result from the last received packet. Format is Signed, Two's Complement. Each LSB represents 15KHz of Frequency Offset
7-2 —	Reserved
1 DCD_EN	DCD_EN 0b - NCD Mode (default) 1b - DCD Mode
0 AFC_EN	AFC_EN the AFC Function 0b - AFC is disabled 1b - AFC is enabled

52.4.4.2.2.9.6.1.9 CCA MODE 2 CONTROL REGISTER (CCA2_CTRL)

Offset

Register	Offset
CCA2_CTRL	1Ch

Diagram



Fields

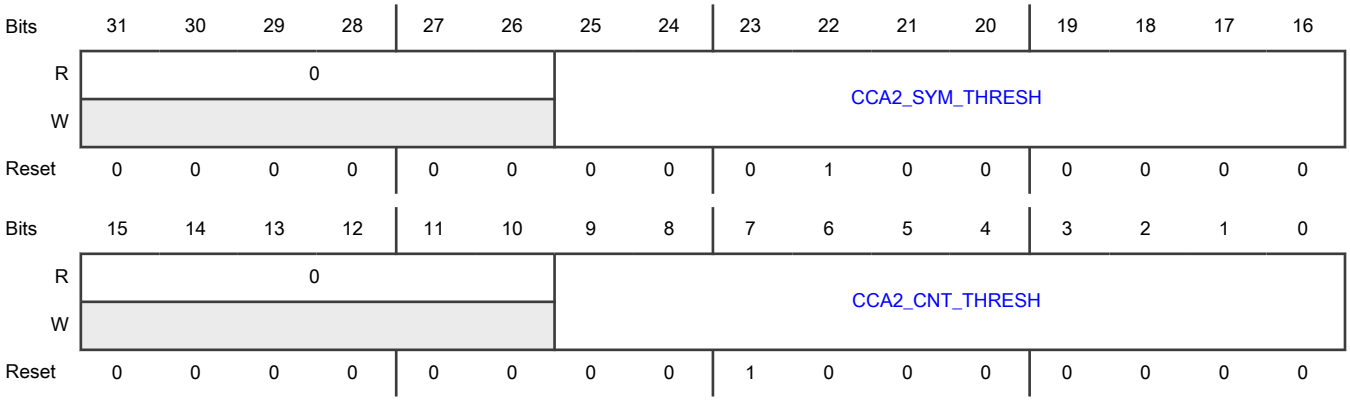
Field	Function
31-16 —	Reserved
15-8 CCA2_REF_SEQ	CCA Mode 2 Sequence Address Selection of the sequence addresses to be used.
7-3 —	Reserved
2 USE_DEMOD_CCA2	Selects CCA Mode 2 Computation Engine Selects between demodulator-based or standalone CCA Mode 2 Computation Engine 0b - Use standalone (new) CCA Mode 2 Engine, decoupled from demodulator 1b - Use 802.15.4 demodulator-based (legacy) CCA Mode 2 Engine (default)
1-0 CCA2_INTERVAL	CCA Mode 2 Measurement Window Duration Specifies the CCA2 measurement window duration: 00b - 64 µs 01b - 128 µs 10b - 256 µs 11b - 512 µs

52.4.4.2.2.9.6.1.10 CCA MODE 2 CONTROL REGISTER (CCA2_THRESH)

Offset

Register	Offset
CCA2_THRESH	20h

Diagram



Fields

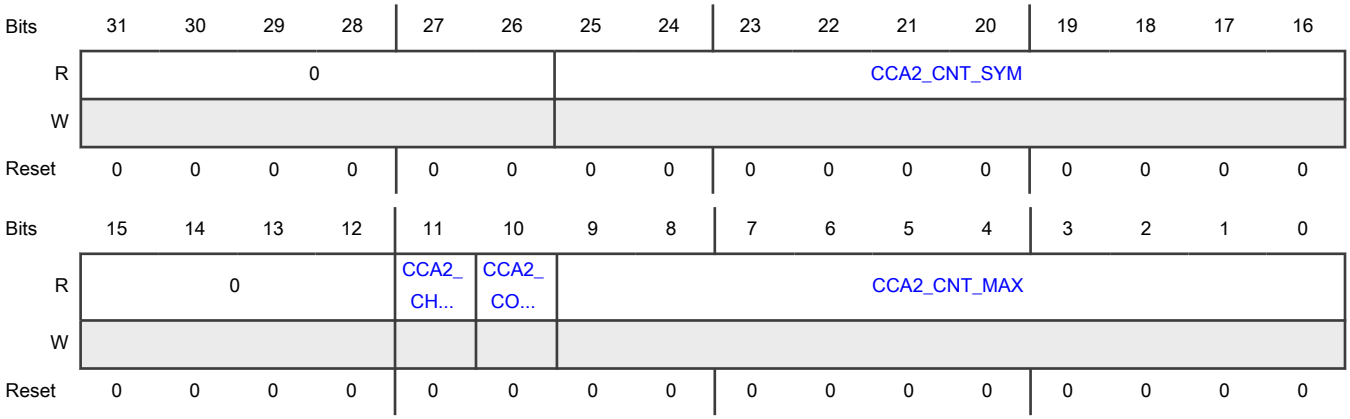
Field	Function
31-26 —	Reserved
25-16 CCA2_SYM_THRESH	CCA Mode 2 Symbol Threshold Threshold used to detect repetition sequence addresses corresponding to correlation products that exceed CCA2_CORR_THRESH[7:0]. **NOTE** CCA2_CORR_THRESH[7:0] resides in 802.15.4 address space
15-10 —	Reserved
9-0 CCA2_CNT_THRESH	CCA Mode 2 Count Threshold Threshold to compare count of correlation products exceeding CCA2_CORR_THRESH[7:0]. **NOTE** CCA2_CORR_THRESH[7:0] resides in 802.15.4 address space

52.4.4.2.2.9.6.1.11 CCA MODE 2 STATUS REGISTER (CCA2_STATUS)

Offset

Register	Offset
CCA2_STATUS	24h

Diagram



Fields

Field	Function
31-26 —	Reserved
25-16 CCA2_CNT_SYM	CCA Mode 2 Repetition Sequence Addresses Count Actual count of repetition sequence addresses corresponding to correlation products that exceed CCA2_CORR_THRESH[7:0]. **NOTE** CCA2_CORR_THRESH[7:0] resides in 802.15.4 address space
15-12 —	Reserved
11 CCA2_CHANNEL_STATE	CCA Mode 2 Channel State Indicates whether the channel is idle or busy; 0=idle, 1=busy. Asserted in any of the following cases: 1. CCA mode 2 measurement finds the channel busy when CCA2 duration expires 2. *rx_preamble_det* signal is asserted (note that, following this event, if *rx_preamble_det* is deasserted and *zb_cca2_complete* is low, *zb_cca2_channel_state* is deasserted also) 3. *rx_sfd_detect* signal is asserted
10 CCA2_COMPLETE	CCA Mode 2 Measurement Complete Indicates when a CCA mode 2 measurement is complete. Asserted in any of the following cases:

Table continues on the next page...

Table continued from the previous page...

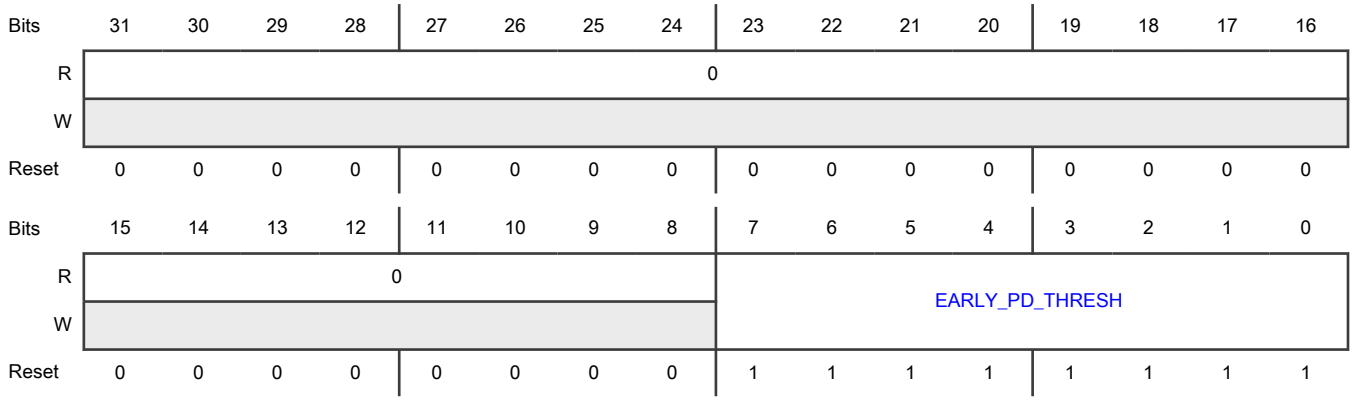
Field	Function
	1. CCA mode 2 measurement is completed (when CCA2 duration has expired) 2. rx_sfd_detect signal is asserted
9-0 CCA2_CNT_MAX	CCA Mode 2 Maximum Count Actual count of correlation products exceeding CCA2_CORR_THRESH[7:0] during the measurement interval. **NOTE** CCA2_CORR_THRESH[7:0] resides in 802.15.4 address space

52.4.4.2.2.9.6.1.12 802.15.4 DEMOD CORRELATOR CONTROL2 (CORR_CTRL2)

Offset

Register	Offset
CORR_CTRL2	28h

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 EARLY_PD_THRESH	EARLY_PD_THRESH Early preamble detection threshold, defines the sensitivity of demod during the early preamble search state.

52.4.4.2.2.10 BLE/MULTI_FSK PHY

52.4.4.2.2.10.1 Overview

This documents describes the PHY and its operation. modules of the 2.4GHz PHY receiver supporting the demodulation of a wide range of use cases employing FSK modulation:

- acquisition (timing and frequency synchronization)
- symbol demodulation interfacing with the PrePHY,
- RBME and LL

The Following protocols are supported: Non-coded Bluetooth LELong range Bluetooth LEANTcustom FSK modulation schemesMSK

52.4.4.2.2.10.1.1 Block Diagram

Figure 376 shows the interface signals and the integration of the PHY module with other blocks of the radio:

- Front-end module
- Receiver
- Radio bit manipulation engine
- Link-layer
- Antenna selection logic for the estimation of the angle-of-arrival

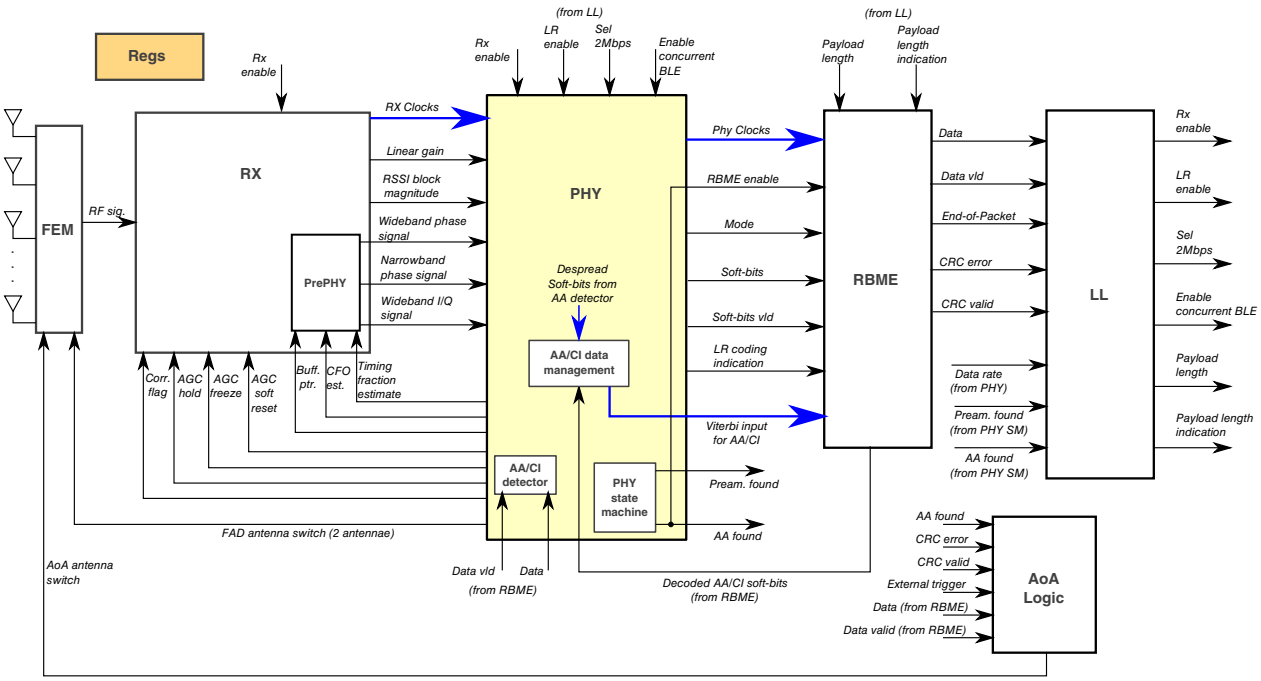


Figure 376. Block diagram

Figure 377 shows the block diagram of the PHY module. It consists of the following components:

- State-machine and clocks responsible with:
  - generation of control signals
  - generation of clock signals for the PHY processing blocks

- Time/frequency synchronization, responsible with the frame time synchronization and CFO estimation for non-coded packets, that consists of:
  - Power threshold responsible with channel energy sensing
  - Phase domain preamble detection
  - Discriminated phase (FM) domain preamble detection
  - AA detection
- Time/frequency synchronization, responsible with the frame time synchronization and CFO estimation for LR packets, that consists of:
  - LR preamble detection
  - LR AA search
- GFSK demodulator, responsible with the symbol demodulation at the over-the-air baud rate
- AA/CI data parallel to serial conversion, responsible with the data and data valid generation for the RBME module, on the AA/CI portion of the long range Bluetooth LE packets
- AA/CI detection, responsible with the decoded AA matching and CI field extraction for the long range Bluetooth LE packets

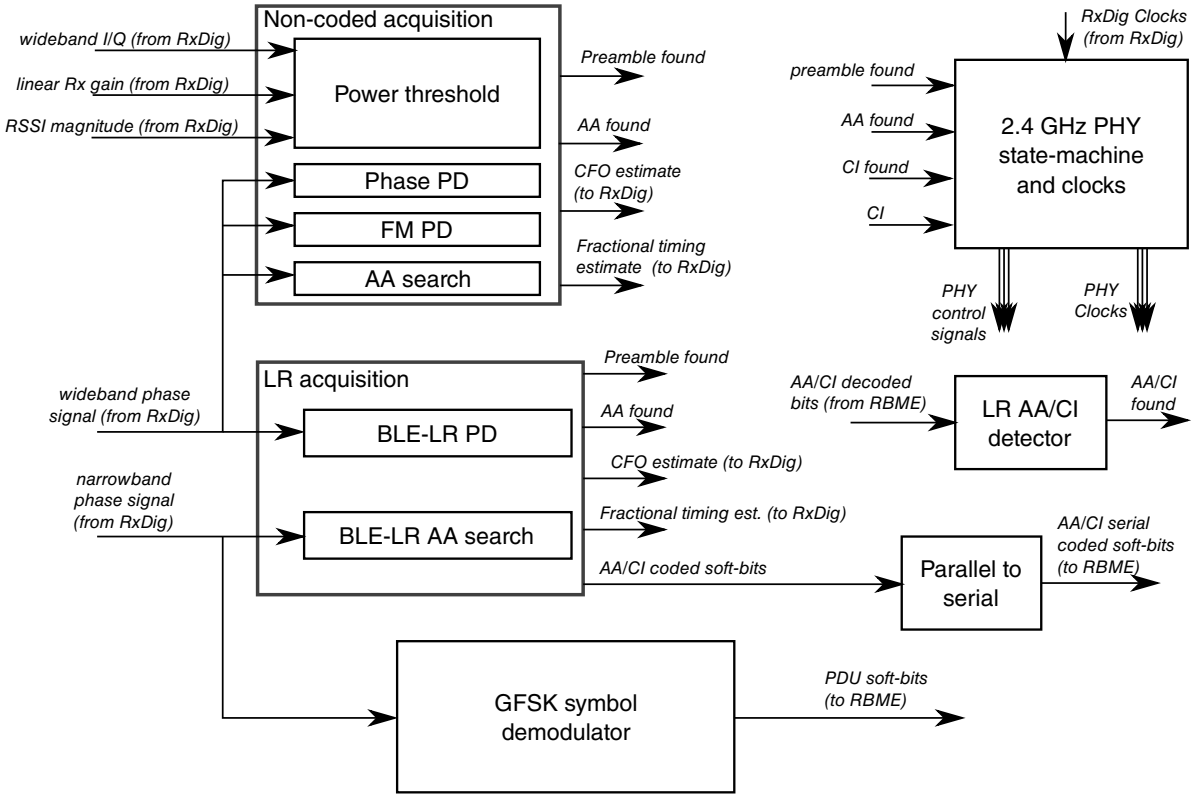


Figure 377. PHY block diagram

A "look-back" buffer provides the required latency of the frequency correction and timing acquisition engines. A pointer is provided from the PHY to the PrePHY via the interface illustrated in Figure 376. The pointer to the IQ buffer has the role of tapping the CFO mixer at the correct sample in the IQ buffer so that the CFO and the fractional timing are properly compensated. The pointer to the buffer is configured by the PHY registers and it is different for different use-cases and configurations. In general the pointer needs to be chosen to account for the following:

- Latency of a detection event, produced by the acquisition block, which is followed by:

  - the enable of the narrowband path
  - the enable of the blocks consuming the output of the narrowband path
- Channel filter pre-filling with enough history samples so that the output is computed using only CFO/fractional timing compensated samples
- The number of history samples has to be equal with at least half of the size of the CHF
- Enough history timing/frequency error compensated samples must be available for the FSK symbol demodulator
- The history needed by the FSK symbol demodulator is 2-symbols worth of samples
- A fine-tune adjustment that accounts for different latencies in the system, intended to ensure a smooth transition when switching from using the wide-band samples to using the narrow-band samples

The size of the IQ buffer needs to be chosen such that it covers for the worst-case scenario. The overall latency of the narrowband path equals the latency of the IQ buffer plus the channel filter latency plus the latencies introduced by the CFO mixer and timing frequency correction interpolator.

52.4.4.2.2.10.1.2 Features

The 2.4GHz PHY includes the following features:

- support preamble detect
- support address match
- support Bluetooth LE long range
- support Bluetooth LE none coded up to 4 address
- support demodulate to RBME/LL
- support custom FSK modulation schemes
- support MSK
- high-accuracy CFO estimation using known sequences embedded in the PDU

52.4.4.2.2.10.2 Functional description

The PHY is made up of several sub-modules. These modules can be viewed as members of two classes: datapath (the flow of the signal and the resultant bits) and control (enable/ disable logic and state control).

52.4.4.2.2.10.2.1 PHY Datapath

There are two data paths used by the PHY. The wide-band path and the narrow-band path. The PHY uses the one of the two data paths at a time or both of them simultaneously depending on the process(acquisition or payload demodulation) and use-case(coded or non-coded).

The signal of interest is passed through the PHY along the data paths. The overall objective is to process phase samples that are presented and create bits that are sent out. The significant sub-systems are here presented in generally chronological order as the signal passes through.

Initially, the phase samples are input, sequentially, at the sampling rate, one at a time. The first step is to buffer the wide-band samples, so they can be used all at once for certain computations.

The buffer of samples is then presented to the acquisition logic. The acquisition module is responsible for detecting the presence of a signal and then indicating the timing and frequency offset when a signal is detected.

Up to 4 AA's can be searched for in the case of non-coded packets and one AA can be searched for in the case of long range Bluetooth LE packets. When an match occurs, the bit timing (the sample offset at which each bit is optimally demodulated) is recorded. The symbol timing information thus determined is used by the symbol demodulator block to perform payload demodulation.

When a packet is detected, the CFO estimate is presented to the corrector and the correction is applied to the incoming samples. In this fashion, the samples leaving the corrector, which is placed on the narrowband data path, will be optimally corrected for any frequency offset before beginning demodulation.

Demodulation is performed on frequency corrected samples, provided by the narrowband data path, and after a packet is detected, the demodulator produces soft-bits information, at the symbol rate, which is presented to the RBME block. More details are provided in the functional description section.

52.4.4.2.2.10.2.2 PHY Control

The control of the PHY blocks is realized from a single place denoted the PHY state-machine. the purpose of this block is to provide:

1. triggers(data valid signals)
2. enable/disable signals
3. indications to the processing blocks of the PHY module

Another aspect of the PHY stat machine is to fast antenna diversity(FAD) preamble search feature. FAD is a mechanism that allows antenna selection on fly.

A more detailed description of the PHY control is provided in the functional description section.

52.4.4.2.2.10.2.1 Protocol Configuration

The PHY has several configurable parameters that can be changed based on the desired protocol behavior. The details of these parameters are described in the following sections and a summary table is provided here for quick reference.

Table 515. FSK schemes supported by the demodulator

Scheme	baud rate (kbps) R	Data rate (kbps) DR	modulation index *h*	Frequency pulse	LO error (ppm)
Bluetooth LE	1000	1000	0.50	Gaussian; BT=0.5	62.50
Bluetooth LE LR 125	1000	125	0.50	Gaussian; BT=0.5	62.50
Bluetooth LE LR 500	1000	500	0.50	Gaussian; BT=0.5	62.50
GFSK_05_07-500	500	500	0.70	Gaussian; BT=0.5	41.67
GFSK_03_05-1000	1000	1000	0.50	Gaussian; BT=0.3	41.67
MSK_05-1000	500	500	0.50	MSK	41.67
GFSK_05_05-250	250	250	0.50	Gaussian; BT=0.5	20.83
GFSK_05_10-250	250	250	1.00	Gaussian; BT=0.5	20.83
GFSK_07_05-1000	1000	1000	0.50	Gaussian; BT=0.7	62.50
GFSK_05_05-2000	2000	2000	0.50	Gaussian; BT=0.5	62.50
MSK_05-250	250	250	0.50	MSK	20.83
GFSK_05_032-2000	2000	2000	0.32	Gaussian; BT=0.5	62.5
FSK_05-500	500	500	0.50	Rectangular	41.67

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Table 515. FSK schemes supported by the demodulator (continued)

Scheme	baud rate (kbps) R	Data rate (kbps) DR	modulation index *h*	Frequency pulse	LO error (ppm)
GFSK_20_05_1000	1000	1000	0.50	Gaussian; BT=2.0	-

52.4.4.2.2.10.2.2 Timing and frequency synchronization

52.4.4.2.2.10.2.2.1 General description

Figure 378 illustrates the block diagram of the timing/frequency synchronization (acquisition) block. It may be configured to operate in any one of the following three operation modes:

1. Acquisition for non-coded use cases only
2. Acquisition for long range Bluetooth LE only
3. Simultaneous acquisition for non-coded and long range Bluetooth LE use cases

The main inputs to the block are:

1. Wideband phase signal - phase domain signal not compensated for CFO
2. Wideband IQ signal - IQ domain signal not compensated for CFO
3. Narrowband phase signal: phase domain signal compensated for CFO and filtered using the channel filter

Acquisition for non-coded and long range Bluetooth LE use cases is handled by separate blocks. The *Power Threshold* block provides two outputs that are used by these blocks to:

1. Disqualify any detection events that may occur when the input signal level is below a specified level because they are deemed unreliable
2. Enable Hamming distance check during AA detection when the input signal level is above a specified threshold

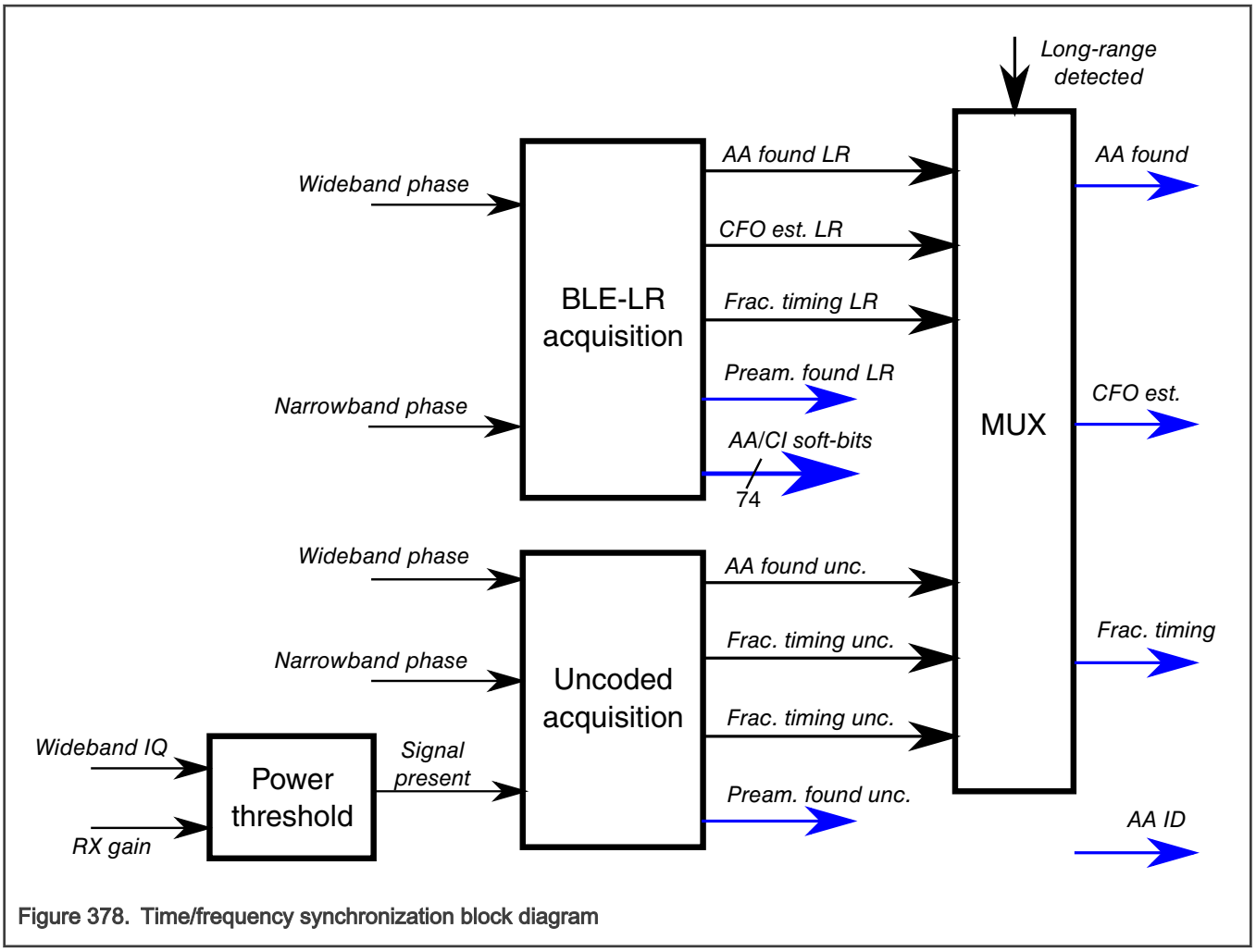


Figure 378. Time/frequency synchronization block diagram

Acquisition for non-coded and long range Bluetooth LE use cases is described later in this section.

52.4.4.2.2.10.2.2.2 Acquisition for non-coded use cases

52.4.4.2.2.10.2.2.2.1 Functional Description

Figure 379 illustrates the three main processing stages involved in the processing of non-coded use cases.

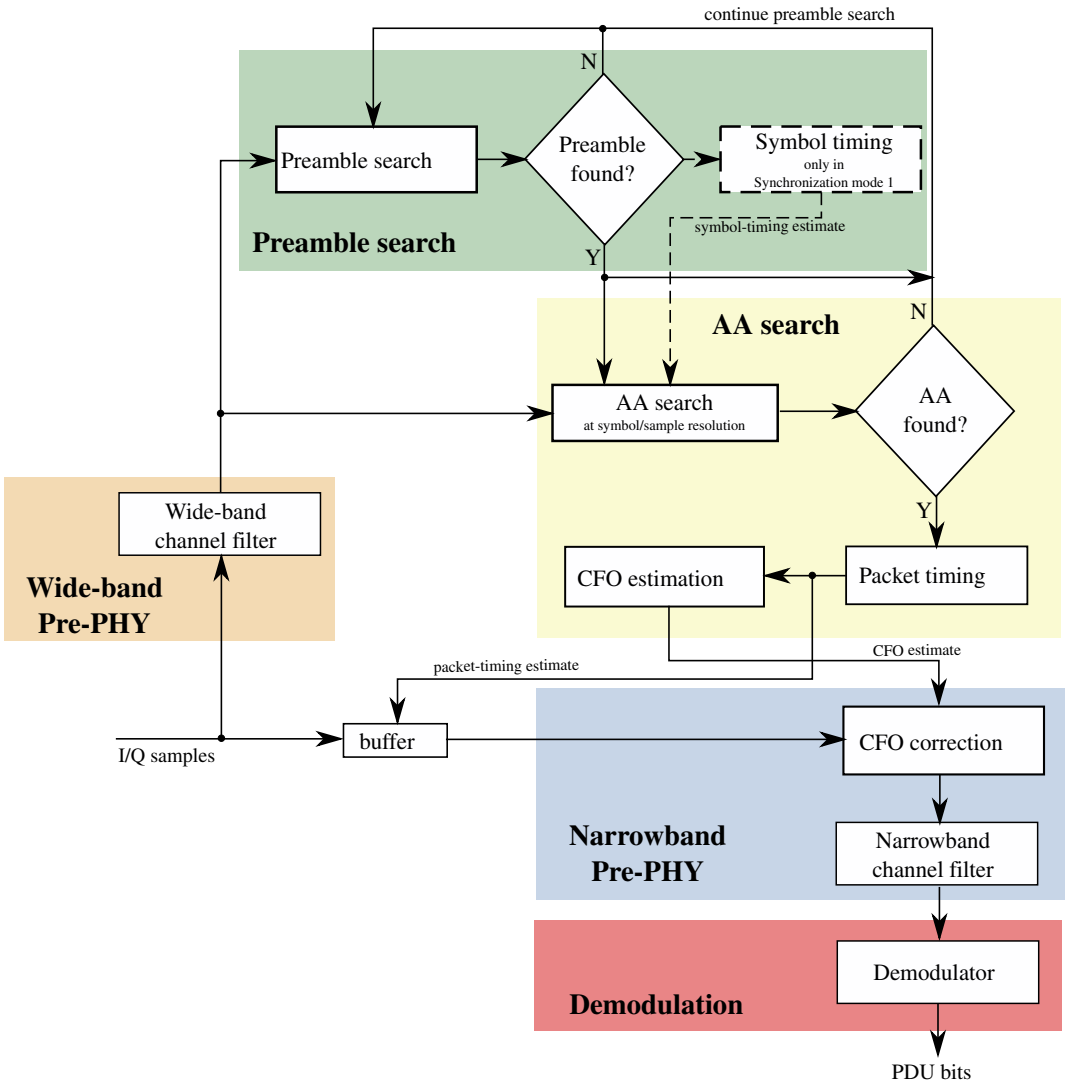


Figure 379. Processing stages of non-coded use cases

52.4.4.2.2.10.2.2.2.1.1 Preamble detection

During the preamble detection stage, the input phase values are processed to detect the preamble pattern and, if detected, AA search is triggered. No frequency acquisition is performed during this step but a timing estimate may be produced. The process shall continue even after starting AA search and is only terminated when AA is found or if *phy_enable* is de-asserted by the MAC.

52.4.4.2.2.10.2.2.2.1.2 AA search

During AA search, the PHY searches for one or more AA's to (i) achieve packet timing synchronization, and (ii) produce a CFO estimate. If the preamble detection stage is also active, its symbol timing estimate may be used during this stage to reduce the search complexity. The receiver can simultaneously search for up to four unique AA's of the same size. The number of AA's to be searched and their patterns need to be programmed *a priori* by the MAC.

This stage gets terminated upon either (i) a successful AA detection and synchronization following which the PHY proceeds to the demodulation stage, or (ii) if the *phy_enable* signal is de-asserted by the MAC.

The quality of the timing and CFO estimates obtained from AA search is strongly dependent on the correlation properties of the AA pattern used. So it is important to choose an AA with good correlation properties; refer to AA requirements & guidelines for related notes.

52.4.4.2.2.10.2.2.2.1.3 Demodulation

During the demodulation stage, using the timing & frequency estimates from the preceding stages, the PHY begins to demodulate the PDU and produces bits which are then sent to the MAC for further processing. In case there is significant timing and/or frequency drift in the PDU, the demodulator can simultaneously perform timing and/or frequency tracking as well.

The demodulator continues its operation until the *phy_enable* signal is de-asserted by the MAC.

52.4.4.2.2.10.2.2.2.2 AA requirements & guidelines

To ensure good synchronization performance, it is important that the AA used during the connection possesses good auto-correlation and cross-correlation properties. In general terms, if the auto-correlation of a candidate AA pattern, for a non-zero lag, exceeds a pre-defined threshold, then it should not be used. A suggested threshold value is 0.40 but recommended to be no more than 0.50.

For AA's of sizes 3 and 4 octets and For AA's of sizes 1 and 2 octets list some requirements which will reduce the likelihood of generating a candidate AA with poor auto-correlation properties.

52.4.4.2.2.10.2.2.2.2.1 For AA's of sizes 3 and 4 octets

The following requirements applicable to AA's of sizes 3 and 4 octets are adopted from Bluetooth specification v5.2; vol 6, part B.

The AA shall:

1. have no more than six consecutive 0's or 1's.
2. not be the advertising channel packet's AA.
3. not be a sequence that differs from the advertising channel packet's AA by only one bit.
4. not have all octets identical.
5. have no more than:
   - twenty-four bit transitions in case of 4-octet AA's.
   - eighteen bit transitions in case of 3-octet AA's.
6. have a minimum of two transitions in the most significant six bits.

The following additional requirements ensure better synchronization performance. Each AA shall:

1. contain no more than two contiguous instances of a bit sequence of length seven or more bits.
2. not contain two instances of a bit sequence, contiguous or otherwise, of length
   - thirteen or more bits in case of 4-octet AA's.
   - ten or more bits in case of 3-octet AA's.
3. have no more than four consecutive 0's or 1's within the least significant octet.
4. have no more than 6 transitions in the least significant octet.
5. have at least one transition in the most significant four bits.

52.4.4.2.2.10.2.2.2.2.2 For AA's of sizes 1 and 2 octets

Below are the requirements applicable to AA's of sizes 1 and 2 octets. Each AA shall:

1. have no more than four consecutive 0's or 1's.
2. not be the advertising channel packet's AA.
3. not be a sequence that differs from the advertising channel packet's AA by only one bit.
4. in case of 2 octets AA's, the two octets shall not be identical.
5. have no more than:
   - eleven bit transitions in case of 2-octet AA's.

- five bit transitions in case of 1-octet AA's.

6. have a minimum of two transitions in the most significant four bits.
7. contain no more than two contiguous instances of a bit sequence of length five or more bits (not applicable to 1-octet AA's).
8. not contain two instances of a bit sequence, contiguous or otherwise, of length:
   - six or more bits in case of 2-octet AA's.
   - four bits in case of 3-octet AA's.
9. have no more than three consecutive 0's or 1's within the least significant octet.
10. no more than 6 transitions in the least significant octet.

52.4.4.2.2.10.2.2.2.3 Synchronization for non-coded use cases

For non-coded use cases, three different modes of synchronization are provided to support the general packet structure. Each mode involves one or two of the following three processes.

1. Correlation-based preamble detection in frequency-domain (Freq-PD)
2. Correlation-based preamble detection in phase-domain (Phase-PD)
3. Correlation-based AA detection (AAD)

52.4.4.2.2.10.2.2.2.3.1 Synchronization modes - functional description, state machines and implementation

52.4.4.2.2.10.2.2.2.3.1.1 Synchronization mode 1

In ACQ mode 1, the Freq-PD and AAD processes are used to achieve synchronization. This mode is only useful, and is especially recommended, when a long preamble is available because it can significantly reduce power consumption.

####### 52.4.4.2.2.10.2.2.2.3.1.1.1 Functional description

Figure 380 shows a functional block diagram of the PHY in mode 1. First, the preamble is searched in the frequency-domain (*i.e.*, using phase-discriminated inputs) and when detected, a symbol-timing estimate is produced. The symbol-timing estimate is then used to begin AA search at symbol resolution thereby achieving significant reduction in computational complexity compared to searching the AA at sample resolution. Upon detecting an AA, an AA-based CFO estimate and a packet-timing estimate are generated.

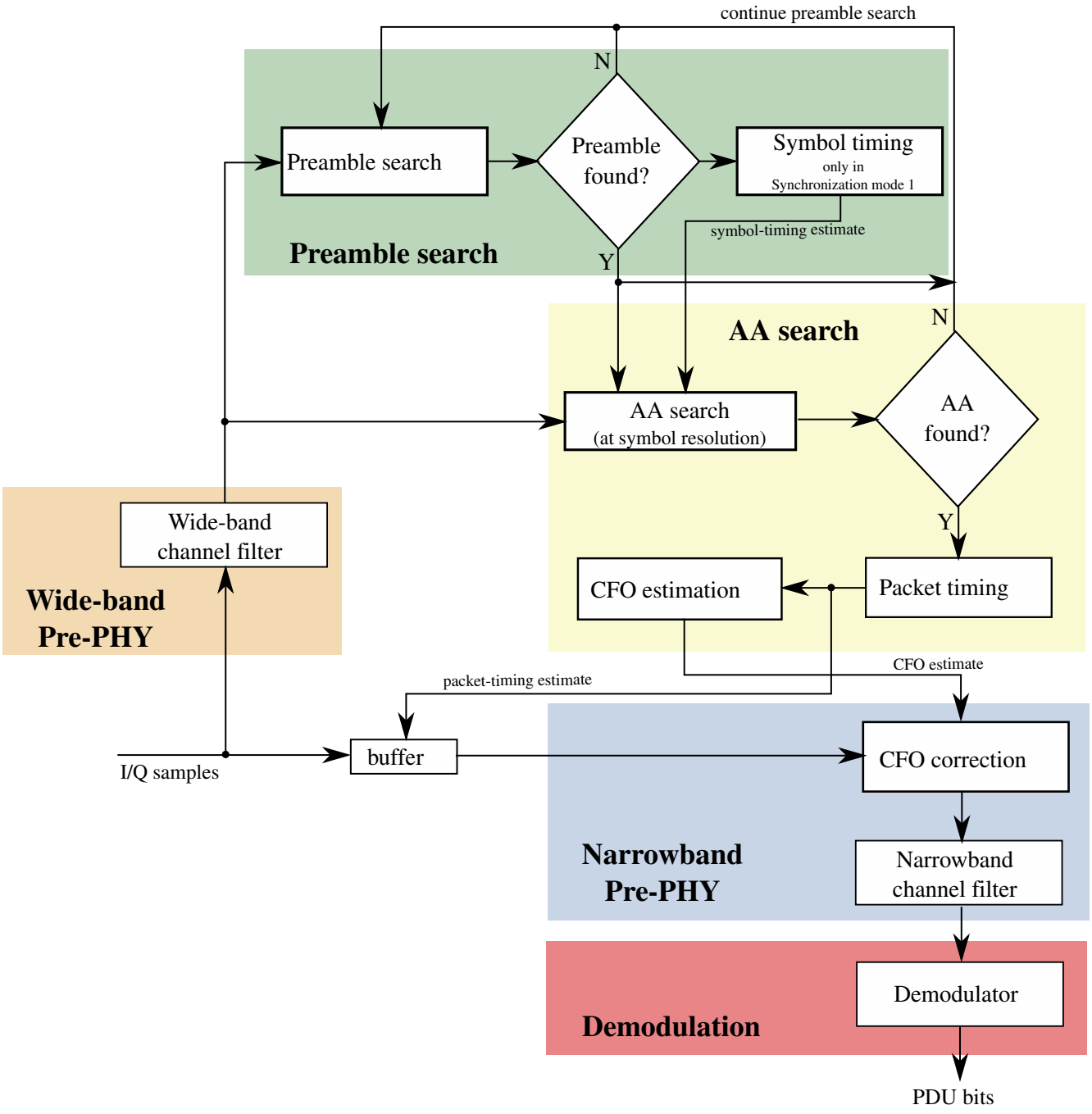


Figure 380. ACQ mode 1 block diagram

52.4.4.2.2.10.2.2.2.3.1.1.2 State machine

Figure 396 shows the state-machine of the PHY operating in mode 1.

52.4.4.2.2.10.2.2.2.3.1.2 Synchronization mode 2

In ACQ mode 2, only the AAD process is used to achieve synchronization. This ACQ mode may be used regardless of the length of the preamble but is recommended only when the preamble is short.

52.4.4.2.2.10.2.2.2.3.1.2.1 Functional description

Figure 381 shows a functional block diagram of the PHY in ACQ mode 2. The receiver begins searching for the AA and, upon detection, produces packet-timing and CFO estimates.

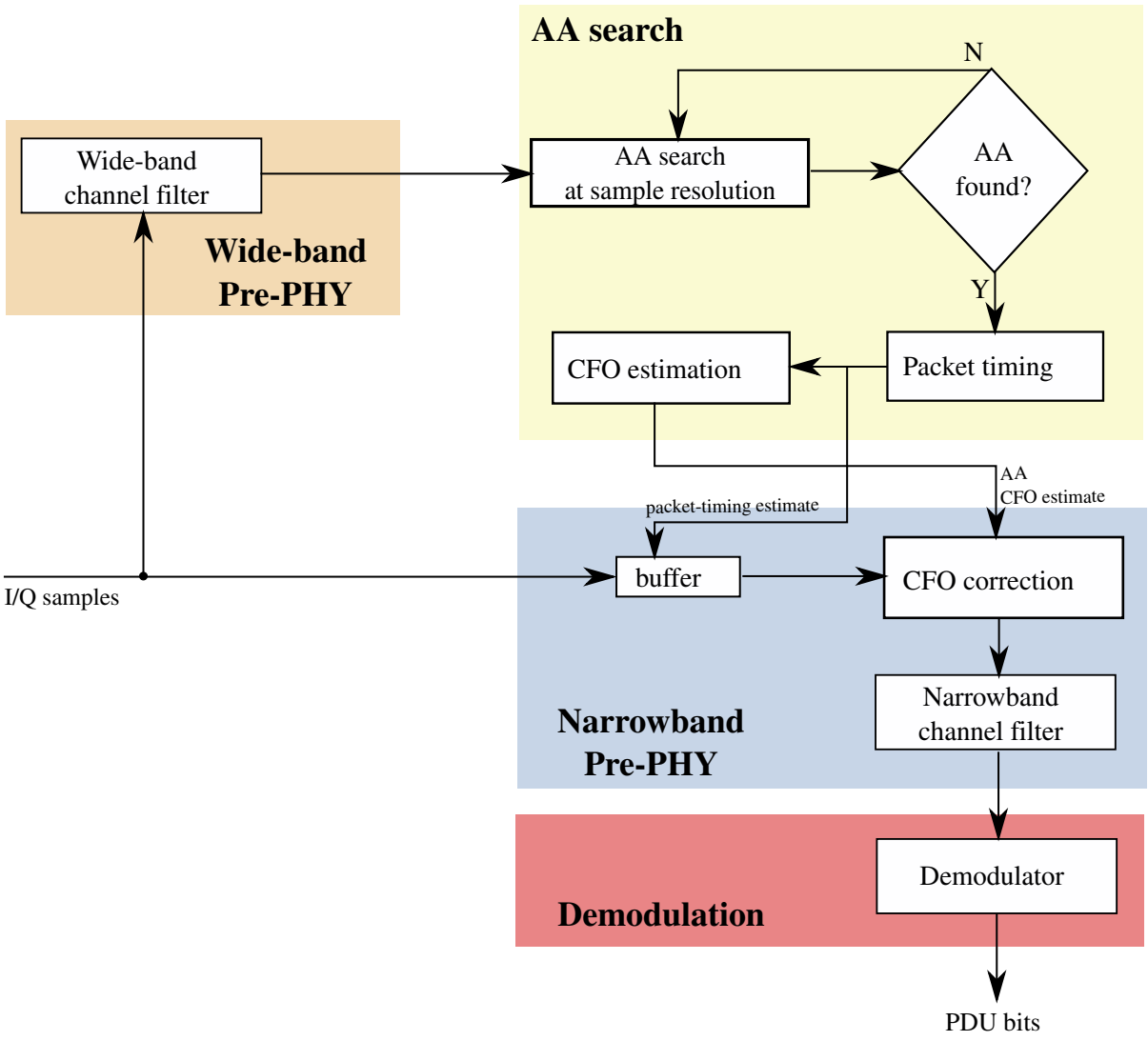


Figure 381. ACQ mode 2 block diagram

52.4.4.2.2.10.2.2.2.3.1.2.2 State machine

Figure 396 shows the state-machine of the PHY operating in mode 2.

52.4.4.2.2.10.2.2.2.3.1.3 Synchronization mode 3

In ACQ mode 3, the Phase-PD and AAD processes are used to achieve synchronization. But , unlike ACQ mode 1, this mode can be used when the preamble is short to quickly detect the arrival of a packet.

52.4.4.2.2.10.2.2.2.3.1.3.1 Functional description

Figure 382 shows a functional block diagram of the PHY in ACQ mode 3. First, the preamble is searched to identify the presence of a packet on the air but no timing or CFO estimate is generated. Like ACQ mode 2, the AA is searched at sample resolution and upon detecting an AA, an AA-based CFO estimate and a packet-timing estimate are generated.

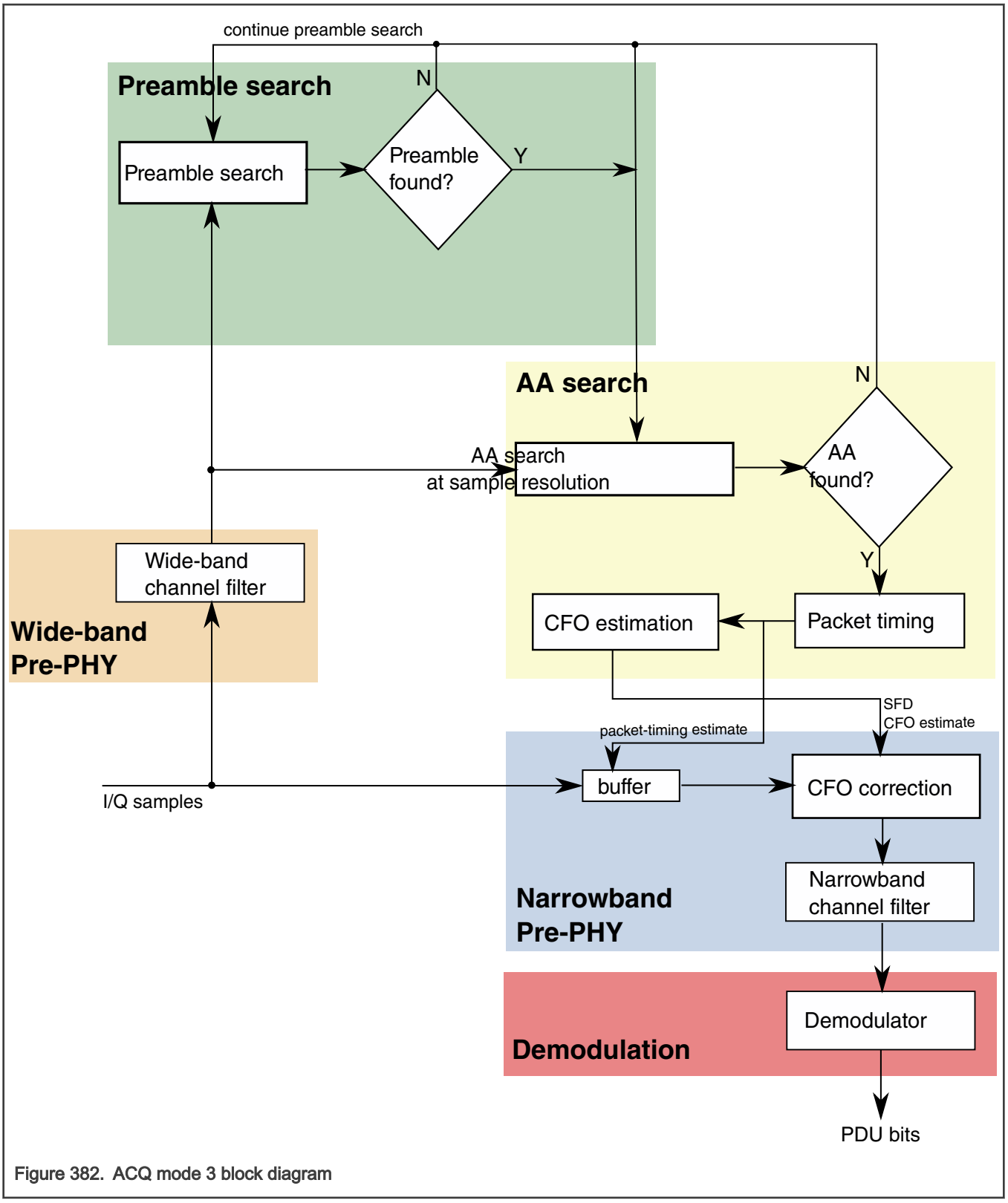


Figure 382. ACQ mode 3 block diagram

52.4.4.2.2.10.2.2.2.3.1.3.2 State machine

Figure 396 shows the state-machine of the PHY operating in mode 3.

52.4.4.2.2.10.2.2.2.3.2 Main component blocks

This section presents the details of the main component blocks used as the building blocks for realizing the various ACQ modes. There are six of them as listed below.

1. Power threshold
2. Pre-processor
3. Freq-PD preamble search engine
4. Phase-PD preamble search engine
5. AA search engine
6. Interpolator

52.4.4.2.2.10.2.2.2.3.2.1 Power threshold

The purpose of this block is to help avoid false preamble/AA detections in the respective search engines when the input signal is purely noise. The fixed-point formats of the block's inputs as well as those used at each internal stage are shown within parentheses.

It measures the input signal magnitude by passing the received I/Q samples through a single-pole IIR filter whose forgetting factor, α, is programmable. This magnitude is compared against two input thresholds - a low power threshold and a high power threshold which are both expected to be adjusted based on the AGC gain setting and the associated NF. If the measured signal magnitude is not less than the low threshold, then the boolean output *signal_present_low* gets asserted; if it is also not less than the high threshold, then both the boolean outputs, *signal_present_low* and *signal_present_high*, get asserted.

The block may alternatively use the narrowband RSSI measured by the RxDIG instead of the signal magnitude computed internally for comparing against the low and high power thresholds. This behavior is configurable through the input parameter BypassWithRSSI.

52.4.4.2.2.10.2.2.2.3.2.1.1 Register parameters

Table 516 lists the register parameters used by the power threshold block.

Table 516. Registers used by the power threshold block

Parameter	Notes
mag_window[3:0]	Indicates the forgetting factor used in received signal level measurement; forgetting factor used is 2^{-mag_window}. Note that *mag_window* values higher than 8 are not typically used.
pow_th_low[10:0]	Low power threshold specifies a power level below which the signal is considered too weak for reliable acquisition; uses (0,11,11) fixed-point format.
pow_th_high[10:0]	High power threshold specifies a power level above which the signal is considered strong enough that a stricter Hamming tolerance may be applied during acquisition; uses (0,11,11) fixed-point format.
bypass_with_rssi	Bypass signal power measurement with RSSI measurement; 0→no, 1→yes.
cond_sig_prst_enable	Enables special conditioning of signal power detection in the Power threshold block; 0→disable, 1→enable.

52.4.4.2.2.10.2.2.2.3.2.2 Pre-processor

It is used as the first step, in both Freq-PD and AAD processes, to pre-process the input I/Q samples and its output is then passed on to the respective search block.

52.4.4.2.2.10.2.2.2.3.2.2.1 Register parameters

Table 517 lists the only register parameter used by the pre-processor. It is used to obtain *1/2h* in the appropriate fixed-point format for providing as input to the pre-processor.

Table 517. Registers used by the pre-processor

Parameter	Notes
recip_mod_idx[8:0]	Reciprocal of modulation index; represented in (0,9,7) format.

52.4.4.2.2.10.2.2.2.3.2.3 Freq-PD preamble search engine

A block diagram of the Freq-PD preamble search engine is shown in Figure 383. It is used for correlation-based preamble detection in the frequency-domain. The fixed-point formats used at various internal points are also shown within parentheses.

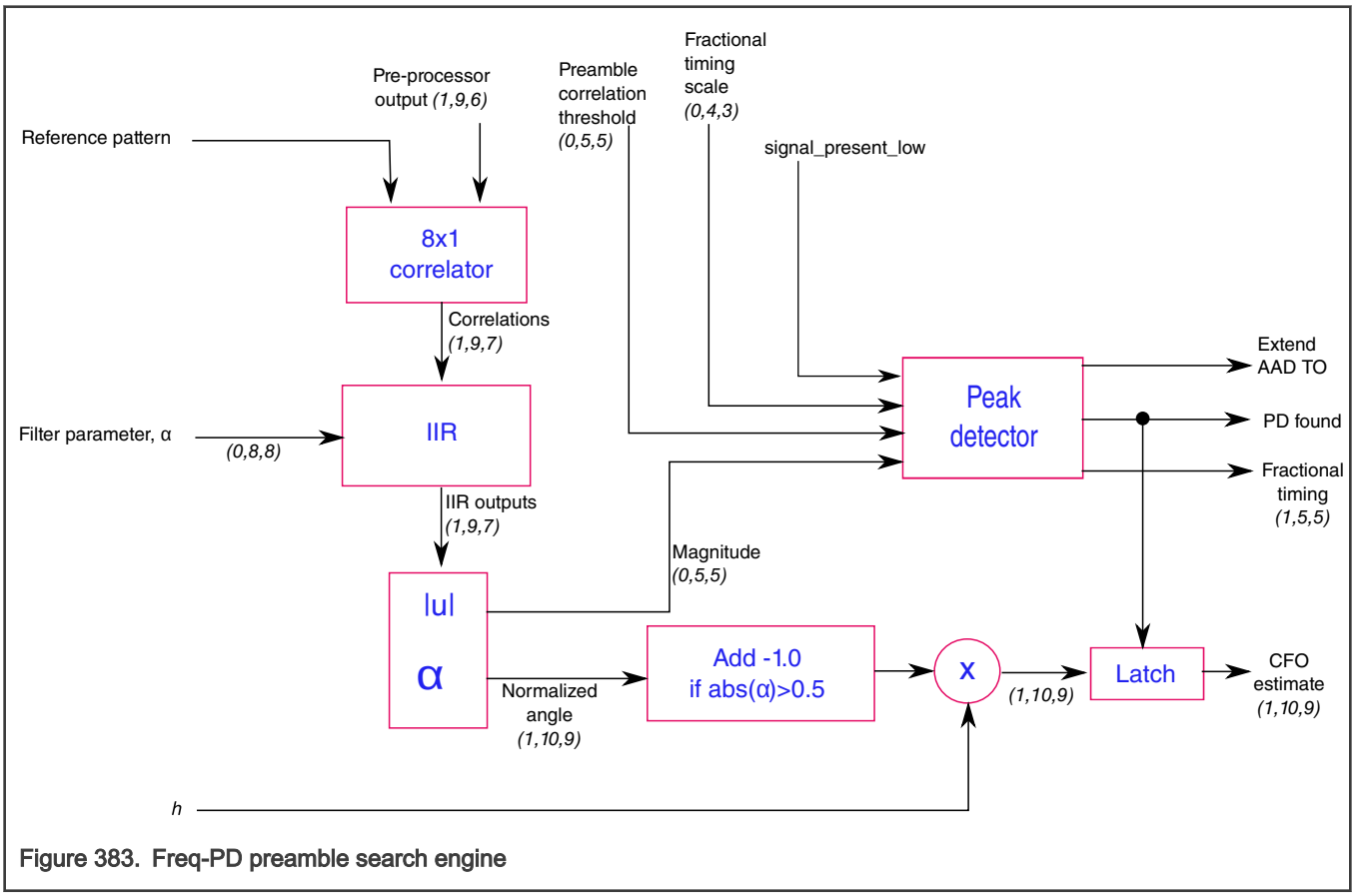


Figure 383. Freq-PD preamble search engine

An 8x1 binary reference pattern along with the pre-processor output phase values is provided as input to the engine. In the first step, each phase value is converted into its equivalent I/Q sample of unit magnitude and a correlation is performed between the I/Q values thus obtained and the reference pattern. The resultant complex correlation values are then passed through a single-pole IIR filter. The outputs of the IIR filter are long-term averages of its inputs and, therefore, are roughly equivalent to much longer correlations. Next, the magnitudes and angles of the complex IIR outputs are obtained using LUTs and passed to the timing detection and CFO estimation circuits respectively.

52.4.4.2.2.10.2.2.2.3.2.3.1 Register parameters

Table 518 lists the register parameters used by the preamble search engine.

Table 518. Registers used by the Freq-PD preamble search engine

Parameter	Notes
preamble_pattern[7:0]	8-bit preamble pattern used in FM-domain preamble detector.

Table continues on the next page...

Table 518. Registers used by the Freq-PD preamble search engine (continued)

Parameter	Notes
preamble_thresh[7:0]	Correlation threshold applicable to preamble detection; uses (0,5,5) fixed-point format which gets written in (0,8,8) format by zeroing out the LSB's.
preamble_frac_time_scale[3:0]	Scaling factor used for fractional time estimation during preamble search; represented in (0,4,3) format.
iir_alpha[7:0]	IIR filter parameter used during preamble detection; represented in (0,8,8) format.
mod_idx[10:0]	Modulation index; represented in (0,11,7) format.

Table 519 lists a suggested preamble correlation threshold value for each non-coded use case listed in Table 515. The values are applicable to ACQ mode 1 but it should be noted that they were optimized for the specific preamble length of 8 octets and, therefore, may need to be adjusted if a different preamble length is used.

Table 519. Suggested Freq-PD correlation thresholds for ACQ mode 1

Use case	Preamble threshold (fraction)	*preamble_thresh[7:0]* (hexadecimal notation)
Bluetooth LE	12/32	0x60
GFSK_05_07-500	14/32	0x70
GFSK_03_05-1000	12/32	0x60
MSK_05-500	10/32	0x50
GFSK_05_05-250	12/32	0x60
GFSK_05_10-250	16/32	0x80
GFSK_07_05-1000	16/32	0x80
GFSK_05_05-2000	16/32	0x80
MSK_05-250	14/32	0x70
GFSK_05_032-2000	16/32	0x80
FSK_05-500	10/32	0x50
FSK_05-500	10/32	0x50

Table 520 lists a suggested value for *preamble_frac_time_scale* applicable to all non_coded use cases. The length of the preamble does not influence this parameter and so the suggested value is applicable regardless of the preamble length.

Table 520. Suggested Freq-PD fractional timing scale for ACQ mode 1

Use case	Preamble fractional timing scale (decimal)	*preamble_frac_time_scale[3:0]* (hexadecimal notation)
All use cases	1.50	0xC

Table 521 lists a suggested value for *iir_alpha* for each non-coded use case listed in Table 515. It was optimized for a preamble length of 8 octets and may need to be adjusted if the preamble length is different.

Table 521. Suggested Freq-PD IIR forgetting factor for ACQ mode 1

Use case	IIR parameter, α (fraction)	*iir_alpha[7:0]* (hexadecimal notation)
Bluetooth LE	6/32	0x30
GFSK_05_07-500	6/32	0x30
GFSK_03_05-1000	4/32	0x20
MSK_05-500	3/32	0x18
GFSK_05_05-250	6/32	0x30
GFSK_05_10-250	4/32	0x20
GFSK_07_05-1000	6/32	0x30
GFSK_05_05-2000	6/32	0x30
MSK_05-250	6/32	0x30
GFSK_05_032-2000	6/32	0x30
FSK_05-500	3/32	0x18

52.4.4.2.2.10.2.2.2.3.2.4 Phase-PD preamble search engine

A block diagram of the Phase-PD preamble search engine is shown in Figure 384. It is used for correlation-based preamble detection in the phase-domain. The fixed-point formats used at various internal points are also shown in the diagram.

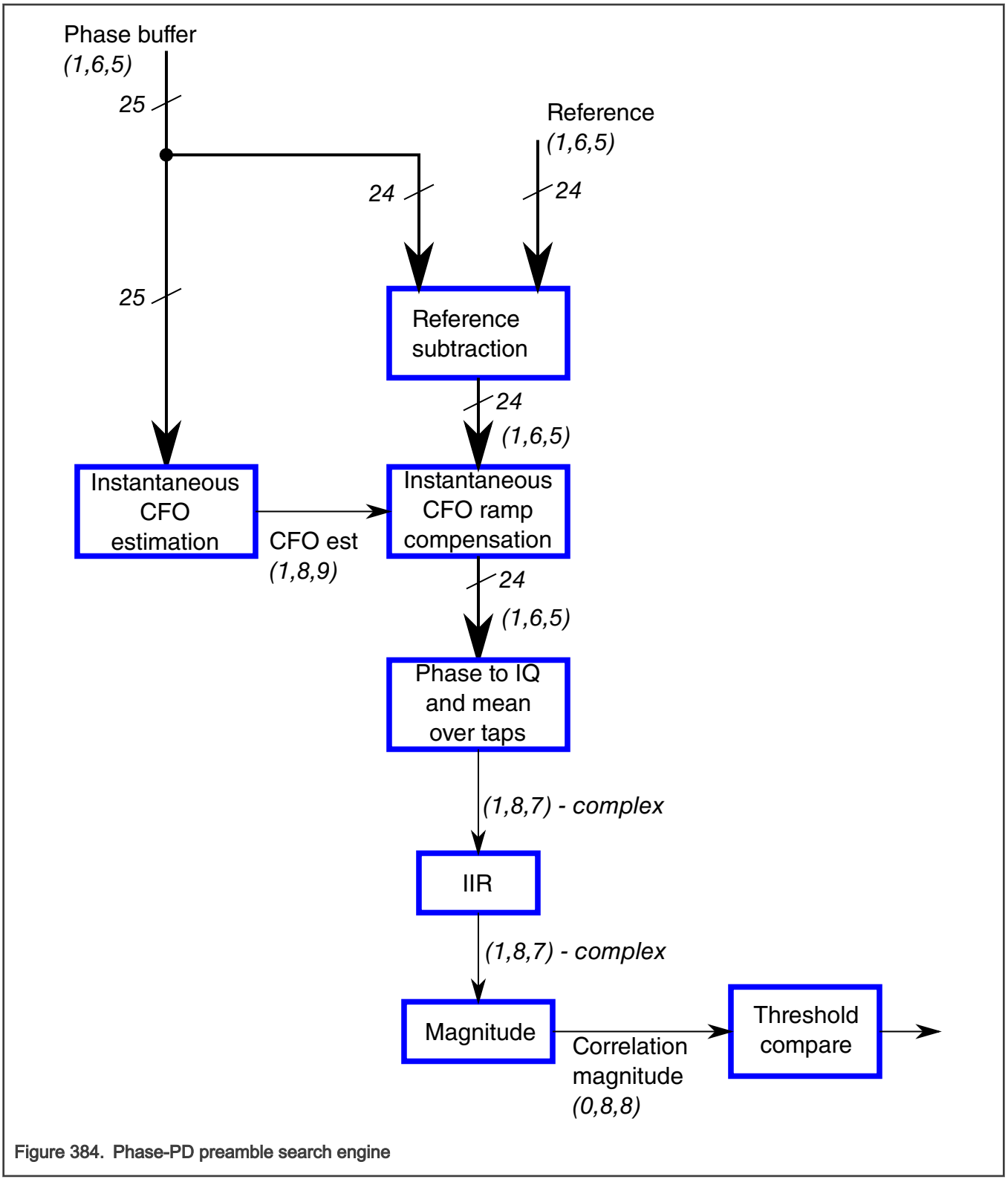


Figure 384. Phase-PD preamble search engine

An 24x1 phase-domain reference pattern along with the pre-processor output phase values is provided as input to the engine. Since the 24x1 vector is periodic with an 8x1 vector repeating three times, only 8 values need to be programmed, as shown in Table 522, in order to save register space. To be able to properly perform phase-domain correlation the phase ramp caused by CFO has to be compensated. In order to achieve that, an instantaneous CFO estimate is computed, by averaging differences between consecutive values in the phase buffer, and all correlation taps are simultaneously compensated by reconstructing the

ramp based upon the estimated CFO. As shown in Figure 384, the CFO is estimated on the input phase vector after the reference is subtracted. After the CFO compensation the phase values are converted to complex values and the taps are averaged over, thus transforming the vector input to a scalar output. An IIR can be optionally used, to average the complex correlation values, if preamble is longer. However it is expected that, for the use cases that use acquisition mode 3, the IIR will be bypassed.

Finally the complex correlation values are converted to real values through absolute operation ("Magitude" block) and compared with a threshold. Given the intrinsic behavior of the phase-domain correlator to output a large correlation magnitude when the buffer is filled with zeros (this happens when the preamble detector is being reset), a timer is used to gate the output of the block until the buffer gets filled with non-zeros samples.

52.4.4.2.2.10.2.2.2.3.2.4.1 Register parameters

Table 522 lists the register parameters used by the preamble search engine.

Table 522. Registers used by the Phase-PD search engine

Parameter	Notes
preamble_pattern[47:0]	8 reference phase values, 6-bits each; uses (1,6,5) fixed-point format.
preamble_thresh[7:0]	Correlation threshold applicable to preamble detection; uses (0,8,8) fixed-point format.
iir_alpha[7:0]	IIR filter parameter used during preamble detection; represented in (0,8,8) format.

Table 519 lists a suggested preamble correlation threshold value for each non-coded use case listed in Table 515.

Table 523. Suggested Phase-PD preamble correlation thresholds for ACQ mode 3

Use case	Preamble threshold (fraction)	*preamble_thresh[7:0]* (hexadecimal notation)
Bluetooth LE	246/256	0xF6
GFSK_05_07-500	215/256	0xD7
GFSK_03_05-1000	246/256	0xF6
MSK_05-500	240/256	0xF0
GFSK_05_05-250	235/256	0xEB
GFSK_05_10-250	215/256	0xD7
GFSK_07_05-1000	235/256	0xEB
GFSK_05_05-2000	235/256	0xEB
MSK_05-250	184/256	0xB8
GFSK_05_032-2000	246/256	0xF6
FSK_05-500	240/256	0xF0
GFSK_20_05-1000	246/256	0xF6

Table 524 lists a suggested value for *iir_alpha* applicable to all use cases that use acquisition mode 3.

Table 524. Suggested Phase-PD IIR forgetting factor for ACQ mode 3

Use case	IIR parameter, α (fraction)	*iir_alpha[7:0]* (hexadecimal notation)
All use cases	1 (bypass)	0xFF

Table 525. Reference waveforms for phase-domain PD

Use case	Phase domain reference pattern (*preamble_pattern[47:0]*) in hexadecimal notation
Bluetooth LE	[0x03, 0x05, 0x03, 0x00, 0x3d, 0x3b, 0x3d, 0x00];
GFSK_05_07-500	[0x05, 0x07, 0x05, 0x00, 0x3b, 0x39, 0x3b, 0x00];
GFSK_03_05-1000	[0x02, 0x03, 0x02, 0x00, 0x3e, 0x3d, 0x3e, 0x00]
MSK_05-500	[0x02, 0x03, 0x02, 0x00, 0x3e, 0x3d, 0x3e, 0x00]
GFSK_05_05-250	[0x03, 0x05, 0x03, 0x00, 0x3d, 0x3b, 0x3d, 0x00]
GFSK_05_10-250	[0x07, 0x0a, 0x07, 0x00, 0x39, 0x36, 0x39, 0x00]
GFSK_07_05-1000	[0x04, 0x06, 0x04, 0x00, 0x3c, 0x3a, 0x3c, 0x00]
GFSK_05_05-2000	[0x03, 0x05, 0x03, 0x00, 0x3d, 0x3b, 0x3d, 0x00]
MSK_05-250	[0x02, 0x03, 0x02, 0x00, 0x3e, 0x3d, 0x3e, 0x00]
GFSK_05_032-2000	[0x02, 0x03, 0x02, 0x00, 0x3e, 0x3d, 0x3e, 0x00]
FSK_05-500	[0x02, 0x03, 0x02, 0x00, 0x3e, 0x3d, 0x3e, 0x00]
GFSK_20_05-1000	[0x03, 0x05, 0x03, 0x00, 0x3e, 0x3b, 0x3d, 0x00]

52.4.4.2.2.10.2.2.2.3.2.5 AA search engine

A block diagram of the AA search engine is shown in Figure 385. It is used for correlation-based AA detection in AAD. The fixed-point formats used at various stages are also shown within parentheses in the diagram.

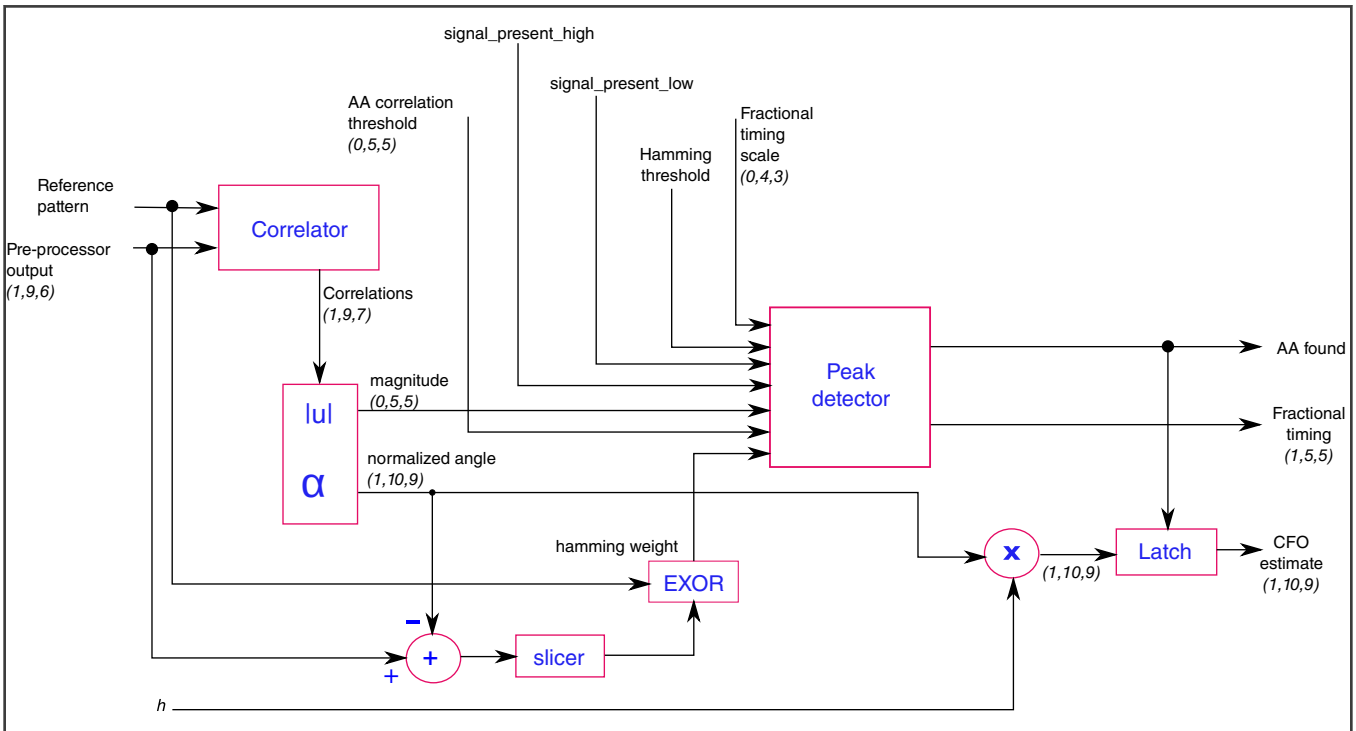


Figure 385. AA search engine

A binary AA reference pattern, along with the pre-processor output phase values, is provided as input to the engine. In the first step, each phase value is converted into its equivalent I/Q sample of unit magnitude and a correlation is performed between the I/Q values thus obtained and the reference pattern. Next, the magnitudes and angles of the complex correlations are obtained

using LUTs and passed to the peak detector and CFO estimation circuits respectively. In addition, a hamming weight is also computed between

1. the reference pattern, and
2. the pre-processor output vector (corresponding to the current correlation) after removing the bias due to CFO.

52.4.4.2.2.10.2.2.2.3.2.5.1 Register parameters

Table 526 lists the register parameters used by the AA search engine.

Table 526. Registers used by the AA search engine

Parameter	Notes
aa_0[31:0]	AA pattern of length 1, 2, 3 or 4 octets used for AA search in ACQ path 0; 1, 2 and 3 octet patterns in bits [7:0], [15:0] and [23:0] respectively.
aa_1[31:0]	AA pattern of length 1, 2, 3 or 4 octets used for AA search in ACQ path 1; 1, 2 and 3 octet patterns in bits [7:0], [15:0] and [23:0] respectively.
aa_2[31:0]	AA pattern of length 1, 2, 3 or 4 octets used for AA search in ACQ path 2; 1, 2 and 3 octet patterns in bits [7:0], [15:0] and [23:0] respectively.
aa_3[31:0]	AA pattern of length 1, 2, 3 or 4 octets used for AA search in ACQ path 3; 1, 2 and 3 octet patterns in bits [7:0], [15:0] and [23:0] respectively.
size_aa[1:0]	Indicates length of active AA's; 0→1 octet, 1→2 octets, 2→3 octets, 3→4 octets.
aa_thresh[4:0]	Correlation threshold applicable to AA detection; uses (0,5,5) fixed-point format.
aa_frac_time_scale[3:0]	Scaling factor used for fractional time estimation during AA search; represented in (0,4,3) format.
search_aa_0	Indicates whether aa_0 should be searched during acquisition; 0→no, 1→yes.
search_aa_1	Indicates whether aa_1 should be searched during acquisition; 0→no, 1→yes.
search_aa_2	Indicates whether aa_2 should be searched during acquisition; 0→no, 1→yes.
search_aa_3	Indicates whether aa_3 should be searched during acquisition; 0→no, 1→yes.
hamming_aa_high_pwr[2:0]	Maximum hamming distance from the given AA pattern that may still be accepted as a match; valid range is [0,7].
hamming_aa_low_pwr[3:0]	Hamming distance tolerance applicable around sensitivity and at low power levels during AA detection; valid range is [0,15].
mod_idx[10:0]	Modulation index; represented in (0,11,7) format.

Table 527 lists the suggested AA correlation threshold values for ACQ modes 2 & 3 while Table 528 lists suggested AA correlation threshold values for ACQ mode 1 for the non-coded use cases listed in Table 515. Note that they are not influenced by the length of the preamble.

Table 527. Suggested AA correlation thresholds for ACQ modes 2 & 3

Use case	AA threshold (fraction)	*aa_thresh[4:0]* (hexadecimal notation)
Bluetooth LE	19/32	0x13
GFSK_05_07-500	16/32	0x10

Table continues on the next page...

Table 527. Suggested AA correlation thresholds for ACQ modes 2 & 3 (continued)

Use case	AA threshold (fraction)	*aa_thresh[4:0]* (hexadecimal notation)
GFSK_03_05-1000	15/32	0x0F
MSK_05-500	18/32	0x12
GFSK_05_05-250	18/32	0x12
GFSK_05_10-250	19/32	0x13
GFSK_07_05-1000	15/32	0x0F
GFSK_05_05-2000	17/32	0x11
MSK_05-250	17/32	0x11
GFSK_05_032-2000	17/32	0x11
FSK_05-500	15/32	0x0F

Table 528. Suggested AA correlation thresholds for ACQ mode 1

Use case	AA threshold (fraction)	*aa_thresh[4:0]* (hexadecimal notation)
Bluetooth LE	17/32	0x11
GFSK_05_07-500	15/32	0x0F
GFSK_03_05-1000	15/32	0x0F
MSK_05-500	13/32	0x0D
GFSK_05_05-250	17/32	0x11
GFSK_05_10-250	17/32	0x11
GFSK_07_05-1000	17/32	0x01
GFSK_05_05-2000	17/32	0x11
MSK_05-250	17/32	0x11
GFSK_05_032-2000	17/32	0x11
FSK_05-500	13/32	0x0D
GFSK_20_05-1000	21/32	0x15

Table 529 lists a suggested value for *aa_frac_time_scale* applicable to all use cases regardless of the preamble length.

Table 529. Suggested AA fractional timing scale for ACQ modes 2 and 3

Use case	AA fractional timing scale (decimal)	*aa_frac_time_scale[3:0]* (hexadecimal notation)
All use cases	1.875	0xF

52.4.4.2.2.10.2.2.2.3.2.6 Interpolator

A block diagram of the interpolator is shown in Figure 386. It is only used in ACQ mode 1 for interpolation in AAD. The fixed-point formats used at various internal stages are also shown within parentheses in the diagram.

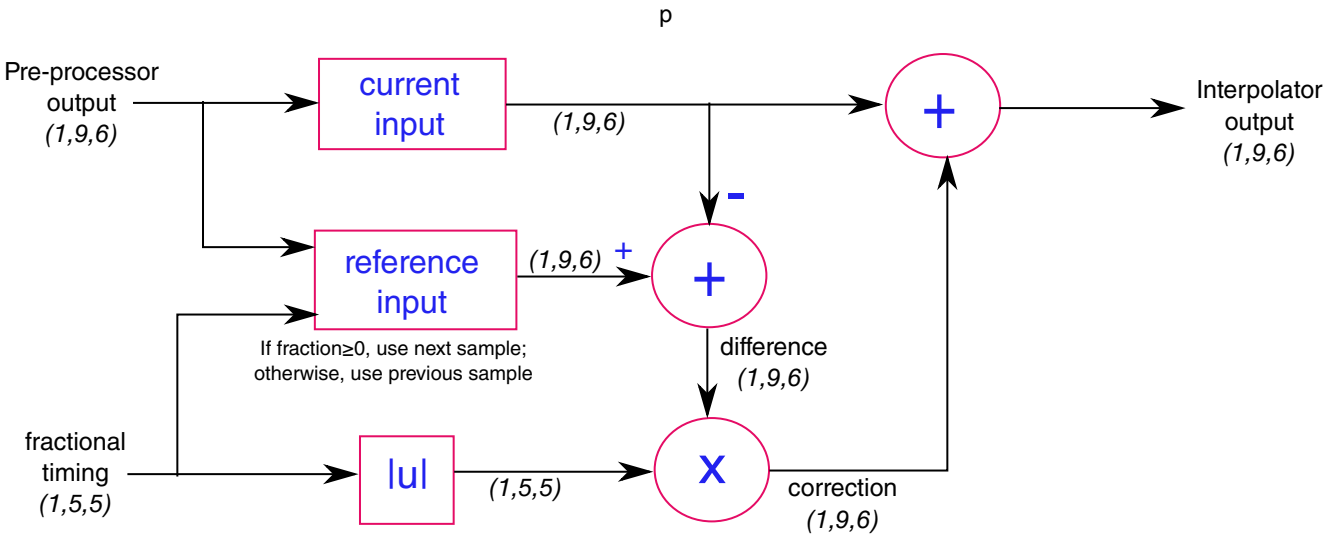


Figure 386. Interpolator

The interpolation in performed by using as reference the immediately preceding sample if the fractional timing estimated in PD is negative or the immediately succeeding sample if the fractional timing is non-negative. For interpolating each input sample, the difference between the itself and the reference is scaled by the fractional timing estimate and added back to itself.

52.4.4.2.2.10.2.2.3 Acquisition for BluetoothLE-LR

52.4.4.2.2.10.2.2.3.1 Long range Bluetooth LE preamble detection

The purpose of the preamble detector is to detect the presence of a long range Bluetooth LE packet and to estimate the CFO.

52.4.4.2.2.10.2.2.3.2 Long range Bluetooth LE AA detection

The soft-bits based AA detector performs AA detection for long range Bluetooth LE packets. It consists of the following components:

- Low complexity FSK symbol demodulator which produces the soft-bits, triggered at the sample rate
- Buffer which converts the scalar input to a vector used for correlation
- Long range Bluetooth LE AA correlator, used to perform long range Bluetooth LE AA detection after a long range Bluetooth LE preamble is detected

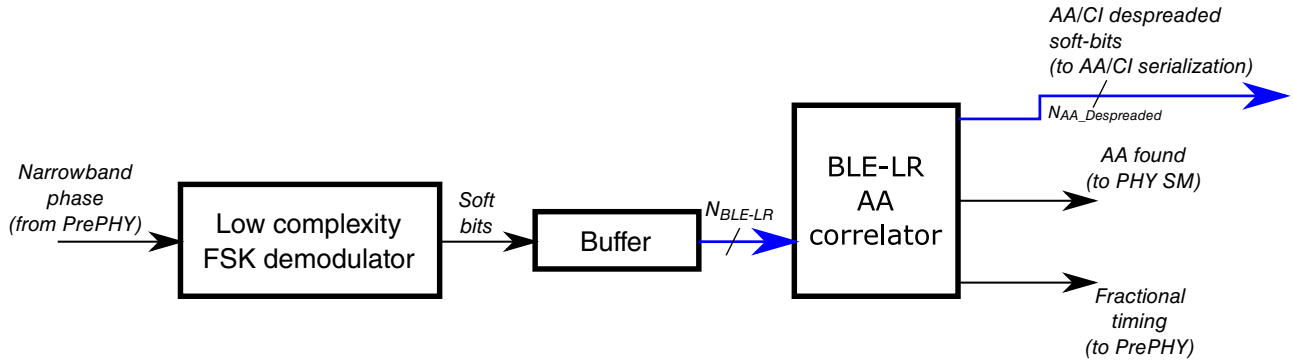


Figure 387. Soft-bits domain AA detector block diagram

It is being recalled here that the AA detection that uses soft-bits is done in parallel with continued preamble detection which has the purpose of improving the CFO estimate and extend the AA search time-out. These details are given in a more detailed manner in the PHY state-machine section. An important aspect to be mentioned is that the long range Bluetooth LE detector supports detection of a single AA pattern. When AA detection starts, the low complexity FSK demodulator and the buffer are first enabled and the correlator is enabled after enough samples are acquired into the buffer to allow a valid correlation product.

52.4.4.2.2.10.2.2.3.2.1 Low-Complexity FSK Symbol Demodulation

The soft-bits are generated at the sample rate *i.e.*, $1/T_s$ and they are used during AA detection. The FSK symbol demodulator takes the CFO-corrected phase-domain samples as input and produces soft-bits as described below. Since the PHY has no knowledge of the PDU size, the process continues until the *activate_search* signal is de-asserted by the MAC.

52.4.4.2.2.10.2.2.3.2.2 Long range Bluetooth LE AA detection

The AA/CI despreaded soft-bits are latched when AA is found and they are further used by the long range Bluetooth LE AA/CI decoding mechanism, which is described in a different section.

In order to match the AA, the despreaded soft-bits are selected in the "Select AA portion" block and 64 despreaded soft bits are provided to the correlation and Hamming distance circuits. The correlator performs real values correlation, against AA corresponding reference waveform, over the input vector and the Hamming distance uses hard-bits to measure the distance between the received vector and the expected, coded AA.

52.4.4.2.2.10.2.3 Long range Bluetooth LE AA/CI decoding

The AA/CI decoding process is illustrated in Figure 388. This process corresponds to state 3 in the PHY state machine and involves both the PHY and the RBME modules. The chronological steps are indicated by the red arrow. Note that the arrow is meant to show data flow not control. The steps are:

- When AA is detected the detector provides a vector containing the despreaded soft-bits corresponding to the AA and CI portions
- The parallel to serial conversion block in the AA/CI decoding block starts producing codewords (consisting of the pairs of soft-bits {Soft-bit 1, Soft-bit 2}) and data valids
- The RBME engine decodes the inputted codewords and provides back data and data valids to the AA/CI detection block
- AA/CI detection is performing AA matching and CI extraction
  - If AA is matched the CI information is sent to the state-machine together with a CI valid indication
    - Following this event, the PHY state-machine transitions to payload demodulation
  - If AA is not matched the CI valid is not sent and a time-out occurs in the PHY state-machine
    - This further leads to returning to the acquisition state and to RBME disable

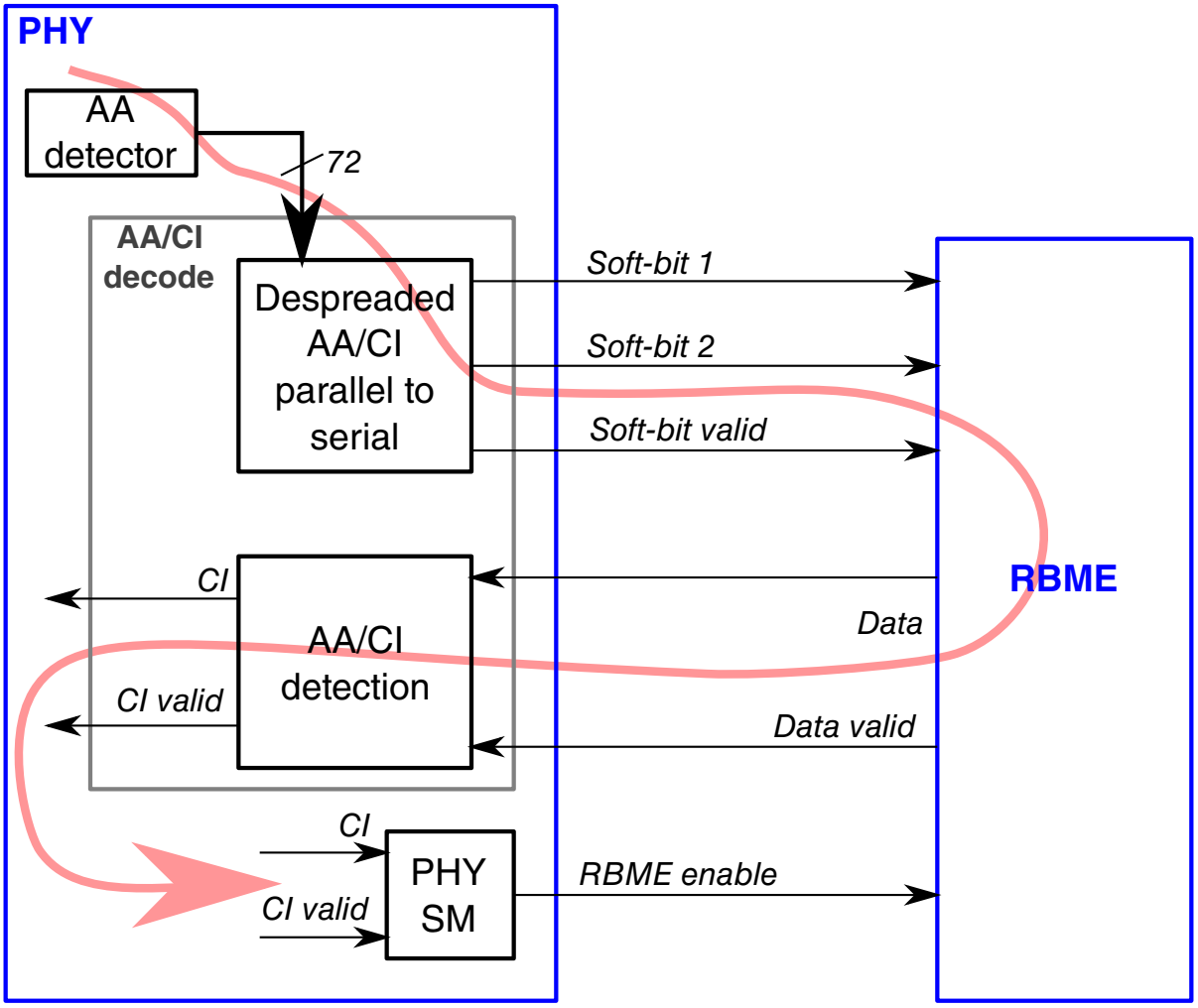


Figure 388. AA/CI decoding process

52.4.4.2.2.10.2.4 FSK payload demodulation

The demodulator consumes the received samples, at an oversampling rate (OSR) equal to 4, after the symbol timing and frame timing have been determined and after the CFO correction was applied. The I/Q samples are first converted to phase, by using the normalizer block.

The demodulator block supports:

- Symbol demodulation using input phase samples at OSR=4:
- Time tracking to compensate for residual timing error and for timing drift
  - Given that the timing drift needs to cover a various range of use-cases, from a maximum packet length perspective, the range is configurable via registers
- Frequency error detection and compensation to compensate for residual frequency error

Each supported feature will be detailed in the sequel of this section. Figure 389 shows the corresponding block diagram.

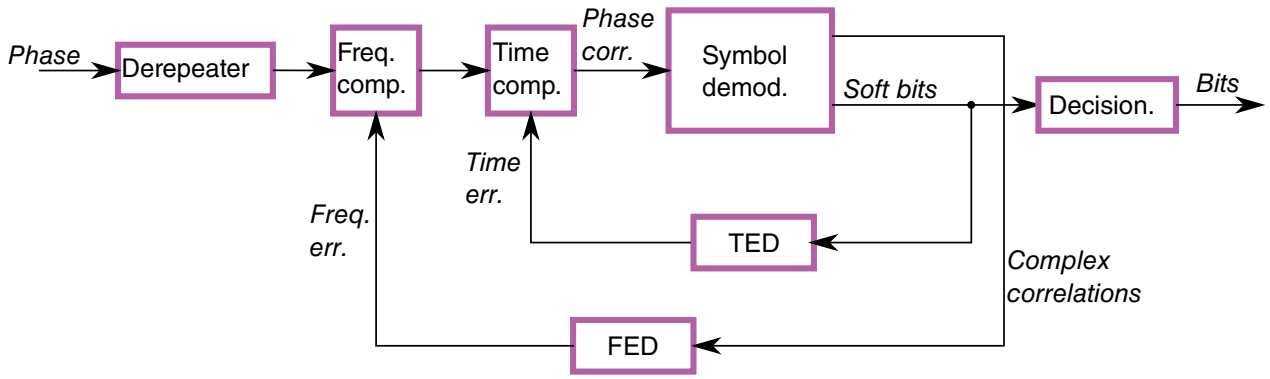


Figure 389. Demodulator block diagram

Symbol demodulation

The symbol demodulation mechanism will be referred to as M3c in the sequel. Figure 390 shows the block diagram of the symbol demodulator.

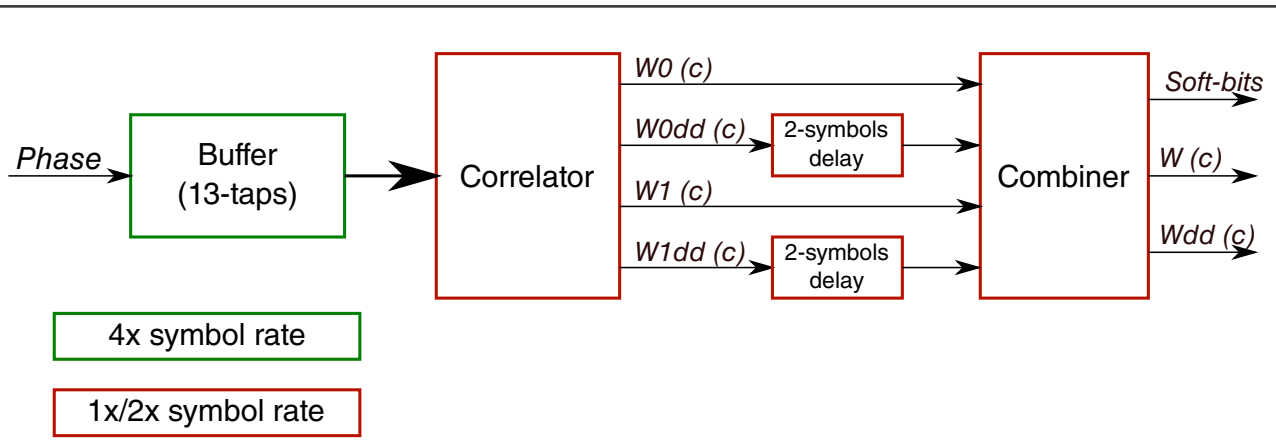


Figure 390. Symbol demodulator block diagram

From a correlation perspective, the symbol demodulator supports four modes:

- Mode 0: uses 12-taps (OSR in the adder tree is 4) and the reference phase vectors are shaped taking into consideration the modulation pulse and the receiver filtering
- Mode 1: uses 4-taps (OSR in the adder tree is 1) and no shaping is performed on the reference phase vectors
- Mode 2: uses 7-taps (OSR in the adder tree is 2) and no shaping is performed on the reference phase vectors
- Mode 4: uses 13-taps (OSR in the adder tree is 4) and no shaping is performed on the reference phase vectors

Some of the modes not only they provide a lower current drain in the correlation circuit but they can also provide a better performance.

Time/frequency error tracking

Following impairments need to be taken into consideration in the demodulator:

- Phase drift which is due to the residual carrier frequency offset, due to imperfect frequency synchronization in the acquisition block (initial frequency error)

- Crystal frequency drift which leads to carrier frequency offset accumulation over time (accumulated frequency error)
- Symbol timing residual error, due to imperfect time synchronization in the acquisition block (initial timing error)
- Timing drift due to misalignment of the frequency of the crystal at the transmitter and at the receiver (accumulated timing error)

The former two impairments are addressed through the frequency tracking mechanism whereas the latter two are handled by the timing tracking loop.

The frequency error tracking algorithm has two components: frequency error detection (FED) and frequency error correction (FED).

The most difficult use-case, from a frequency tracking perspective, is long range Bluetooth LE. This is because no frequency tracking is performed during the AA search. This means that there is a ~300 microseconds period between the moment when the CFO estimate is provided by the preamble detector and the start of the frequency tracking on the PDU portion. Long range Bluetooth LE 500 kbps is particularly affected due to the shorter duration of the informational symbol.

The timing error compensator provides:

1. integer compensation using a buffer
2. fractional compensation using a linear interpolator

The range of the timing error compensator is configurable and determines the latency of this block.

52.4.4.2.2.10.2.5 AA-confirmation block

The Bluetooth LE specification stipulates that a spec-compliant device be capable of detecting and rejecting a Bluetooth LE packet if the received AA is different from the desired AA even in only one bit position. But the AAD block requires a received power level which is at least 4-5 dB above sensitivity to fulfil this stipulation as it is a simple correlation-based detector. However, by using a symbol demodulator, a mechanism can be created to meet the stipulation even at 0.2 dB above sensitivity. The AA-confirmation block is a manifestation of such a mechanism.

52.4.4.2.2.10.2.5.1 Functional description

The AA-confirmation block may be used as a supplementary step with any of the three ACQ modes. It can be enabled/disabled using the parameter *dmd_aa_enable* (see Table 530 for a list of all the parameters used by this block) but will begin its operation only after a successful AA detection has occurred.

A block diagram of the AA-confirmation block is shown in Figure 391. If enabled and a successful AA detection is declared by the AAD block, the AA-confirmation block obtains the symbol timing and CFO estimates produced by the synchronization stage; and simultaneously, a buffer containing the recent history of incoming samples is frozen (or disabled). The buffer then holds all the samples required by the symbol demodulator for a successful demodulation of the AA bits.

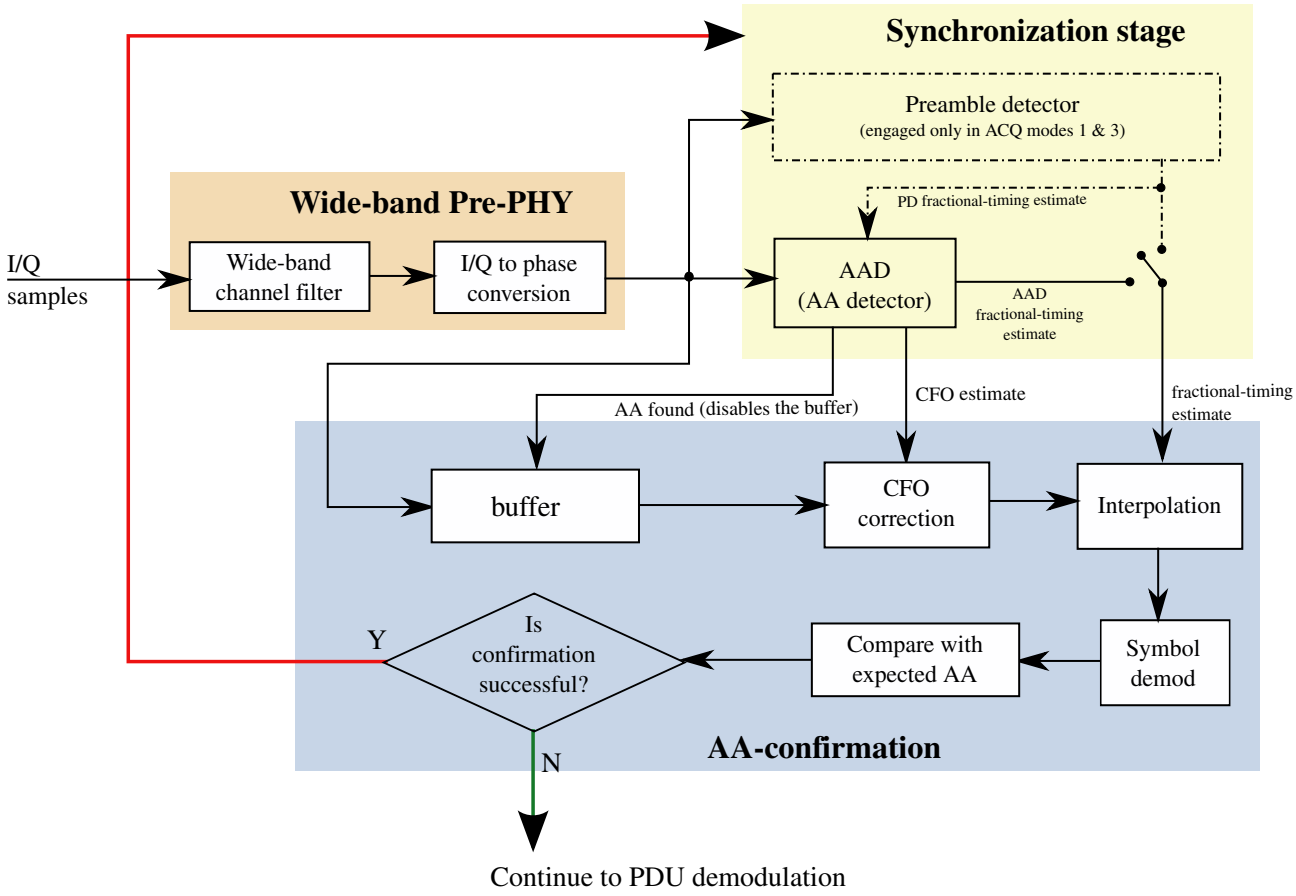


Figure 391. AA-confirmation functional block diagram

Next, the block begins operation by fetching successive samples from the frozen buffer and performs the following steps.

1. First, a CFO correction and timing interpolation is applied to compensate for the frequency offset and timing offset obtained from the synchronization stage.
2. The samples are then passed to a symbol demodulator which processes them and outputs one symbol decision for every *P* input samples.
3. The symbol decisions are then passed to a comparator which compares the demodulated sequence to the desired AA. If they match to within the Hamming distance specified, then AA-confirmation is declared successful and the PHY will continue with PDU demodulation; if not successful, then the AA-confirmation block sends a signal to the PHY state machine to resume acquisition.

52.4.4.2.2.10.2.5.2 Registers used by the AA-confirmation block

Table 530. AA-confirmation block parameters

Parameter	Notes
aa_0[31:0]	AA pattern of length 1, 2, 3 or 4 octets; 1, 2 and 3 octet patterns in bits [7:0], [15:0] and [23:0] respectively.
aa_1[31:0]	AA pattern of length 1, 2, 3 or 4 octets; 1, 2 and 3 octet patterns in bits [7:0], [15:0] and [23:0] respectively.

Table continues on the next page...

Table 530. AA-confirmation block parameters (continued)

Parameter	Notes
aa_2[31:0]	AA pattern of length 1, 2, 3 or 4 octets; 1, 2 and 3 octet patterns in bits [7:0], [15:0] and [23:0] respectively.
aa_3[31:0]	AA pattern of length 1, 2, 3 or 4 octets; 1, 2 and 3 octet patterns in bits [7:0], [15:0] and [23:0] respectively.
size_aa[1:0]	Indicates length of active AA's; 0→1 octet, 1→2 octets, 2→3 octets, 3→4 octets.
acq_mode[1:0]	Indicates the ACQ mode used for timing & frequency synchronization in non-coded use cases; 1→mode 1, 2→mode 2, 3→mode 3.
dmd_aa_enable	Enables demodulator-based AA-confirmation; 0→disable, 1→enable.
dmd_aa_hamming_high_pwr[2:0]	Hamming distance tolerance allowed at high power level during AA-confirmation; valid range is [0,7].
dmd_aa_hamming_low_pwr[2:0]	Hamming distance tolerance applicable around sensitivity and at low power levels during AA-confirmation; valid range is [0,7].
dmd_aa_hipow_disable_ovrd	Overrides the default disablement of AA-confirmation at high power levels; 0→no override, 1→override.

52.4.4.2.2.10.2.6 High accuracy RTT (round-trip time) block (HARTT)

The purpose of this block is to determine an accurate estimate of the timing information and also of the CFO, upon detection of an expected GFSK modulated bit pattern. From a detection perspective, it can be used in two possible cases:

1. Regular packets (i.e. packets that are composed of a preamble, an access address and a PDU)
2. RTT packets (i.e. packets that contain only a preamble and a 32 or a 64 bit PN sequence that does not bear any information bits)

The CFO is directly estimated by the HARTT block. On the other hand, from a timing estimation perspective, the time-stamp is not directly determined by the HARTT block. Squared correlation magnitudes around the peak of the main lobe are instead provided to the application, which needs to further use this information to compute the accurate timing.

52.4.4.2.2.10.2.6.1 Block description

52.4.4.2.2.10.2.6.1.1 Introduction

In principle, the HARTT block re-uses the arithmetic from the AA detection blocks in the acquisition module. The main difference is that it has a much lower duty-cycle (to save power) and a much higher resolution on the fixed-point formats (to achieve increased time/frequency accuracy). The expected accuracy is <2 ns for the timing estimation and <600 Hz for the CFO. The operation is triggered by an AA found event, provided by the AA detector in the acquisition block. A re-evaluation of the correlation peak is performed, assuming that the peak may not have been correctly detected during acquisition.

52.4.4.2.2.10.2.6.1.2 I/Os and settings

Note that all the outputs in the input/output signals table are packed in a 31-bit result (rtt_data[30:0]) and provided to the system memory via DMA. The results provided to software are sents as {rtt_data[30:0],1'b1} if a valid RTT pattern was detected and as{rtt_data[30:0],1'b0} when a valid RTT pattern is not detected in the expected time-slot.

Table 531. Input/output signals

Signal name	Type	Dimension	Description
fm_buffer[7:0]	I	134	The content of the FM buffer shared between acquisition and HARTT

Table continues on the next page...

Table 531. Input/output signals (continued)

Signal name	Type	Dimension	Description
rtt_bits	I	64	The bit sequence which is expected by the HARTT block when *overrd_progr_aa* is true
progr_aa	I	32	The AA programmed for the AA0 detector in the acquisition module
aa_found	I	1	Flag that indicates that AA was found in the AA0 detector
cfo_est[9:0]	I	1	The CFO estimate computed by the AA0 detector
PDelta[9:0]	O	1	Difference between the squared correlation magnitude values, *pm-pp*, provided by the HARTT block (format is sfix10En9)
rtt_int_adj[1:0]	O	1	An integer adjustment of the timing which takes a value different of 0 when the early-late mechanism in the HARTT block chooses a peak different of the one chosen in the acquisition module (format is ufix2En0 and possible values are {-1,0,+1})
ham_rtt_dist_sat[1:0]	O	1	Computed Hamming distance saturated to 2 bits (ufix2)
ha_rtt_cfo[15:0]	O	1	The high accuracy CFO computed by the HARTT block through the CORDIC algorithm
ha_rtt_found	O	1	Flag that indicates that the HARTT operation is done and a valid PN pattern was detected

Table 532. HARTT parameters

Parameter	Description
en_hartt	Enables the HARTT block
overrd_progr_aa	Overrides the programmed AA with an input sequence, which is used as reference for both the AA detector and for the HARTT correlation
rtt_seq_len	Allows payload demodulation of channel sounding packets during RTT computation. 0 - no payload demodulation 1 - payload demodulation
first_pdu_bit	Allows providing to the HARTT block the value of the first bit of the PDU. This information is used to generate the HARTT correlator reference sequence when *overrd_progr_aa* is false
fm_ref_111[7:0]	Weight applied to the current symbol, in the HARTT correlation sequence, when both the adjacent bits are the same
fm_ref_110[7:0]	Weight applied to the current symbol, in the HARTT correlation sequence, when one of the adjacent bits is the same and the other one is different
fm_ref_010[7:0]	Weight applied to the current symbol, in the HARTT correlation sequence, when both the adjacent bits are different
ha_rtt_threshold[8:0]	Threshold used to compare p0 with in order to validate RTT found

52.4.4.2.2.10.2.6.1.3 Block diagram

Figure below shows the block diagram of the HARTT block, which has 4 main components:

- Control engine

- it is a state-machine which controls the behaviour of the correlator and of the combiner
- responsible of the generation of the enable/disable signal for the arithmetic
- it manages the generation of the reference sequences used by the correlator

- Correlator
  - responsible with computing the complex correlation values and the Hamming distances
  - the maximum supported correlation width is 32 bits
  - when the HARTT block is programmed to perform a 64-bit correlation, the correlator performs two 32-bits correlations
- Combiner
  - combines the results computed inside the correlator, when a 64-bits correlation is required
  - performs a peak selection based upon an early-late criterion
- IQ to phase conversion
  - determines the CFO using CORDIC algorithm

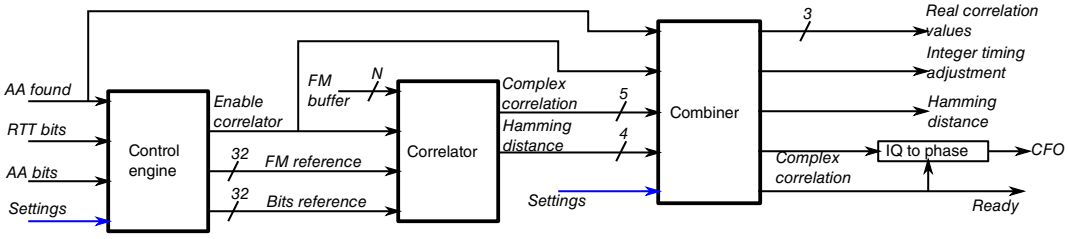


Figure 392. Block diagram

The "Ready" signal is asserted when the result is ready. One example of use of the HARTT block is to interface it with the RSM (ranging sequence manager) block which, when the "Ready" signal is asserted, manages the DMA transfer of the result, packed in a 32-bit word, to the packet RAM. When the HARTT block is used in conjunction with the RSM block, an interrupt is issued to soft-ware for every RSM step (RTT steps included).

More details about each component are provided in the following subsections.

52.4.4.2.2.10.2.6.1.3.1 Control engine

The state machine consists of 3 states. Two active states and an idle state. When the correlation width is 64 bits both the active states are being used. Otherwise only state 0 is necessary. During each active state, the correlator arithmetic is run for a 5 samples worth of time.

Besides the main states there are secondary states. Their purpose is, they represent transitional states which are meant for preparing the reference sequences or for wait periods. The most complex operation of the state machine is when a 64-bit correlation is required. In this case, after the first 32-bit correlation completes, the state machine manages the change of the reference sequence and also it manages the timing of the second 32-bit chunk correlation.

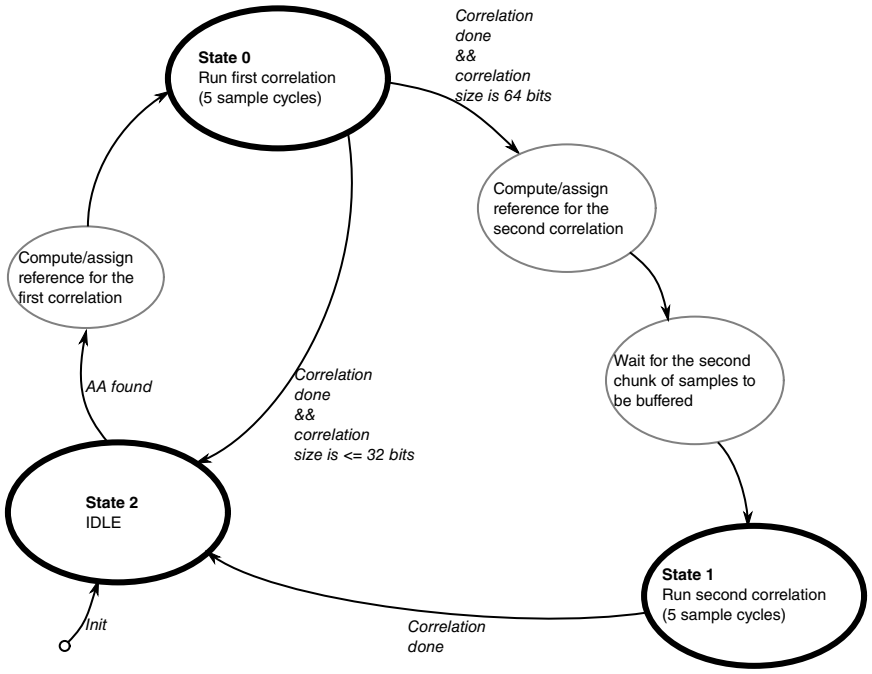


Figure 393. Control engine state-machine diagram

For each active state, an enable signal is sent to the correlator, which drives the computation of 5 complex correlation products at the PHY sampling rate. In order to compute the timing only 3 squared correlation magnitude values are required. However, 5 such values are being computed in order to be able to re-evaluate the position of the correlation peak. Computing 5 values allows moving the estimation of the peak timing by 1 sample at most.

The reference sequence used for correlation is computed by combining the reference symbols with the programmed FM weights. Table below shows an example of how the reference is being derived.

Table 533. Example of FM reference sequence computation

Bit	1	0	1	0	0	0	1	1	1
Bipolar symbol	+1	-1	+1	-1	-1	-1	+1	+1	+1
FM reference value	N/A	*-fm_ref_010*	*+fm_ref_010*	*-fm_ref_110*	*-fm_ref_111*	*-fm_ref_110*	*+fm_ref_110*	*+fm_ref_111*	N/A

A few comments on the reference waveforms:

- Reference values are the result of the multiplication between the bipolar symbols and the programmed weights
- Weights depend on the modulation scheme (more specifically they depend in the BT product and on the modulation index)
- Programmed reference values depend on the context
  - inter-symbol interference is considered negligible from symbols other than the immediate neighbours
  - in order to determine a certain value both the preceding and the succeeding bits need to be known
  - for the reason on the bullet above the values are indeterminate for the first and the last columns of the table above
- When determining an FM reference sequence corresponding to *N* bits, actually (*N*+2) bits need to be known
  - means that the last bit of the preamble and the first bit of the PDU (for regular packets) or the first bit of the post-padding (for the RTT packets) need to be known

— the best timing estimation is obtained when the sequence to be searched for starts and ends with a transition (i.e. the last bit of the preamble is the inverse of the first bit of the searched sequence and the first bit of the PDU/post-padding is the inverse of the last bit of the searched sequence)

- If *N*=64 the correlator needs to perform 2 correlation products of 32-bit width - the correct provisioning of the FM reference sequences, corresponding to the first and the second half, are managed by the control engine

Table below shows an example of FM reference values that correspond to BT=0.5/h=0.5 (RTT 1 Mbps) and BT=2/h=0.5 (RTT 2 Mbps).

Table 534. FM reference values for BT=0.5 / h=0.5

	fm_ref_111	*fm_ref_110*	*fm_ref_010*
Real value [rad]	*π*/2	1.22	0.88
Fixed point value [normalized]	0.5	0.387	0.281
Fixed point value [hex]	0x80	0x63	0x48

Table 535. FM reference values for BT=2 / h=0.5

	fm_ref_111	*fm_ref_110*	*fm_ref_010*
Real value [rad]	*π*/2	1.4	1.2
Fixed point value [normalized]	0.5	0.445	0.382
Fixed point value [hex]	0x80	0x72	0x61

52.4.4.2.2.10.2.6.1.3.2 Correlator

This sub-block is responsible with computing the complex correlation values and the Hamming distance. It is implemented in a similar fashion as the adder tree in the acquisition AA detectors. The difference is that more resolution is provided to the correlator taps in order to obtain a better timing accuracy.

52.4.4.2.2.10.2.6.1.3.3 Combiner

This sub-block is responsible with combining the complex correlation and Hamming distance computation results when a 64-bit correlation is required. It is also responsible with the re-evaluation of the correlation peak. The figure below shows a flowchart diagram of the combiner.

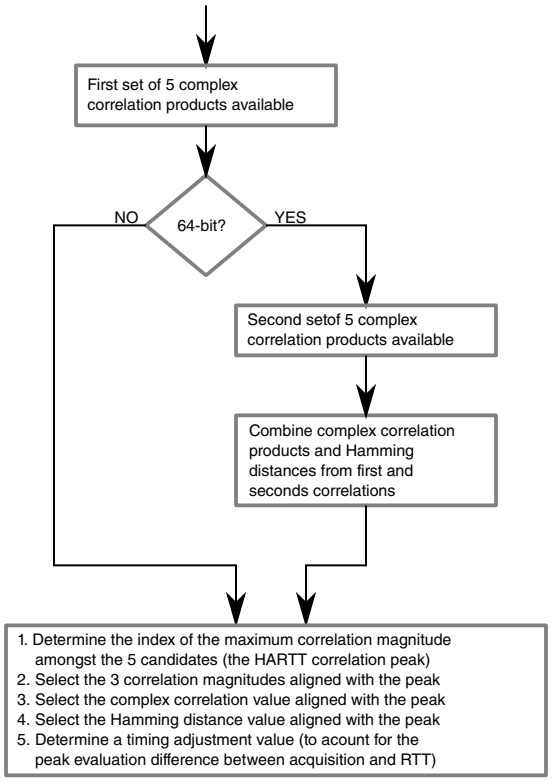


Figure 394. Combiner operation flowchart

The complex magnitude outputted by the combiner is further used by the CFO estimation algorithm.

52.4.4.2.2.10.2.6.1.3.4 Accurate CFO estimation

For a detailed description of the CFO estimation via CORDIC algorithm please consult the "Radio Frequency Fingerprinting (Fine CFO estimation)" section of the current chapter.

52.4.4.2.2.10.2.6.2 Integration considerations

As mentioned in the block description there are a few signals provided by the acquisition AA0 detector to the HARTT block. *aa_found* provides the timing reference and triggers the operation of the HARTT block. *cfo_est* is used by the Hamming distance computation for the FM symbols demodulation. Regarding the settings of the AA0 detector, when *overrd_progr_aa* is true the programmed AA is overwritten by the first half of the *rtt_bits* signal and the programmed AA length (a.k.a. SFD length) is overwritten by value 3 (which is the value corresponding to 32-bits).

Impact on other blocks in the PHY is described in the sequel.

52.4.4.2.2.10.2.6.2.1 Integration with the AA Hamming confirmation block

The purpose of the Hamming confirmation block is to provide a more reliable assessment on the Hamming distance than the one provided by the AA detectors in the acquisition module. When enabled, the operation of the AA Hamming confirmation block is triggered following the assertion of *aa_found*. After a while the AA detection is either confirmed or disconfirmed. When *overrd_progr_aa* is true, the programmed AA used by the AA Hamming confirmation block is overwritten by the first half of the *rtt_bits* signal.

When the operation of the confirmation block is enabled, the *ha_rtt_ready* indication from the HARTT is qualified by the AA confirmation event, which results in *ha_rtt_vld* signal.

52.4.4.2.2.10.2.6.2.2 Integration with the PHY state-machine

In order to support the reception of RTT packets (which have no PDU) a dedicated state is defined in the PHY state-machine, called RTT state. If *overrd_progr_aa* is true, the PHY SM transitions to the RTT state after AA is detected and confirmed.

RTT state is responsible to providing the control signals to all the blocks in the PHY, after an RTT packet is detected.

52.4.4.2.2.10.2.6.3 Computation of the fractional timing (intended for the application)

The time-stamps, used for the round-trip time computation, are locally determined by the application using the information from HARTT. It has two components:

- an integer component, computed by combining the timing of "AA detection" event (issued by the radio) with the *rtt_int_adj* value provided by HARTT
- a fractional component, computed using the 3 values contained in the *pm_pp_p0* result provided by the HARTT block

While the determination of the integer part is trivial, the computation of the fractional timing is not. The latter is addressed in the current section.

A few consideration on the main correlation lobe:

- When the data is oversampled it can be approximated by a sinc function
- A property of the sinc function is that peak of the sinc function can be estimated as $p=k*(\alpha-\gamma)$
  - where α and γ are the correlation output samples (squared correlation magnitudes) before and after the peak
  - p is the deviation from the center of the main lobe
  - α and γ are computed by the HARTT block and reported in the *pm_p0_pp* result (they represent the first and the last value of the result)
  - from now on the following notation will be used $\delta=(\alpha-\gamma)$
- k depends on the bit-sequence used for correlation
  - for RTT packets the sequence is randomly generated so it doesn't have to respect strict rules
  - there is a lot of variability of the used sequences leading to variability of k
  - flatter the main lobe larger the required k - sequences close to all-ones or all-zeros lead to very flat lobes
  - some sequences may have a periodical structure which leads to lobe smearing

52.4.4.2.2.10.2.6.3.1 Modelling of the fractional delay

Modelling of p (which is the fractional delay) as a first order polynomial was not satisfactory. Indeed a third order polynomial is used. In this case, k is replaced by a vector of 3 elements and the equation becomes:

$p=k_1*\delta+k_2*\delta^2+k_3*\delta^3$

Usually only the first and the third order terms are significant in the equation above. The coefficients k_1, k_2 and k_3 are related to the structure of the correlation sequence and they are computed for each sequence separately. Different sequences with similar properties will map on the same set of coefficients.

52.4.4.2.2.10.2.6.3.2 Dependence of the coefficients on the correlation sequence

More specifically, k_1, k_2 and k_3 depend on the context of each composing bit. To formalize this, the following notations are used for a certain sequence:

- c_{010} - count of the bits having both the adjacent neighbours logically inverted
- c_{011} - count of the bits having one of the adjacent neighbours logically inverted
- c_{111} - count of the bits having none of the adjacent neighbours logically inverted

The relation between the coefficients and the count consists in a third order polynomial. This is formalized in the equation below:

$[k_1, k_2, k_3]=[c_{010}, c_{011}, c_{111}, c_{010}^2, c_{011}^2, c_{111}^2, c_{010}^3, c_{011}^3, c_{111}^3]*\Gamma$

where Γ is the 9x3 transformation matrix.

This transformation is very useful because it greatly reduces the storage requirements. It also slightly increases the computation requirements because, first, the counts need to be determined for each sequence and second a multiplication is required to determine k_1, k_2 and k_3. **Γ** is unique for all possible sequences and it depends on the modulation scheme (modulation index - BT combination). Matrix **Γ** is pre-determined using intensive simulations and it is made available to the application from memory.

52.4.4.2.2.10.2.6.3.2.1 Γ matrix values for *N*=32, *R*=1 Mbps (h=0.5 / BT=0.5)

0.134045	-0.01074	-1.50855
-0.0689	0.084502	3.240881
0.140553	-0.0119	-0.9309
-0.00192	-0.00165	0.02838
0.00597	-0.00568	-0.18365
6.15E-05	-0.00107	0.016142
8.73E-06	8.06E-05	0.000279
-7.48E-05	9.96E-05	0.002691
0.000147	5.57E-05	-0.00151

52.4.4.2.2.10.2.6.3.2.2 Γ matrix values for *N*=32, *R*=2 Mbps (h=0.5 / BT=2)

0.049461	0.027639	-0.35573
0.023867	-0.03173	0.578603
0.083292	0.000394	-0.06136
-3.83E-05	-0.0017	0.010247
0.001268	0.001771	-0.0328
1.61E-03	0.001144	-0.02035
-3.67E-06	4.09E-05	-4.87E-05
-2.20E-05	-2.49E-05	0.000476
6.18E-05	-3.92E-05	0.000372

52.4.4.2.2.10.2.6.3.2.3 Γ matrix values for *N*=64, *R*=1 Mbps (h=0.5 / BT = 0.5)

0.065958	0.001162	-0.7422
-0.04655	0.011012	2.207578
0.068705	0.007808	-0.14743
-4.64E-04	-0.00057	0.004103
0.002112	-9.60E-05	-0.07448
3.05E-04	-0.001	-0.02855
3.53E-06	1.25E-05	4.53E-06

Table continues on the next page...

Table continued from the previous page...

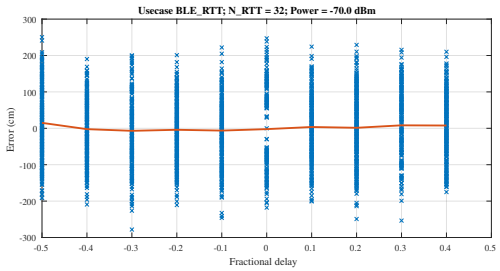
-1.73E-05	-3.72E-06	0.000684
1.07E-05	2.17E-05	0.000561

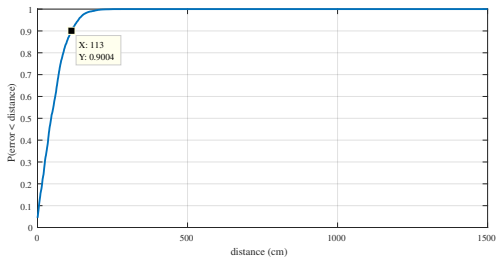
52.4.4.2.2.10.2.6.3.2.4 Γ matrix values for *N*=64, *R*=2 Mbps (h=0.5 / BT=2)

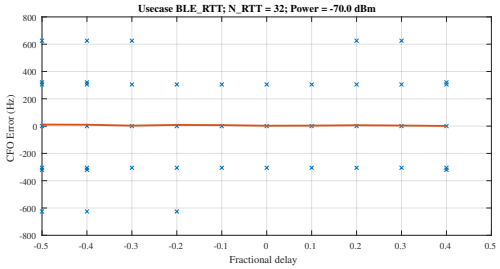
0.02593	-0.02971	-0.32042
0.007891	0.013627	0.634331
0.049023	0.005655	-0.13215
-3.35E-05	0.00173	0.007166
0.000397	-3.68E-04	-0.02022
-3.76E-05	-0.00047	-0.00146
4.63E-07	-3.24E-05	-9.79E-05
-3.06E-06	3.01E-06	0.000178
1.66E-05	1.27E-05	-5.94E-05

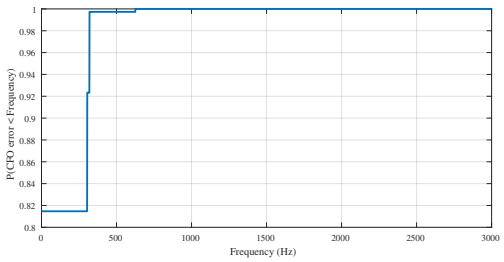
52.4.4.2.2.10.2.6.3.3 RTT block timing/frequency accuracy at hight SNR

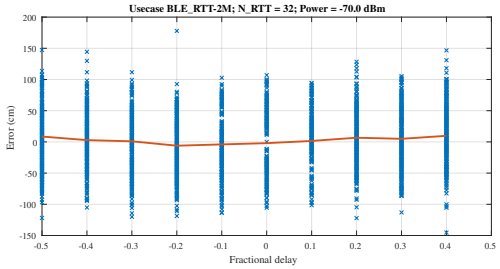
In the figures below each blue "x" dot is the distance estimate corresponding to one RTT measurement. The red line corresponds to the averaging of all the measurements corresponding to a certain fractional delay (i.e. averaging all the dots on the vertical). To determine the red line, which is intended to show that there is no bias in the estimation, 100 distance estimates were used (i.e. 100 distance estimates per fractional delay value). The fractional delay reflects the timing uncertainty due to the sample clock which is 4 MHz for 1Mbps and 8 MHz for 2Mbps. As an example, when the frequency of the sample clock is 4 MHz, a fractional delay of 0.25 corresponds to a timing delay of 0.25/(4 MHz) = 62.5 nanoseconds.

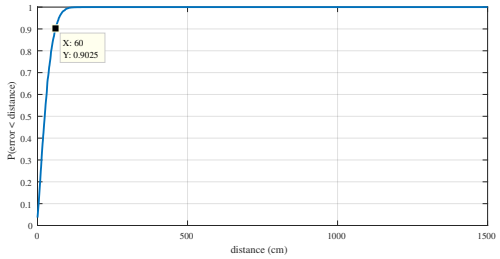


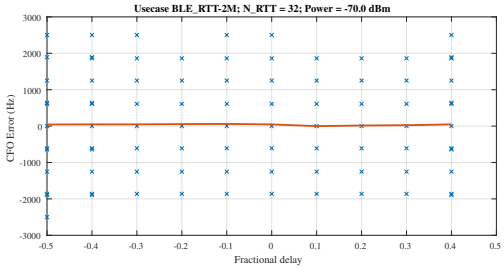


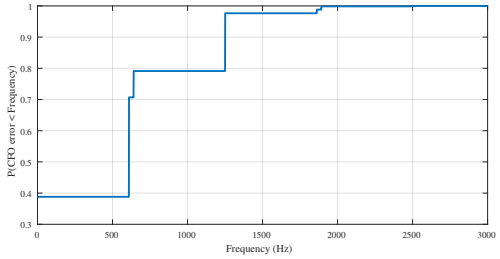


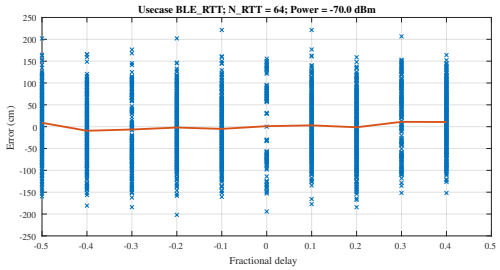


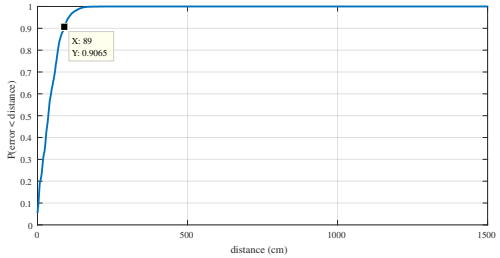

Usecase BLE_RTT-2M; N_RTT = 32; Power = -70.0 dBm
Error (cm)
Fractional delay

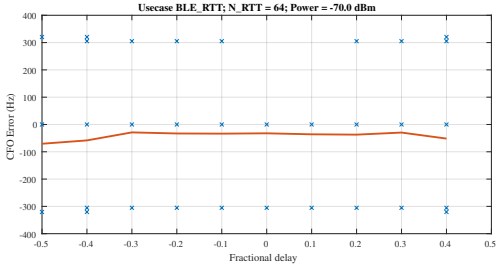

X: 60
Y: 0.9025
P(error < distance)
distance (cm)

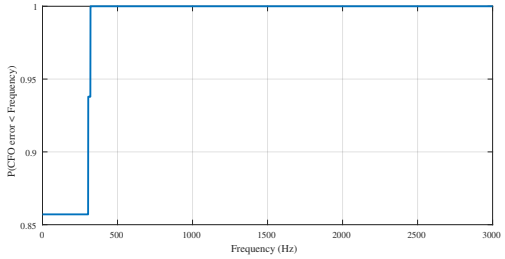

Usecase BLE_RTT-2M; N_RTT = 32; Power = -70.0 dBm
CFO Error (Hz)
Fractional delay

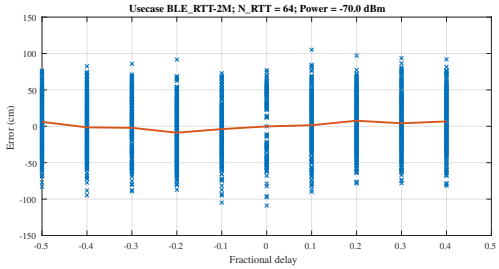

P(CFO error < Frequency)
Frequency (Hz)

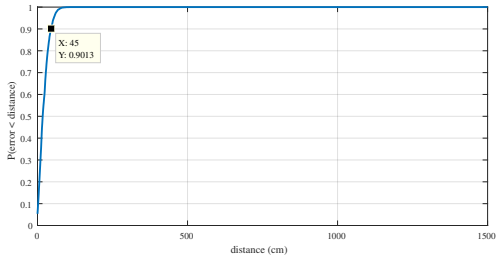

Usecase BLE_RTT; N_RTT = 64; Power = -70.0 dBm
Error (cm)
Fractional delay

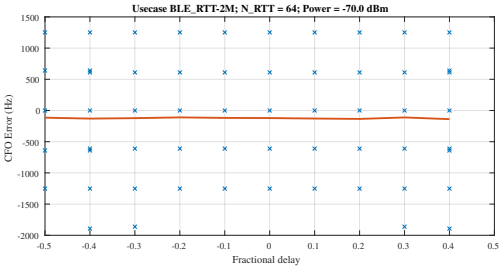

X: 89
Y: 0.9065
P(error < distance)
distance (cm)

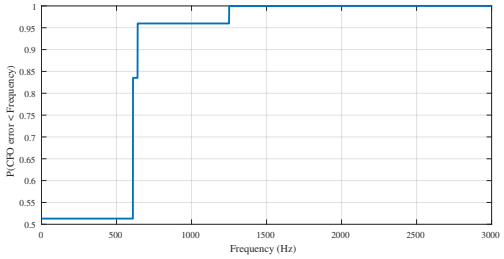

Usecase BLE_RTT; N_RTT = 64; Power = -70.0 dBm
CFO Error (Hz)
Fractional delay


P(CFO error < Frequency)
Frequency (Hz)

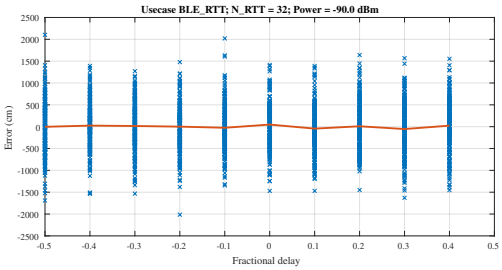


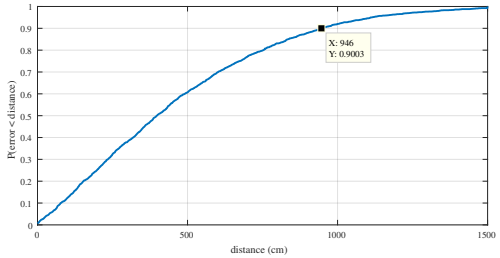


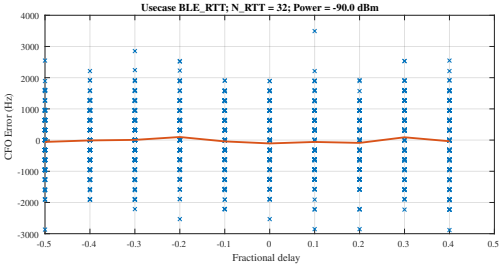


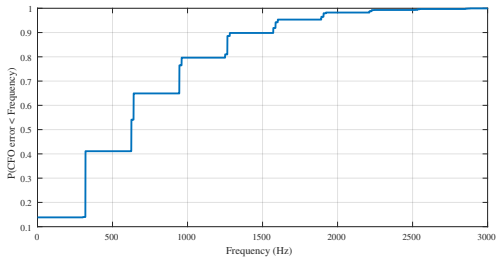


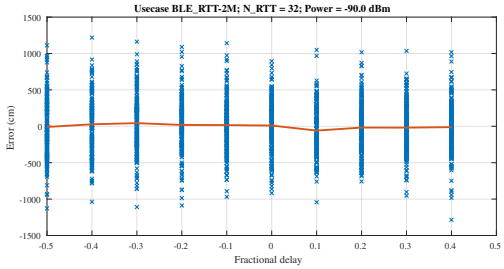
52.4.4.2.2.10.2.6.3.4 RTT block timing/frequency accuracy at low SNR

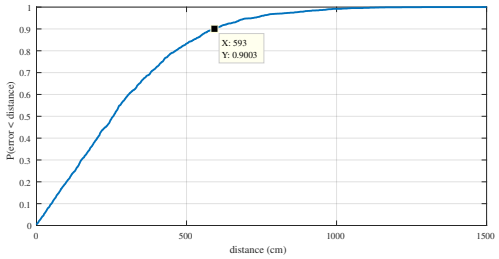


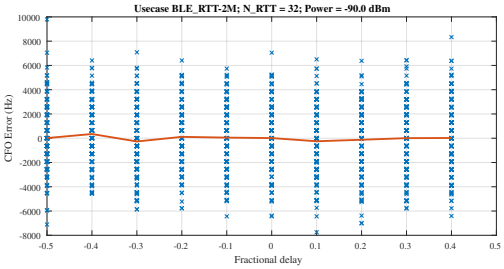


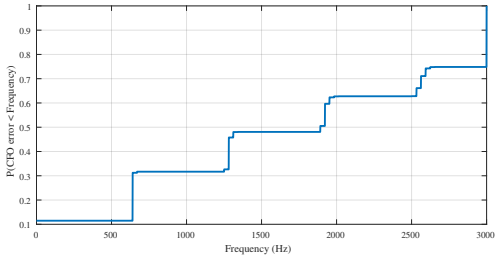


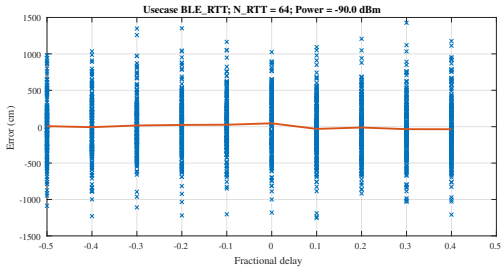


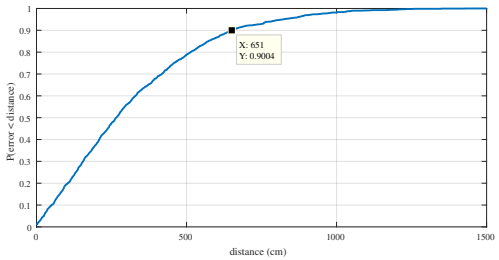

Usecase BLE_RTT-2M; N_RTT = 32; Power = -90.0 dBm
Error (cm)
Fractional delay

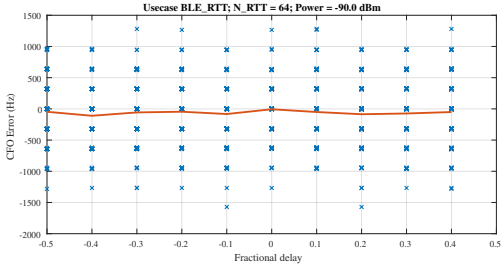

X: 593
Y: 0.9003
P(error < distance)
distance (cm)

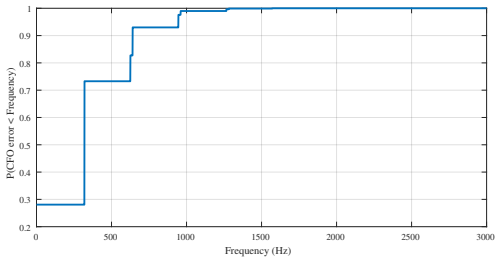

Usecase BLE_RTT-2M; N_RTT = 32; Power = -90.0 dBm
CFO Error (Hz)
Fractional delay

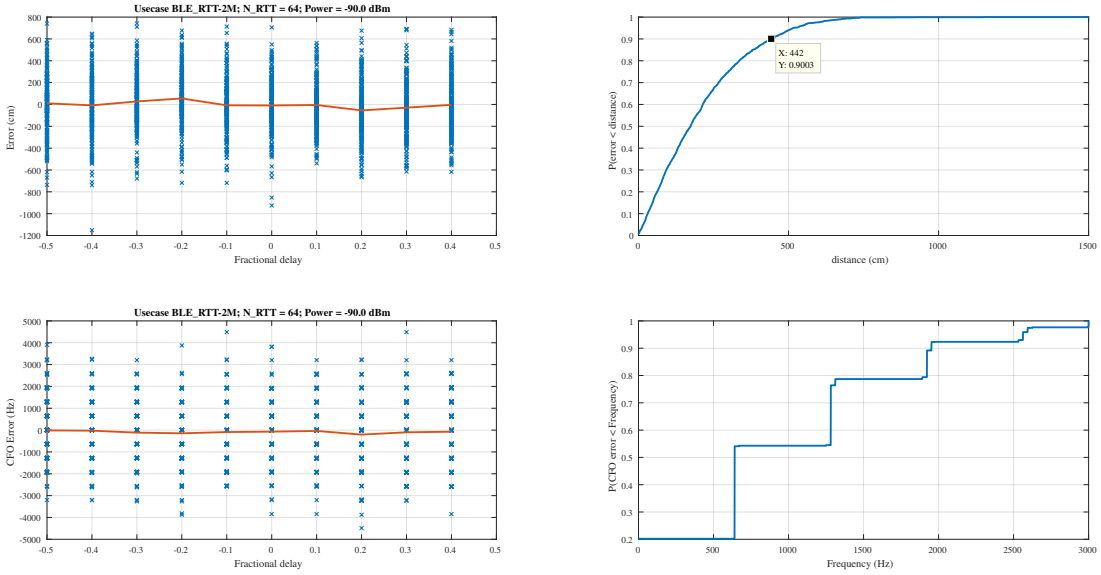

P(CFO error < Frequency)
Frequency (Hz)


Usecase BLE_RTT; N_RTT = 64; Power = -90.0 dBm
Error (cm)
Fractional delay


X: 651
Y: 0.9004
P(error < distance)
distance (cm)


Usecase BLE_RTT; N_RTT = 64; Power = -90.0 dBm
CFO Error (Hz)
Fractional delay


P(CFO error < Frequency)
Frequency (Hz)



52.4.4.2.2.10.2.6.4 Methodology for time-stamp determination

Following steps are required to determine the time-stamp for each transaction:

1. Determine the integer component of the time-stamp by capturing the "AA detection" event
2. Adjust the integer value using *rtt_int_adj* value provided in a HARTT status register (note that this value is expressed in PHY sampling rate cycles and it needs to be properly adjusted to the clock frequency)
3. Determine the [c_{010}, c_{011}, c_{111}] that correspond to the PN sequence used for the RTT transaction
4. Determine the [k_1, k_2, k_3] coefficients using the matrix transformation **Γ**
5. Compute the fractional delay using relation $p=k_1*\delta+k_2*\delta^2+k_3*\delta^3$ (δ is reported in the *PDelta* result)
6. Compute the final time-stamp combining the integer and the fractional components (note that the fractional value is expressed in PHY sampling rate cycles and it needs to be properly adjusted to the clock frequency)

52.4.4.2.2.10.2.6.5 Considerations for the choice of AA patterns

In order to get an accurate RTT estimation the AA pattern must have good autocorrelation properties and a controllable ISI at the beginning and at the end of the over-the-air transmitted waveform. In order to achieve that there are a few measures that can be taken:

- Make sure that there is a transition between the bit preceding the AA pattern and the first bit of AA
- Make sure that there is a transition between the last bit of AA and the first bit that follows after
- Use a scoring mechanism to select AA with good correlation properties
- Take into account the flatness of the main correlation lobe

The BLE protocol already imposes a transition between the last bit of the preamble and the first bit of the AA. For HADM RTT packets a rule was put in place to insure a transition at the end of the AA by defining 4 trailing bits that look like the preamble. However, for legacy packets the AA has to be chosen such that its' last bit is the complement of the first bit of the PDU transmitted over the air. It is important to keep in mind that, if FEC is used (e.g. whitening), the first OTA bit may not be the protocol bit. So, when choosing the AA pattern, the application has to have knowledge of the first protocol bit and the FEC operation that this bit may be subject to.

The BLE AA generation rules are not used in HADM because they can degrade the entropy and reduce security. This is why a scoring mechanism is required, to achieve a tradeoff between security and correlation properties. The score is computed by summing up the bit autocorrelation of the AA pattern in the vicinity of the main lobe. In HADM, at each RTT transaction, two AA patterns are computed and the one with the best score is used. An alternative would use an AA pattern that has a score less or equal than a threshold. The methodology of computing the score is given in the code below:

```
C = zeros(depth,1);
N = length(aa_pattern);
for m = 1:depth
C(m) = 2*sum(mod(aa_pattern(1:N-m)+aa_pattern((1+m):N),2)) - (N-m);
end
score = sum(abs(C));
```

The value for *depth* used by HADM is 3.

As previously shown in the current section it has been observed that the structure of the AA pattern influences the shape of the correlation (which is used to determine the ToF and thus the distance). To correlate the structure with the correlation a set of counts is being used. The flatness of the main lobe is mainly determined by c_{111}, i.e. higher this count flatter the main autocorrelation lobe. It was shown in this section how to compute the polynomial fit coefficients, depending on the counts, in order to get best accuracy. However, if the methodology presented here is not possible to implement, the AA with flat autocorrelation can be avoided by imposing a threshold for c_{111}.

As an example, for $depth$=3, the application can use only AAs for which $depth$<9 and c_{111}<8.

52.4.4.2.2.10.2.7 Operation

This section describes the 2.4GHz PHY module's operations.

52.4.4.2.2.10.2.7.1 PHY state-machine

The state-machine state diagram is depicted in Figure 395. As per the depiction in Scan mode three modes of operation are defined for the 2.4 GHz PHY:

- Non-coded FSK search: look only for non-coded packets, while keeping all the long range Bluetooth LE acquisition blocks disabled
- Long range Bluetooth LE search: search only for long range Bluetooth LE packets while keeping all the non-coded acquisition blocks disabled
- Simultaneous Non-coded and long range Bluetooth LE search: simultaneously look for long range Bluetooth LE and non-coded packets by enabling both long range and non-coded acquisition blocks

Note that the PHY block can simultaneously search for non-coded FSK packets and long range Bluetooth LE packets; however the only tested configurations are for simultaneous non-coded Bluetooth LE with long range Bluetooth LE.

The state-machine has 6 main states:

- State 0: Initialization state
  - Reset state used to recycle all the blocks in the PHY
- State 1: Acquisition state
  - Completely (for non-coded) or partially (for long range Bluetooth LE) responsible with time/frequency synchronization
    - More details about state1 are given in the sequel of this section
  - When the PHY is configured to perform simultaneous non-coded and long range Bluetooth LE search
    - Makes a decision whether to continue treating the packet as a non-coded or as a long range Bluetooth LE
- State 2: long range Bluetooth LE PD/AA

  - Only when a long range Bluetooth LE packet is detected
  - Responsible with the simultaneous LR preamble and AA search
  - It can only be entered following a long range Bluetooth LE preamble detection event
    - Keeps the preamble search to improve the CFO estimate
    - Extends the time used for the AA search process as required
- State 3: Long range Bluetooth LE AA/CI check
  - Only when a long range Bluetooth LE packet is detected
  - Tells the PHY and RBME to unpack the AA despread soft-bits
    - More details about these in the long range Bluetooth LE AA detection section
  - Turns on the Viterbi decoder
  - Looks for a match to the AA bits
  - Extracts the CI information
    - The CI is further used to configure RBME for PSDU decoding.
- State 4: Demodulation & Decoding
  - handles the PSDU demodulation and decoding for both non-coded and long range Bluetooth LE packets
- State 5: RTT state
  - This state is used for the RTT operation (for more details please consult the description of the RTT module)
  - This represents an idle state for the PHY to transition to when the reception of an RTT packets is done
  - PHY exists this state following a PHY reset issued at a higher level in the hierarchy
  - (Figures below don't show state 5 as this state is not representative for regular communication packets exchanges)

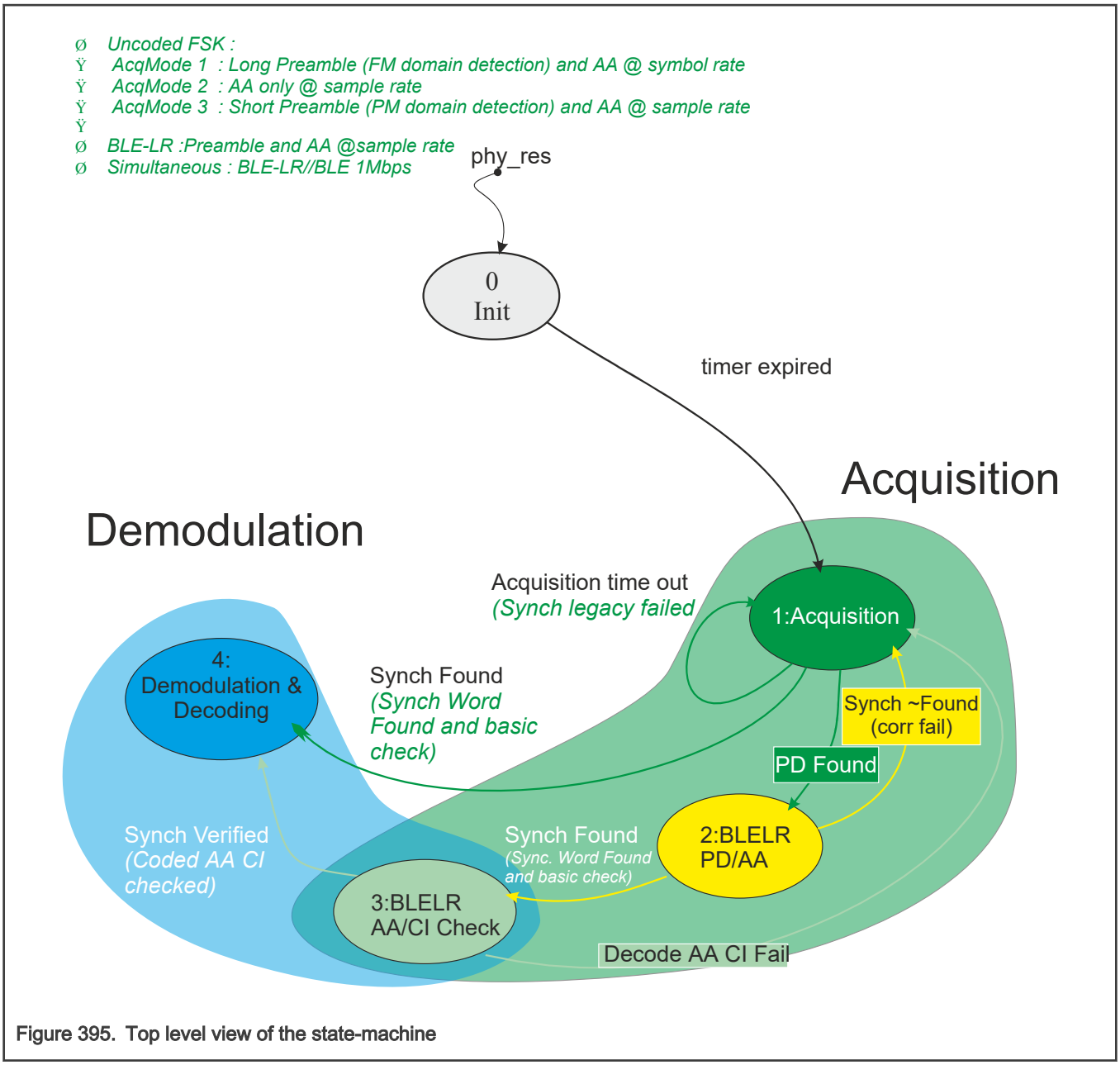


Figure 395. Top level view of the state-machine

A time out is used for the AA detection to allow for a prompt recovery. In long range and non-coded acquisition modes 1 and 3, AA detection runs in parallel with preamble detection in order to: 1) extend the AA search as needed and 2) to update the synchronization information. If neither a preamble detection nor an AA detection occur during the time-out period, the PHY state machine returns to the Acquisition state, disables AA detection and recycles all the PD block memory excepting the samples buffer.

Figure 395 illustrates two functions. The green areas are all about acquisition in a larger sense, meaning that all the processing concerning packets detection are associated to it and the blue region is about demodulation, responsible for PSDU processing and/or decoding in the RBME (Radio Bit Manipulation Engine).

For long range Bluetooth LE packets the preamble detection is responsible for packet acquisition and frequency synchronization (i.e. CFO estimation). Following a preamble found event: 1) the incoming samples are demodulated; 2) the resulting soft bits are correlated to the AA pattern; 3) finally, the correlation peak marks the location of the incoming frame and symbol timing is estimated. The soft-bits are now re-aligned to symbol timing and passed through the Viterbi decoder (State 2 of the SM) . The decoded bits are then matched to the AA pattern and the CI is extracted (State 3 of the SM) .

From a non-coded perspective as the depiction in Acquisition mode there are three acquisition modes:

- Acquisition mode 1
  - Both preamble and AA are used for packet detection and synchronization
  - The preamble detector detects the packet and synchronizes timing
  - Following a preamble detection, the AA is searched at the symbol rate
    - The AA detection outputs frequency and frame synchronization
  - This mode is suitable for packets that have long enough preambles (usually more than 6 octets)
- Acquisition mode 2
  - Only the AA is used for packet detection and time/frequency synchronization
  - This acquisition mode is suitable to be used when the packet being searched has a short preamble
- Acquisition mode 3
  - Both preamble and AA are used for packet detection and synchronization
  - The preamble detector is used merely to detect the presence of a packet
  - Following a preamble detection, the AA is searched at the sample rate
    - The AA detection outputs frequency synchronization and symbol/frame timing synchronization
  - This acquisition mode is
    - Suitable for packets which short preambles
    - Lowers power consumption and an earlier packet detection than mode 2

The figures below show detailed instantiations of the top-level state-machine, considering all the acquisition modes described earlier and all the operation modes. Figure 396 illustrates the state-machine instantiation for non-simultaneous non-coded acquisition modes or long range Bluetooth LE.

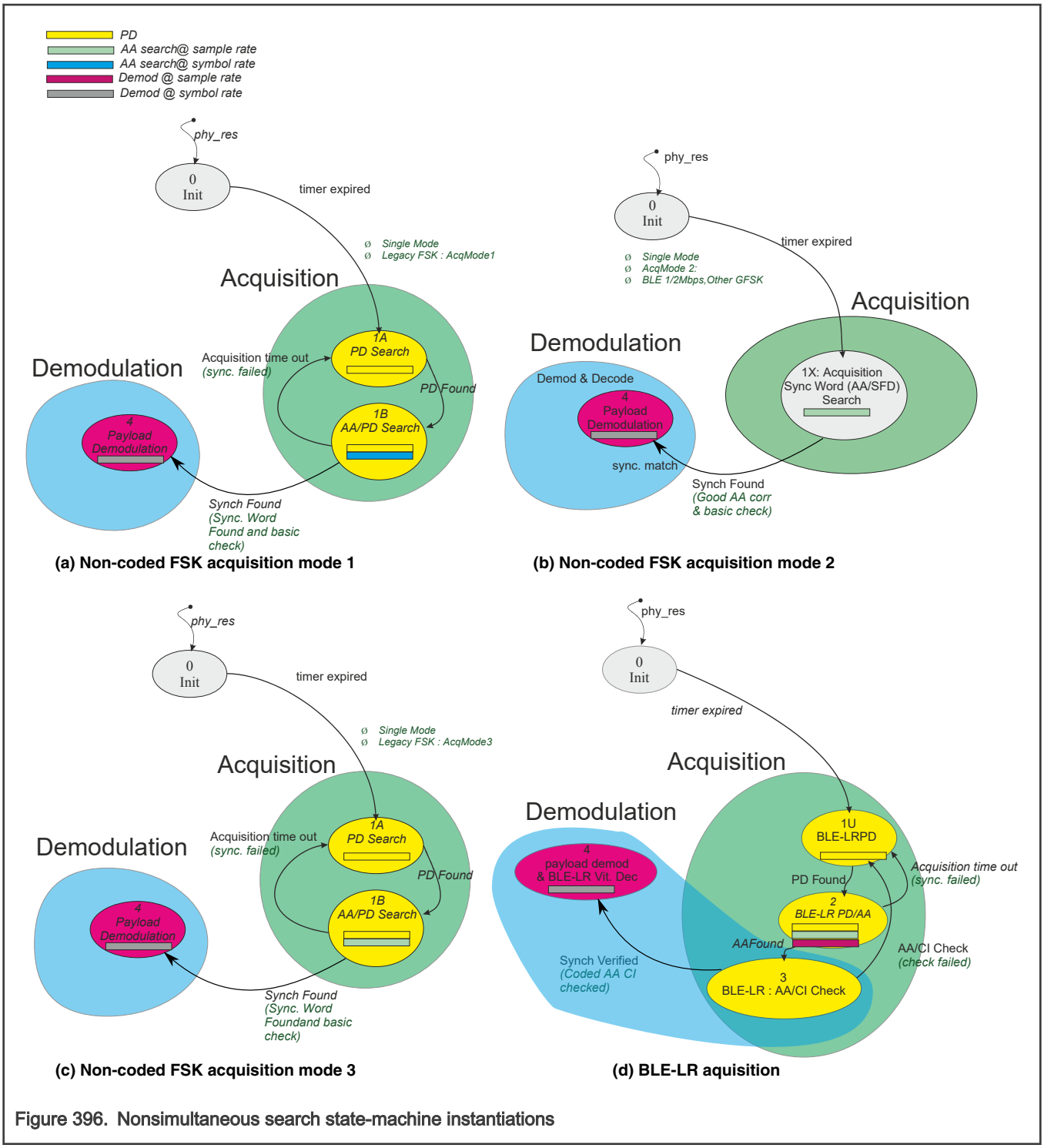
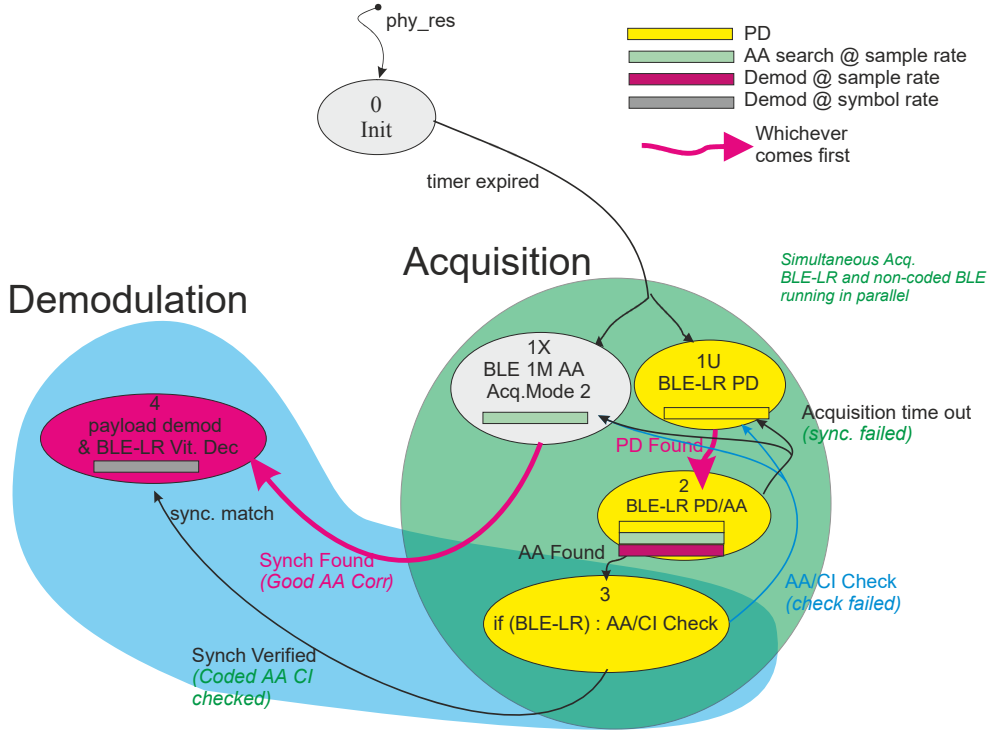
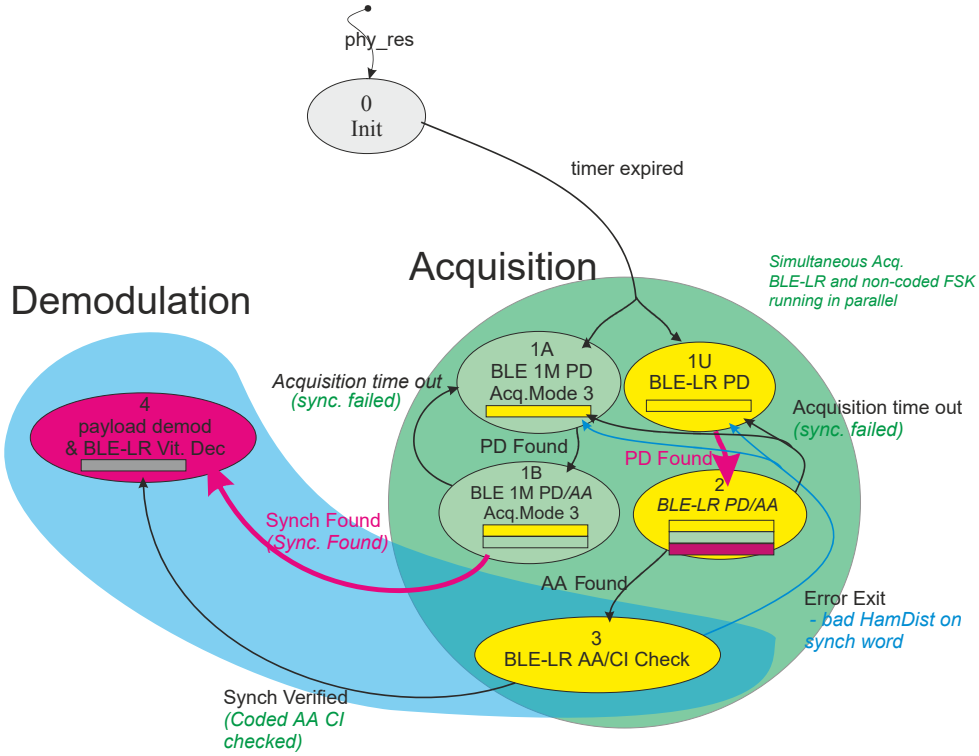


Figure 396. Nonsimultaneous search state-machine instantiations

The simultaneous search mode is intended for Bluetooth LE (non-coded or long range) packets. Since the non-coded Bluetooth LE packets have a one octet long preamble, only non-coded acquisition modes 2 and 3 are suitable for the simultaneous search. Figure 397 illustrates the instantiation of the state-machine for simultaneous search of long range Bluetooth LE and non-coded Bluetooth LE 1Mbps in acquisition modes 2 and 3.



(a) Simultaneous BLE-LR and non-coded BLE 1Mbps using acquisition mode 2



(b) Simultaneous BLE-LR and non-coded BLE 1Mbps using acquisition mode 3

Figure 397. Simultaneous search state-machine instantiations

Another aspect of the PHY state machine is the fast antenna diversity (FAD) preamble search feature. FAD is a mechanism that allows antenna selection on the fly. Two antennas and a single receiver chain are used, thus, the receiving chain is used in a time-shared manner. If a detection occurs, the current antenna is immediately selected. FAD involves using the preamble detection mechanism, i.e., one of the two antennas is selected when a preamble is first found. During the FAD process the receiver has to deal with blind spots due to transient behaviour of the different blocks on the receiver chain, so, the preamble must be fairly long to be able to support FAD. The minimal preamble length needed to support FAD depends on a series of factors:

- Receiver latency (without dynamic processes)
- Time required for dynamic control processes (in the sequel AGC only is considered)
- Number of samples needed by the preamble detector to reliably provide detection, timing and CFO estimate

From simulation it has been concluded that the preamble has to be at least 4 octets long. Due to the short preamble portions available for correlation, the FAD feature can only use the preamble detection engine used by acquisition mode 3 in a non-simultaneous search. Note that, the FAD state machine is coded in state 1A, in Figure 396, subfigure (c). A more detailed illustration of the FAD state-machine is provided in Figure 398.

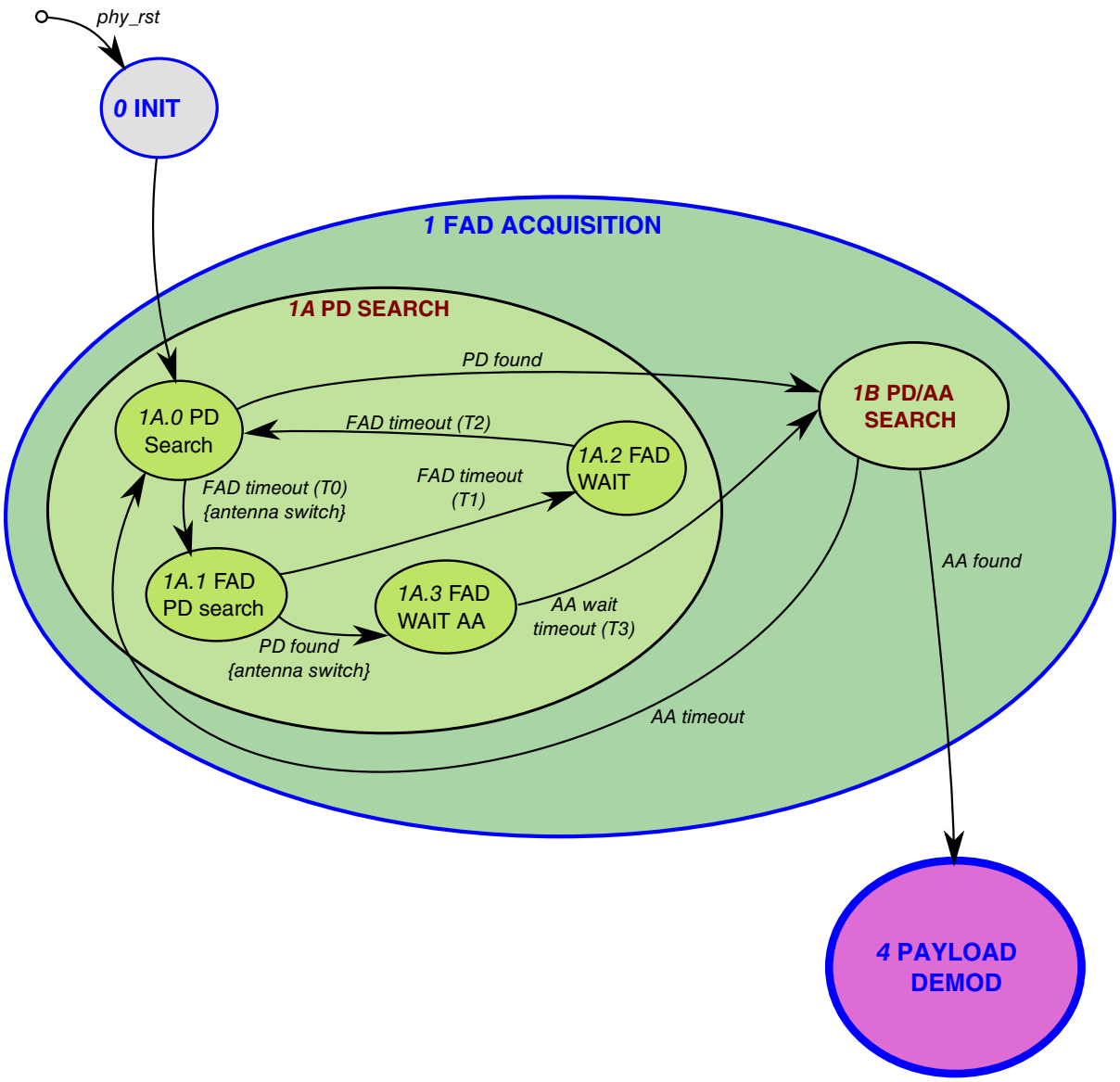


Figure 398. FAD detailed state-machine

The FAD states are:

- FAD sub-state 0 (PD Search)
  - Preamble detection over samples received from the currently selected antenna
    - Note that when the FAD is disabled in acquisition mode 3 this is the only attainable sub-state in "PD search"
- FAD sub-state 1 (FAD PD search)
  - Preamble detection over samples received from the previously selected antenna
    - Note that this is possible due to the propagation latency in the receiver
- FAD sub-state 2 (FAD wait)
  - The state machine waits for transients if a preamble pattern was not detected after antenna switch
- FAD sub-state 3 (FAD wait AA)
  - Before transitioning to AA search PHY state
  - The state machine waits for transients if a preamble pattern was detected after antenna switch

Time constants T_0, T_1 and T_2 from Figure 398 represent the dwell durations the FAD states having the same index and are illustrated in the time diagram from Figure 399. These values are configurable from registers. Figure 399 does not show T_3 because the antenna is not switched after the preamble is found so transition to the PHY state 1B occurs from FAD sub-state 0.

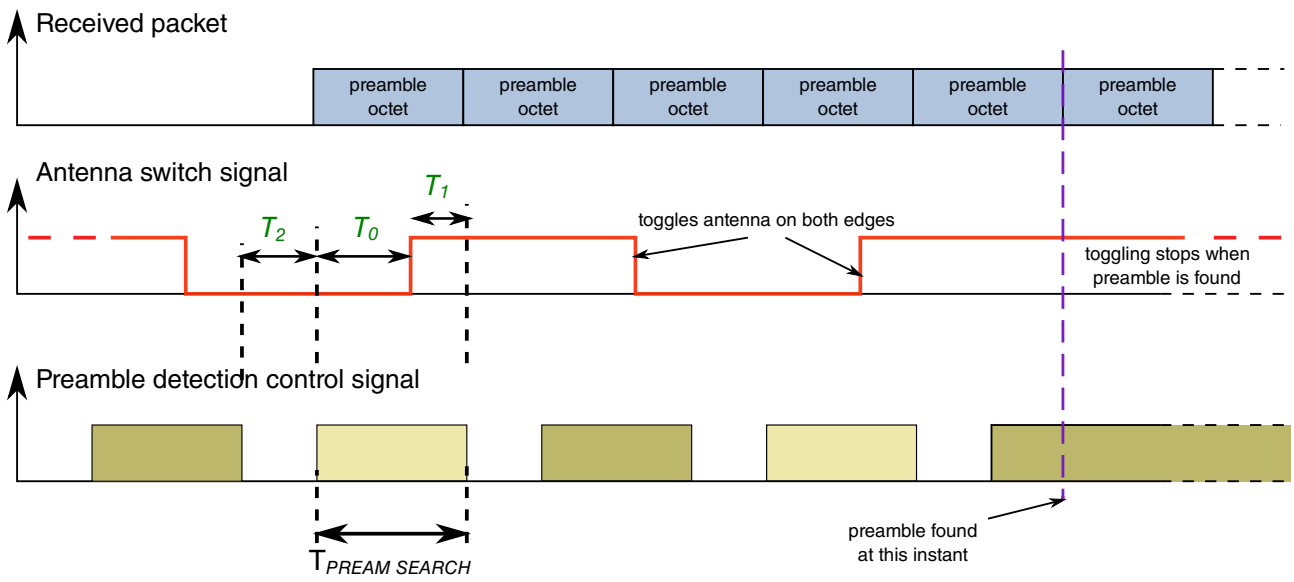


Figure 399. FAD process time diagram

Table 536 presents the recommended settings for FAD.

Table 536. Recommended parameters for FAD

Parameter name	Value
search_pd_window[6:0]	32
fad_search_pd_window[6:0]	12
fad_wait_pd_window[6:0]	12
fad_wait_synch_window[6:0]	12

52.4.4.2.2.10.2.8 Mode

This section describes all functional operation modes of the 2.4GHz PHY module.

52.4.4.2.2.10.2.8.1 Scan mode

Scan mode determines the way packets are being search for. As shown three modes of operation are defined for the 2.4 GHz PHY:

- Non-coded FSK search: look only for non-coded packets, while keeping all the Long range Bluetooth LE acquisition blocks disabled;
- Long range Bluetooth LE search: search only for long range Bluetooth LE packets while keeping all the non-coded acquisition blocks disabled;
- Simultaneous Non-coded and long range Bluetooth LE search: simultaneously look for long range and non-coded Bluetooth LE packets by enabling both long range and non-coded acquisition blocks.

Note that the PHY block is capable of performing simultaneous search of any non-code FSK use-case and long range Bluetooth LE but, from an use-cases perspective, this mode of operation is restricted to non-coded Bluetooth LE.

52.4.4.2.2.10.2.8.2 Acquisition mode

From a non-coded perspective there are three acquisition modes:

- Acquisition mode 1: both preamble and AA are used for packet detection and synchronization. The preamble detector is used to detect the packet and to realize symbol timing synchronization and, following a preamble detection, AA is being searched at symbol rate in order to get frequency and frame synchronization. This mode is suitable for packets that have long enough preambles (usually more than 6 octets) so that the symbol timing synchronization can be reliably realized;
- Acquisition mode 2: only the AA is used for packet detection and time/frequency synchronization. This acquisition mode is suitable to be used when the packet being searched has a short preamble;
- Acquisition mode 3: both preamble and AA are used for packet detection and synchronization. The preamble detector is used merely to detect the presence of a packet and, following a preamble detection, AA is being searched at sample rate in order to get frequency synchronization and symbol/frame timing synchronization. This acquisition mode is suitable for packets which short preamble, and it provides not only a lower power consumption but also an earlier packet presence indication than mode 2.

52.4.4.2.2.10.2.9 Interface

The PHY interacts with the system in a few distinct ways. The interfaces can be grouped into 5 categories: configuration, signal input, demodulation output, miscellaneous and debug.

52.4.4.2.2.10.2.9.1 PHY Configuration Interface

The PHY is configured by static signals that are observed and used throughout the receive process. It is important that these signals (typically originating from IP registers) remain static during a receive operation to avoid unpredictable behavior. Some examples of these types of configurations are PD thresholds, AA to search for, etc.

52.4.4.2.2.10.2.9.2 Signal Input Interface

The PHY processes the inputs signal from a set of signed, 6-bit phase inputs. There are three class of input data, wide band, narrow band, and raw IQ.

52.4.4.2.2.10.2.9.3 Demodulation Output

The demodulator produces soft bits in fixed-point format which are presented to the RBME block.

52.4.4.2.2.10.2.9.4 Miscellaneous

There are various other outputs from the PHY that are mostly intended for hand shake with other modules. A few significant signals are described here:

- Preamble found: indicates that Preamble was found.
- CFO estimate: Frequency offset as determined by the preamble detect engine.
- FRAC estimate: Fractional timing error estimate computed in the AA detector;
- Data rate:identified received data rate.
- AA found: indicates that an acceptable address synchronization has occurred.
- AA id: indicates which access address was found.
- corr flag: Indicates to the LQI calculator that the correlation magnitude, exceeds a specified threshold value.
- ant_out: indicates the requested antenna when FAD is enabled. May be ignored when FAD is not enabled.

52.4.4.2.2.10.2.9.5 Debug

There are various other outputs from the PHY that are mostly intended for debug. A few significant signals are described here:

- dtest_*: various outputs send to DTEST module, and then send to GPIO pin.
- phy_dma_mux: muxed one of five DMA data send to DMA module, then finally dumped to RAM

52.4.4.2.2.10.2.10 Clocking

This section describes clocks and special clocking requirements of the 2.4GHz PHY module.

Table 537. Clock signals

Signal name	Direction	Description
clk	input	32 or 26 MHz clock
vit_fast_clk_en	input	replace rx_adc_clkdiv2_vld, 8MHz for Gen4, 16MHz for Gen3.5
scan_enable	input	only used for clock gate bypass

52.4.4.2.2.10.2.11 Reset

This section describes how to reset the 2.4GHz PHY module and explains special requirements related to reset.

Table 538. Reset signals

Signal name	Direction	Description
ipg_hard_soft_reset_b	input	reset logic except regs
ipg_hard_async_reset_b	input	reset registers
phy_init	input	Soft reset to entire PHY
phy_ext_rst	input	L1_11 added, require at least one sample clock

52.4.4.2.2.10.2.12 Interrupts

This Module has no interrupts.

52.4.4.2.2.10.2.13 DMAs

This section describes all the DMAs that the 2.4GHz PHY module generates.

Table 539. DMA signal list

Page Name	Page description	Data valid used by DMA capture(as per model)	Signals names in (as per model)	Signal bit-width	data type	location in bus	Signals description
PHY_DMA_P0	Demodulator and frequency synchronization	PHY sample clock (PhySampClk)	Sb	7	sfix7_en4	[31:25]	Soft-bits
			Bits	1	bool	[24]	Demod. hard-bits
			Ferr	9	sfix9_en8	[23:15]	Freq. tracking err. estimate
			PhNb	6	sfix6_En5	[14:9]	Narrowband phase
			CfoEst	9	sifx9_en8	[8:0]	CFO estimate,can byte read [7:0] as sfix8_en8
PHY_DMA_P1	Demodulator and timing synchronization	Symbol valid (SymVld)	Sb	7	sfix7_en4	[31:25]	Soft-bits,wih [24]=1'b0, can byte read as sfix8_en5
			1'b0	1		[24]	reserved
			Terr	9	sfix9_en4	[23:15]	Timing tracking err. estimate
			Bits	1	bool	[14]	Demod. hard-bits
			3'b0	3		[13:11]	reserved
			Magnitude	11	ufix11_en11	[10:0]	RSSI Magnitude
PHY_DMA_P2	Un-coded acquisition	PHY sample clock (PhySampClk)	PhWb	6	sfix6_En5	[31:26]	Wideband phase
			CfoEst	10	sfix10_en9	[25:16]	CFO estimate of uncoded AA0
			Found SFD	1	bool	[15]	AA found
			Signal high	1	bool	[14]	High signal presence detection
			Signal present	1	bool	[13]	Low signal presence detection
			Pp	5	ufix5_en5	[12:8]	AA complex correlation magnitude
			1'b0	1		[7]	reserved
			Hamming Value	7	ufix7	[6:0]	AA Hamming distance,can byte read[7:0] as ufix8
PHY_DMA_P3	LR PD	PHY sample clock (PhySampClk)	mag	8	ufix8_en8	[31:24]	LR preamble correlation magnitude
			cfoC	9	sfix9_en8	[23:15]	LR preamble instantaneous CFO est.
			Cnt	3	ufix3	[14:12]	LR peaks above threshold count
			PDLR	2	ufix2	[11:10]	LR preamble found
			Cfo est.	10	sfix10_en9	[9:0]	LR CFO estimate,can byte read [7:0] as sfix8_en9, or word read [9:0] as sfix10_en9

Table continues on the next page...

Table 539. DMA signal list (continued)

Page Name	Page description	Data valid used by DMA capture(as per model)	Signals names in (as per model)	Signal bit-width	data type	location in bus	Signals description
PHY_DMA_P4	LR AAD	PHY sample clock (PhySampClk)	AACorr	11	sfix11_en1	[31:21]	LR AA correlation magnitude
			2'b0	2		[20:19]	reserved
			AAFndLR	1	bool	18	LR AA found
			AAFracLR[2:1]	2	sfix2_en1	[17:16]	LR fractional estimate
			AAHam	7	ufix7	[15:9]	LR AA Hamming distance
			AASbs	3	sfix3_en1	[8:6]	LR soft-bits used for corr. (from M2n)
			PhNb	6	sfix6_En5	[5:0]	Narrowband phase

52.4.4.2.2.10.3 External signals

This Module has no external signals.

52.4.4.2.2.10.4 Initialization

The PHY is initialized with the configuration required by the active link layer before performing any transmit or receive operations.

52.4.4.2.2.10.5 Application information

This section describes applications supported by the 2.4GHz PHY module.

One of the possible uses of the PHY module is the frames time/frequency synchronization and PDU bits demodulation corresponding to different protocols. As an example, the PHY module supports the packet reception for Bluetooth low energy uncoded (1Mbps and 2 Mbps) and long range (125 kbps and 500 kbps).

Another use of the PHY is the high accuracy time of flight estimation which is used for localization.

52.4.4.2.2.10.6 Register descriptions

This section includes the 2.4GHz PHY module memory map and detailed descriptions of all registers.

52.4.4.2.2.10.6.1 2.4GHz PHY REGISTERS register descriptions

52.4.4.2.2.10.6.1.1 IPR memory map

RADIO.XCVR_2P4GHz_PHY base address: 48A0_7600h

Offset	Register	Width (In bits)	Access	Reset value
0h	PHY Uncoded Preamble Detect Config 0 (FSK_PD_CFG0)	32	RW	0000_0000h
4h	PHY Uncoded Preamble Detect Config 1 (FSK_PD_CFG1)	32	RW	0000_0000h
8h	PHY Uncoded Preamble Detect Config 2 (FSK_PD_CFG2)	32	RW	0000_0000h
Ch	PHY Uncoded Preamble Detect Phase (FSK_PD_PH0)	32	RW	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
10h	PHY Uncoded Preamble Detect Phase (FSK_PD_PH1)	32	RW	0000_0000h
14h	PHY Uncoded Preamble Detect Read Only Phase (FSK_PD_RO_PH2)	32	R	0000_0000h
18h	PHY Uncoded Preamble Detect Read Only Phase (FSK_PD_RO_PH3)	32	R	0000_0000h
1Ch	PHY Uncoded Preamble Detect Read Only Phase (FSK_PD_RO_PH4)	32	R	0000_0000h
20h	PHY Uncoded Preamble Detect Read Only Phase (FSK_PD_RO_PH5)	32	R	0000_0000h
24h	PHY Uncoded Config 0 (FSK_CFG0)	32	RW	0000_0000h
28h	PHY Uncoded Config 1 (FSK_CFG1)	32	RW	0000_0000h
2Ch	PHY Uncoded Config 2 (FSK_CFG2)	32	RW	0000_0000h
34h	PHY Uncoded Power Threshold Config (FSK_PT)	32	RW	0000_0000h
38h	PHY Uncoded FAD Control (FSK_FAD_CTRL)	32	RW	0000_0000h
3Ch	PHY Uncoded FAD Config (FSK_FAD_CFG)	32	RW	0000_0000h
40h	PHY Uncoded Status (FSK_STAT)	32	R	0000_0000h
44h	PHY Long Range Preamble Detect Config (LR_PD_CFG)	32	RW	0000_0000h
48h	PHY Long Range Preamble Detect Phase 0 (LR_PD_PH0)	32	RW	0000_0000h
4Ch	PHY Long Range Preamble Detect Phase 1 (LR_PD_PH1)	32	RW	0000_0000h
50h	PHY Long Range Preamble Detect Phase 2 (LR_PD_PH2)	32	RW	0000_0000h
54h	PHY Long Range Preamble Detect Phase 3 (LR_PD_PH3)	32	RW	0000_0000h
58h	PHY Long Range Preamble Detect Read Only Phase 4 (LR_PD_RO_PH4)	32	R	0000_0000h
5Ch	PHY Long Range Preamble Detect Read Only Phase 5 (LR_PD_RO_PH5)	32	R	0000_0000h
60h	PHY Long Range Preamble Detect Read Only Phase 6 (LR_PD_RO_PH6)	32	R	0000_0000h
64h	PHY Long Range Preamble Detect Read Only Phase 7 (LR_PD_RO_PH7)	32	R	0000_0000h
68h	PHY Long Range Preamble Detect Read Only Phase 8 (LR_PD_RO_PH8)	32	R	0000_0000h
6Ch	PHY Long Range Preamble Detect Read Only Phase 9 (LR_PD_RO_PH9)	32	R	0000_0000h

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Offset	Register	Width (In bits)	Access	Reset value
70h	PHY Long Range Preamble Detect Read Only Phase 10 (LR_PD_RO_PH10)	32	R	0000_0000h
74h	PHY Long Range Preamble Detect Read Only Phase 11 (LR_PD_RO_PH11)	32	R	0000_0000h
78h	PHY Long Range Preamble Detect Read Only Phase 12 (LR_PD_RO_PH12)	32	R	0000_0000h
7Ch	PHY Long Range Preamble Detect Read Only Phase 13 (LR_PD_RO_PH13)	32	R	0000_0000h
80h	PHY Long Range Preamble Detect Read Only Phase 14 (LR_PD_RO_PH14)	32	R	0000_0000h
84h	PHY Long Range Preamble Detect Read Only Phase 15 (LR_PD_RO_PH15)	32	R	0000_0000h
88h	PHY Long Range Preamble Detect Read Only Phase 16 (LR_PD_RO_PH16)	32	R	0000_0000h
8Ch	PHY Long Range AA Config (LR_AA_CFG)	32	RW	0000_0000h
90h	PHY Long Range Status (LR_STAT)	32	R	0000_0000h
94h	PHY State Machine Config (SM_CFG)	32	RW	0000_0000h
98h	PHY Misc Config (MISC)	32	RW	0000_0000h
9Ch	PHY Status 0 (STAT0)	32	R	0000_0000h
A0h	PHY Status 1 (STAT1)	32	R	0000_0000h
A4h	PHY Status 2 (STAT2)	32	R	0000_0000h
A8h	PHY PrePHY Misc Config (PREPHY_MISC)	32	RW	0000_0000h
ACh	PHY Demodulator Control 0 (DMD_CTRL0)	32	RW	0000_0000h
B0h	PHY Demodulator Control 1 (DMD_CTRL1)	32	RW	0000_0000h
B4h	PHY Demodulator Control 2 (DMD_CTRL2)	32	RW	0000_0111h
B8h	PHY Demodulator Wave0 Register 0 (DMD_WAVE0_REG0)	32	RW	0000_0000h
BCh	PHY Demodulator Wave0 Register 1 (DMD_WAVE0_REG1)	32	RW	0000_0000h
C0h	PHY Demodulator Wave0 Register 2 (DMD_WAVE0_REG2)	32	RW	0000_0000h
C4h	PHY Demodulator Wave1 Register 0 (DMD_WAVE1_REG0)	32	RW	0000_0000h
C8h	PHY Demodulator Wave1 Register 1 (DMD_WAVE1_REG1)	32	RW	0000_0000h
CCh	PHY Demodulator Wave1 Register 2 (DMD_WAVE1_REG2)	32	RW	0000_0000h
D0h	PHY Demodulator Wave2 Register 0 (DMD_WAVE2_REG0)	32	RW	0000_0000h
D4h	PHY Demodulator Wave2 Register 1 (DMD_WAVE2_REG1)	32	RW	0000_0000h

Table continues on the next page...

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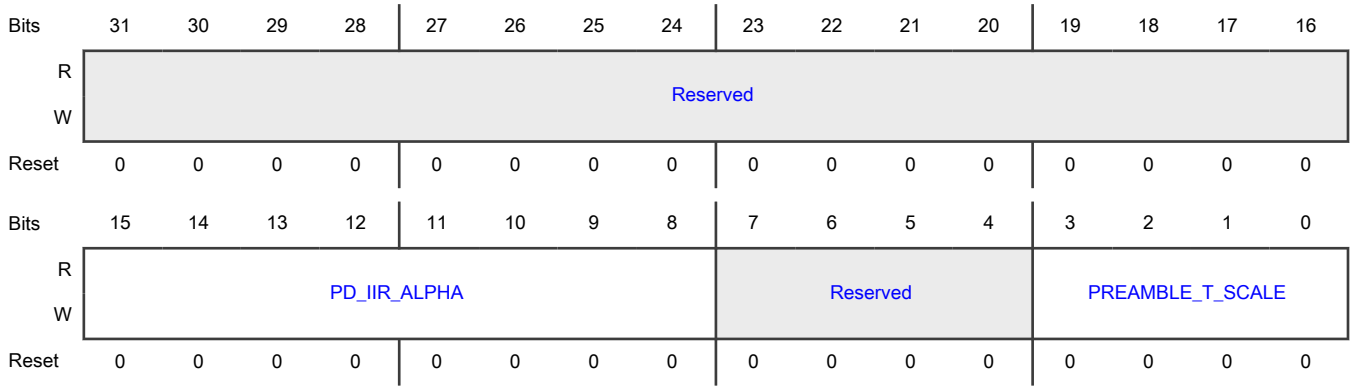
Offset	Register	Width (In bits)	Access	Reset value
D8h	PHY Demodulator Wave2 Register 2 (DMD_WAVE2_REG2)	32	RW	0000_0000h
DCh	PHY Demodulator Wave3 Register 0 (DMD_WAVE3_REG0)	32	RW	0000_0000h
E0h	PHY Demodulator Wave3 Register 1 (DMD_WAVE3_REG1)	32	RW	0000_0000h
E4h	PHY Demodulator Wave3 Register 2 (DMD_WAVE3_REG2)	32	RW	0000_0000h
E8h	PHY Demodulator Wave4 Register 0 (DMD_WAVE4_REG0)	32	RW	0000_0000h
ECh	PHY Demodulator Wave4 Register 1 (DMD_WAVE4_REG1)	32	RW	0000_0000h
F0h	PHY Demodulator Wave4 Register 2 (DMD_WAVE4_REG2)	32	RW	0000_0000h
F4h	PHY Demodulator Wave5 Register 0 (DMD_WAVE5_REG0)	32	RW	0000_0000h
F8h	PHY Demodulator Wave5 Register 1 (DMD_WAVE5_REG1)	32	RW	0000_0000h
FCh	PHY Demodulator Wave5 Register 2 (DMD_WAVE5_REG2)	32	RW	0000_0000h
100h	PHY Demodulator Wave6 Register 0 (DMD_WAVE6_REG0)	32	RW	0000_0000h
104h	PHY Demodulator Wave6 Register 1 (DMD_WAVE6_REG1)	32	RW	0000_0000h
108h	PHY Demodulator Wave6 Register 2 (DMD_WAVE6_REG2)	32	RW	0000_0000h
10Ch	PHY Demodulator Wave7 Register 0 (DMD_WAVE7_REG0)	32	RW	0000_0000h
110h	PHY Demodulator Wave7 Register 1 (DMD_WAVE7_REG1)	32	RW	0000_0000h
114h	PHY Demodulator Wave7 Register 2 (DMD_WAVE7_REG2)	32	RW	0000_0000h
164h	PHY Demodulator Based SFD Confirmation control register. (DMDAA_CTRL)	32	RW	0000_0009h
168h	High resolution Time-Of-Flight calculation Status. (RTT_STAT)	32	R	5401_0001h
16Ch	PHY RTT control register. (RTT_CTRL)	32	RW	0000_0000h
170h	PHY RTT reference register. (RTT_REF)	32	RW	0000_0000h

52.4.4.2.2.10.6.1.2 PHY Uncoded Preamble Detect Config 0 (FSK_PD_CFG0)

Offset

Register	Offset
FSK_PD_CFG0	0h

Diagram



Fields

Field	Function
31-16 —	Reserved
15-8 PD_IIR_ALPHA	Forgetting factor used by the complex correlations smoothing leaky integrator.
7-4 —	Reserved
3-0 PREAMBLE_T_SCALE	Scaling factor used for fractional time estimation during preamble search.

52.4.4.2.2.10.6.1.3 PHY Uncoded Preamble Detect Config 1 (FSK_PD_CFG1)

Offset

Register	Offset
FSK_PD_CFG1	4h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	Reserved															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	Reserved								PREAMBLE_PATTERN							
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-8 —	Reserved
7-0 PREAMBLE_PATTERN	8-bit preamble pattern used in FM-domain preamble detector.

52.4.4.2.2.10.6.1.4 PHY Uncoded Preamble Detect Config 2 (FSK_PD_CFG2)

Offset

Register	Offset
FSK_PD_CFG2	8h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	Reserved								PD_THRESH_ACQ_1_3_2M							
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	Reserved								PD_THRESH_ACQ_1_3_1M							
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

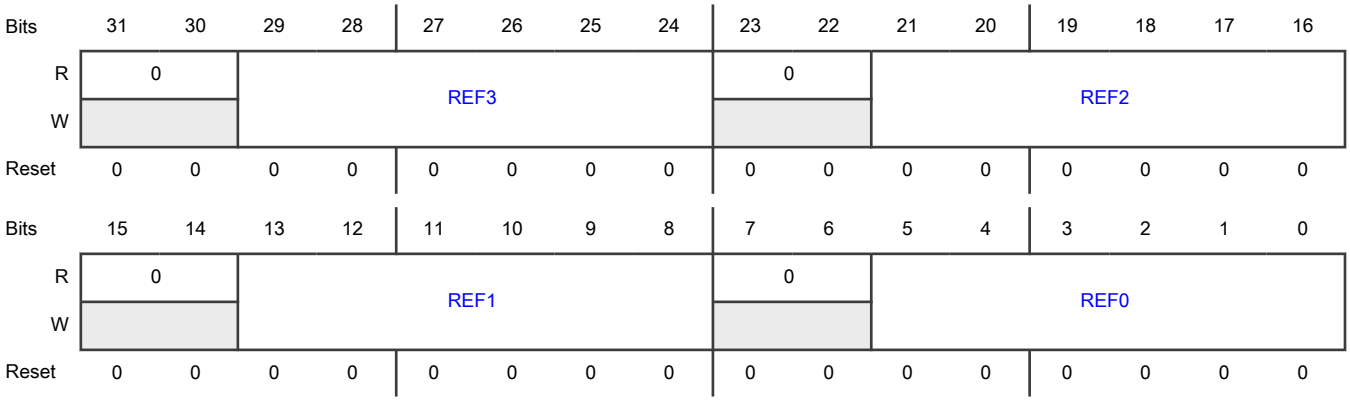
Field	Function
31-24 —	Reserved
23-16 PD_THRESH_ACQ_1_3_2M	Preamble detect threshold for acq mode 1 and 3 at data rate 2Mbps Preamble detect correlation threshold (ufix8en8). This threshold is used to define high correlation for the preamble detect logic.
15-8 —	Reserved
7-0 PD_THRESH_ACQ_1_3_1M	Preamble detect threshold for acq mode 1 and 3 at data rate 1Mbps Preamble detect correlation threshold (ufix8en8). This threshold is used to define high correlation for the preamble detect logic.

52.4.4.2.2.10.6.1.5 PHY Uncoded Preamble Detect Phase (FSK_PD_PH0)

Offset

Register	Offset
FSK_PD_PH0	Ch

Diagram



Fields

Field	Function
31-30 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
29-24 REF3	Uncoded preamble reference waveform sample 3 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Uncoded preamble reference waveform sample 2 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Uncoded preamble reference waveform sample 1 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Uncoded preamble reference waveform sample 0 (sfix6en5)

52.4.4.2.2.10.6.1.6 PHY Uncoded Preamble Detect Phase (FSK_PD_PH1)

Offset

Register	Offset
FSK_PD_PH1	10h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Uncoded preamble reference waveform sample 7 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Uncoded preamble reference waveform sample 6 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Uncoded preamble reference waveform sample 5 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Uncoded preamble reference waveform sample 4 (sfix6en5)

52.4.4.2.2.10.6.1.7 PHY Uncoded Preamble Detect Read Only Phase (FSK_PD_RO_PH2)

Offset

Register	Offset
FSK_PD_RO_PH2	14h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Uncoded preamble reference waveform sample 19 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Uncoded preamble reference waveform sample 18 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Uncoded preamble reference waveform sample 17 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Uncoded preamble reference waveform sample 16 (sfix6en5)

52.4.4.2.2.10.6.1.8 PHY Uncoded Preamble Detect Read Only Phase (FSK_PD_RO_PH3)

Offset

Register	Offset
FSK_PD_RO_PH3	18h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Uncoded preamble reference waveform sample 23 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Uncoded preamble reference waveform sample 22 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Uncoded preamble reference waveform sample 21 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Uncoded preamble reference waveform sample 20 (sfix6en5)

52.4.4.2.2.10.6.1.9 PHY Uncoded Preamble Detect Read Only Phase (FSK_PD_RO_PH4)

Offset

Register	Offset
FSK_PD_RO_PH4	1Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Uncoded preamble reference waveform sample 27 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Uncoded preamble reference waveform sample 26 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Uncoded preamble reference waveform sample 25 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Uncoded preamble reference waveform sample 24 (sfix6en5)

52.4.4.2.2.10.6.1.10 PHY Uncoded Preamble Detect Read Only Phase (FSK_PD_RO_PH5)

Offset

Register	Offset
FSK_PD_RO_PH5	20h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Uncoded preamble reference waveform sample 31 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Uncoded preamble reference waveform sample 30 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Uncoded preamble reference waveform sample 29 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Uncoded preamble reference waveform sample 28 (sfix6en5)

52.4.4.2.2.10.6.1.11 PHY Uncoded Config 0 (FSK_CFG0)

Offset

Register	Offset
FSK_CFG0	24h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	Reserved				AA_ACQ_1_2_3_THRESH_2M				Reserved	BLE_NTW_ADR_THR			HAMMING_AA_LOW_PWR			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	Reserved				AA_ACQ_1_2_3_THRESH_1M				Reserved	MSK2FSK...	MSK_EN	Reserved	Reserved	FSK_BIT...	AA_OUT_...	Reserved
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-29 ——	Reserved
28-24 AA_ACQ_1_2_3_THRESH_2M	For 2Mbps data rate, correlation threshold applicable to AA detection; uses ufix5_En5 fixed-point format.
23 ——	Reserved
22-20 BLE_NTW_ADR_THR	Maximum hamming distance from the given AA pattern that may still be accepted as a match; valid range [0,7].
19-16 HAMMING_AA_LOW_PWR	Maximum hamming distance from the given AA pattern that may still be accepted as a match; valid range [0,7]. This threshold value are performed on lower power case.
15-13 ——	Reserved
12-8 AA_ACQ_1_2_3_THRESH_1M	For 1Mbps data rate, Correlation threshold applicable to AA detection; uses ufix5_En5 fixed-point format.
7 ——	Reserved
6 MSK2FSK_SEED	Last bit of preamble. It is used as seed of the MSK to FSK transformation to derive the FM access address pattern when MSK is enabled
5 MSK_EN	Configures PHY for MSK decoding.
4 ——	Reserved
3 ——	Reserved
2	This applies at the demodulator, so it affects both AA and the data portions of the packet. 0b - Normal demodulation

Table continues on the next page...

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Field	Function
FSK_BIT_INVERT	1b - Invert demodulated bits
1 AA_OUT_SEL	Specifies which AA bits to be played-back to the LL: 0b - output the received AA bits 1b - output the programmed AA bits
0 —	Reserved

52.4.4.2.2.10.6.1.12 PHY Uncoded Config 1 (FSK_CFG1)

Offset

Register	Offset
FSK_CFG1	28h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	Reserved				SYNCTSCALE				Reserved				OVERH_INV			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	OVERH_INV				Reserved				OVERH							
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 —	Reserved
27-24 SYNCTSCALE	Scaling factor used for fractional time estimation during AA search; represented in ufix4_En3 format.
23-20	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
19-11 OVERH_INV	Reciprocal of modulation index; represented in ufix9_En7 format.
10-9 —	Reserved
8-0 OVERH	Modulation index; represented in ufix11_En6 format.

52.4.4.2.2.10.6.1.13 PHY Uncoded Config 2 (FSK_CFG2)

Offset

Register	Offset
FSK_CFG2	2Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	MAG_WIN				Reserved											
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	Reserved				Reserved											
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 MAG_WIN	Indicates the forgetting factor used in received signal level measurement; forgetting factor used is 2^(-mag_window). Note that mag_window values higher than 8 are not typically used.
27-16 —	Reserved

Table continues on the next page...

Table continued from the previous page...

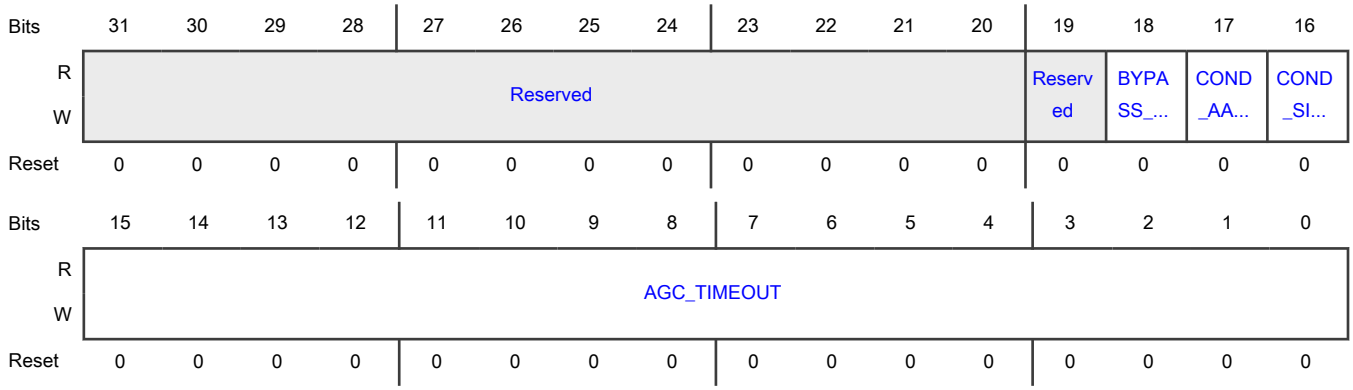
Field	Function
15-12 —	Reserved
11-0 —	Reserved

52.4.4.2.2.10.6.1.14 PHY Uncoded Power Threshold Config (FSK_PT)

Offset

Register	Offset
FSK_PT	34h

Diagram



Fields

Field	Function
31-20 —	Reserved
19 —	Reserved
18 BYPASS_WITH_RSSI	Bypass signal power measurement with RSSI measurement; 0b - no 1b - yes
17	Enables special condition for enabling AA detector buffer;

Table continues on the next page...

Table continued from the previous page...

Field	Function
COND_AA_BUFF_EN	0b - disable. 1b - enable.
16 COND_SIG_PRST_EN	Enables special conditioning of signal detection; 0b - disable. 1b - enable.
15-0 AGC_TIMEOUT	Time-out, applicable to special conditioning of signal power detection in the Power threshold block, after each AGC gain adjustment. It is expressed in number of samples.

52.4.4.2.2.10.6.1.15 PHY Uncoded FAD Control (FSK_FAD_CTRL)

Offset

Register	Offset
FSK_FAD_CTRL	38h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	Reserved															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	Reserved															FAD_EN
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

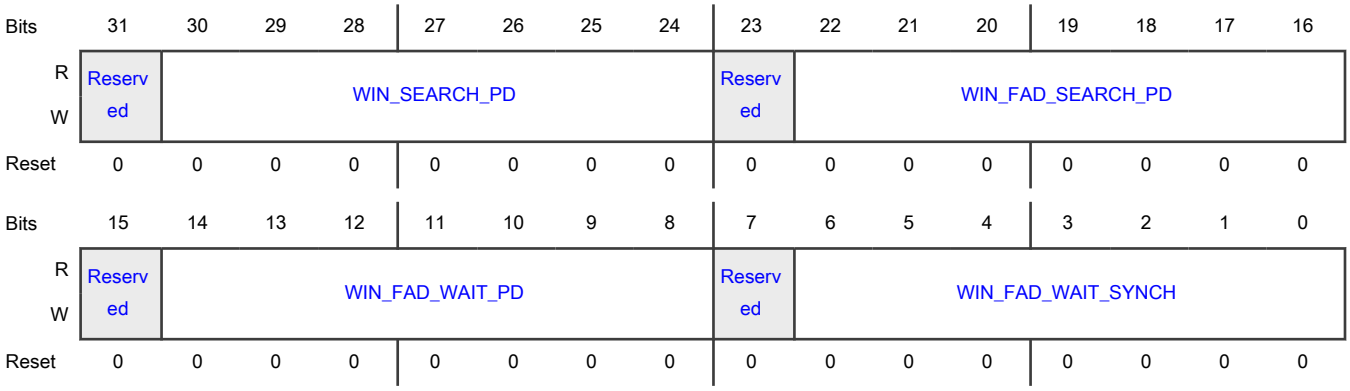
Field	Function
31-1 —	Reserved
0 FAD_EN	Enables FAD; 0b - disable. 1b - enable.

52.4.4.2.2.10.6.1.16 PHY Uncoded FAD Config (FSK_FAD_CFG)

Offset

Register	Offset
FSK_FAD_CFG	3Ch

Diagram



Fields

Field	Function
31 —	Reserved
30-24 WIN_SEARCH_PD	Time-window to match preamble pattern on samples coming from the currently selected antenna, in sample clock cycles (referred to as T0 in the PHY state-machine section).
23 —	Reserved
22-16 WIN_FAD_SEARCH_PD	Time-window to match preamble pattern on samples coming from the previously selected antenna , in sample clock cycles(referred to as T1 in the PHY state-machine section).
15 —	Reserved
14-8 WIN_FAD_WAIT_PD	Time-window to wait for clean samples if PD was not found after antenna switch , in sample clock cycles(referred to as T2 in the PHY state-machine section).
7 —	Reserved

Table continues on the next page...

Table continued from the previous page...

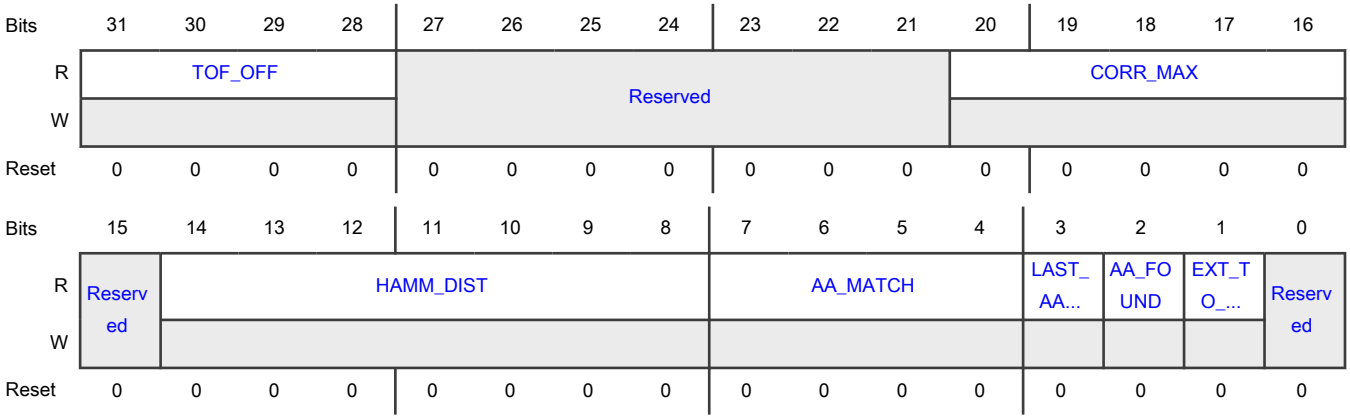
Field	Function
6-0 WIN_FAD_WAIT_SYNCH	Time-window to wait for clean samples, before transitioning to AA search PHY state, if PD was found after antenna switch , in sample clock cycles(referred to as T3 in the PHY state-machine section).

52.4.4.2.2.10.6.1.17 PHY Uncoded Status (FSK_STAT)

Offset

Register	Offset
FSK_STAT	40h

Diagram



Fields

Field	Function
31-28 TOF_OFF	Timing offset for use in time-of-flight calculation. It is a modulo 16 value which is modified from PHY enabled until AA is found. This provides a fine, sample-time resolution, timing information. Time unit is sample rate, for example, 0.25us for 1M data rate.
27-21 —	Reserved
20-16 CORR_MAX	Indicates the correlation witnessed when AA match occurred This represents the maximum AA correlation magnitude, this value is frozen from the moment AA detection occurs until the next PHY reset.
15	Reserved

Table continues on the next page...

Table continued from the previous page...

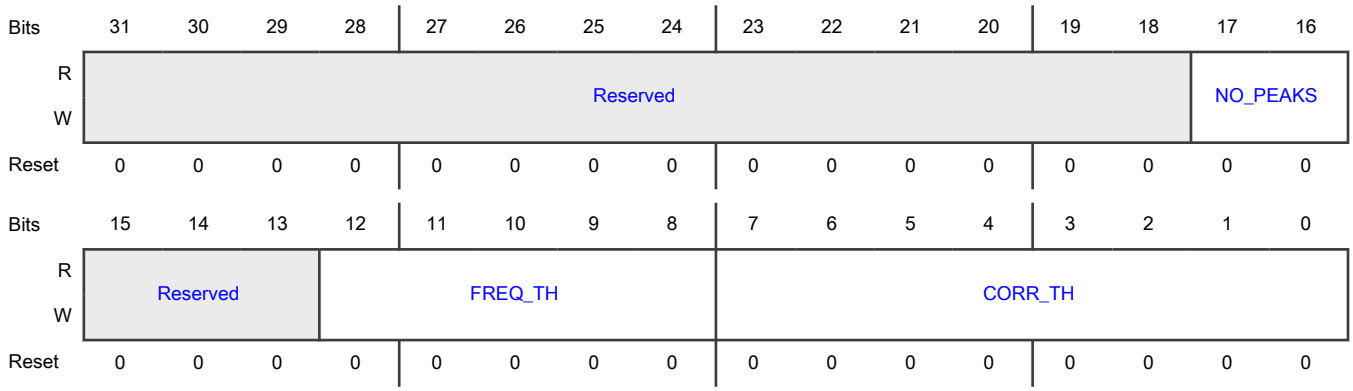
Field	Function
—	
14-8 HAMM_DIST	Indicates the hamming distance witnessed when AA match occurred.
7-4 AA_MATCH	Indicates which non-coded AA has matched. This will clear when the PHY is re-initialized.
3 LAST_AA_BIT	reserved
2 AA_FOUND	Indicates that a uncoded AA detect is active.
1 EXT_TO_MODES_13	Indicates Timeout extension for modes 1 et 3
0 —	Reserved

52.4.4.2.2.10.6.1.18 PHY Long Range Preamble Detect Config (LR_PD_CFG)

Offset

Register	Offset
LR_PD_CFG	44h

Diagram



Fields

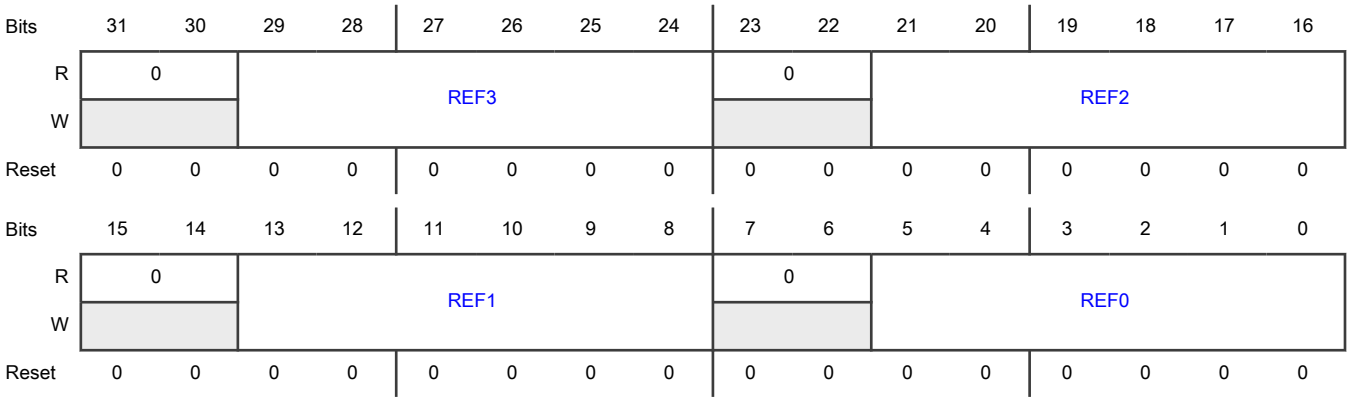
Field	Function
31-18 —	Reserved
17-16 NO_PEAKS	Number of consecutive correlation values that have to exceed the PD correlation threshold,for the same preamble phase, to assert preamble found; 00b - 2 peaks; 01b - 3 peaks; 10b - 4 peaks; 11b - 5 peaks;
15-13 —	Reserved
12-8 FREQ_TH	Threshold used to compare CFO estimates in the LR preamble detector; uses ufix5_En5 format.
7-0 CORR_TH	Correlation threshold applicable to preamble detection; uses (0,8,8) fixed-point format.

52.4.4.2.2.10.6.1.19 PHY Long Range Preamble Detect Phase 0 (LR_PD_PH0)

Offset

Register	Offset
LR_PD_PH0	48h

Diagram



Fields

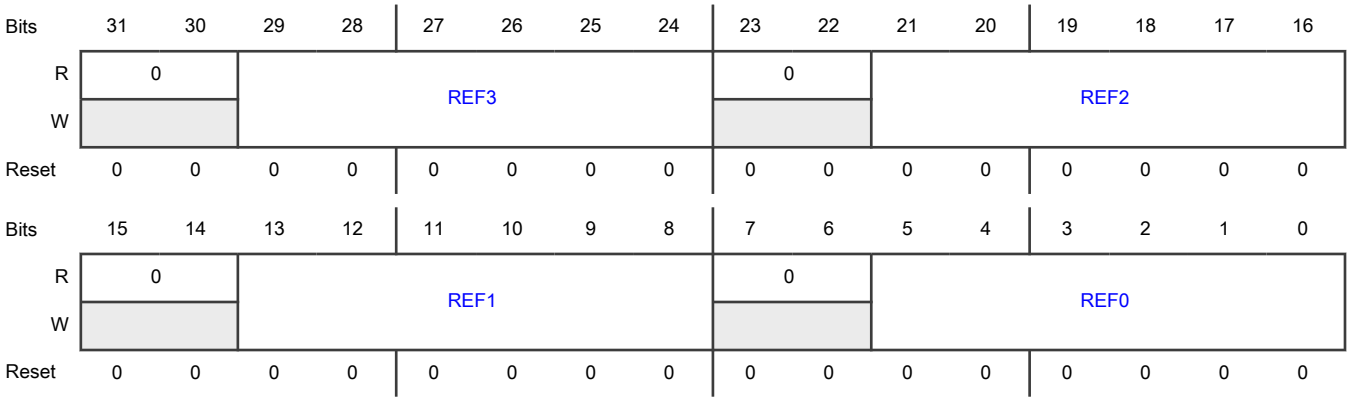
Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 3 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 2 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 1 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 0 (sfix6en5)

52.4.4.2.2.10.6.1.20 PHY Long Range Preamble Detect Phase 1 (LR_PD_PH1)

Offset

Register	Offset
LR_PD_PH1	4Ch

Diagram



Fields

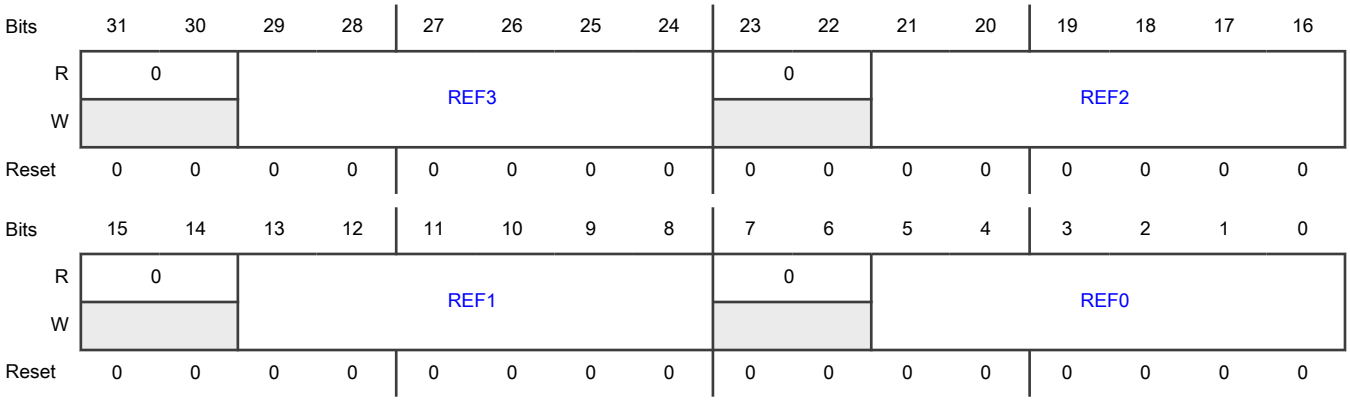
Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 7 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 6 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 5 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 4 (sfix6en5)

52.4.4.2.2.10.6.1.21 PHY Long Range Preamble Detect Phase 2 (LR_PD_PH2)

Offset

Register	Offset
LR_PD_PH2	50h

Diagram



Fields

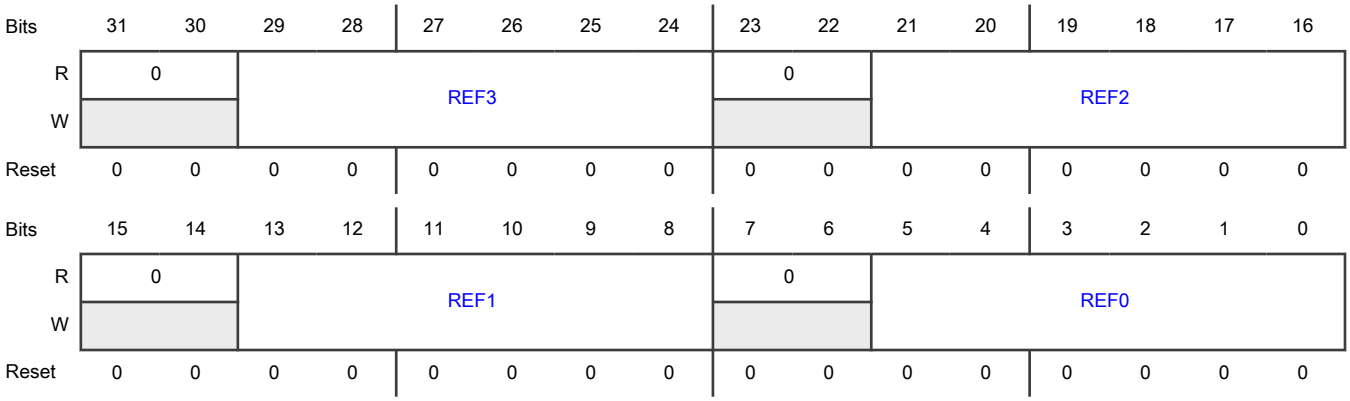
Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 11 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 10 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 9 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 8 (sfix6en5)

52.4.4.2.2.10.6.1.22 PHY Long Range Preamble Detect Phase 3 (LR_PD_PH3)

Offset

Register	Offset
LR_PD_PH3	54h

Diagram



Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 15 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 14 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 13 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 12 (sfix6en5)

52.4.4.2.2.10.6.1.23 PHY Long Range Preamble Detect Read Only Phase 4 (LR_PD_RO_PH4)

Offset

Register	Offset
LR_PD_RO_PH4	58h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 19 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 18 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 17 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 16 (sfix6en5)

52.4.4.2.2.10.6.1.24 PHY Long Range Preamble Detect Read Only Phase 5 (LR_PD_RO_PH5)

Offset

Register	Offset
LR_PD_RO_PH5	5Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 23 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 22 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 21 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 20 (sfix6en5)

52.4.4.2.2.10.6.1.25 PHY Long Range Preamble Detect Read Only Phase 6 (LR_PD_RO_PH6)

Offset

Register	Offset
LR_PD_RO_PH6	60h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

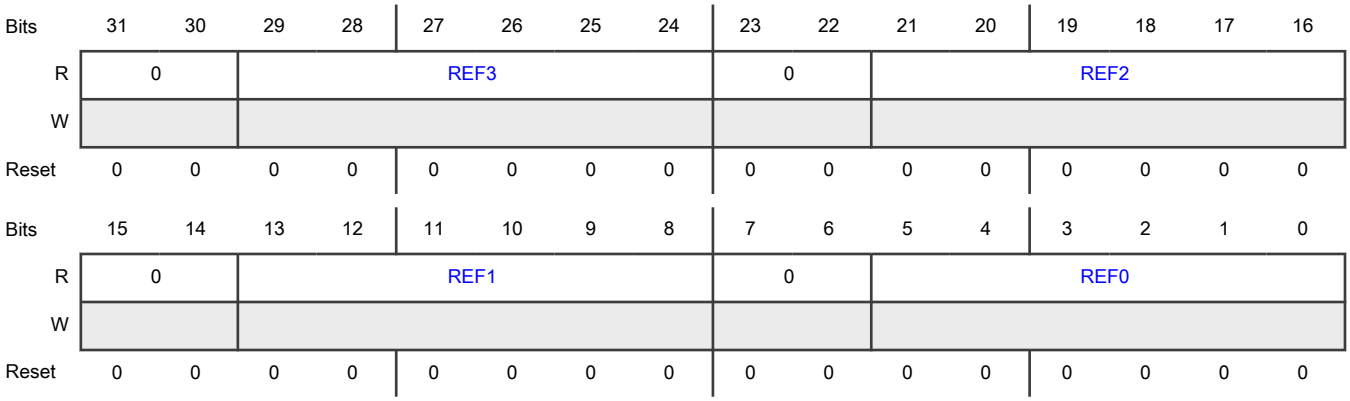
Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 27 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 26 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 25 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 24 (sfix6en5)

52.4.4.2.2.10.6.1.26 PHY Long Range Preamble Detect Read Only Phase 7 (LR_PD_RO_PH7)

Offset

Register	Offset
LR_PD_RO_PH7	64h

Diagram



Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 31 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 30 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 29 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 28 (sfix6en5)

52.4.4.2.2.10.6.1.27 PHY Long Range Preamble Detect Read Only Phase 8 (LR_PD_RO_PH8)

Offset

Register	Offset
LR_PD_RO_PH8	68h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 35 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 34 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 33 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 32 (sfix6en5)

52.4.4.2.2.10.6.1.28 PHY Long Range Preamble Detect Read Only Phase 9 (LR_PD_RO_PH9)

Offset

Register	Offset
LR_PD_RO_PH9	6Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 39 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 38 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 37 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 36 (sfix6en5)

52.4.4.2.2.10.6.1.29 PHY Long Range Preamble Detect Read Only Phase 10 (LR_PD_RO_PH10)

Offset

Register	Offset
LR_PD_RO_PH10	70h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 43 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 42 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 41 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 40 (sfix6en5)

52.4.4.2.2.10.6.1.30 PHY Long Range Preamble Detect Read Only Phase 11 (LR_PD_RO_PH11)

Offset

Register	Offset
LR_PD_RO_PH11	74h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 47 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 46 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 45 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 44 (sfix6en5)

52.4.4.2.2.10.6.1.31 PHY Long Range Preamble Detect Read Only Phase 12 (LR_PD_RO_PH12)

Offset

Register	Offset
LR_PD_RO_PH12	78h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 51 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 50 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 49 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 48 (sfix6en5)

52.4.4.2.2.10.6.1.32 PHY Long Range Preamble Detect Read Only Phase 13 (LR_PD_RO_PH13)

Offset

Register	Offset
LR_PD_RO_PH13	7Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

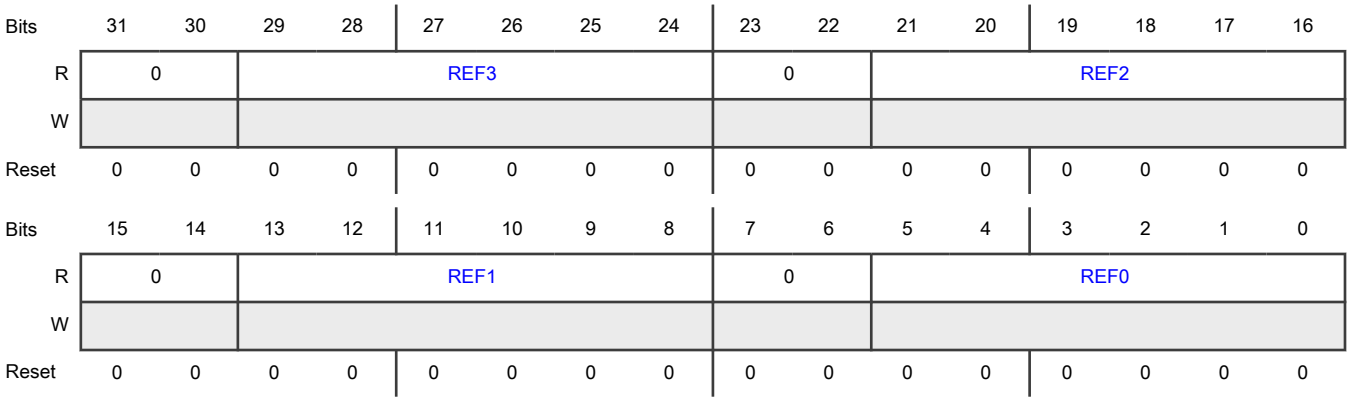
Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 55 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 54 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 53 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 52 (sfix6en5)

52.4.4.2.2.10.6.1.33 PHY Long Range Preamble Detect Read Only Phase 14 (LR_PD_RO_PH14)

Offset

Register	Offset
LR_PD_RO_PH14	80h

Diagram



Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 59 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 58 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 57 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 56 (sfix6en5)

52.4.4.2.2.10.6.1.34 PHY Long Range Preamble Detect Read Only Phase 15 (LR_PD_RO_PH15)

Offset

Register	Offset
LR_PD_RO_PH15	84h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 63 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 62 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 61 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 60 (sfix6en5)

52.4.4.2.2.10.6.1.35 PHY Long Range Preamble Detect Read Only Phase 16 (LR_PD_RO_PH16)

Offset

Register	Offset
LR_PD_RO_PH16	88h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		REF3						0		REF2					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		REF1						0		REF0					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 REF3	Long range preamble reference waveform sample 67 (sfix6en5)
23-22 —	Reserved
21-16 REF2	Long range preamble reference waveform sample 66 (sfix6en5)
15-14 —	Reserved
13-8 REF1	Long range preamble reference waveform sample 65 (sfix6en5)
7-6 —	Reserved
5-0 REF0	Long range preamble reference waveform sample 64 (sfix6en5)

52.4.4.2.2.10.6.1.36 PHY Long Range AA Config (LR_AA_CFG)

Offset

Register	Offset
LR_AA_CFG	8Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	Reserved				AA_LR_CORR_GAIN				Reserved				ACCESS_ADDR_HAM			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	Reserved				AA_HAM_THRESH				AA_COR_THRESH							
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

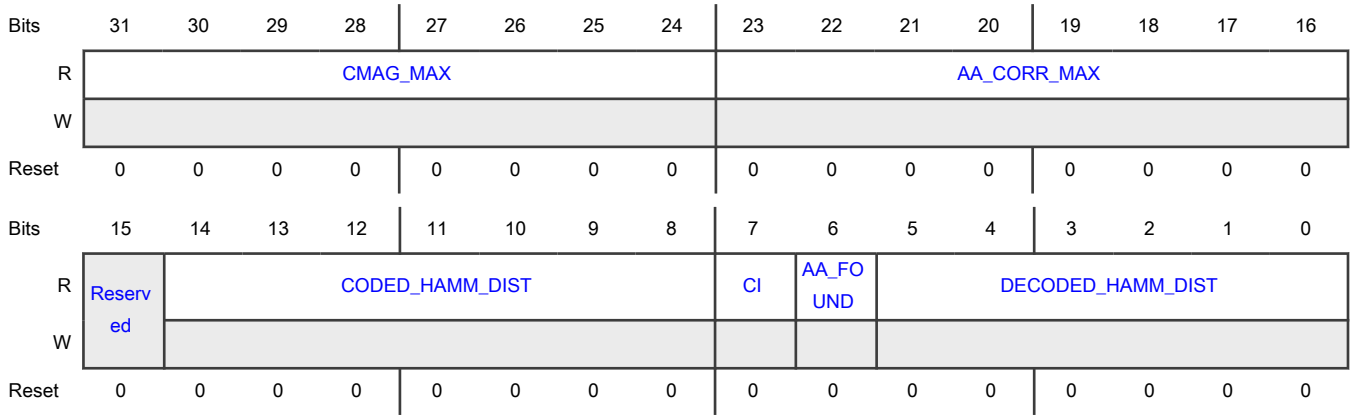
Field	Function
31-30 —	Reserved
29-24 AA_LR_CORR_GAIN	AA correlator gain. Format ufix6en3. This gain is applied to soft bits from the demodulator before they are used for address search synchronization.
23-21 —	Reserved
20-16 ACCESS_ADDR_HAM	Threshold use to compare the Hamming distance, between the reference AA sequence and the received Viterbi decoded AA sequence.
15-14 —	Reserved
13-8 AA_HAM_THRESH	Threshold use to compare the Hamming distance, between reference coded sequence and received coded sequence, in the long-range AA correlator.
7-0 AA_COR_THRESH	Threshold use to compare the correlation magnitude in the long-range AA correlator.

52.4.4.2.2.10.6.1.37 PHY Long Range Status (LR_STAT)

Offset

Register	Offset
LR_STAT	90h

Diagram



Fields

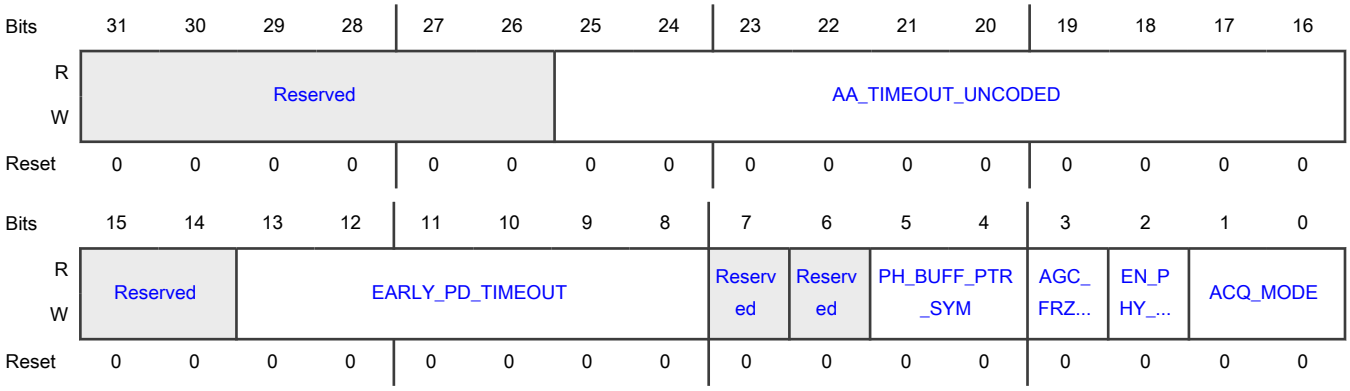
Field	Function
31-24 CMAG_MAX	Indicates the maximum preamble correlation magnitude during preamble found
23-16 AA_CORR_MAX	Indicates the AA correlation magnitude witnessed when AA match occurred
15 —	Reserved
14-8 CODED_HAMM_DIST	Hamming distance between the coded reference sequence and the coded received sequence. This hamming distance is computed in the "Bluetooth LE long range AA correlator" block.
7 CI	CI received.
6 AA_FOUND	Indicates that a AA detect is active for both LR and uncoded.
5-0 DECODED_HAMM_DIST	Hamming distance between the reference sequence and the Viterbi decoded received sequence This is computed in the "AA/CI Detector" block

52.4.4.2.2.10.6.1.38 PHY State Machine Config (SM_CFG)

Offset

Register	Offset
SM_CFG	94h

Diagram



Fields

Field	Function
31-26 —	Reserved
25-16 AA_TIMEOUT_UNCODED	Time-out value for access address search for uncoded packets, expressed in number of sample clock cycles
15-14 —	Reserved
13-8 EARLY_PD_TIMEOUT	Time-out used to reset the AGC state-machine for the eventuality that an "PD found early" , expressed in number of sample clock cycles. Event occurs but it is not followed by an "PD found" event
7 —	Reserved
6 —	Reserved
5-4 PH_BUFF_PTR_SYM	Phase buffer size to demodulator, long range only. for system 32MHz case, it should be 0, for system 26MHz case, it should be 1

Table continues on the next page...

Table continued from the previous page...

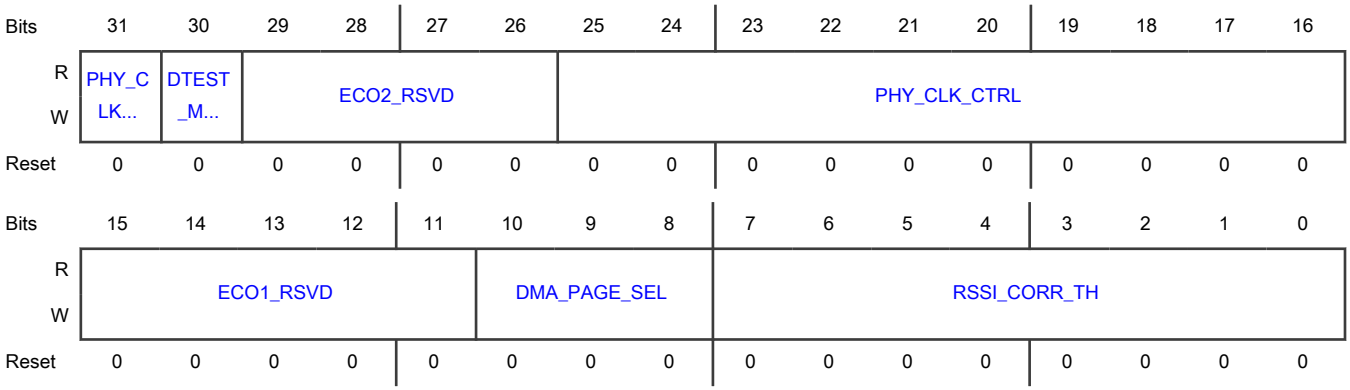
Field	Function
3 AGC_FRZ_ON_PD_FOUND_ACQ1_LR	Specifies AGC freeze condition for non-coded acq.1 and Bluetooth LE long range. 0b - AGC freeze on AA found. 1b - AGC freeze asserted on PD found.
2 EN_PHY_SM_EXT_RST	Enable PHY state-machine reset on the external reset port; Reserved, should keep 0. 0b - Reset is not allowed. 1b - Reset is allowed.
1-0 ACQ_MODE	Acquisition mode for non-coded reception 00b - Reserved 01b - Use preamble and verify a correlation peak, the synch at the symbol rate as symbol timing is established by the preamble acquisition 10b - Use synch only (which may incorporate part of the preamble) 11b - Use mainly the sync detection: Use a low threshold on the preamble detector and launch the synch detection only if the preamble has shown a recent peak

52.4.4.2.2.10.6.1.39 PHY Misc Config (MISC)

Offset

Register	Offset
MISC	98h

Diagram



Fields

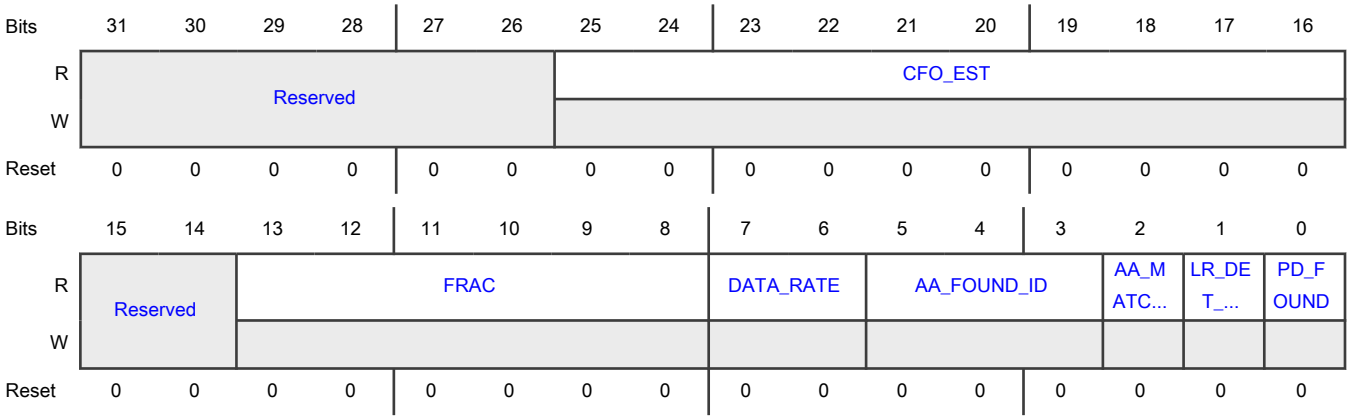
Field	Function
31 PHY_CLK_ON	Force PHY clock ON Forces the system to keep the PHY clock on
30 DTEST_MUX_EN	Reserved . Should be programed as reset value 0.
29-26 ECO2_RSVD	Reserved it should be programed as reset value 0
25-16 PHY_CLK_CTRL	Enables various clock gating features. Bits are individually decoded, so any combination is allowable. • 0000000001b - Gate off PHY clock when phy_en is not asserted. • 0000000010b - Gate off uncoded preamble detect clock when pd_enable is not asserted (internal signal). • 0000000100b - Gate off uncoded AA synchronizer clock when synchronizer is not in use. • 0000001000b - Gate off m2n demodulator clock when demodulator is not in use. • 0000010000b - Gate off long range preamble detect clock when pd_enable is not asserted (internal signal). • 0000100000b - Gate off long range AA synchronizer clock when synchronizer is not in use. • 0001000000b - Gate off m3c demodulator clock when demodulator is not in use. • 0010000000b - Gate off AA CI detect clock when it is not in use • 0100000000b - Gate off Viterbi input formatting clock when it is not in use • 1000000000b - Gate off phy state machine clock dynamically when it is not toggle
15-11 ECO1_RSVD	Reserved . Must be programed as reset value 0.
10-8 DMA_PAGE_SEL	Select which DMA page is send out 000b - Select DMA PAGE 0 for M3C with cfo; 001b - Select DMA PAGE 1 for M3C with magnitude; 010b - Select DMA PAGE 2 for un-coded; 011b - Select DMA PAGE 3 for Long Range Preamble Detect; 100b - Select DMA PAGE 4 for Long Range AA Detect;
7-0 RSSI_CORR_TH	Threshold use to compare a correlation magnitude value, computed in the acquisition block, in order to determine the correlation flag value provided by the PHY to the LQI computation block. Format is ufix8_En8

52.4.4.2.2.10.6.1.40 PHY Status 0 (STAT0)

Offset

Register	Offset
STAT0	9Ch

Diagram



Fields

Field	Function
31-26 —	Reserved
25-16 CFO_EST	Indicates the currently estimated CFO. Format is sfix10_en9(sign extend from sfix8_en9)
15-14 —	Reserved
13-8 FRAC	Indicates the fractional timing estimate determined in the acquisition block. Format is sfix6_en5(sign extend from sfix3_En2).
7-6 DATA_RATE	Indicates the data rate of received bit 00b - 1Mbps 01b - 2Mbps 10b - 125kbps 11b - 500kbps
5-3 AA_FOUND_ID	Indicates which AA was matched for LR and uncode 000b - uncoded address 0 matched 001b - uncoded address 1 matched

Table continues on the next page...

Table continued from the previous page...

Field	Function
	010b - uncoded address 2 matched 011b - uncoded address 3 matched 100b - long range address matched
2 AA_MATCHED	Indicates AA was matched for LR or uncoded
1 LR_DET_FLAG	Indicates Bluetooth LE long range was detected
0 PD_FOUND	PD_FOUND for LR or uncoded

52.4.4.2.2.10.6.1.41 PHY Status 1 (STAT1)

Offset

Register	Offset
STAT1	A0h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	AA_BITS															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	AA_BITS															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

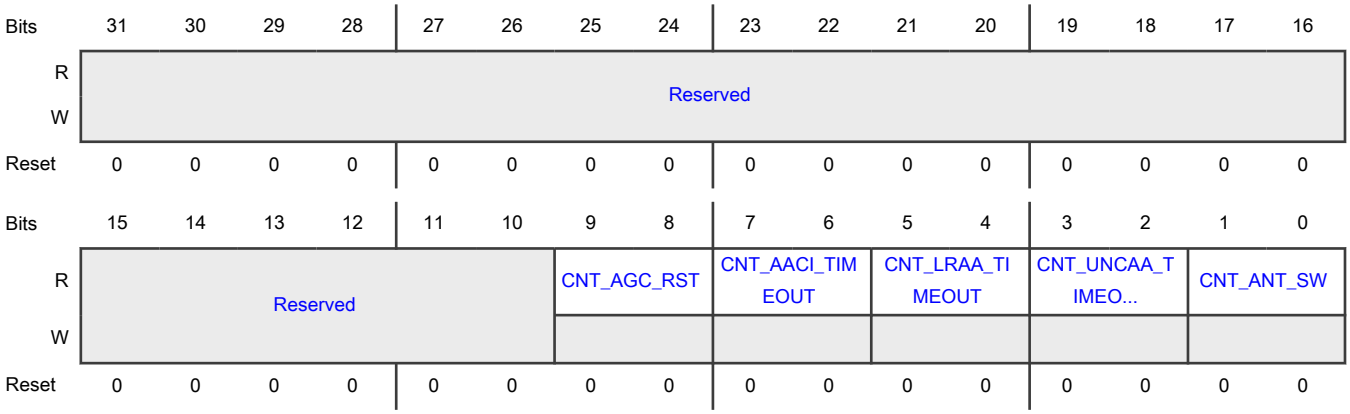
Field	Function
31-0 AA_BITS	AA bits either received or programed

52.4.4.2.2.10.6.1.42 PHY Status 2 (STAT2)

Offset

Register	Offset
STAT2	A4h

Diagram



Fields

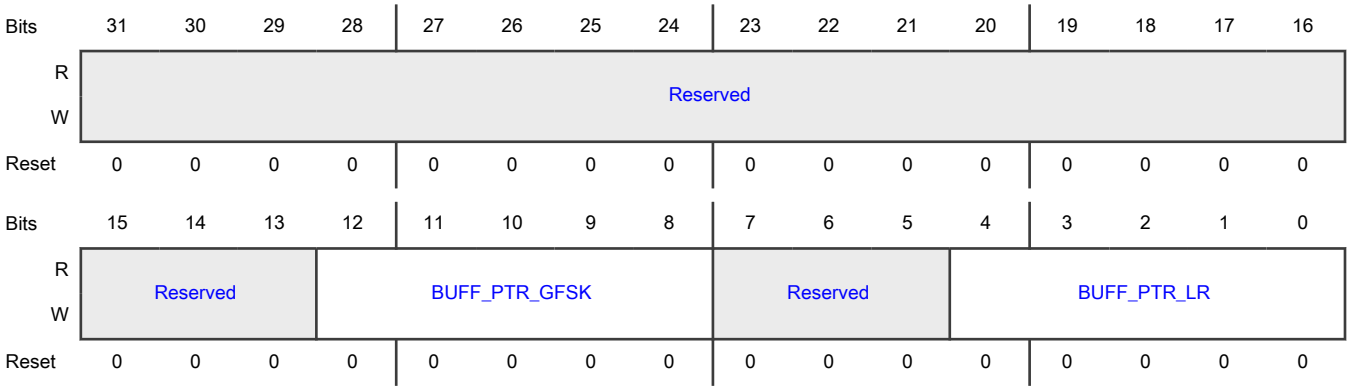
Field	Function
31-10 —	Reserved
9-8 CNT_AGC_RST	Count of AGC soft reset event
7-6 CNT_AACI_TIMEOUT	Count of long range AACI detect timeout event
5-4 CNT_LRAA_TIMEOUT	Count of long range AA search timeout event
3-2 CNT_UNCAA_TIMEOUT	Count of uncoded AA search timeout event
1-0 CNT_ANT_SW	Count of uncoded ANT switch event when FAD was enabled.

52.4.4.2.2.10.6.1.43 PHY PrePHY Misc Config (PREPHY_MISC)

Offset

Register	Offset
PREPHY_MISC	A8h

Diagram



Fields

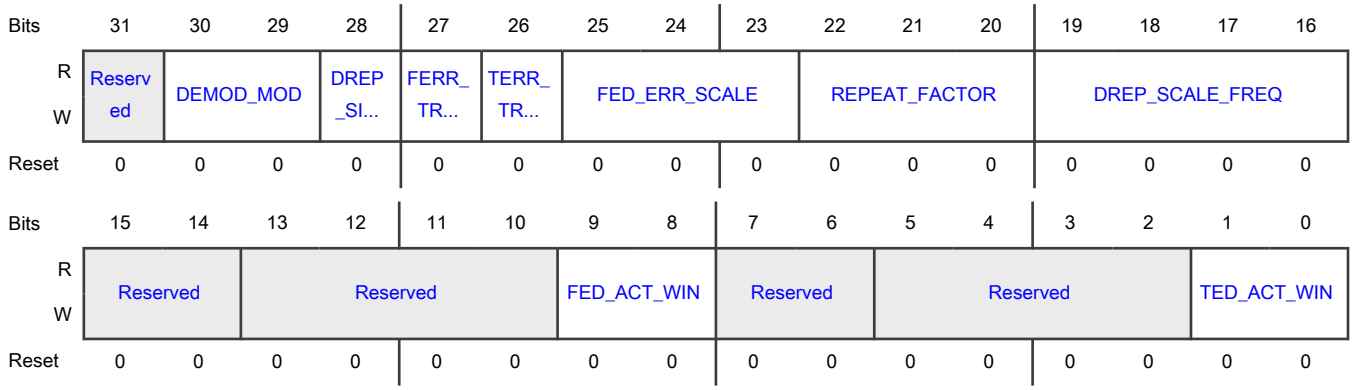
Field	Function
31-13 —	Reserved
12-8 BUFF_PTR_GFSK	Pointer to the PrePHY IQ buffer for the reception of the uncoded packets.
7-5 —	Reserved
4-0 BUFF_PTR_LR	Pointer to the PrePHY IQ buffer for the reception of the long-range packets.

52.4.4.2.2.10.6.1.44 PHY Demodulator Control 0 (DMD_CTRL0)

Offset

Register	Offset
DMD_CTRL0	ACh

Diagram



Fields

Field	Function
31 —	Reserved
30-29 DEMOD_MOD	Determines the number of taps used by the demodulator correlators; 00b - use 12 taps 01b - use 4 taps 10b - use 7 taps 11b - use 13 taps
28 DREP_SINE_EN	Flag used to enable the non-linear operation in the de-repeater.
27 FERR_TRK_EN	Enables frequency tracking in the demodulator.
26 TERR_TRK_EN	Enables time tracking in the demodulator.
25-23 FED_ERR_SCALE	Scaling factor used by the frequency tracking loop. Value used to scale the frequency drift estimation in the frequency tracking loop. data format is ufix3_en2
22-20 REPEAT_FACTOR	Repetition factor used by the de-repeater. Positive integer which specifies the repetition factor, i.e. the ratio between the PHY sampling rate (at the input of the demodulator) and the 4x oversampling sampling rate used by the demodulator. Data format is ufix3
19-16	Frequency domain signal scaling factor used by the de-repeater.

Table continues on the next page...

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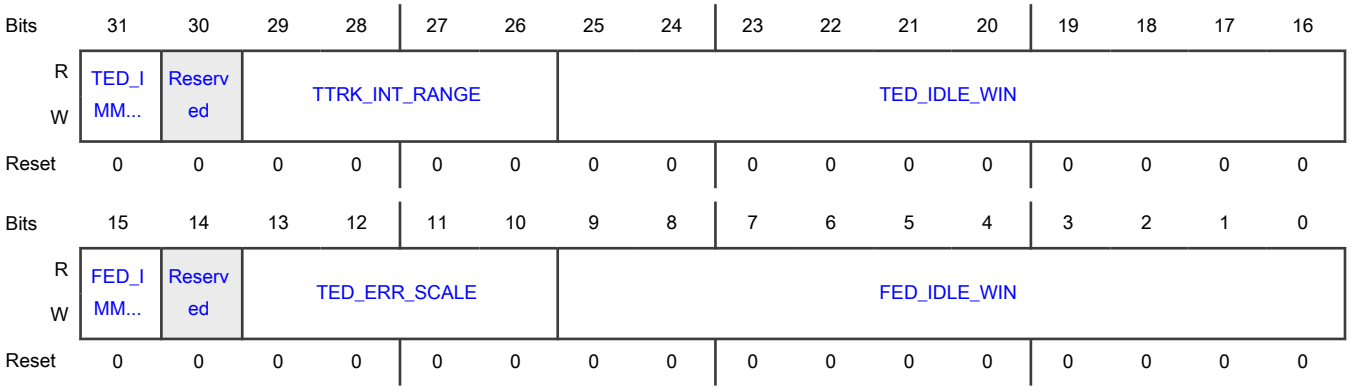
Field	Function
DREP_SCALE_FREQ	Value used to scale the discriminated phase inside the de-repeater (the de-repeater is used to drop the sampling rate by "REPEAT_FACTOR" times inside the demodulator). Data format is ufix4_en2.
15-14 —	Reserved
13-10 —	Reserved
9-8 FED_ACT_WIN	Active window size for the frequency tracking mechanism, expressed in symbols. • 00b - 8. • 01b - 16. • 10b - 32. • 11b - 64.
7-6 —	Reserved
5-2 —	Reserved
1-0 TED_ACT_WIN	Active window size for the time tracking mechanism, expressed in symbols. • 00b - 8. • 01b - 16. • 10b - 32. • 11b - 64.

52.4.4.2.2.10.6.1.45 PHY Demodulator Control 1 (DMD_CTRL1)

Offset

Register	Offset
DMD_CTRL1	B0h

Diagram



Fields

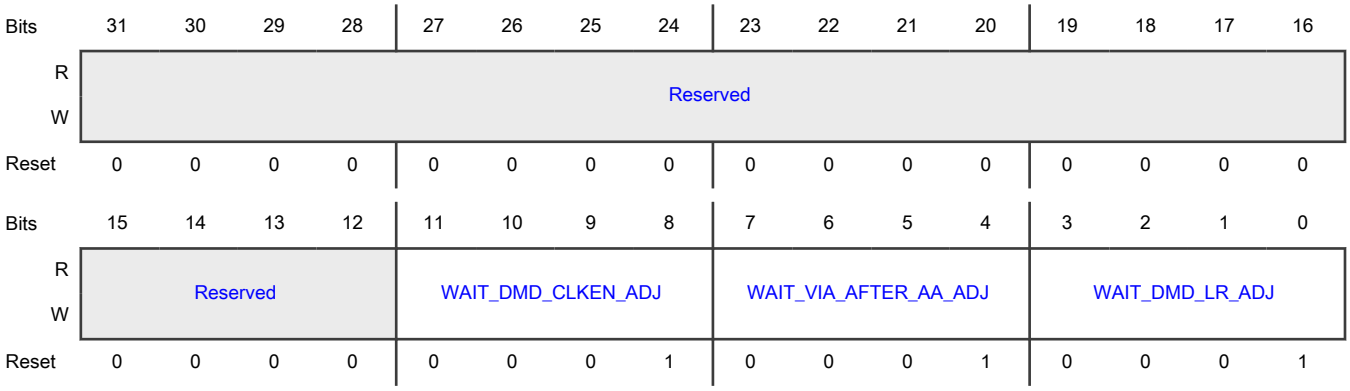
Field	Function
31 TED_IMM_MEAS_EN	Specifies whether the time tracking starts with an active window; 0b - start with idle window 1b - start with active window
30 —	Reserved
29-26 TTRK_INT_RANGE	Timing error correction interpolation range, expressed in samples. The value must equal or bigger than 1.
25-16 TED_IDLE_WIN	Idle window size for the time tracking mechanism, expressed in symbols.
15 FED_IMM_MEAS_EN	Specifies whether the frequency tracking starts with an active window; 0b - start with idle window 1b - start with active window
14 —	Reserved
13-10 TED_ERR_SCALE	Scaling factor used by the time tracking loop. Value used to scale the time drift estimation in the frequency tracking loop. Data format is sfix4_en2
9-0 FED_IDLE_WIN	Idle window size for the frequency tracking mechanism, expressed in symbols.

52.4.4.2.2.10.6.1.46 PHY Demodulator Control 2 (DMD_CTRL2)

Offset

Register	Offset
DMD_CTRL2	B4h

Diagram



Fields

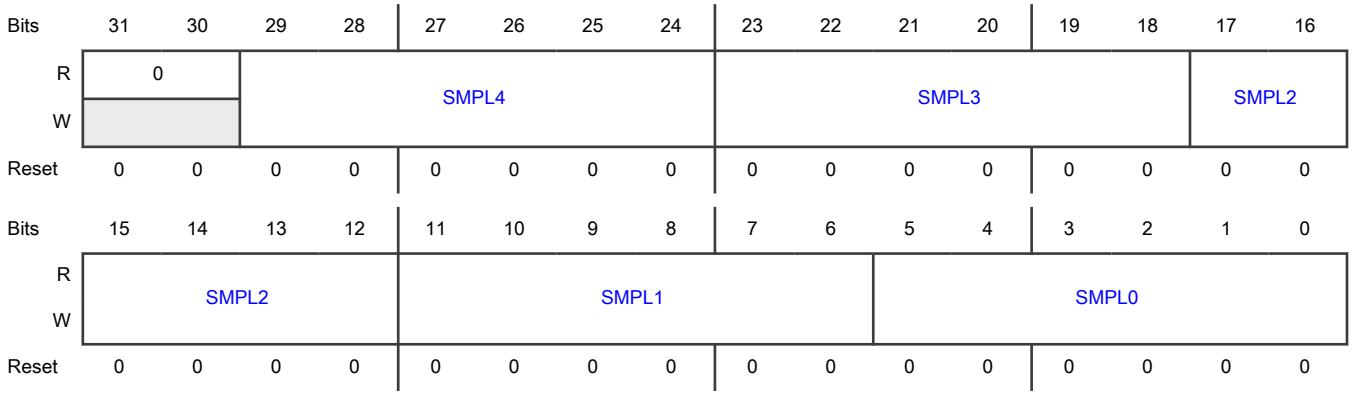
Field	Function
31-12 —	Reserved
11-8 WAIT_DMD_CLKEN_ADJ	Reserved Must be programed as reset value 1.
7-4 WAIT_VIA_AFTER_AA_ADJ	Reserved Must be programed as reset value 1.
3-0 WAIT_DMD_LR_ADJ	Reserved Must be programed as reset value 1.

52.4.4.2.2.10.6.1.47 PHY Demodulator Wave0 Register 0 (DMD_WAVE0_REG0)

Offset

Register	Offset
DMD_WAVE0_REG0	B8h

Diagram



Fields

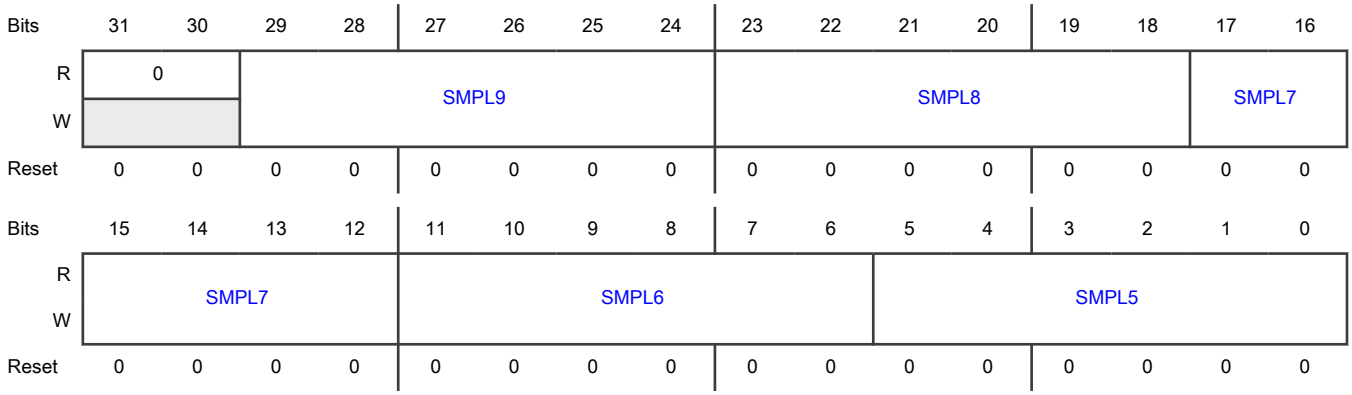
Field	Function
31-30 —	Reserved
29-24 SMPL4	Demodulator waveform 0 sample 4 (sfix6en5)
23-18 SMPL3	Demodulator waveform 0 sample 3 (sfix6en5)
17-12 SMPL2	Demodulator waveform 0 sample 2 (sfix6en5)
11-6 SMPL1	Demodulator waveform 0 sample 1 (sfix6en5)
5-0 SMPL0	Demodulator waveform 0 sample 0 (sfix6en5)

52.4.4.2.2.10.6.1.48 PHY Demodulator Wave0 Register 1 (DMD_WAVE0_REG1)

Offset

Register	Offset
DMD_WAVE0_REG1	BCh

Diagram



Fields

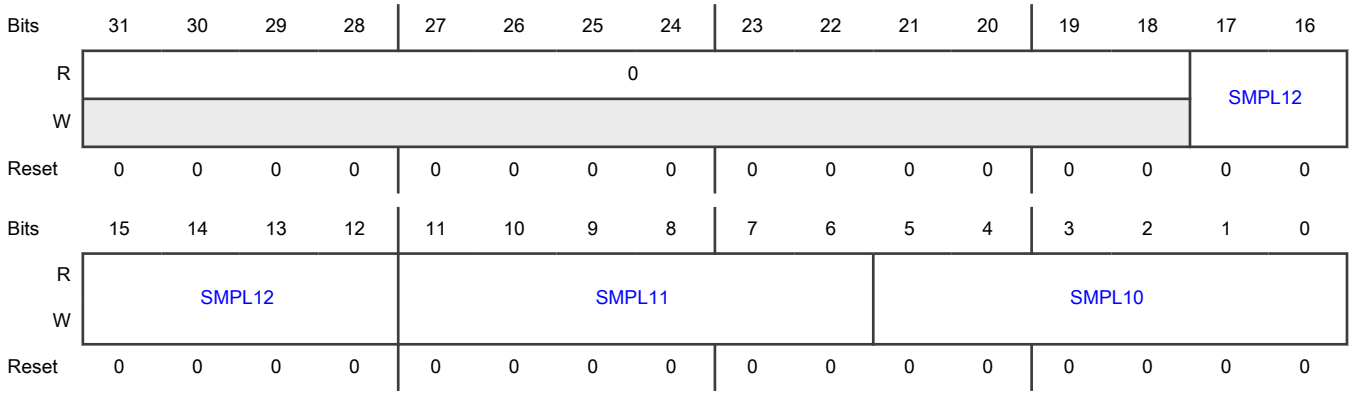
Field	Function
31-30 —	Reserved
29-24 SMPL9	Demodulator waveform 0 sample 9 (sfix6en5)
23-18 SMPL8	Demodulator waveform 0 sample 8 (sfix6en5)
17-12 SMPL7	Demodulator waveform 0 sample 7 (sfix6en5)
11-6 SMPL6	Demodulator waveform 0 sample 6 (sfix6en5)
5-0 SMPL5	Demodulator waveform 0 sample 5 (sfix6en5)

52.4.4.2.2.10.6.1.49 PHY Demodulator Wave0 Register 2 (DMD_WAVE0_REG2)

Offset

Register	Offset
DMD_WAVE0_REG2	C0h

Diagram



Fields

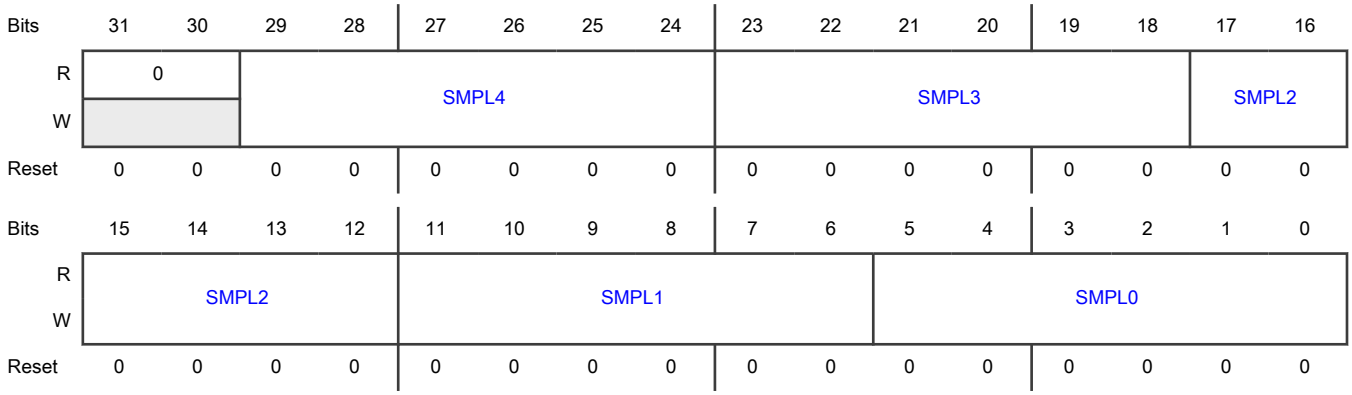
Field	Function
31-18 —	Reserved
17-12 SMPL12	Demodulator waveform 0 sample 12 (sfix6en5)
11-6 SMPL11	Demodulator waveform 0 sample 11 (sfix6en5)
5-0 SMPL10	Demodulator waveform 0 sample 10 (sfix6en5)

52.4.4.2.2.10.6.1.50 PHY Demodulator Wave1 Register 0 (DMD_WAVE1_REG0)

Offset

Register	Offset
DMD_WAVE1_REG0	C4h

Diagram



Fields

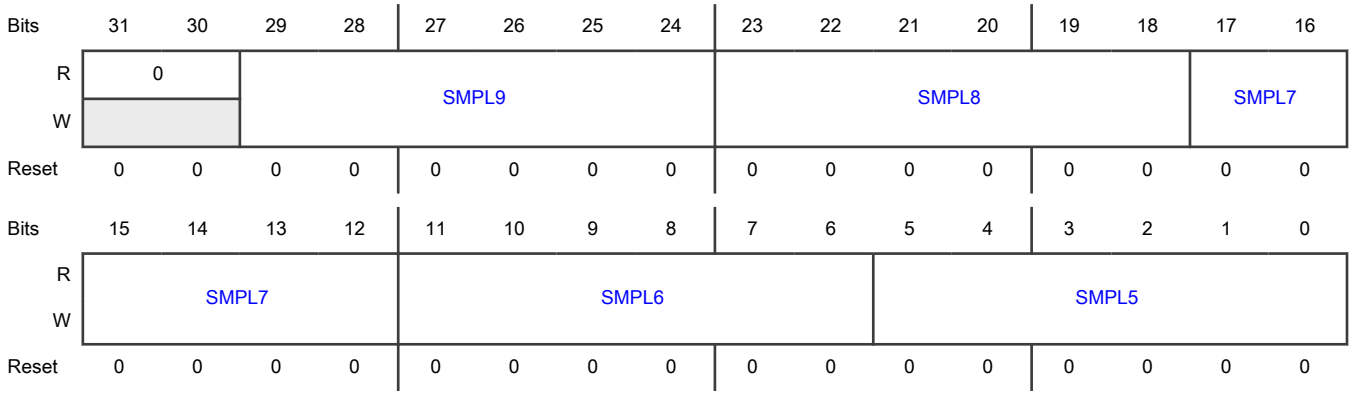
Field	Function
31-30 —	Reserved
29-24 SMPL4	Demodulator waveform 1 sample 4 (sfix6en5)
23-18 SMPL3	Demodulator waveform 1 sample 3 (sfix6en5)
17-12 SMPL2	Demodulator waveform 1 sample 2 (sfix6en5)
11-6 SMPL1	Demodulator waveform 1 sample 1 (sfix6en5)
5-0 SMPL0	Demodulator waveform 1 sample 0 (sfix6en5)

52.4.4.2.2.10.6.1.51 PHY Demodulator Wave1 Register 1 (DMD_WAVE1_REG1)

Offset

Register	Offset
DMD_WAVE1_REG1	C8h

Diagram



Fields

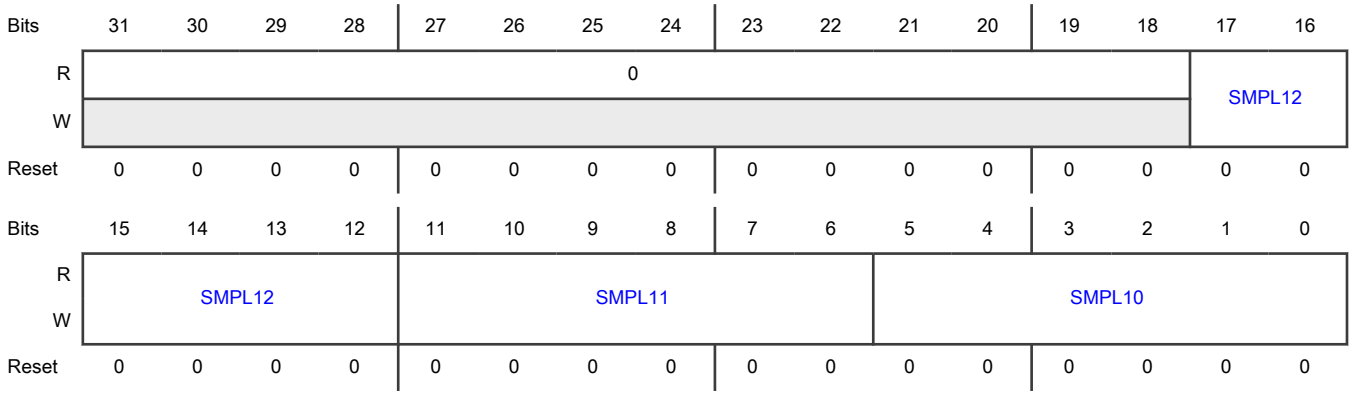
Field	Function
31-30 —	Reserved
29-24 SMPL9	Demodulator waveform 1 sample 9 (sfix6en5)
23-18 SMPL8	Demodulator waveform 1 sample 8 (sfix6en5)
17-12 SMPL7	Demodulator waveform 1 sample 7 (sfix6en5)
11-6 SMPL6	Demodulator waveform 1 sample 6 (sfix6en5)
5-0 SMPL5	Demodulator waveform 1 sample 5 (sfix6en5)

52.4.4.2.2.10.6.1.52 PHY Demodulator Wave1 Register 2 (DMD_WAVE1_REG2)

Offset

Register	Offset
DMD_WAVE1_REG2	CCh

Diagram



Fields

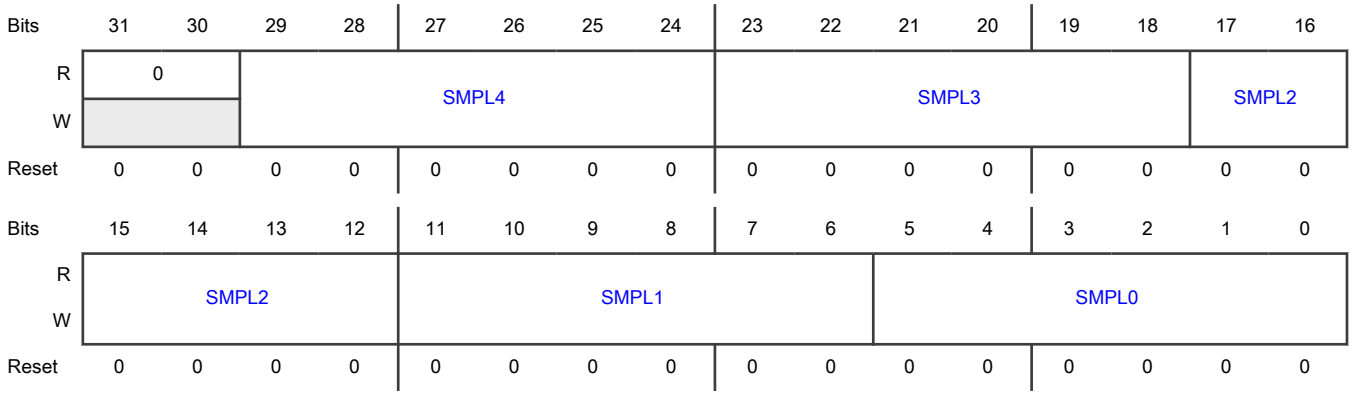
Field	Function
31-18 —	Reserved
17-12 SMPL12	Demodulator waveform 1 sample 12 (sfix6en5)
11-6 SMPL11	Demodulator waveform 1 sample 11 (sfix6en5)
5-0 SMPL10	Demodulator waveform 1 sample 10 (sfix6en5)

52.4.4.2.2.10.6.1.53 PHY Demodulator Wave2 Register 0 (DMD_WAVE2_REG0)

Offset

Register	Offset
DMD_WAVE2_REG0	D0h

Diagram



Fields

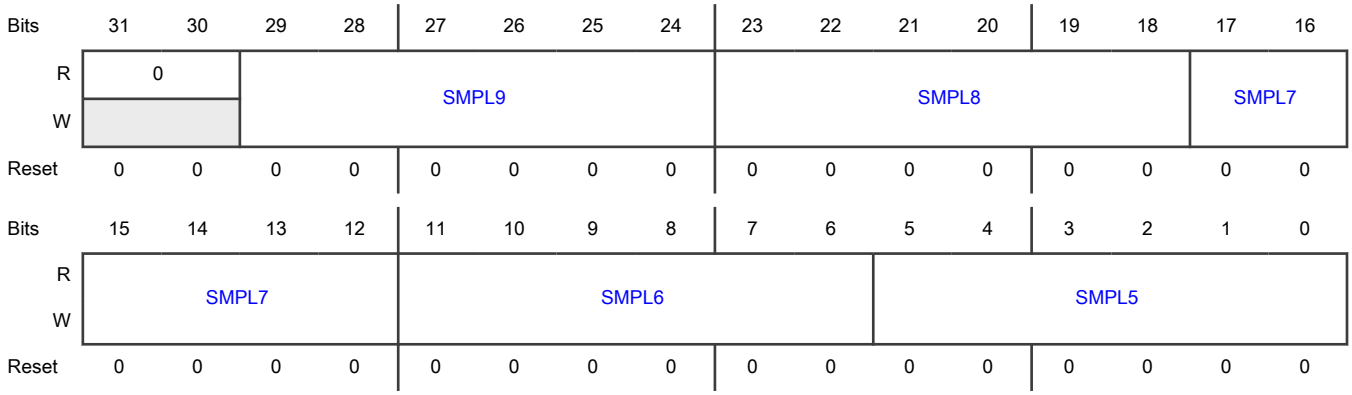
Field	Function
31-30 —	Reserved
29-24 SMPL4	Demodulator waveform 2 sample 4 (sfix6en5)
23-18 SMPL3	Demodulator waveform 2 sample 3 (sfix6en5)
17-12 SMPL2	Demodulator waveform 2 sample 2 (sfix6en5)
11-6 SMPL1	Demodulator waveform 2 sample 1 (sfix6en5)
5-0 SMPL0	Demodulator waveform 2 sample 0 (sfix6en5)

52.4.4.2.2.10.6.1.54 PHY Demodulator Wave2 Register 1 (DMD_WAVE2_REG1)

Offset

Register	Offset
DMD_WAVE2_REG1	D4h

Diagram



Fields

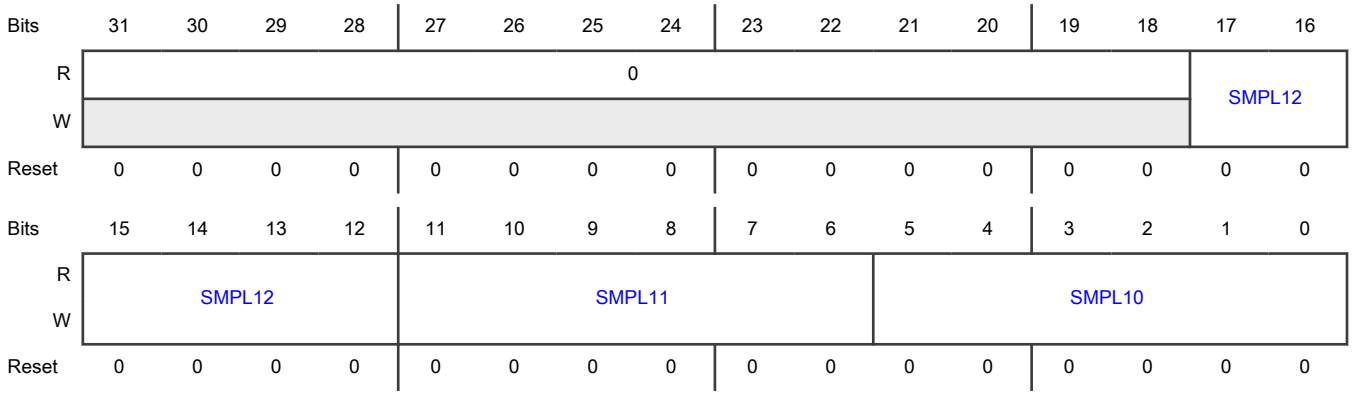
Field	Function
31-30 —	Reserved
29-24 SMPL9	Demodulator waveform 2 sample 9 (sfix6en5)
23-18 SMPL8	Demodulator waveform 2 sample 8 (sfix6en5)
17-12 SMPL7	Demodulator waveform 2 sample 7 (sfix6en5)
11-6 SMPL6	Demodulator waveform 2 sample 6 (sfix6en5)
5-0 SMPL5	Demodulator waveform 2 sample 5 (sfix6en5)

52.4.4.2.2.10.6.1.55 PHY Demodulator Wave2 Register 2 (DMD_WAVE2_REG2)

Offset

Register	Offset
DMD_WAVE2_REG2	D8h

Diagram



Fields

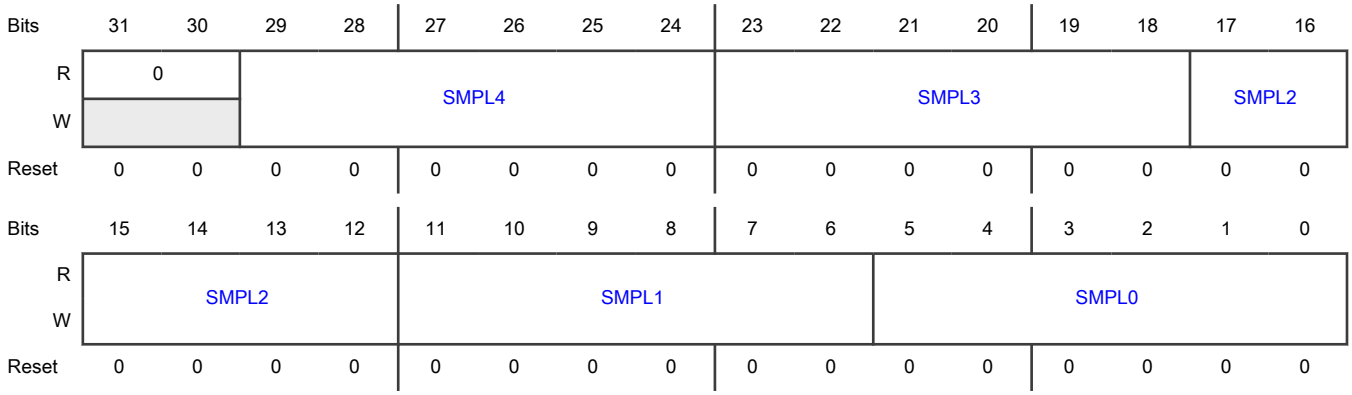
Field	Function
31-18 —	Reserved
17-12 SMPL12	Demodulator waveform 2 sample 12 (sfix6en5)
11-6 SMPL11	Demodulator waveform 2 sample 11 (sfix6en5)
5-0 SMPL10	Demodulator waveform 2 sample 10 (sfix6en5)

52.4.4.2.2.10.6.1.56 PHY Demodulator Wave3 Register 0 (DMD_WAVE3_REG0)

Offset

Register	Offset
DMD_WAVE3_REG0	DCh

Diagram



Fields

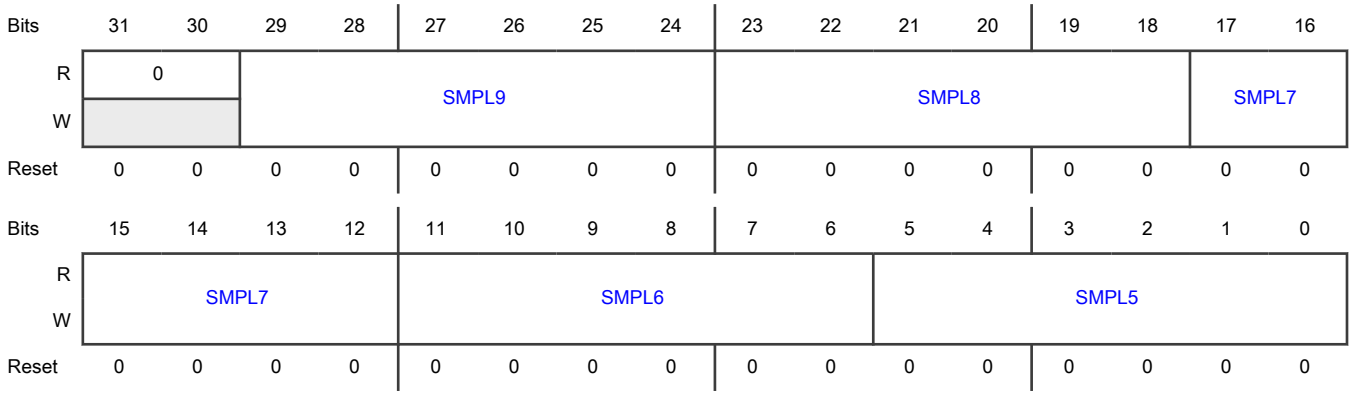
Field	Function
31-30 —	Reserved
29-24 SMPL4	Demodulator waveform 3 sample 4 (sfix6en5)
23-18 SMPL3	Demodulator waveform 3 sample 3 (sfix6en5)
17-12 SMPL2	Demodulator waveform 3 sample 2 (sfix6en5)
11-6 SMPL1	Demodulator waveform 3 sample 1 (sfix6en5)
5-0 SMPL0	Demodulator waveform 3 sample 0 (sfix6en5)

52.4.4.2.2.10.6.1.57 PHY Demodulator Wave3 Register 1 (DMD_WAVE3_REG1)

Offset

Register	Offset
DMD_WAVE3_REG1	E0h

Diagram



Fields

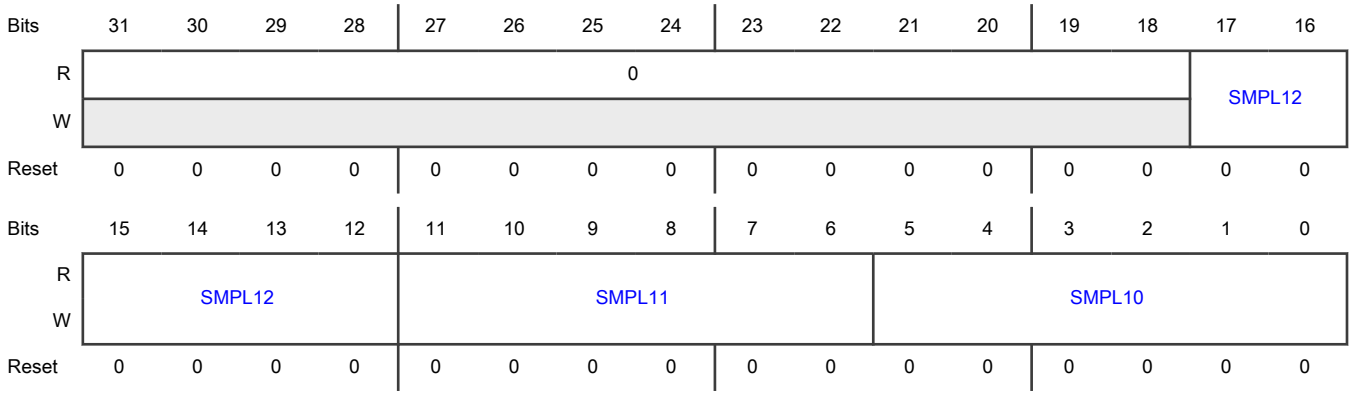
Field	Function
31-30 —	Reserved
29-24 SMPL9	Demodulator waveform 3 sample 9 (sfix6en5)
23-18 SMPL8	Demodulator waveform 3 sample 8 (sfix6en5)
17-12 SMPL7	Demodulator waveform 3 sample 7 (sfix6en5)
11-6 SMPL6	Demodulator waveform 3 sample 6 (sfix6en5)
5-0 SMPL5	Demodulator waveform 3 sample 5 (sfix6en5)

52.4.4.2.2.10.6.1.58 PHY Demodulator Wave3 Register 2 (DMD_WAVE3_REG2)

Offset

Register	Offset
DMD_WAVE3_REG2	E4h

Diagram



Fields

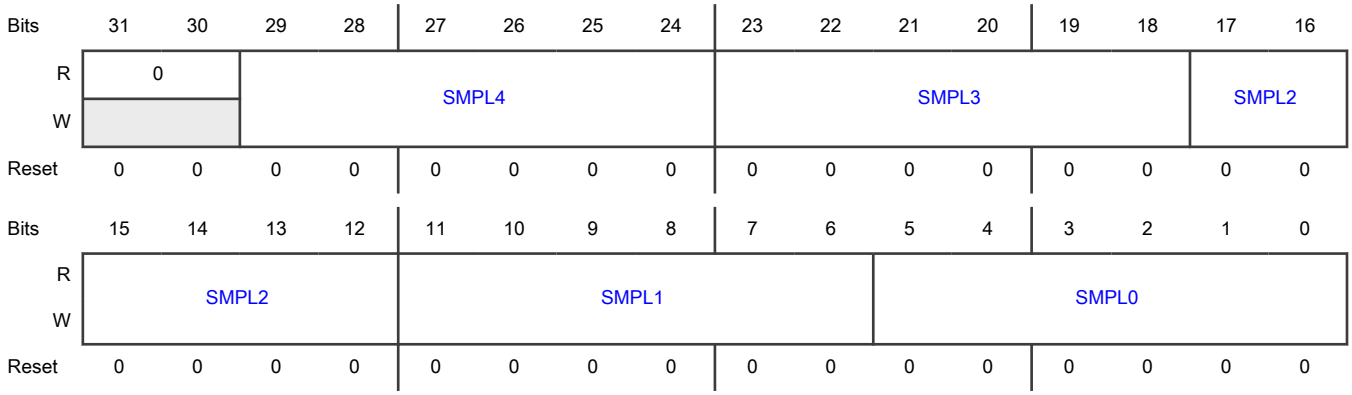
Field	Function
31-18 —	Reserved
17-12 SMPL12	Demodulator waveform 3 sample 12 (sfix6en5)
11-6 SMPL11	Demodulator waveform 3 sample 11 (sfix6en5)
5-0 SMPL10	Demodulator waveform 3 sample 10 (sfix6en5)

52.4.4.2.2.10.6.1.59 PHY Demodulator Wave4 Register 0 (DMD_WAVE4_REG0)

Offset

Register	Offset
DMD_WAVE4_REG0	E8h

Diagram



Fields

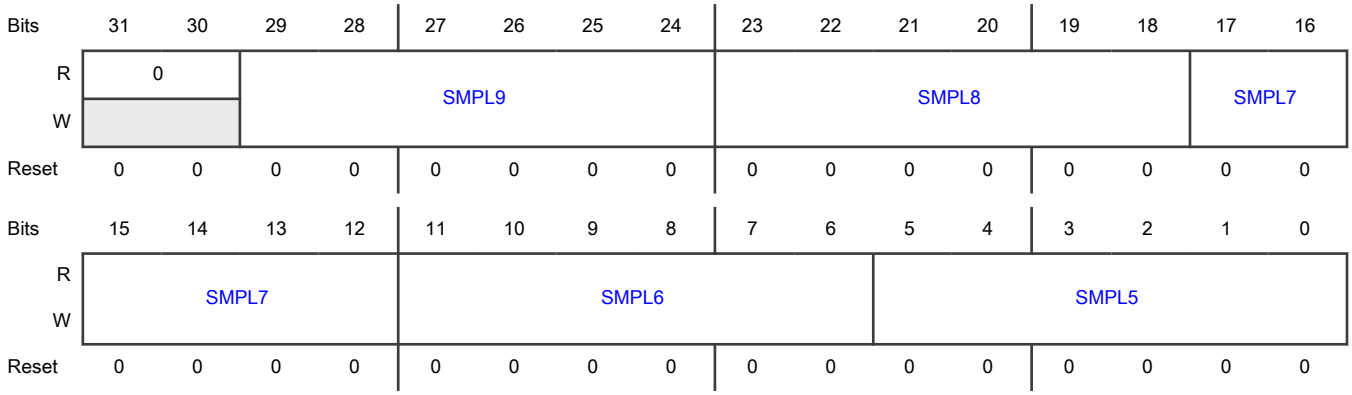
Field	Function
31-30 —	Reserved
29-24 SMPL4	Demodulator waveform 4 sample 4 (sfix6en5)
23-18 SMPL3	Demodulator waveform 4 sample 3 (sfix6en5)
17-12 SMPL2	Demodulator waveform 4 sample 2 (sfix6en5)
11-6 SMPL1	Demodulator waveform 4 sample 1 (sfix6en5)
5-0 SMPL0	Demodulator waveform 4 sample 0 (sfix6en5)

52.4.4.2.2.10.6.1.60 PHY Demodulator Wave4 Register 1 (DMD_WAVE4_REG1)

Offset

Register	Offset
DMD_WAVE4_REG1	ECh

Diagram



Fields

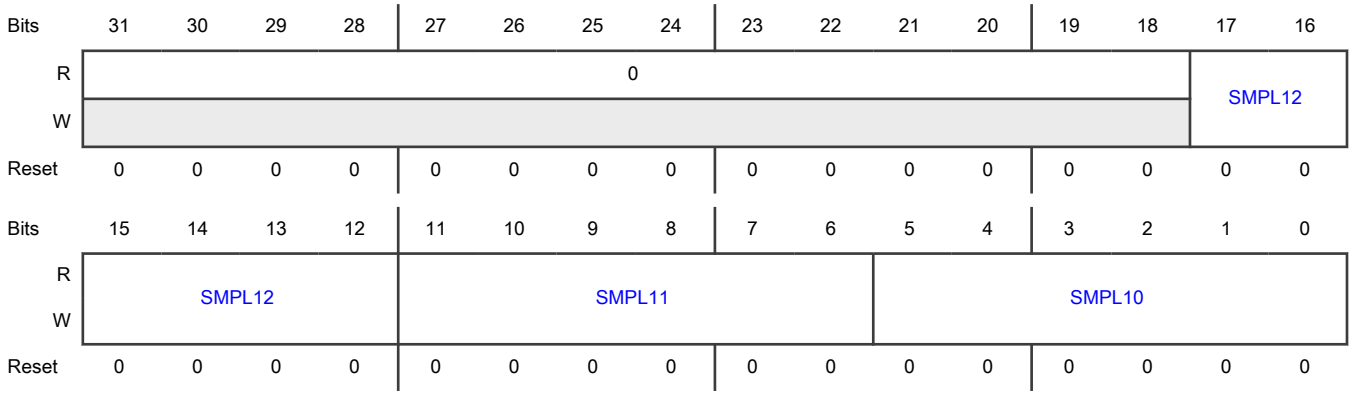
Field	Function
31-30 —	Reserved
29-24 SMPL9	Demodulator waveform 4 sample 9 (sfix6en5)
23-18 SMPL8	Demodulator waveform 4 sample 8 (sfix6en5)
17-12 SMPL7	Demodulator waveform 4 sample 7 (sfix6en5)
11-6 SMPL6	Demodulator waveform 4 sample 6 (sfix6en5)
5-0 SMPL5	Demodulator waveform 4 sample 5 (sfix6en5)

52.4.4.2.2.10.6.1.61 PHY Demodulator Wave4 Register 2 (DMD_WAVE4_REG2)

Offset

Register	Offset
DMD_WAVE4_REG2	F0h

Diagram



Fields

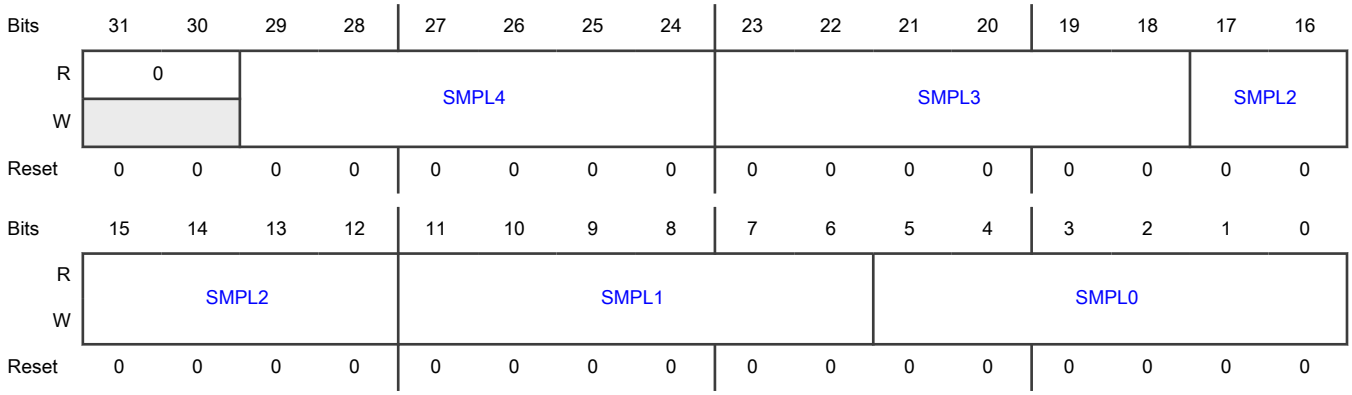
Field	Function
31-18 —	Reserved
17-12 SMPL12	Demodulator waveform 4 sample 12 (sfix6en5)
11-6 SMPL11	Demodulator waveform 4 sample 11 (sfix6en5)
5-0 SMPL10	Demodulator waveform 4 sample 10 (sfix6en5)

52.4.4.2.2.10.6.1.62 PHY Demodulator Wave5 Register 0 (DMD_WAVE5_REG0)

Offset

Register	Offset
DMD_WAVE5_REG0	F4h

Diagram



Fields

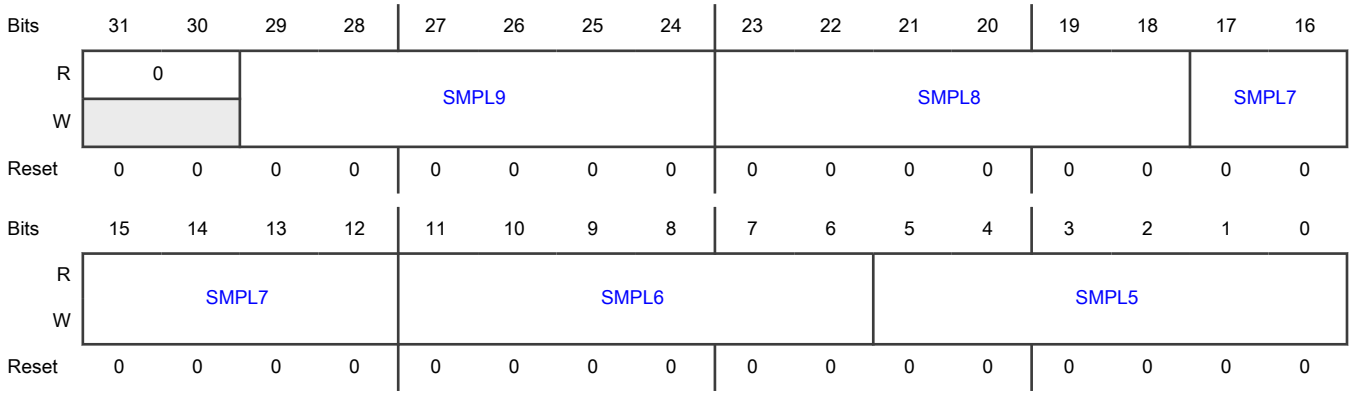
Field	Function
31-30 —	Reserved
29-24 SMPL4	Demodulator waveform 5 sample 4 (sfix6en5)
23-18 SMPL3	Demodulator waveform 5 sample 3 (sfix6en5)
17-12 SMPL2	Demodulator waveform 5 sample 2 (sfix6en5)
11-6 SMPL1	Demodulator waveform 5 sample 1 (sfix6en5)
5-0 SMPL0	Demodulator waveform 5 sample 0 (sfix6en5)

52.4.4.2.2.10.6.1.63 PHY Demodulator Wave5 Register 1 (DMD_WAVE5_REG1)

Offset

Register	Offset
DMD_WAVE5_REG1	F8h

Diagram



Fields

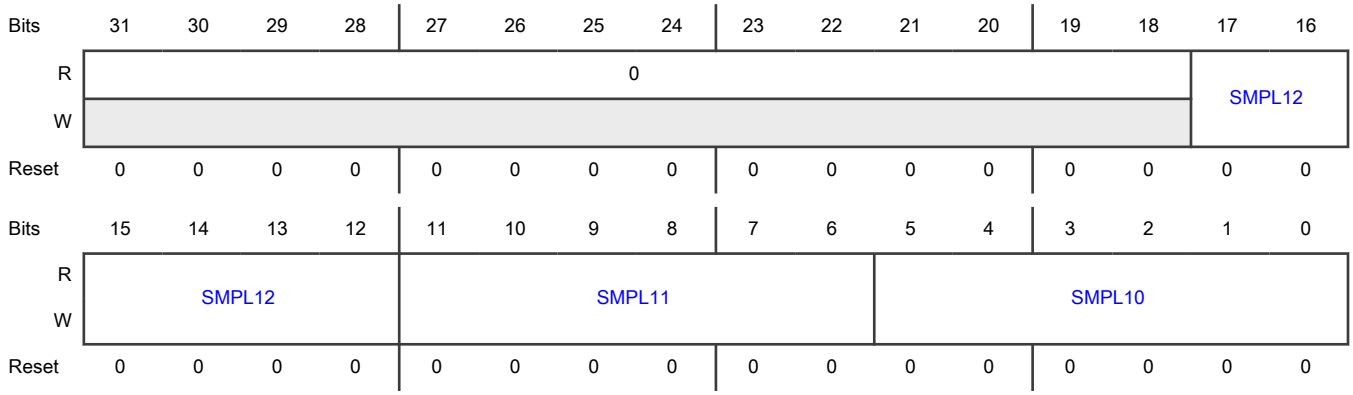
Field	Function
31-30 —	Reserved
29-24 SMPL9	Demodulator waveform 5 sample 9 (sfix6en5)
23-18 SMPL8	Demodulator waveform 5 sample 8 (sfix6en5)
17-12 SMPL7	Demodulator waveform 5 sample 7 (sfix6en5)
11-6 SMPL6	Demodulator waveform 5 sample 6 (sfix6en5)
5-0 SMPL5	Demodulator waveform 5 sample 5 (sfix6en5)

52.4.4.2.2.10.6.1.64 PHY Demodulator Wave5 Register 2 (DMD_WAVE5_REG2)

Offset

Register	Offset
DMD_WAVE5_REG2	FCh

Diagram



Fields

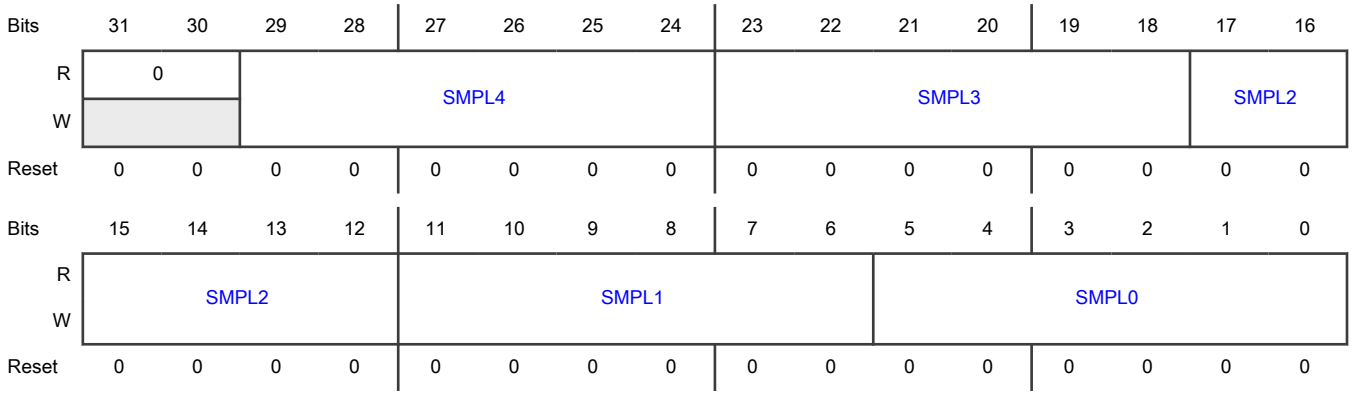
Field	Function
31-18 —	Reserved
17-12 SMPL12	Demodulator waveform 5 sample 12 (sfix6en5)
11-6 SMPL11	Demodulator waveform 5 sample 11 (sfix6en5)
5-0 SMPL10	Demodulator waveform 5 sample 10 (sfix6en5)

52.4.4.2.2.10.6.1.65 PHY Demodulator Wave6 Register 0 (DMD_WAVE6_REG0)

Offset

Register	Offset
DMD_WAVE6_REG0	100h

Diagram



Fields

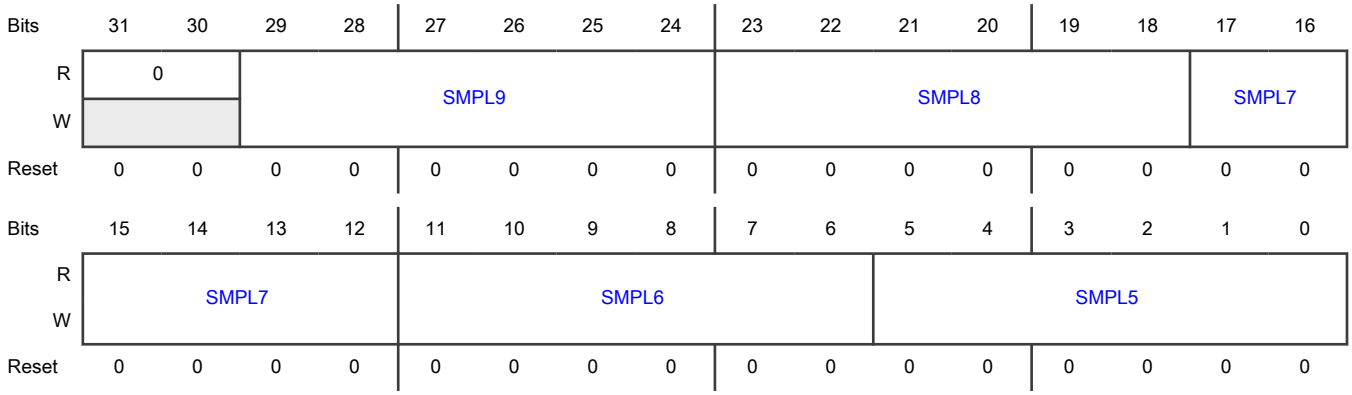
Field	Function
31-30 —	Reserved
29-24 SMPL4	Demodulator waveform 6 sample 4 (sfix6en5)
23-18 SMPL3	Demodulator waveform 6 sample 3 (sfix6en5)
17-12 SMPL2	Demodulator waveform 6 sample 2 (sfix6en5)
11-6 SMPL1	Demodulator waveform 6 sample 1 (sfix6en5)
5-0 SMPL0	Demodulator waveform 6 sample 0 (sfix6en5)

52.4.4.2.2.10.6.1.66 PHY Demodulator Wave6 Register 1 (DMD_WAVE6_REG1)

Offset

Register	Offset
DMD_WAVE6_REG1	104h

Diagram



Fields

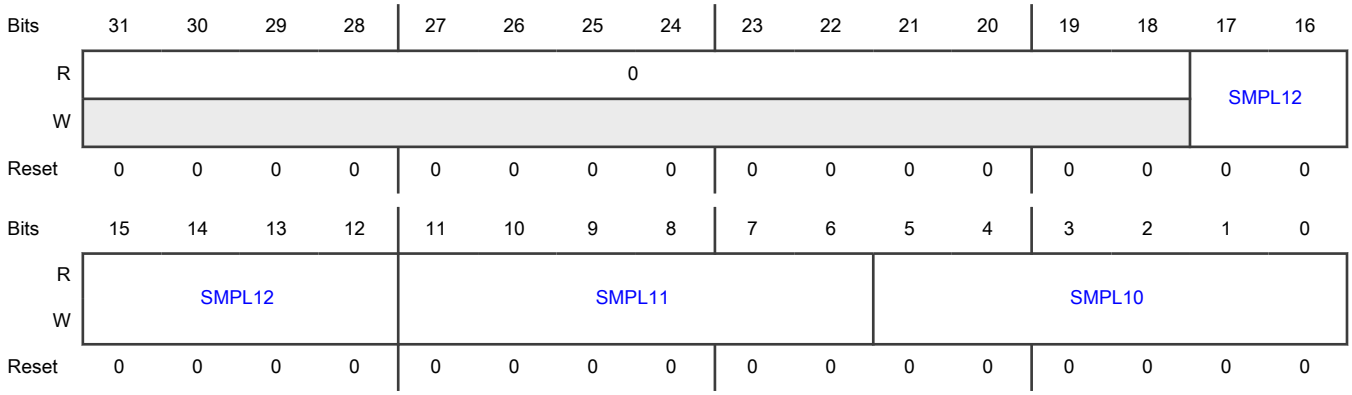
Field	Function
31-30 —	Reserved
29-24 SMPL9	Demodulator waveform 6 sample 9 (sfix6en5)
23-18 SMPL8	Demodulator waveform 6 sample 8 (sfix6en5)
17-12 SMPL7	Demodulator waveform 6 sample 7 (sfix6en5)
11-6 SMPL6	Demodulator waveform 6 sample 6 (sfix6en5)
5-0 SMPL5	Demodulator waveform 6 sample 5 (sfix6en5)

52.4.4.2.2.10.6.1.67 PHY Demodulator Wave6 Register 2 (DMD_WAVE6_REG2)

Offset

Register	Offset
DMD_WAVE6_REG2	108h

Diagram



Fields

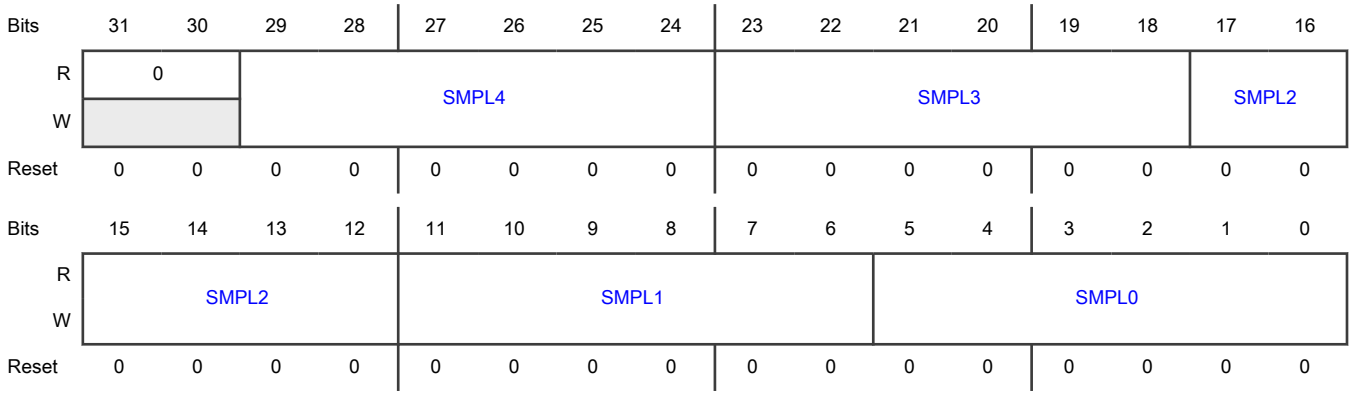
Field	Function
31-18 —	Reserved
17-12 SMPL12	Demodulator waveform 6 sample 12 (sfix6en5)
11-6 SMPL11	Demodulator waveform 6 sample 11 (sfix6en5)
5-0 SMPL10	Demodulator waveform 6 sample 10 (sfix6en5)

52.4.4.2.2.10.6.1.68 PHY Demodulator Wave7 Register 0 (DMD_WAVE7_REG0)

Offset

Register	Offset
DMD_WAVE7_REG0	10Ch

Diagram



Fields

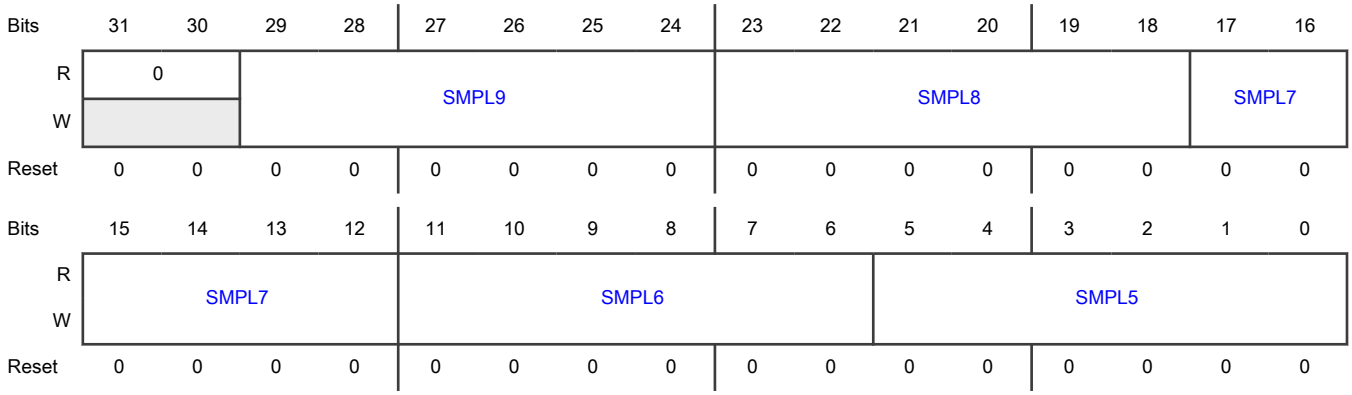
Field	Function
31-30 —	Reserved
29-24 SMPL4	Demodulator waveform 7 sample 4 (sfix6en5)
23-18 SMPL3	Demodulator waveform 7 sample 3 (sfix6en5)
17-12 SMPL2	Demodulator waveform 7 sample 2 (sfix6en5)
11-6 SMPL1	Demodulator waveform 7 sample 1 (sfix6en5)
5-0 SMPL0	Demodulator waveform 7 sample 0 (sfix6en5)

52.4.4.2.2.10.6.1.69 PHY Demodulator Wave7 Register 1 (DMD_WAVE7_REG1)

Offset

Register	Offset
DMD_WAVE7_REG1	110h

Diagram



Fields

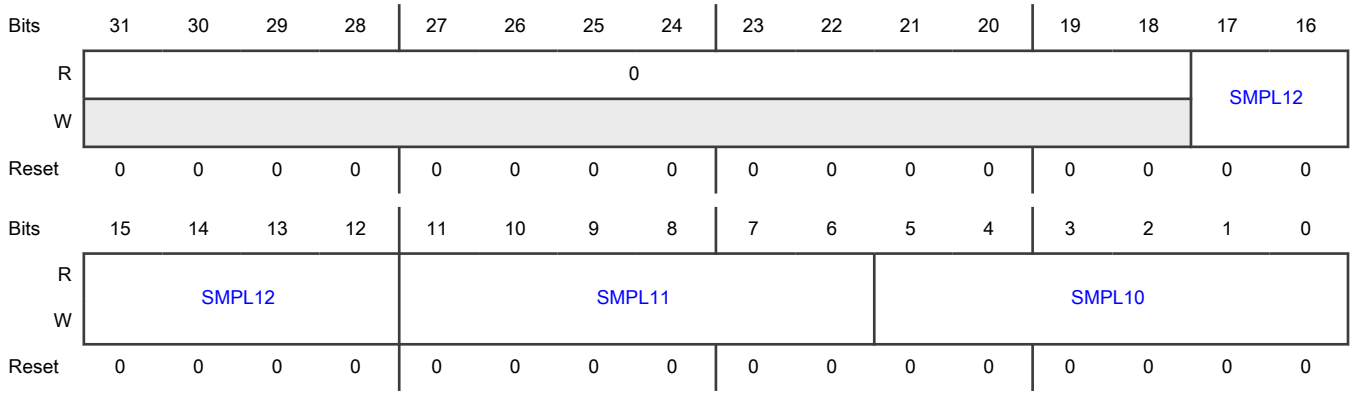
Field	Function
31-30 —	Reserved
29-24 SMPL9	Demodulator waveform 7 sample 9 (sfix6en5)
23-18 SMPL8	Demodulator waveform 7 sample 8 (sfix6en5)
17-12 SMPL7	Demodulator waveform 7 sample 7 (sfix6en5)
11-6 SMPL6	Demodulator waveform 7 sample 6 (sfix6en5)
5-0 SMPL5	Demodulator waveform 7 sample 5 (sfix6en5)

52.4.4.2.2.10.6.1.70 PHY Demodulator Wave7 Register 2 (DMD_WAVE7_REG2)

Offset

Register	Offset
DMD_WAVE7_REG2	114h

Diagram



Fields

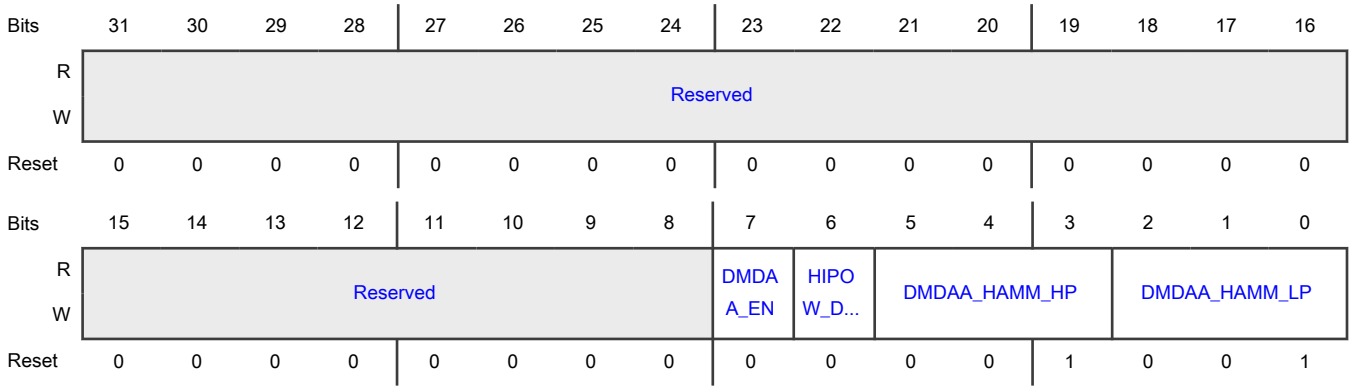
Field	Function
31-18 —	Reserved
17-12 SMPL12	Demodulator waveform 7 sample 12 (sfix6en5)
11-6 SMPL11	Demodulator waveform 7 sample 11 (sfix6en5)
5-0 SMPL10	Demodulator waveform 7 sample 10 (sfix6en5)

52.4.4.2.2.10.6.1.71 PHY Demodulator Based SFD Confirmation control register. (DMDAA_CTRL)

Offset

Register	Offset
DMDAA_CTRL	164h

Diagram



Fields

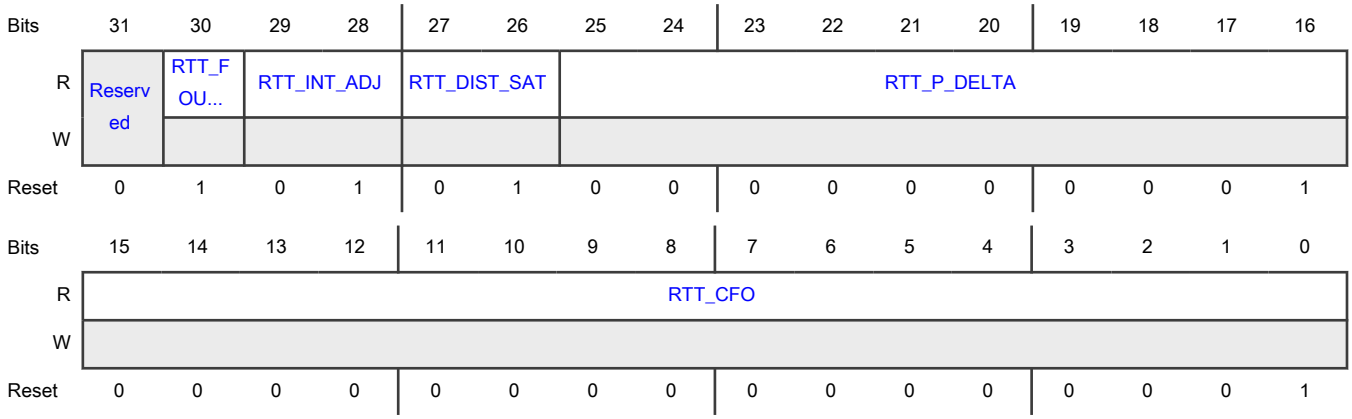
Field	Function
31-8 —	Reserved
7 DMDAA_EN	Enables Demodulator Based SFD Confirmation; DMDAA can perform a secondary AA hamming check in parallel to AA search which high precision, which is started when AA search matched. By default, DMDAA is only applied when signal power near Sensitivity. 0b - disable 1b - enable
6 HIPOW_DIS_OVRD	Override the feature: disable DMDAA when power sensitivity is higher; 0b - disable override, DMDAA disabled when power is high 1b - enable override, DMDAA enabled when power is high
5-3 DMDAA_HAMM_HP	Maximum hamming distance from the given AA pattern that may still be accepted as a match in high power case; valid range [0,7].
2-0 DMDAA_HAMM_LP	Maximum hamming distance from the given AA pattern that may still be accepted as a match in low power case; valid range [0,7].

52.4.4.2.2.10.6.1.72 High resolution Time-Of-Flight calculation Status. (RTT_STAT)

Offset

Register	Offset
RTT_STAT	168h

Diagram



Fields

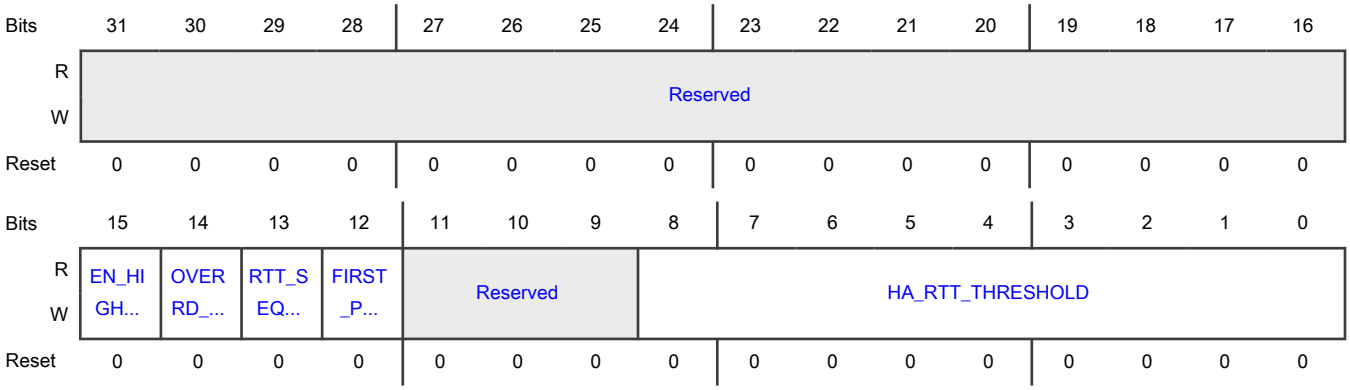
Field	Function
31 —	Reserved
30 RTT_FOUND	Flag that indicates that the HARTT operation is done and a valid PN pattern was detected.
29-28 RTT_INT_ADJ	An integer adjustment of the timing which takes a value different of 0 when the early-late mechanism in the HARTT block chooses a peak different of the one chosen in the acquisition module (possible values are {-1,0,+1}).
27-26 RTT_DIST_SAT	Computed Hamming distance saturated to 2 bits, format is ufix2.
25-16 RTT_P_DELTA	Difference between the squared correlation magnitude values, pm-pp provided by the HARTT block, format is sfix10En9.
15-0 RTT_CFO	The high accuracy CFO computed by the HARTT block through the CORDIC algorithm.

52.4.4.2.2.10.6.1.73 PHY RTT control register. (RTT_CTRL)

Offset

Register	Offset
RTT_CTRL	16Ch

Diagram



Fields

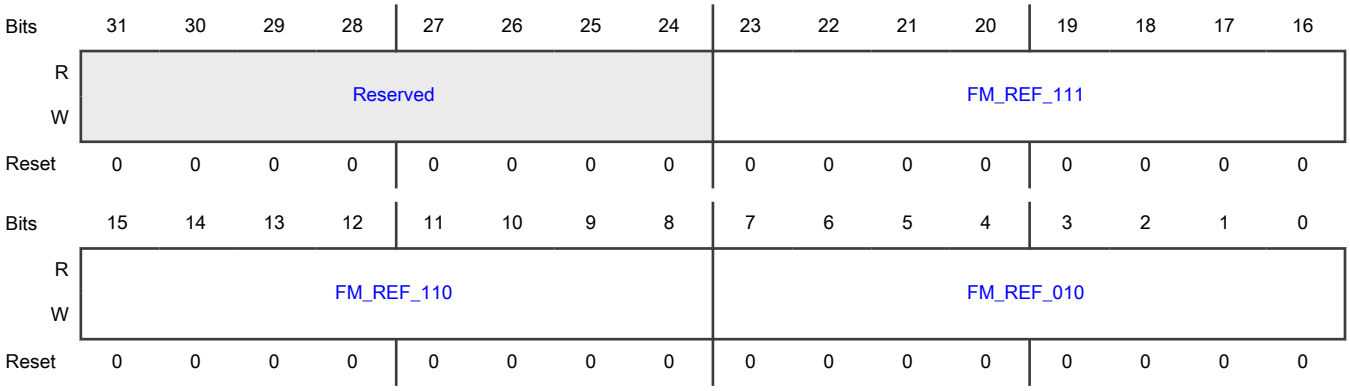
Field	Function
31-16 —	Reserved
15 EN_HIGH_ACC_RTT	enables the use of the HA RTT block;
14 OVERRD_PROGR_AA	Enables overriding the programmed AA bits with the PN sequence used by RTT;
13 RTT_SEQ_LEN	Allow PHY Demodulation during RTT computation If set, this bit enables the CS packet demodulation even if RTT computation is required. It can be used to get the received packet payload during Rx sounding sequence. When this bit is set, register DMD_CTRL2[WAIT_DMD_CLKEN_ADJ] has to be tuned to ensure correct demodulation of the first payload bit.
12 FIRST_PDU_BIT	Programmed by software - used for regular packets high accuracy RTT; First PDU bit gets programmed into this field
11-9 —	Reserved
8-0 HA_RTT_THRESHOLD	threshold used to validate a HA RTT result. Format ufix9en9

52.4.4.2.2.10.6.1.74 PHY RTT reference register. (RTT_REF)

Offset

Register	Offset
RTT_REF	170h

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 FM_REF_111	Contextual values used to derive the FM reference ha_rtt_threshold . Threshold used to validate a HA RTT result. Format sfix8en7.
15-8 FM_REF_110	Contextual values used to derive the FM reference ha_rtt_threshold . Threshold used to validate a HA RTT result. Format sfix8en7.
7-0 FM_REF_010	Contextual values used to derive the FM reference ha_rtt_threshold . Threshold used to validate a HA RTT result. Format sfix8en7.

52.4.4.2.2.11 Coexistence BLE/CS - WIFI

52.4.4.2.2.11.1 Introduction

The coexistence is driven by an external chip which will send rf_not_allowed information via the MCXW72 input pin. This information will be routed to the corresponding feature (could be several, for instance BLE+RSM or BLE+Zigbee), which are :

- BLE NBU → RF_NOT_ALLOWED_EN[0]
- Antenna/Ranging (RSM) → RF_NOT_ALLOWED_EN[1]
- Zigbee 802.15.4 → RF_NOT_ALLOWED_EN[2]
- Generic LL → RF_NOT_ALLOWED_EN[3]

Inside the transceiver, the coexistence for channel sounding with Ranging (RSM) will be managed and also the protocol to interface with Qualcomm chip and future connectivity NXP platform.

52.4.4.2.2.11.2 Coexistence for BLE/CS protocol

The chip will provide priority/status/active signals to external and will manage incoming rf_not_allowed signal for BLE and channel sounding.

When asserting bt_active, tx data will not be sent if rf_not_allowed occurs (with timings defined int the protocol). The signal bt_active will be deasserted when rf_not_allowed_asserted (always in BTLE ; not always in CS – see Method 2 in CS protocol section).

Several protocol will be supported for existing customer chips and also for future connectivity NXP chip compatibility , protocol mode can be chosen with field : coex_mode.coex_dualprio[1:0] : M=mode (0=BLE/1=CS),P=priority, S=status

- 00 -> PS (PS multiplexed on priority wire) , 01 -> MPS (mode added, MP multiplexed on priority wire)
- 10 -> several status , PS+ (PS SSSS...), 11: several status with mode MPS+ (MPS SSSS...)
- For mode 01 and 11 , (priority=tsm_prio or tsm_status ☐ , tsm_prio and tsm_status must be exclusive -> tsm_prio should be a pulse , and tsm_status set after prio)
- Modes 00 and 01 only supported in CS , all modes supported in BLE but need register tsm_rf_active_extend for 10/11 in BLE to ensure rf_active continuity

The status will indicate the rx_en ou tx_en activity but we could also use another mode via the field : coex_mode.coex_conflict_channel_en which will indicate the coexistence activity on this wire.

Interrupt coex_irq_rf_deny[2:0] is added on rise/fall/bta(rf_deny=1 when rising bt_active) with ena/clear/status for all standards (Zigbee/BLE/CS/generic LL)

The register coex_mode.coex_prio1_sw[1:0] will add a feature to take control of priority[1] by software (bit 0=en, bit 1=val)

NB : an early NBU trigger to start bt_active can be activated with register coex_ble_early_event (extra mode pre-event , not planned to be used in typical cases)

Below 3 examples protocol with/without abort:

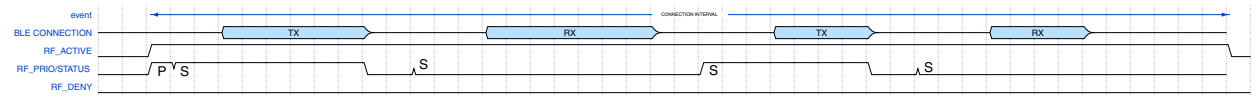


Figure 400. Coexistence BLE protocol PS+ (dualprio=10 , not aborted)

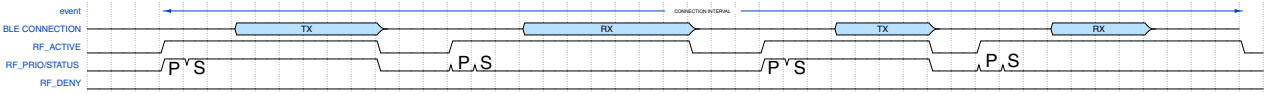


Figure 401. Coexistence BLE protocol PS (dualprio=00 , not aborted)

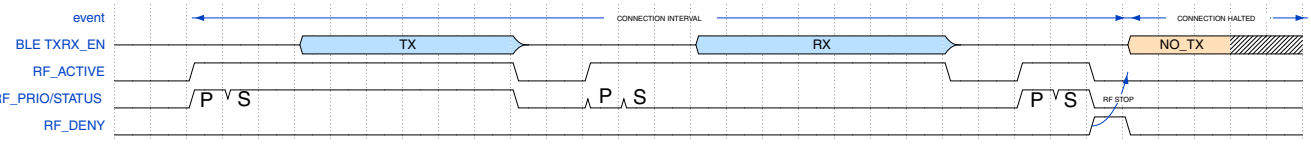


Figure 402. Coexistence BLE protocol PS (dualprio=00 , aborted by host)

52.4.4.2.2.11.3 Coexistence for Channel Sounding protocol

The feature will be enable via field coex_mode.coex_cs_en . This will route rf_not_allowed to the RSM bloc and in this way manage the coexistence for Channel Sounding.

There are several ways to manage coexistence in Channel Sounding, the FCS steps (modes 0) could be managed in a different manner from other steps., we have 3 configuration possible:

- 1° Method in 1 shot : register coex_cs_dualreq = 0 (use case more for QC) the bt_active/priority/status will be managed only at beginning of sub-event => abort in case of rf_deny (same method as BTLE in NBU)
- 2° Method in 2 bt_active : register coex_cs_dualreq = 1 (usecase more for WCS)
  - 1 bt_active beginning modes 0 (synchro) -> high priority (p0=1,p1=1) to ensure synchro mandatory for channel sounding alignment -> abort sub-event if rf_deny occurs
  - 1 other bt_active after mode 0 :
    - (P0=1,P1=0) with PA tx_en have gating mode, bt_active maintained to 1 whatever rf_not_allowed status
    - some channels will be skipped , but distance estimation in theory possible with some degradation
- 3° Method in 1 shot and 2 phases : coex_cs_dualphase=1 , abort will be done during mode 0 but only PA tx_en have gating mode after mode 0 (no abort and keep rf_active) -> only compatible with coex_cs_dualreq=0

52.4.4.2.2.11.4 Coexistence channels lock mode

The field coex_mode.coex_channel_allow_en will allow possibility to lock some channels and use them whatever coexistence status.

A channel mapping will give the possibility to allow transceiver activity whatever coexistence status, we can for instance allow some upper channels for ble/cs because we have the knowledge that WIFI will be in lower band, or vice-versa. A register coex_mode.coex_rf_channel_allow[0..127] will be available to map the ble/cs bandwidth area (1: ignore rf_not_allowed signal from external , 0:rf_not_allowed is taken into account to stop RF activity)

52.4.4.2.2.12 LDO Calibration

The LDO Calibration module uses a binary search to find the best 6bit calibration code (ldo_cal_trim[5:0]) for the LDO calibration circuit in the analog, and then performs subsequent incremental trims for PLL, VCO and RTXHF LDOs. It is expected that the LDO calibration will be performed on each TX and RX warmup. The entire LDO calibration sequence with incremental calibration requires no more than 8us for all XO reference frequencies supported.

The calibration timing is illustrated in Figure 403 and Figure 404 below.

The calibration sequence is initiated by a TSM control signal (tsm_ldocal_en). The ldo_cal_trim[5:0] is initialized to 6'b10_0000 (6'h20) while the trim codes for the PLL, VCO, RXTXHF and RXTXLF LDOs are initialized to 6'b01_1111 (6'h1F). During each of the 6 steps of the calibration, each bit of the ldo_cal_trim[5:0] is individually set, and a comparator output from the analog (ldo_trim_cmpout) is used to determine whether the bit should remain set of be cleared. By default, the comparator output signal is captured 2 clk cycles after the ldo_trim_sample signal is de-asserted, but this can also be programmed to 1clk or 3clks if desired. At the end of the 6 steps, the best ldo_cal_trim[5:0] value has been found. The PLL, VCO, RXTXHF and RXTXLF LDO's trim codes are then updated using ldo_cal_trim[5:0] and signed, 4-bit offsets which can be programmed differently for PLL, VCO, RXTXHF and RXTXLF as needed.

The total time needed to determine the ldo_cal_trim is as follows, where LDO_TRIM_SMPL_DLY is a programmable value which is 2 by default but which can also be programmed for values of 1 or 3

1clk + 6*(0.5us + 1clk + LDO_TRIM_SMPL_DLY clks)

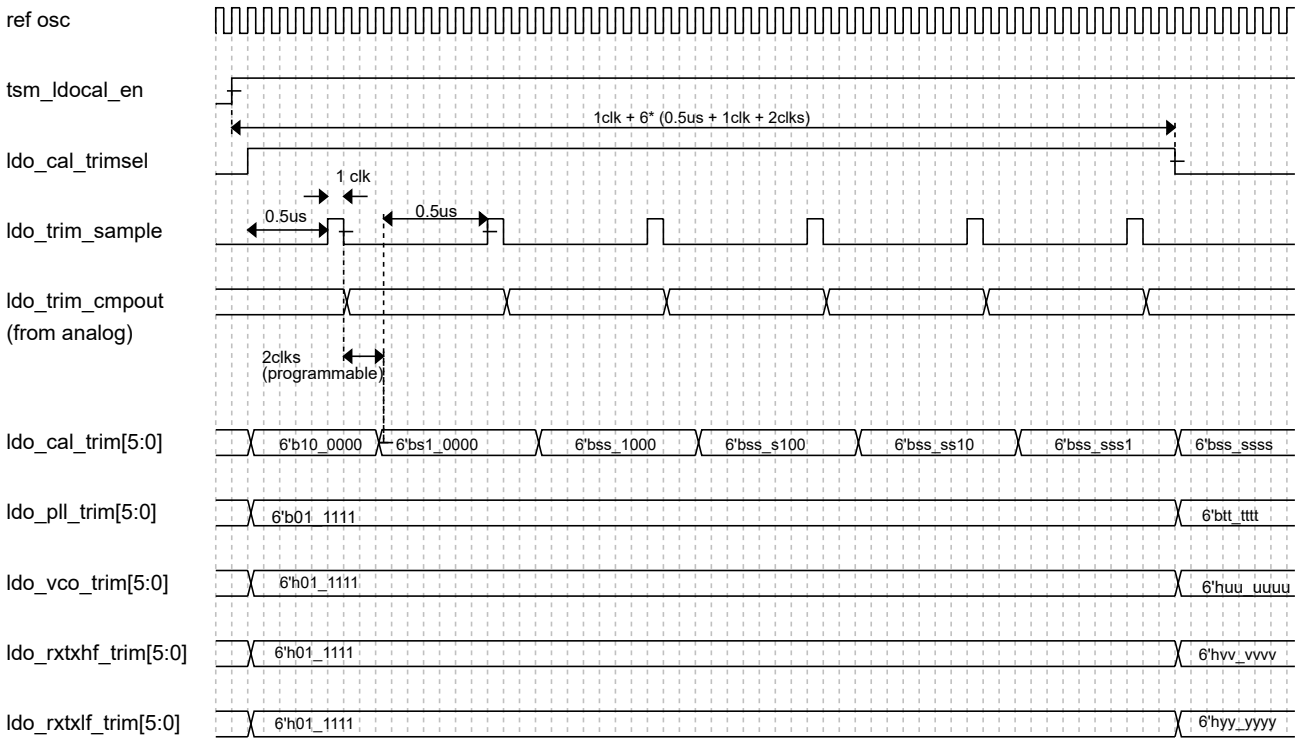


Figure 403. LDO trim part 1: ldo_cal_trim

Incremental calibration allows the PLL, VCO and RXTXHF LDO trim codes to be tested individually and adjusted by +1 trim code value. After the best ldo_trim_code[5:0] has been found from the main calibration, the ldocal module will wait at least 2us but no more than 3us. Following this, trim select signals for the PLL, VCO and RXTXHF LDOs will be sequentially asserted so that the trim code for each of these LDOs can be individually tested. In each case, based on the comparator value the LDO's trim code will either be left as is or incremented by +1 (there is no option to decrease the trim code by 1). Note that the RXTXLF LDO is not incrementally calibrated.

Excluding the +2us wait time before incremental trim, the total time for the incremental calibration is as follows:

3*(0.5us + 1clk + LDO_TRIM_SMPL_DLY clks + 1 clk) + 1 clk

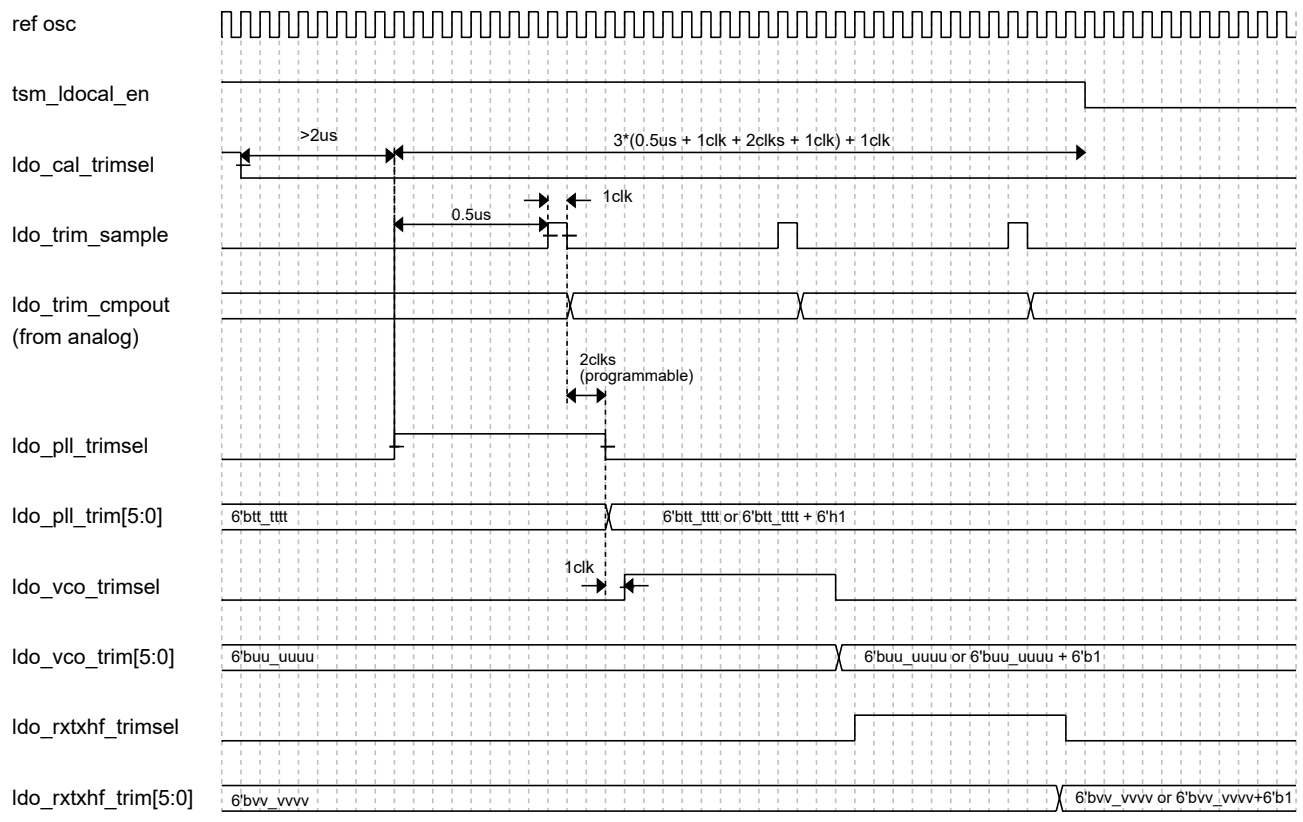


Figure 404. LDO trim part 2: incremental calibrations

The total time for the both parts of the calibrations is as follows:

$ceiling(1clk + 6*(0.5uw + 1clk + LDO_TRIM_SMPL_DLY clks)) + 2us + 3*(0.5us + 1clk + LDO_TRIM_SMPL_DLY clks + 1 clk) + 1 clk

For the default value of LDO_TRIM_SMPL_DLY=2, this is less than 8us for all supported XO frequencies.

Normally, the tsm_ldocal_en remains asserted after the ldo_cal_trim[5:0] has been found in order to perform the incremental calibrations. However, if incremental calibrations are not needed, the tsm_ldocal_en can be de-asserted after ldo_cal_trim[5:0] has been found. This scenario is shown in the figure below. In this case, for the default value of LDO_TRIM_SMPL_DLY=2, only 4us is required for the LDO calibration.

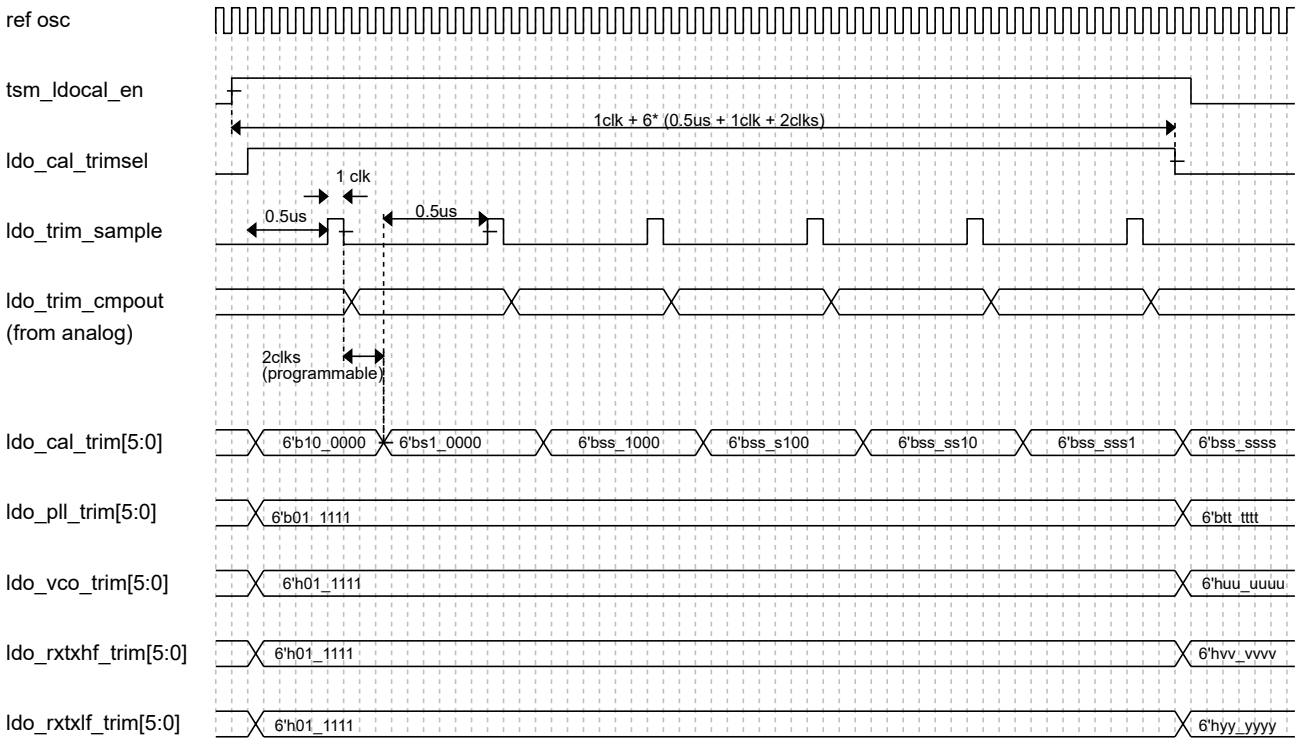


Figure 405. LDO trim without incremental calibrations

52.4.4.2.2.13 Clocking

The transceiver contains a single clock source xcvr_ref_clk which is used directly or drives several clock gating inside xcvr_cgm module.

The table below shows the transceiver clock distribution.

Table 540. Internal Transceiver Clocks

Clock Source	Module	Input	Clock Name	Clock Enable
xcvr_ref_clk	rx_digital	clk	xcvr_ref_clk	-
		ips_clk	ips_clk_rx_dig	IPS access to rx_digital registers
	tx_digital	ref_clk	xcvr_ref_clk	-
		ips_clk	ips_clk_tx_dig	IPS access to tx_digital registers
	pll_digital	ref_clk	xcvr_ref_clk	-
		ipg_clk	ips_clk_pll_dig	IPS access to pll_digital registers
	tsm	ref_clk	xcvr_ref_clk	-

Table continues on the next page...

Table 540. Internal Transceiver Clocks (continued)

Clock Source	Module	Input	Clock Name	Clock Enable
		ips_clk	ips_clk_tsm	IPS access to tsm registers
		tsm_clk	ipg_clk_tsm	(tsm_clk_en | rsm_clk_en) & cg1m_en
		tsm_dly_clk	ipg_clk_tsm_dly	tsm_clk_en & cg1m_dly_en
	xcvr_glue	xcvr_ref_clk	xcvr_ref_clk	-
	tpm	xcvr_ref_clk	xcvr_ref_clk	-
	gen4_phy	clk	ipg_clk_gen4_phy	(rx_phy_en&demod_sel[0])|phy_clk_on
		ips_clk	ips_clk_gen4_phy	IPS access to gen4_phy registers
	zigbee_phy	ck	ipg_clk_zbdem	((rx_phy_en|rx_phy_en_xtend)&demod_sel[1])|zbdem_clk_on
		rx_gck	ipg_clk_zbdem	((rx_phy_en|rx_phy_en_xtend)&demod_sel[1])|zbdem_clk_on
		ipg_clk_zbdem_cca	ipg_clk_zbdem_cca	((rx_phy_en|rx_phy_en_xtend)&demod_sel[1]&zbdem_cca_clk_on)| zbdem_clk_on
		ipg_clk_cca2_32m	ipg_clk_cca2_32m	((rx_phy_en| rx_phy_en_xtend)&demod_sel[1]&~use_demod_cca2&(cca2_en | cca3_en))|zbdem_clk_on
		ipg_clk_cca2_2m	ipg_clk_cca2_2m	(((rx_phy_en| rx_phy_en_xtend)&demod_sel[1]&~use_demod_cca2&(cca2_en | cca3_en))|zbdem_clk_on)&cg2m_en
		ips_clk	ips_clk_zigbee_phy	IPS access to zigbee registers
	ranging_data	ref_clk	ipg_clk_rsm	rsm_clk_en
	ranging_sm	ref_clk	ipg_clk_rsm	rsm_clk_en
		ipg_clk_tsm	ipg_clk_tsm	(tsm_clk_en | rsm_clk_en) & cg1m_en
	lcl_ctrl	clk	ipg_clk_lcl_ctrl	lcl_en
		clk_tsm	ipg_clk_tsm	(tsm_clk_en | rsm_clk_en) & cg1m_en
	xcvr_dma_dbg	ipg_clk_dma	ipg_clk_dma	dma_clk_en
		ipg_clk_ram_dbg		dbg_clk_en
	xcvr_ana_regs	ipg_clk	ips_clk_xcvr_ana	IPS access to analog registers

Table continues on the next page...

Table 540. Internal Transceiver Clocks (continued)

Clock Source	Module	Input	Clock Name	Clock Enable
	xcvr_misc_regs	ipg_clk	ips_clk_xcvr_misc	IPS access to transceiver_misc registers
	ips_fom	clk	ipg_clk_ips_fom	IPS access
	ldocal	clk	ipg_clk_ldocal	ldo_cal_en

52.4.4.2.2.14 Reset

All Transceiver logic that require a reset are reset by a global asynchronous reset. In addition, a software reset from 2P4Ghz Radio can reset internal modules except the register modules.

52.4.4.2.2.15 Interrupts

The transceiver interrupt sources are summarized in the table below.

Signal	I/O	Description
ipi_int_rsm_async	output	RSM interrupt for BTLE Link Layer
ipi_int_lant_sw_async	output	LCL interrupt for BTLE Link Layer
ipi_int_pll_unlock_async	output	Unlock PLL interrupt for BTLE Link Layer
tsm_irq_ble	output	TSM interrupt for BTLE Link Layer
tsm_irq_zigbee	output	TSM interrupt for Zigbee Link Layer
tsm_irq_gen	output	TSM interrupt for GenFSK Link Layer

52.4.4.2.2.16 DMA

52.4.4.2.2.16.1 Introduction

For debug and evaluation purposes, the Radio provides the capability to capture a variety of internal data during the reception process, and store it to either system memory (using Transceiver DMA mode) or radio packet ram (using Packet RAM Debug mode), for analysis and post-processing

52.4.4.2.2.16.1.1 Overview

During silicon debug and evaluation, it is often desirable to gain access to data internal to the digital receiver, in order to, for example:

- troubleshoot packet loss issues
- troubleshoot unexpectedly high Bit Error Rate
- fine-tune receiver initialization and configuration parameters

The radio offers 3 methods of accessing such internal data:

1. Transceiver DMA mode
2. Packet RAM Debug mode
3. Digital Test Mux (DTEST)

This section describes the first 2 methods.

Examples of internal data desirable for capture are raw ADC samples, RX digital I and Q outputs, and PHY soft decision data. Transceiver DMA and Packet RAM Debug modes allow a source of internal data to be selected, automate the acquisition of the data, pack the data into a format suitable and optimized for its destination (system or radio memory), implement the interfaces required to access those memories, store the data to memory under program control, and subsequently allow host MCU access to the acquired data for analysis and post-processing. For DMA mode, the SoC's RAM is used via the SoC DMA. For RAM debug mode, the radio packet RAM is made available for this debug mode.

52.4.4.2.2.16.1.2 Features

- Captures any of several sources from RX_DIG or PHY
- DMA engine outputs data to an Async FIFO in the SoC which communicates with SoC DMA controller to access system memory
- Packet RAM Debug engine automates transfers to radio memory
- Efficient packing of source data optimized to destination memory dimensions
- Efficient packing of source data optimized to make best use of available bandwidth
- Samples can be decimated by x1, x2, x4, or x8 independently for DMA and Packet RAM
- DMA mask feature allows RSM and LCL_CTRL to specify when samples should be captured
- DMA and Packet RAM engine clocking disabled in mission mode to reduce power
- Simultaneous DMA and Packet RAM Debug operation possible
- Hardware start-triggering capability with several hardware sources
- Start trigger can be delayed by programmable amount up to 2ms (11bits @ 1us resolution)
- Stop-on-trigger capability for Packet RAM Debug

52.4.4.2.2.16.1.3 Block Diagram

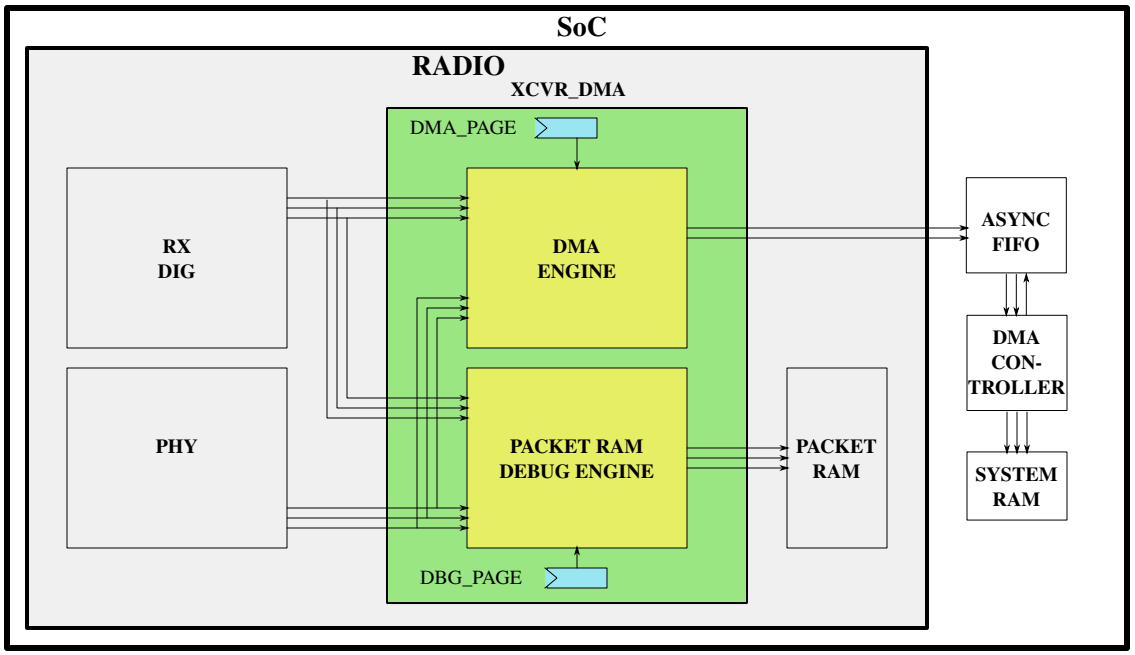


Figure 406. Transceiver DMA and Packet RAM Debug

52.4.4.2.2.16.2 Functional Description

52.4.4.2.2.16.2.1 DMA Engine

Tranceiver DMA Engine takes internal receive data from the RX_DIG or PHY, packs the data into an optimal format for bandwidth or RAM dimensions, and hands off the data to an external (SoC) Async FIFO which in turn communicates with the SoC DMA controller for ultimate transfer to system memory. Control and configuration of transceiver DMA operation is governed by the bit fields in the DMA_CTRL register of XCVR address space. These bit fields are referenced in the description that follows. In a typical transceiver DMA debug session, the transceiver DMA hardware performs the following steps:

1. Selects a source of internal data from RX_DIG or PHY for capture based on DMA_PAGE[3:0] setting
2. Waits for a hardware start-trigger, if so configured
3. Waits for a programmable delay (up to 2ms @ 1us resolution), if so configured
4. Uses a defined capture signal from RX_DIG or PHY to latch the internal data into a holding register. Depending on DMA_DEC[1:0], every sample, every other sample, every 4th sample, or every 8th sample will be captured.
5. If capture size is less than 32-bits, packs 2 or more captures of internal data into a 32-bit register until the packing requirements for that DMA_PAGE setting are met
6. Drives 32-bit data along with a valid strobe signal to an SoC Asynchronous FIFO which communicates with the SoC DMA controller
7. Repeats steps 3-5 until the debug session is complete (DMA_PAGE set to 0).

If a hardware start-trigger is selected (DMA_START_TRG > 0), the dma engine will wait until the selected triggering event occurs before acquiring any samples; otherwise, acquisition begins as soon as DMA_PAGE is set to a non-zero value.

The maximum DMA transfer rate in this mode is not limited by the radio: the transceiver DMA is capable of sustained 32bit transfers at the reference clock rate, so any limitation would be due to the Async FIFO, DMA, or SoC clocking.

52.4.4.2.2.16.2.1.1 PAGE TABLE for 2.4GHz Transceiver Gen4.5

The following table describes the available DMA_PAGE settings. The internal source data selected, the capture signal employed, the data packing method, the OSR setting, and the data rate, are provided for each DMA_PAGE setting.

MNEMONIC	PACKING	CAPTURE SIGNAL	REMARKS
DMAIDLE	---	---	No DMA Activity. All clocks to transceiver DMA hardware gated off.
RXDIG-IQ	{rx_dft_iq_out_q[10:0], rx_dft_if_mixer_idx[4:0], rx_dft_iq_out_i[10:0], rsm_dt_rx_flag, rsm_pm_rx_flag, rsm_fm_rx_flag, aa_sfd_matched, rsm_current_steps[0]}	rx_dft_iq_out_vld	Q and I data captured at various locations in RXDIG. Data is MSB aligned in each 16bit half-word. Check XCVR_RX_DIG->CTRL1[RX_MIXER_IDX_OUT_MODE] for rx_mixer_idx[9:0] mapping.
RXDIG-IQ-ALT	{rx_dft_iq_out_q[10:0], 3'b0, antx_out, crc_fail, rx_dft_iq_out_i[10:0], 3'b0, rx_pd_fnd, aa_sfd_matched}	rx_dft_iq_out_vld	Q and I data captured at various locations in RXDIG plus additional info in the LSBs. I/Q data is MSB aligned in each 16bit half-word.
ADC-IQ	{adc_code_q[10:0], 5'b0, adc_code_i[10:0], 5'b0}	rx_dig_en	Raw ADC capture of I and Q channel. Data is MSB

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MNEMONIC	PACKING	CAPTURE SIGNAL	REMARKS
			aligned in each 16bit half-word. Bandwidth requirement is 1 word per reference clock cycle.
PHASE	{rx_dft_ph_out[5:0], 2'b0,rx_dft_ph_out[5:0], 2'b0,rx_dft_ph_out[5:0], 2'b0,rx_dft_ph_out[5:0], 2'b0}	rx_dft_ph_out_vld	Sync phase or demod phase (as selected in RXDIG). Newest sample in MSB. Each byte contains a MSB-aligned phase sample.
RSSI-PHASE	{rx_dft_rssi_out[7:0], rx_dig_ph_hi_res[7:0], rx_dft_rssi_out[7:0], rx_dig_ph_hi_res[7:0]}	rx_dft_rssi_ph_hi_res_vld	8bit Narrowband RSSI (rssi, rssi raw, lqi, snr, noise) or Wideband RSSI (rss, rssi raw) plus 8bit high-resolution phase. Newest sample in MS bytes.
MAG-PHASE	{rx_dig_ph_hi_res[7:0], 8'b0, rx_dft_mag_out[11:0], 4'b0}	rx_dft_mag_out_vld	RSSI magnitude + 8bit high-resolution phase.
2P4GHz-PHY	{phy_dma_mux[31:0]}	phy_dma_vld	PHY DMA mux output as selected in PHY
DETERMINISTIC	{counter_q[10:0], 5'b0, counter_i[10:0], 5'b0}	rx_dig_iq_vld	Mimics the RXDIGIQ page, but uses deterministic data for software debug purposes. The Q up-counter start from 0x400, the I up-counter starts from 0x000. The counters reset when dma_page=0, and start counting when the selected trigger fires

52.4.4.2.2.16.2.1.2 Example Procedure

The following steps outline the setup and execution of a Transceiver DMA debug session. This example acquires RX DIG I/Q data:

1. Program Receiver for desired protocol
2. If needed, configure RXDIG or PHY to enable the desired DMA output signals from those modules.
3. Enable clocking to the DMA engine by setting DMA_CTRL[DMA_EN]=1
4. Select a DMA start-trigger source, if desired, by setting DMA_CTRL[DMA_START_TRIG] to a non-zero value
5. Select a start-trigger delay value, if desired, by setting DMA_CTRL[DMA_START_DLY] to a non-zero value in microseconds.
6. Select a decimation rate for samples captured, if desired, by setting DMA_CTRL[DMA_DEC] to a non-zero value
7. Program DMA_CTRL[DMA_PAGE]=RXDIGIQ
8. Program the SOC DMA to capture data
9. Start the transceiver's RX sequence by e.g. setting TSM_CTRL[FORCE_RX_EN]=1
10. Begin transmitting RF to the DUT

11. Wait for sufficient RX data to be collected to satisfy the requirements of the debug session. E.g., wait for SOC DMA interrupt
12. Program DMA_CTRL[DMA_PAGE]=0 to terminate the acquisition
13. Download the captured data from system memory

Note: Step 7 (select the DMA_PAGE to enable the DMA engine) should be performed as a sequential, discrete write to the DMA_CTRL register, after steps 3-6 (enabling the clock, and configuring start delay, decimation, and start trigger) have been completed. A single write to DMA_CTRL is permitted for steps 3-6.

52.4.4.2.2.16.2.2 Packet RAM Debug Mode

Packet RAM Debug mode takes internal receive data from the RX_DIG or PHY, packs the data into an format suitable for storage in the radio's Packet RAM, and then directly fills the Rams with source data, under program control. Control and configuration of Packet RAM Debug operation is governed by the bit fields in the DBG_RAM* register of XCVR address space. These bit fields are referenced in the description that follows. In a typical Packet RAM debug session, the debug hardware performs the following steps:

1. Selects a source of internal data from RX_DIG or PHY for capture based on DBG_PAGE[3:0] setting
2. Waits for a hardware start-trigger, if so configured
3. Waits for a programmable delay (up to 2ms @ 1us resolution), if so configured
4. Uses a defined capture signal from RX_DIG or PHY to latch the internal data into a holding register. Depending on DBG_DEC[1:0], every sample, every other sample, every 4th sample, or every 8th sample will be captured.
5. If capture size is less than 32-bits, packs 2 or more captures of internal data into a 32-bit register until the packing requirements for that DBG_PAGE setting are met
6. Directly accesses the Packet RAM to store the receive data (addressing, write enabling, chip enabling, etc.). The first and last address to use in the ram can be programmed.
7. Repeats steps 3-5 until the debug session is complete: DBG_PAGE set to 0 ; a stop-on-trigger event occurs if so configure; or packet RAM (last address above reached) is full.

The bandwidth to Packet RAM is expected to be higher than Transceiver DMA, since the overhead of DMA-related synchronization and multi-master arbitration can be avoided. The tradeoff is that the total Packet RAM space is smaller than the space available in system memory, restricting the size of the block of data that can be saved.

52.4.4.2.2.16.2.2.1 Acquisition

In a typical debug session, the selection of a receive data source is made by setting DBG_PAGE to a non-zero value (see the table below for a description of the debug pages). Setting DBG_PAGE to a non-zero value activates the Packet RAM Debug Engine. The engine has write-only access to the RAM while receive data is being collected. (XCVR host IPS access is not blocked, but should be avoided during acquisition). If a hardware start-trigger is selected (DBG_START_TRG > 0), the debug engine will wait until the selected triggering event occurs before acquiring any samples; otherwise, acquisition begins as soon as DBG_PAGE is set to a non-zero value. Starting at the address indicated by DBG_RAM_FIRST, the RAM will fill with receive data determined by the DBG_PAGE setting. The address for the RAM is always reset to DBG_RAM_FIRST when DBG_PAGE=0.

If a stop-trigger is not selected (DBG_STOP_TRG = 0): When the RAM reaches DBG_RAM_LAST (programmable last address), further write attempts by the debug engine to the RAM are halted, and the DBG_RAM_FULL status bit become set. When sufficient receive data has been acquired to satisfy the requirements of the debug session, the acquisition should be terminated by setting DBG_PAGE=0. The DBG_RAM_FULL and DBG_RAM_STOP status bits are "sticky"; they will remain valid even after DBG_PAGE is set to 0 to end the session. The bits will self-clear when a new acquisition is started.

If a stop-trigger is selected (DBG_STOP_TRG > 0): When the RAM reaches DBG_RAM_LAST address, further write attempts by the debug engine to the RAM are not halted, but the DBG_RAM_FULL status bits do become set. The debug engine will wrap back to the starting address (DBG_RAM_FIRST) and continue filling, until the selected stop-trigger event occurs. When the stop-trigger event occurs, the debug engine will stop filling the RAM immediately, the DBG_STOP_TRIGGERED status bit will become set, and the register DBG_RAM_STOP will hold the address of the last RAM word filled with a valid sample before the trigger. At this point, the acquisition should be terminated by setting DBG_PAGE=0. The DBG_STOP_TRIGGERED and STOP_ADDRESS are

"sticky"; they will hold their state even after DBG_PAGE is set to 0 to end the session. DBG_TRIGGERED will self-clear, and DBG_RAM_STOP will reset to 0, when a new acquisition is started by setting DBG_PAGE to a non-zero value.

52.4.4.2.2.16.2.2.2 Downloading

As soon as sufficient data has been collected to satisfy the requirements of the debug session, DBG_PAGE should be set to 0 to end the acquisition. The receive data stored in RAM may now be downloaded from the Packet RAM for analysis and post-processing.

52.4.4.2.2.16.2.2.3 PAGE TABLE for 2.4GHz Transceiver Gen4.5

The DBG_PAGE table settings are the same as the DMA_PAGE table except that the DETERMINISTIC page is not supported for DBG_PAGE

52.4.4.2.2.16.2.2.4 Example Procedure

The following steps outline the setup and execution of a Packet RAM debug session. This example acquires RX DIG I/Q data

1. Program Receiver for desired protocol
2. If needed, configure RXDIG or PHY to enable the desired DMA output signals from those modules.
3. Enable clocking to the Packet RAM Debug engine by setting DBG_RAM_CTRL[DBG_EN]=1
4. Select a DBG start-trigger source, if desired, by setting DBG_RAM_CTRL[DBG_START_TRG] to a non-zero value
5. Select a start-trigger delay value, if desired, by setting DBG_RAM_CTRL[DBG_START_DLY] to a non-zero value in microseconds.
6. Select a decimation rate for samples captured, if desired, by setting DBG_RAM_CTRL[DBG_DEC] to a non-zero value
7. Select a DBG stop-trigger source, if desired, by setting DBG_RAM_CTRL[DBG_STOP_TRG] to a non-zero value
8. Program DBG_RAM_ADDR to select the desired starting address (DBG_RAM_FIRST) and ending address (DBG_RAM_LAST) in the RAM
9. Program DBG_RAM_CTRL[DBG_PAGE]=RXDIGIQ
10. Start the transceiver's RX sequence by e.g. setting TSM_CTRL[FORCE_RX_EN]=1
11. Begin transmitting RF to the DUT
12. **If a stop-trigger is selected (DBG_STOP_TRG > 0)** wait for DBG_STOP_TRIGGERED=1, indicating a stop-trigger occurred
13. **If a stop-trigger is not selected (DBG_STOP_TRG = 0)** wait for sufficient RX data to be collected, or poll DBG_RAM_FULL, to satisfy the requirements of the debug session
14. Program DBG_RAM_CTRL[DBG_PAGE]=0 to terminate the acquisition
15. Download the captured data from Packet RAM

Note: Step 9 (select the DBG_PAGE to enable the DBG engine) should be performed as a sequential, discrete write to the DBG_RAM_CTRL register, after steps 3-8 (enabling the clock, and configuring start delay, decimation, start/stop triggers and ram starting address) have been completed. A single write to DBG_RAM_CTRL is permitted for steps 3-7.

52.4.4.2.2.16.2.3 DMA Mask

The DMA mask feature allows the XCVR_DMA to remain enabled but only be active when the DMA mask input is asserted high, indicating that there are desirable samples to be captured.

The DMA mask feature in XCVR_DMA is only enabled if the DBG_SIGNAL_VALID_MASK_EN bit (Packet RAM Debug Mode) or DMA_SIGNAL_VALID_MASK_EN bit (Transceiver DMA Mode) bit is set. When enabled, the data valid strobe input selected by DBG_PAGE (Packet RAM Debug Mode) or DMA_PAGE(Transceiver DMA Mode) is AND'ed with the DMA mask input signal so that samples are only captured while the DMA mask signal is high and when there is valid data.

The DMA mask may be a conbination of several basic masks and unique to transceiver DMA and debug RAM depending on DMA_SIGNAL_VALID_MASK_SEL and DBG_SIGNAL_VALID_MASK_SEL values respectively.

Here are the four basic masks:

1. The legacy DMA mask input to the Transceiver DMA module is generated by an OR of the DMA mask outputs from the following modules:
   - LCL_CTRL:
     - for CTE use case: the DMA mask output ensures that samples are captured during the reference period and during sample slots, but not during switching slots or other times
     - when use with RSM: the DMA mask output is used to avoid capture of samples after the antenna is switched during RSM's PM_RX state
   - RSM: the DMA mask output is used to identify samples during RSM FM_RX state, and optionally during PM_RX states (if LCL_CTRL is not enabled during RSM's PM_RX states)

     Also note that, for RSM use cases, the Transceiver DMA can remain enabled through an entire RSM event which consists of multiple RX (and TX) bursts; that it, it is not necessary to re-enable the Transceiver DMA for each individual RX burst within an RSM event.
2. The RX frequency compensation mask which ensures that data from FM_RX step are captured.
3. The RX tone mask which ensures that data from PM_RX step are captured.
4. The RX packet mask which ensures that data from DT_RX step are captured.

Table 541. DMA mask combination

	DMA_SIGNAL_VALID_MASK_SEL[3:0]	DBG_SIGNAL_VALID_MASK_SEL[3:0]
Legacy DMA mask	bit 0	bit 0
RX frequency compensation mask	bit 1	bit 1
RX tone mask	bit 2	bit 2
RX packet mask	bit 3	bit 3

NOTE

The RXDIG also supports a feature to mask its data valid strobe outputs. This RXDIG feature (enabled by setting RXDIG's RX_IQ_PH_OUTPUT_COND bit) can also be combined with RXDIG's IQ phase output average windowing feature to reduce the number of samples which need to be stored to RAM.

52.4.4.2.2.16.2.4 Simultaneous DMA Engine and Packet RAM Debug

Transceiver DMA Engine and Packet RAM Debug mode are described in the previous sections. The DMA and Debug engines are separate, independent entities, which theoretically allows both to be employed simultaneously. The most practical case for simultaneous operation would be to select an RX_DIG source for DMA_PAGE and a PHY source for DBG_PAGE. During such a simultaneous debug session, RX_DIG data would go to system memory and PHY data to Packet RAM. After acquisition, data would be downloaded from both memories. Post-processing software could consolidate the data and take advantage of the synergy that results from combining data captured simultaneously from multiple sources. (DTEST allows a possible third simultaneous source, beyond the scope of this Block Guide).

In addition, it is also theoretically possible to combine either or both debug modes with mission-mode packet reception, with the caveat that the Packet RAM would not be available to receive mission-mode packet data in such a scenario. (Packet processing, filtering, CRC checking, and Link Layer interrupts don't rely on packet RAM and so would not be impacted by the debug modes). Such a combination has been demonstrated successfully in radio-level simulation, with the following setup:

1. The GEN_FSK Link Layer is engaged in RX mode
2. Transceiver DMA mode is engaged with DMA_PAGE set to PHYPHASE (PHY phase capture)

3. Packet RAM Debug mode is engaged with DBG_PAGE set to DMDSOFT (PHY soft decision data)
4. A GEN_FSK standard packet is received, CRC passes, and GEN_FSK RX_IRQ and SEQ_END_IRQ are asserted (GEN_FSK packet data not stored)
5. RX phase data is downloaded from system memory and verified
6. Demod soft decision data is downloaded from Packet RAM and verified

52.4.4.2.2.16.2.5 Start Trigger Sources

Registers DMA_CTRL[DMA_START_TRG] and DBG_RAM_CTRL[DBG_START_TRG], enable a hardware trigger that must assert before acquisition begins, for the transceiver DMA and Packet RAM debug engines, respectively. The same description applies to both registers (i.e., trigger sources are the same), as indicated in the following table:

xxx_START_TRG[3:0]	HARDWARE TRIGGER for 2.4GHz
0	no trigger
1	PHY: pd_fnd_to_ll
2	PHY: aa_fnd_to_ll
3	ZBDEMOD: rx_preamble_det
4	ZBDEMOD: rx_sfd_detect
5	RXDIG: agc_gain_chg
6	TSM: rx_dig_en
7	TSM: tsm_irq0_start_trig
8	CRC pass
9	CRC done (Not used for 15.4 LL)
10	Localization control: pattern match
11	GenericLL: cte_present
12	Ranging sequence manager: dma_trigger

52.4.4.2.2.16.2.6 Stop Trigger Sources

Register DBG_RAM_CTRL[DBG_STOP_TRG], enables a hardware trigger such that, when it asserts, acquisition terminates immediately, in Packet RAM debug mode, as indicated in the following table (some of these table entries need discussion):

DBG_STOP_TRG[3:0]	HARDWARE TRIGGER for 2.4GHz
0	no trigger
1	PHY: pd_fnd_to_ll
2	PHY: aa_fnd_to_ll
3	ZBDEMOD: rx_preamble_det
4	ZBDEMOD: rx_sfd_detect
5	RXDIG: agc_gain_chg
6	TSM: rx_dig_en

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DBG_STOP_TRG[3:0]	HARDWARE TRIGGER for 2.4GHz
7	TSM: tsm_irq1_stop_trig
8	CRC fail
9	CRC done (Not used for 15.4 LL)
10	RBME ERROR
11	GenLL: HEADER FAIL
12	TSM: pll unlock

Note: For DBG_STOP_TRIG=11 (HEADER FAIL), register GEN_WHITEN_SZ_THR[REC_BAD_PKT] must be set to 0 (default) to cause an RX recycle on a header violation.

52.4.4.2.3 External signals

Some of the transceiver I/O signals are shown in the table below.

Signal	I/O	Description
ipg_hard_async_reset_b	input	Async reset
xcvr_ref_clk	input	Reference CLK
scan_mode	input	Scan mode
ipt_se_gatedclk	input	Forces all clock gating to be bypassed
cg16m_en	input	16Mhz CLK gating enable
cg4m_en	input	4Mhz CLK gating enable
cg2m_en	input	2Mhz CLK gating enable
cg1m_en	input	1Mhz CLK gating enable
cg500k_en	input	500khz CLK gating enable
cg250k_en	input	250khz CLK gating enable
cg125k_en	input	125khz CLK gating enable
cg62p5k_en	input	62.5khz CLK gating enable
ips_addr	input	IPS address
ips_rwb	input	IPS read/write select
ips_byte_en	input	IPS byte enable
ips_wdata	input	IPS write data
ips_rdata	output	IPS read data
ips_xfr_wait	output	IPS Transceiver wait request
ips_xfr_err	output	IPS Transceiver error status

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Signal	I/O	Description
btle_tx_en	input	Btle Tx enable
btle_rx_en	input	Btle Rx enable
zigbee_tx_en	input	Zigbee/ Tx enable
zigbee_rx_en	input	Zigbee/ Rx enable
generic_tx_en	input	Generic FSK Tx enable
generic_rx_en	input	Generic FSK Rx enable
tsm_combined_tx_en	output	Transceiver Tx enable
tsm_combined_rx_en	output	Transceiver Rx enable
adc_code_i_act	input	ADC I channel input
adc_code_q_act	input	ADC Q channel input
aa_matched_to_ll	output	Access Address correlation flag
pd_fnd_to_ll	output	Preamble detecttion flag
active_ll	input	Current active link layer
ll_aa_0	input	Zigbee/Btle/gfsk Access Address[31:0]
ll_aa_1	input	Zigbee/Btle/gfsk Access Address[63:32]
ll_aa_2	input	Zigbee/Btle/gfsk Access Address[95:64]
ll_aa_3	input	Zigbee/Btle/gfsk Access Address[127:96]
ll_aa_en_0	input	Zigbee/Btle/gfsk Access Address[31:0] enable
ll_aa_en_1	input	Zigbee/Btle/gfsk Access Address[63:32] enable
ll_aa_en_2	input	Zigbee/Btle/gfsk Access Address[95:64] enable
ll_aa_en_3	input	Zigbee/Btle/gfsk Access Address[127:96] enable
ll_aa_size	input	Access Address correlation size
ll_aa_hamm	input	Access Address bit errors threshold
hop_freq_word	input	Hopping frequency word
btle_start_rif_cs	input	Channel sounding start request from BTLE LL
btle_early_event	input	Btle early event flag
btle_lr_en	input	Btle Long Range enable
btle_sel_2mbps	input	Btle 2Mbps rate selection
ll_tx_data_out	input	Btle/gfsk tx data
ll_tx_data_out_vld	input	Btle/gfsk tx data valid
first_bit_of_preamble	input	Btle/gfsk preamble start flag
rbme_tx_done	input	Rbme tx done flag

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Signal	I/O	Description
symb_clk_en	output	Rbme symbol clock enable (depending on data rate)
tx_data_latch	input	Zigbee tx data valid
tx_datapad_latch	input	Zigbee tx data_padding valid
tx_sym_out_802_15_4	input	Zigbee tx data
data_padding_en	output	Zigbee data padding enable
ipi_int_rsm_async	output	RSM interrupt for BTLE Link Layer
ipi_int_lant_sw_async	output	LCL interrupt for BTLE Link Layer
ipi_int_pll_unlock_async	output	Unlock PLL interrupt for BTLE Link Layer
tsm_irq_ble	output	TSM interrupt for BTLE Link Layer
tsm_irq_zigbee	output	TSM interrupt for Zigbee Link Layer
tsm_irq_gen	output	TSM interrupt for GenFSK Link Layer
dft_ram_rdata	input	Tx digital memory data
dft_ram_access	output	Tx digital memory request
dft_ram_addr	output	Tx digital memory address
config_ram_rdata	input	RSM config data
config_ram_en	output	RSM config data read enable
config_ram_addr	output	RSM config address
config_ram_sel	output	RSM config location
result_ram_sel	output	RSM result location
result_ram_en	output	RSM result data write enable
result_ram_wben	output	RSM result write byte enable
result_ram_addr	output	RSM result write address
result_ram_wdata	output	RSM result write data
lant_sw	output	Antenna switch command
lant_lut_gpio	output	Antenna GPIOs
tsm_rf_active	output	Coexistence RF activity flag
tsm_rf_status	output	Coexistence RF status flag
tsm_rf_priority	output	Coexistence RF priority information
seq_*	output	Analog signals driven by TSM sequencer
reg_*	output	Analog registers from xcvr_ana_regs_2p4ghz
hdi_mode	input	HDI mode enable
hdi_dbus_mode	input	HDI DBUS mode enable

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Signal	I/O	Description
hdi_dbus_dout*	input	HDI DBUS configuration data
ext_tx_modulator_out	input	HDI mode TX data
rx_hdi_data_out	output	HDI mode I/Q value output
hdi_rx_iq_out_vld	output	HDI mode I/Q valid output
dtest_*	output	Debug signals

52.4.4.2.4 Initialization

There is no particular sequence to initialize the Transceiver.

The registers of the transceiver sub-modules are initialized with the configuration required by the active link layer before performing any transmit or receive operations.

52.4.4.2.5 Application information

The procedures to use this module are described in the link layer documentations.

52.4.4.2.6 Register descriptions

52.4.4.2.6.1 XCVR_ANALOG register descriptions

52.4.4.2.6.1.1 XCVR_ANALOG_ADDR memory map

RADIO.XCVR_ANALOG base address: 48A0_7C00h

Offset	Register	Width (In bits)	Access	Reset value
0h	RF Analog Baseband LDO Control 1 (LDO_0)	32	RW	0000_0000h
4h	RF Analog Baseband LDO Control 2 (LDO_1)	32	RW	0000_0080h
8h	RF Analog XO DIST Control (XO_DIST)	32	RW	0000_0000h
Ch	RF Analog PLL Control (PLL)	32	RW	0007_4240h
10h	RF Analog RX Control0 (RX_0)	32	RW	0100_0002h
14h	RF Analog RX Control1 (RX_1)	32	RW	0002_2008h
18h	RF Analog TX DAC PA Control (TX_DAC_PA)	32	RW	0118_0000h
1Ch	RF Analog DIAG Control 1 (DIAG)	32	RW	4000_0000h
20h	RF Analog SPARE Control (SPARE)	32	RW	0000_0000h

52.4.4.2.6.1.2 RF Analog Baseband LDO Control 1 (LDO_0)

Offset

Register	Offset
LDO_0	0h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		LDOTRIM_TRIM_VR...		LDO_CAL...	LDO_CAL_PTAT_BU...		LDO_CAL...	LDO_VCO...	LDO_VCO_PTAT_BU...		LDO_VCO...	LDO_PLL...	LDO_PLL_PTAT_BU...		LDO_PLL...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	LDO_RXT...	LDO_RXTXLF_PTAT...		LDO_RXT...	LDO_RXT...	LDO_RXTXHF_PTAT...		LDO_RXT...	0	LDO_LV_...	LDO_LV_TRIM		BG_FORCE	0		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-28 LDOTRIM_TRIM_VREF	reg_ldotrim_trim_vref_dig[1:0] Trim of vref in ldotrim block. 00b - 0.810 01b - 0.832 10b - 0.854 11b - 0.788
27 LDO_CAL_BYPASS	reg_ldo_cal_bypass_dig LDO bypass control. 0b - disable CAL bypass 1b - eable CAL bypass
26-25 LDO_CAL_PTAT_BUMP	reg_ldo_vco_ptat_bump_dig[1:0] LDO PTAT current boost 00b - nominal 01b - +30%

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Field	Function
	10b - nominal 11b - +30%
24 LDO_CAL_FORCE	reg_ldo_cal_force_dig LDO force control 0b - Force disable 1b - Force enable
23 LDO_VCO_BYPASS	reg_ldo_vco_bypass_dig LDO bypass control. 0b - disable VCO bypass 1b - eable VCO bypass
22-21 LDO_VCO_PTAT_BUMP	reg_ldo_vco_ptat_bump_dig[1:0] LDO PTAT current boost 00b - nominal 01b - +30% 10b - nominal 11b - +30%
20 LDO_VCO_FORCE	reg_ldo_vco_force_dig LDO force control 0b - Force disable 1b - Force enable
19 LDO_PLL_BYPASS	reg_ldo_pll_bypass_dig LDO bypass control. 0b - Bypass disabled. 1b - Bypass enabled
18-17 LDO_PLL_PTAT_BUMP	reg_ldo_pll_ptat_bump_dig[1:0] LDO PTAT current boost 00b - nominal 01b - +30% 10b - nominal 11b - +30%
16	reg_ldo_pll_force_dig

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Field	Function
LDO_PLL_FORCE	LDO force control 0b - force disable 1b - force enable
15 LDO_RXTXLF_BYPASS	reg_ldo_rxtxlf_bypass_dig LDO bypass control. 0b - Bypass disable 1b - Bypass enable
14-13 LDO_RXTXLF_PTAT_BUMP	reg_ldo_rxtxlf_ptat_bump_dig[1:0] LDO PTAT current boost 00b - nominal 01b - +30% 10b - nominal 11b - +30%
12 LDO_RXTXLF_FORCE	reg_ldo_rxtxlf_force_dig LDO force control 0b - disable force 1b - enable force
11 LDO_RXTXHF_BYPASS	reg_ldo_rxtxihf_bypass_dig LDO bypass control
10-9 LDO_RXTXHF_PTAT_BUMP	reg_ldo_rxtxhf_ptat_bump_dig LDO PTAT current boost 00b - nominal 01b - +30% 10b - nominal 11b - +30%
8 LDO_RXTXHF_FORCE	reg_ldo_rxtxhf_force_dig LDO force control. 0b - Force disabled. 1b - Force enabled
7	Reserved

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Field	Function
—	
6 LDO_LV_BYPASS	reg_ldo_lv_bypass_dig bypass control for LDO_LV. 0b - disable bypass for ldo_lv 1b - enable bypass for ldo_lv
5-4 LDO_LV_TRIM	reg_ldo_lv_trim_dig[1:0] Trim control for LDO_LV. 00b - 0.91V Default LDO output 01b - 0.86V 10b - 0.97V 11b - 1.3V
3 BG_FORCE	reg_bg_force_dig bandgap force startup 0b - force disable 1b - force enable
2-0 —	Reserved

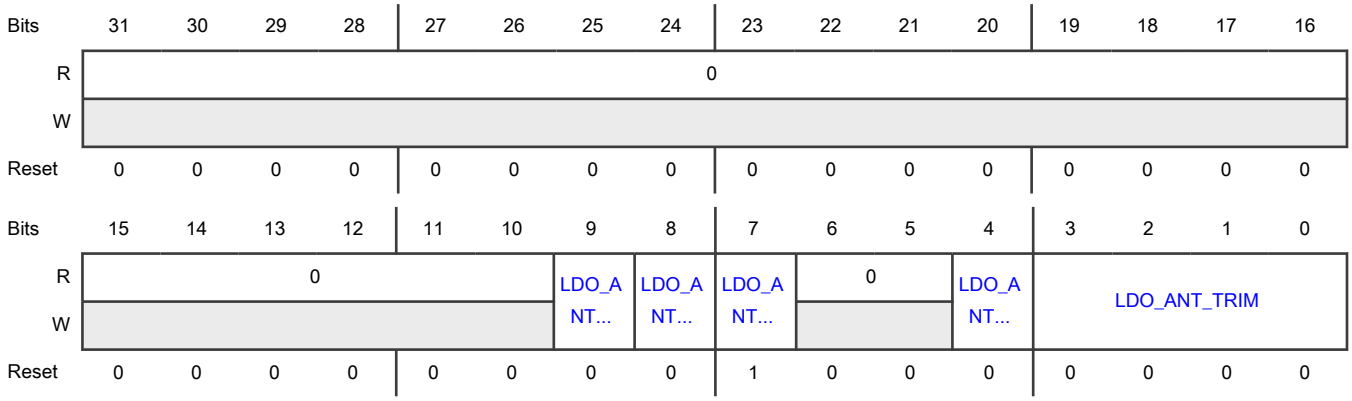
52.4.4.2.6.1.3 RF Analog Baseband LDO Control 2 (LDO_1)

Offset

Register	Offset
LDO_1	4h

Function

Diagram



Fields

Field	Function
31-10 —	Reserved
9 LDO_ANT_REF_SEL	reg_ldo_ant_ref_sel_dig Input reference voltage type select 0b - sel type disable (Default) 1b - sel type enable
8 LDO_ANT_BYPASS	reg_ldo_ant_bypass_dig LDO bypass control. 0b - ANT bypass disable 1b - ANT bypass enable
7 LDO_ANT_HIZ	reg_ldo_ant_hiz_dig LDO output high-impedance control 0b - high-impedance disabled. 1b - high-impedance enabled
6-5 —	Reserved
4 LDO_ANT_POWMOD_SEL	LDO_ANT_POWMOD_SEL LDO PA power mode selection (forces HiZ mode when pup is low to minimize the discharging of VDD_PA in power down). 0b - KW45 Legacy mode 1b - When pup is low, force HiZ mode
3-0	reg_ldo_ant_trim_dig[3:0]

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Field	Function
LDO_ANT_TRIM	LDO output voltage trim control.SETTING IN RX MODE: 0,SETTING IN TX MODE: depends on desired output power 0000b - 0.91 V (Default) 0001b - 0.97 V 0010b - 1.04 V 0011b - 1.12 V 0100b - 1.21 V 0101b - 1.32 V 0110b - 1.45 V 0111b - 1.52 V 1000b - 1.61 V 1001b - 1.80 V 1010b - 2.06 V 1011b - 2.13 V 1100b - 2.21 V 1101b - 2.30 V 1110b - 2.39 V 1111b - 2.50 V

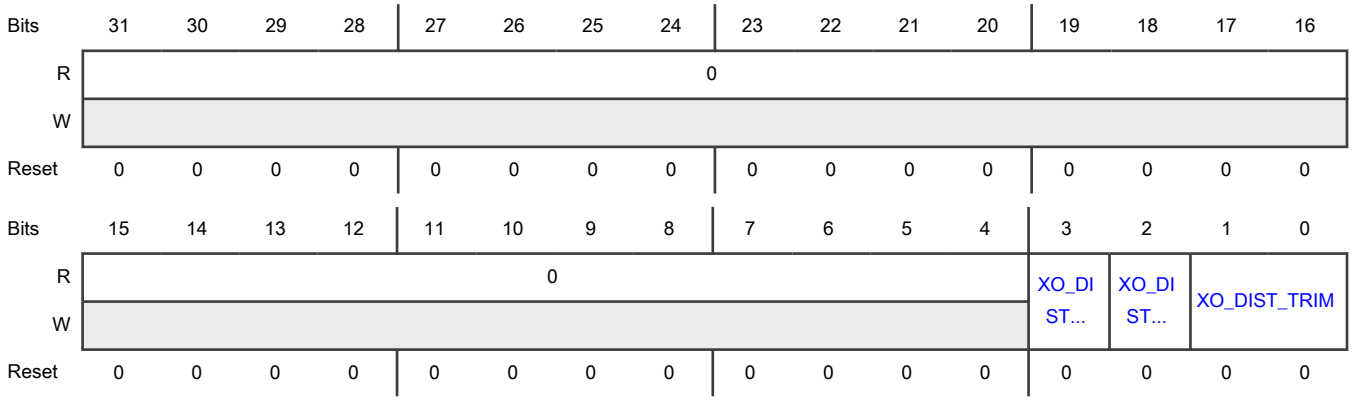
52.4.4.2.6.1.4 RF Analog XO DIST Control (XO_DIST)

Offset

Register	Offset
XO_DIST	8h

Function

Diagram



Fields

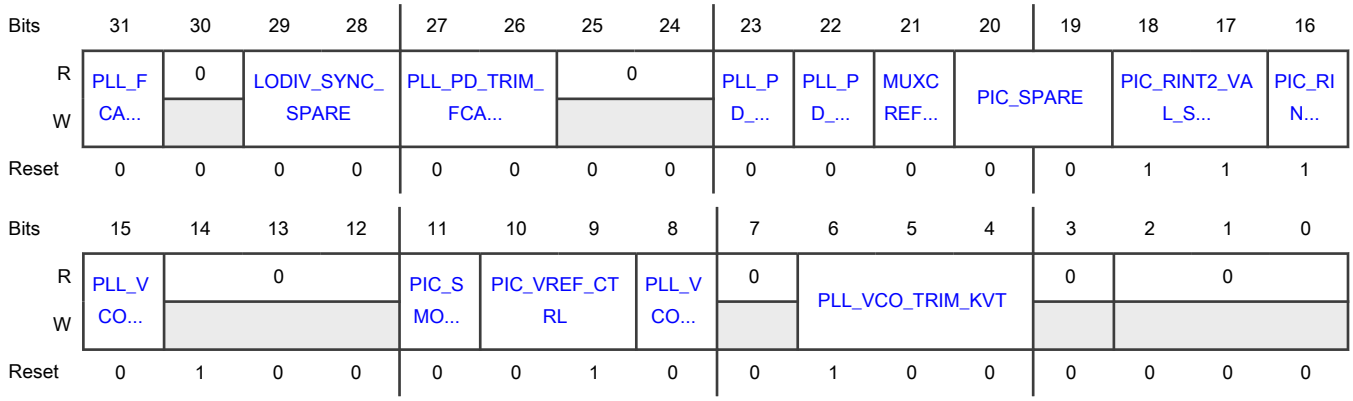
Field	Function
31-4 —	Reserved
3 XO_DIST_BYPASS	reg_xo_dist_bypass XO DIST bypass 0b - XO DIST not bypass 1b - XO DIST bypass
2 XO_DIST_FLIP	reg_xo_dist_flip_dig XO DIST flip output clock relative to input clock 0b - XO DIST doesn't flip the output clock relative to input clock 1b - XO DIST flip the output clock relative to input clock
1-0 XO_DIST_TRIM	reg_xo_dist_trim_dig[1:0] XO DIST LDO output voltage trim 00b - 0.9 V (Default) 01b - 0.86 V 10b - 0.95 V 11b - 1.21 V

52.4.4.2.6.1.5 RF Analog PLL Control (PLL)

Offset

Register	Offset
PLL	Ch

Diagram



Fields

Field	Function
31 PLL_FCAL_EN_STATIC_RES	reg_fcal_en_static_res_dig Resistor from LDO output to ground control. 0b - resistor is dynamically switched during FCAL operation 1b - resistor is always on during FCAL operation
30 —	Reserved
29-28 LODIV_SYNC_SPARE	reg_lodiv_sync_spare_dig[1:0] lodiv_sync reg spare
27-26 PLL_PD_TRIM_FCAL_BIAS	reg_pd_trim_fcal_bias_dig[1:0] Sets the ouput of PD positive precharge output 00b - 0.276V (recommended setting for legacy operation) 01b - 0.164V 10b - 0.320V (recommended setting for PIC use) 11b - 0.391V
25-24 —	Reserved
23 PLL_PD_EN_VPD_PULLUP	reg_pd_en_vpd_pullup_dig If '1' pulls up the PD precharger output that drives the PD positive output to test the Full Scale range. Needs seq_pd_en_pd_drv_dig='0'. 0b - not pull up vpd output 1b - pull up vpd output

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Field	Function
22 PLL_PD_EN_VPD_PULLDN	reg_pd_en_vpd_pulldn_dig If '1' pulls down the PD precharger output that drives the PD positive output to test the Full Scale range. Needs seq_pd_en_pd_drv_dig='0'. 0b - not pull down vpd output 1b - pull down vpd output
21 MUXCREF_DIVN	reg_muxcref_divn Mux to select the alternative 32M clock for PLL DivN
20-19 PIC_SPARE	reg_pic_spare_dig[1:0] pic spare [1:0]
18-17 PIC_RINT2_VAL_SLOW_MODE	reg_pic_rint2_val_slow_mode_dig[1:0] Rint2 value in slow mode 00b - Rint2=90 kohms 01b - Rint2=210 kohms 10b - Rint2=450 kohms (recommended setting) 11b - Rint2=450 kohms
16 PIC_RINT1_HVAL_SM_EN	reg_pic_rint1_hval_sm_en_dig Enable the highR value on Rint1 (slow mode)– Fast mode integration resistance selection. 0b - PIC_RINT1_HVAL_SM disable (Rint1=30 kohms) - (recommended setting) 1b - PIC_RINT1_HVAL_SM enable (Rint1=60 kohms)
15 PLL_VCO_PIC_INPUT_EN	reg_vco_pic_input_en_dig enable for VCO pic input switch. . Enables two varicaps of the VCO to be assigned to the output of the PIC (VPIC) instead of VTUNE. This bit should be set if PIC operation (coherent quasi-type II PLL) is to be supported. 0b - PIC_INPUT disable 1b - PIC_INPUT enable
14-12 —	Reserved
11 PIC_SMOOTH_SWITCH_EN	reg_pic_smooth_switch_en_dig enable for the slow switching of resistor(RFB) 0b - smoothing disable (recommended setting) 1b - Reserved

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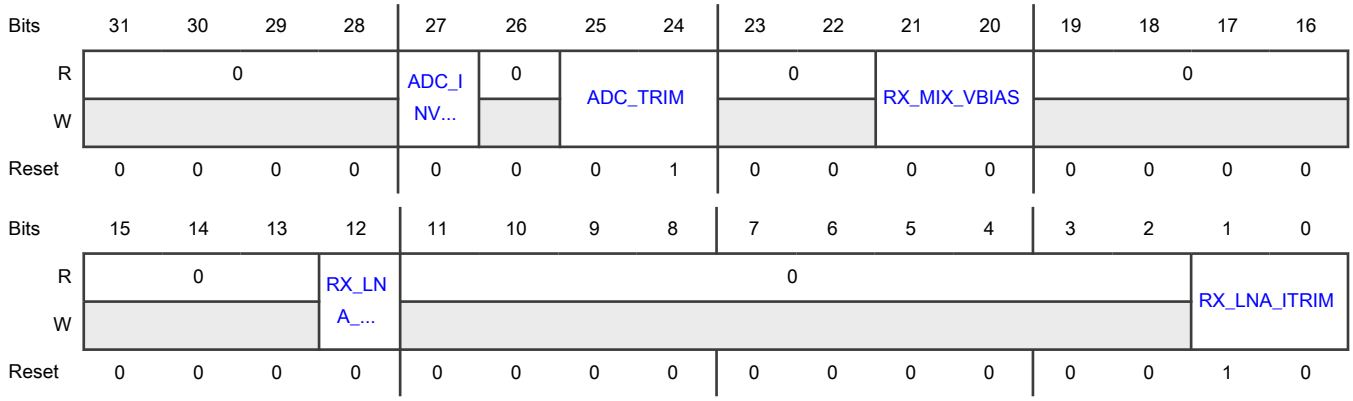
Field	Function
10-9 PIC_VREF_CTRL	reg_pic_vref_ctrl_dig[1:0] 2-bit control of the pic reference voltage. It is a fraction of VDDX provided by the LDO. 00b - VREF=0.268*VDDX (VREF=245 mV for VDDX=0.9 V) 01b - VREF=0.292*VDDX (VREF=266 mV for VDDX=0.9 V) 10b - VREF=0.317*VDDX (VREF=287 mV for VDDX=0.9 V) 11b - VREF=0.341*VDDX (VREF=307 mV for VDDX=0.9 V) - (recommended setting)
8 PLL_VCO_EN_PKDET	reg_vco_en_pkdet_dig enable peak detector operation 0b - PKDET disable 1b - PKDET enable
7 —	Reserved
6-4 PLL_VCO_TRIM_KVT	reg_vco_trim_kvt_dig[2:0] kv tune control (for loop gain adjustment vs. fref frequency) 000b - 50MHz/V 100b - 60MHz/V for fref = 32M 110b - 70MHz/V 111b - 80MHz/V for fref = 26M
3 —	Reserved
2-0 —	Reserved

52.4.4.2.6.1.6 RF Analog RX Control0 (RX_0)

Offset

Register	Offset
RX_0	10h

Diagram



Fields

Field	Function
31-28 —	Reserved
27 ADC_INVERT_CLK	reg_adc_invert_clk_dig Invert the ADC clock 0b - not invert clk 1b - invert clk
26 —	Reserved
25-24 ADC_TRIM	reg_adc_trim_dig[1:0] trim of the adc reference current 00b - 0.965V 01b - 0.935V 10b - 0.905V 11b - 0.875V
23-22 —	Reserved
21-20 RX_MIX_VBIAS	reg_rx_mix_vbias_dig[1:0] Mixer bias voltage control 00b - 0.800V 01b - 0.742V 10b - 0.689V 11b - 0.857V

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Field	Function
19-13 —	Reserved
12 RX_LNA_PTAT_FORCE_START	reg_rtfe_ptat_force_dig RTFE PTAT biasing force startup.
11-2 —	Reserved
1-0 RX_LNA_ITRIM	reg_rx_lna_itrim_dig[1:0] lna PTAT biasing current trim 00b - 3.7u -25% 01b - 4.4u -15% 10b - 5.1u Default 11b - 5.6u +10%

52.4.4.2.6.1.7 RF Analog RX Control1 (RX_1)

Offset

Register	Offset
RX_1	14h

Function

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0														CBPF_TRIM_SHORT...	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		CBPF_VCM_TRIM		0		CBPF_TRIM_Q		0		CBPF_TRIM_I		CBPF_TY...		0	
W																
Reset	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0

Fields

Field	Function
31-18 —	Reserved
17-16 CBPF_TRIM_SHORT_DCBIAS	reg_cbpf_trim_short_dcbias_dig[1:0] Trim of dc voltage to which the inputs of the ADC will be shorted when reg_cbpf_short_dig=1 00b - 470mV 01b - 438mV 10b - 413mV 11b - 385mV
15-14 —	Reserved
13-12 CBPF_VCM_TRIM	reg_cbpf_vcm_trim_dig[1:0] vcm trim bits 00b - 480mV 01b - 453mV 10b - 426mV 11b - 401mV
11-10 —	Reserved
9-8 CBPF_TRIM_Q	reg_cbpf_trim_q_dig[1:0] trim of the amplifier reference current (q-path) 00b - 5u (Default) 01b - 6.25u 10b - 7.5u 11b - 8.75u
7-6 —	Reserved
5-4 CBPF_TRIM_I	reg_cbpf_trim_i_dig[1:0] trim of the amplifier reference current (i-path) 00b - 5u (Default) 01b - 6.25u 10b - 7.5u

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Field	Function
	11b - 8.75u
3 CBPF_TYPE	reg_cbpf_type_dig Filter type 0b - Real 1b - Complex,
2-0 —	Reserved

52.4.4.2.6.1.8 RF Analog TX DAC PA Control (TX_DAC_PA)

Offset

Register	Offset
TX_DAC_PA	18h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				DAC_TRIM_CFBK_D...		DAC_TRIM_CFBK		0		PA_SMOOTHER_CUR			PA_SMOO...	TX_PA_VBIAS	
W																
Reset	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				DAC_TRIM_IBIAS		DAC_TRIM_RLOAD		0				DAC_INV...	0		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 —	Reserved
27-26 DAC_TRIM_CFBK_DRS	reg_dac_trim_cfbk_dig[1:0] trim of amplifier feedback capacitor when datarate is 2Mbps 00b - 675fF

Table continues on the next page...

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Field	Function
	01b - 1.35pF 10b - 1.35pF 11b - 2.025pF
25-24 DAC_TRIM_CFBK	reg_dac_trim_cfbk_dig[1:0] trim of amplifier feedback capacitor 00b - 675fF 01b - 1.35pF 10b - 1.35pF 11b - 2.025pF
23-22 —	Reserved
21-19 PA_SMOOTHER_CUR	reg_pa_smoother_cur_dig[2:0] Current adjustment for the PA slope. The value of this register affects the speed of the analog ramping. Speed is inversely proportional to the register value.
18 PA_SMOOTHER_EN	reg_pa_smoother_en_dig Enable for the smooth analog pa ramp-up feature. 0b - PA_SMOOTHER disable 1b - PA_SMOOTHER enable
17-16 TX_PA_VBIAS	reg_tx_pa_vbias_dig[1:0] TX PA bias voltage control 00b - 0.460V 01b - 0.431V 10b - 0.403V 11b - 0.375V
15-12 —	Reserved
11-10 DAC_TRIM_IBIAS	reg_dac_trim_ibias_dig[1:0] trim of DAC bias current 00b - 3.0uA (I_lsb=250nA) 01b - 2.5uA 10b - 3.8uA

Table continues on the next page...

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Field	Function
	11b - 5.0uA
9-8 DAC_TRIM_RLOAD	reg_dac_trim_rload_dig[1:0] trim of DAC resistor load 00b - 3K 01b - 2.25K 10b - 3.75K 11b - 4.5K
7-4 —	Reserved
3 DAC_INVERT_CLK	reg_dac_invert_clk_dig Invert clk coming to DAC. Changes the polarity in which the input data is captured
2-0 —	Reserved

52.4.4.2.6.1.9 RF Analog DIAG Control 1 (DIAG)

Offset

Register	Offset
DIAG	1Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	ATX_ON_...	DIAG_DIS	DAC_AMP...	LDO_ANT...	XO_DIST...	PIC_DIA...	DAC_DIA...	VCO_DIA...	PD_DIAG...	0	ADC_DIA...	CBPF_EN...	CBPF_Q_...	CBPF_Q_...	CBPF_I_...	CBPF_I_...
W																
Reset	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	RTFE_DI...	0	PROC_MO...	LDOTRIM...	BG_DIAG...	LDO_LV_...	LDO_RXT...	LDO_RXT...	0		LDO_PLL...	LDO_VCO...	LDO_CAL...	DIAG_CODE		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 ATX_ON_2P4GHZ	reg_2p4ghz_atx_on_dig Enable the pathway to route diag into the SOC
30 DIAG_DIS	reg_diag_dis_dig diag_sel control signal
29 DAC_AMP_DIAG_SEL	reg_dac_amp_diag_sel_dig diag_sel control signal for DAC AMP
28 LDO_ANT_DIAG_SEL	reg_ldo_ant_diag_sel_dig diag_sel control signal for LDO
27 XO_DIST_DIAG_SEL	reg_xo_dist_diag_sel_dig diag_sel control signal for XO DIST
26 PIC_DIAG_SEL	reg_pic_diag_sel_dig diag_sel control signal for PIC
25 DAC_DIAG_SEL	reg_dac_diag_sel_dig diag_sel control signal for DAC
24 VCO_DIAG_SEL	reg_vco_diag_sel_dig diag_sel control signal for VCO
23 PD_DIAG_SEL	reg_pd_diag_sel_dig diag_sel control signal for PD
22 —	Reserved
21 ADC_DIAG_SEL	reg_adc_diag_sel_dig diag_sel control signal for ADC
20 CBPF_EN_DIAG_MEAS	reg_cbpf_en_diag_meas_dig Enable diag measurement through ADC. The ouput of CBPF is put in Hiz in diag mode and the diag voltages are routed to the ADC

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Field	Function
19 CBPF_Q_DIAG_SEL_2	reg_cbpf_q_diag_sel_2_dig diag_sel control signal for CBPF Q
18 CBPF_Q_DIAG_SEL_1	reg_cbpf_q_diag_sel_1_dig diag_sel control signal for CBPF Q
17 CBPF_I_DIAG_SEL_2	reg_cbpf_i_diag_sel_2_dig diag_sel control signal for CBPF I
16 CBPF_I_DIAG_SEL_1	reg_cbpf_i_diag_sel_1_dig diag_sel control signal for CBPF I
15 RTFE_DIAG_SEL	reg_rtfe_diag_sel_dig diag_sel control signal
14 —	Reserved
13 PROC_MON_DIAG_SEL	reg_proc_mon_diag_sel_dig diag_sel control signal
12 LDOTRIM_DIAG_SEL	reg_ldotrim_diag_sel_dig diag_sel control signal
11 BG_DIAG_SEL	reg_bg_diag_sel_dig diag_sel control signal
10 LDO_LV_DIAG_SEL	reg_ldo_lv_diag_sel_dig diag_sel control signal
9 LDO_RXTXHF_DIAG_SEL	reg_ldo_rxtxhf_diag_sel_dig diag_sel control signal
8	reg_ldo_rxtxlf_diag_sel_dig diag_sel control signal

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Field	Function
LDO_RXTXLF_DIAG_SEL	
7-6 —	Reserved
5 LDO_PLL_DIAG_SEL	reg_ldo_pll_diag_sel_dig diag_sel control signal
4 LDO_VCO_DIAG_SEL	reg_ldo_vco_diag_sel_dig diag_sel control signal
3 LDO_CAL_DIAG_SEL	reg_ldo_cal_diag_sel_dig diag_sel control signal
2-0 DIAG_CODE	reg_diag_code_dig[2:0] Diag code

52.4.4.2.6.1.10 RF Analog SPARE Control (SPARE)

Offset

Register	Offset
SPARE	20h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		SPARE_DIAG_SEL		0								SPARELV			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-14 —	Reserved
13-12 SPARE_DIAG_SEL	reg_spare_diag_sel_dig[1:0] diag_sel control signal for RX peak detector.
11-4 —	Reserved
3-0 SPARELV	reg_sparelv_dig[3:0] Spare register input signals

52.4.4.2.6.2 XCVR_MISC register descriptions

52.4.4.2.6.2.1 XCVR_MISC_ADDR memory map

RADIO.XCVR_MISC base address: 48A0_7D00h

Offset	Register	Width (In bits)	Access	Reset value
0h	TRANSCEIVER CONTROL (XCVR_CTRL)	32	RW	0000_0140h
4h	TRANSCEIVER STATUS (XCVR_STATUS)	32	RW	0000_0000h
8h	FAD CONTROL (FAD_CTRL)	32	RW	0000_F080h
Ch	TRANSCEIVER DMA CONTROL (DMA_CTRL)	32	RW	0000_0000h
10h	DBG Ram control register (DBG_RAM_CTRL)	32	RW	0000_0000h
14h	DBG RAM ADDRESS (DBG_RAM_ADDR)	32	RW	47FC_0000h
18h	DBG RAM STOP ADDRESS (DBG_RAM_STOP_ADDR)	32	R	0000_0000h
1Ch	LDO TRIM Configuration 0 (LDO_TRIM_0)	32	RW	0000_0000h
20h	LDO TRIM Configuration 1 (LDO_TRIM_1)	32	RW	0000_0000h
24h	RF Analog LDO Trim Res Control 0 (LDO_TRIM_RES_0)	32	R	0000_0000h
28h	RF Analog LDO Trim Res Control 1 (LDO_TRIM_RES_1)	32	R	0000_0000h
2Ch	LCL CTRL CFG 0 (LCL_CFG0)	32	RW	0000_0000h
30h	LCL CTRL CFG 1 (LCL_CFG1)	32	RW	0000_0000h
34h	LCL CTRL TX CONFIG0 (LCL_TX_CFG0)	32	RW	0000_0000h
38h	LCL CTRL TX CONFIG1 (LCL_TX_CFG1)	32	RW	0000_0000h
3Ch	RSM CTRL 6 (RSM_CTRL6)	32	RW	0000_2C25h

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Offset	Register	Width (In bits)	Access	Reset value
40h	LCL CTRL RX CONFIG0 (LCL_RX_CFG0)	32	RW	0000_0000h
44h	LCL CTRL RX CONFIG1 (LCL_RX_CFG1)	32	RW	0000_0000h
48h	LCL CTRL RX CONFIG2 (LCL_RX_CFG2)	32	R	0000_0000h
4Ch	LCL CTRL PM MSB (LCL_PM_MSB)	32	RW	0000_0000h
50h	LCL CTRL PM LSB (LCL_PM_LSB)	32	RW	0000_0000h
54h	LCL GPIO CTRL 0 (LCL_GPIO_CTRL0)	32	RW	0000_0000h
58h	LCL GPIO CTRL 1 (LCL_GPIO_CTRL1)	32	RW	0000_0000h
5Ch	LCL GPIO CTRL 2 (LCL_GPIO_CTRL2)	32	RW	0000_0000h
60h	LCL GPIO CTRL 3 (LCL_GPIO_CTRL3)	32	RW	0000_0000h
64h	LCL GPIO CTRL 4 (LCL_GPIO_CTRL4)	32	RW	0000_0000h
68h	LCL_DMA_MASK_DELAY (LCL_DMA_MASK_DELAY)	32	RW	0000_0000h
6Ch	LCL_DMA_MASK_PERIOD (LCL_DMA_MASK_PERIOD)	32	RW	0000_0000h
70h	Ranging Sequence Manager Control and Status (RSM_CSR)	32	R	0000_0000h
74h	Ranging Sequence Manager Control (RSM_CTRL0)	32	RW	0000_0000h
78h	Ranging Sequence Manager Control (RSM_CTRL1)	32	RW	0000_0000h
7Ch	Ranging Sequence Manager Control (RSM_CTRL2)	32	RW	0000_0000h
80h	Ranging Sequence Manager Control (RSM_CTRL3)	32	RW	0000_0000h
84h	Ranging Sequence Manager Control (RSM_CTRL4)	32	RW	0000_0000h
88h	Ranging Sequence Manager Control (RSM_CTRL5)	32	RW	0000_0000h
8Ch	Ranging Sequence Manager Control (RSM_CTRL7)	32	RW	0000_0000h
90h	Ranging Sequence Manager interrupt status (RSM_INT_STATUS)	32	RW	0000_0000h
94h	Ranging Sequence Manager interrupt enable (RSM_INT_ENABLE)	32	RW	0000_0000h
98h	DMA_MASK management (DMA_MASK_CTRL)	32	RW	0000_0000h
9Ch	RF DFT CTRL (RF_DFT_CTRL)	32	RW	0000_0000h
A0h - BCh	IPS FAST OVERWRITE ADDRESS (IPS_FO_ADDR0 - IPS_FO_ADDR7)	32	RW	0000_0000h
C0h - DCh	IPS FAST OVERWRITE DRS0 DATA (IPS_FO_DRS0_DATA0 - IPS_FO_DRS0_DATA7)	32	RW	0000_0000h
E0h - FCh	IPS FAST OVERWRITE DRS1 DATA (IPS_FO_DRS1_DATA0 - IPS_FO_DRS1_DATA7)	32	RW	0000_0000h
100h	Ranging Sequence Manager Configuration Buffer (RSM_CONFIG_BUFF)	32	RW	0000_0000h

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Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
104h	Ranging Sequence Manager Config Pointer (RSM_CONFIG_PTR)	32	RW	0000_0000h
108h	Ranging Sequence Manager Result Buffer (RSM_RESULT_BUFF)	32	RW	0000_0000h
10Ch	Ranging Sequence Manager Config Pointer (RSM_RESULT_PTR)	32	RW	0000_0000h
110h	Ranging Sequence Manager Pointer (RSM_PTR)	32	R	0000_0000h
120h	Radio to Host Buffer (RADIO2HOST)	32	RW	0000_0000h
124h	Host to Radio Buffer (HOST2RADIO)	32	R	0000_0000h
128h	skip coex rf_denied for channel 0 to 31 (COEX_CHANNEL0)	32	RW	0000_0000h
12Ch	skip coex rf_denied for channel 32 to 63 (COEX_CHANNEL1)	32	RW	0000_0000h
130h	skip coex rf_denied for channel 64 to 95 (COEX_CHANNEL2)	32	RW	0000_0000h
134h	skip coex rf_denied for channel 96 to 127 (COEX_CHANNEL3)	32	RW	0000_0000h
138h	Coexistence mode (COEX_MODE)	32	RW	0000_0000h
13Ch	Coexistence status (COEX_STATUS)	32	R	0000_0000h

52.4.4.2.6.2.2 TRANSCEIVER CONTROL (XCVR_CTRL)

Offset

Register	Offset
XCVR_CTRL	0h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0											LL_CFG_...	TOF_TX_...	TOF_RX_...	FO_TX_EN	FO_RX_EN
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	REF_CLK...	0	DATA_RATE_DRS		DATA_RATE				DEMOD_SEL		0		SDCLK_O...	0	LPPS_EN...	XCVR_SO...
W																
Reset	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0

Fields

Field	Function
31-21 —	Reserved
20 LL_CFG_CAPT_DIS	Link Layer Configuration Capture Disable A few of the link layer configuration signals used by the transceiver can be captured at the start of TX to ensure that they do not change value until after the TSM completes warmdown. This feature is normally enabled but it can be disabled by setting this bit. 0b - Enabled: Link Layer configuration inputs are captured. 1b - Disabled: Link Layer configurations are not captured.
19 TOF_TX_SEL	Time-of-Flight TX Select Selects the signal output to SOC timer for time-of-flight timestamping, when TSM is in tx_mode. 0b - TSM: tx_dig_en 1b - TXDIG: pa_wu_complete
18 TOF_RX_SEL	Time-of-Flight RX Select Selects the signal output to SOC timer for time-of-flight timestamping, when TSM is in rx_mode. 0b - PHY: aa_fnd_to_ll 1b - Localization Control: pattern_found
17 FO_TX_EN	Fast Overwrite TX Enable If set, Fast Overwrite is enabled for TX
16 FO_RX_EN	Fast Overwrite RX Enable If set, Fast Overwrite is enabled for RX
15 REF_CLK_FREQ	Transceiver ref clk freq control This register selects the Reference Clock Frequency for the Radio. 0b - 32MHz 1b - 26MHz
14 —	Reserved
13-11 DATA_RATE_DRS	Radio data rate setting, Data Rate Switch This register selects the data rate for TXDIG when the alternate data rate is selected (Bluetooth LE sel_2mbps=1, or Generic LL datarate_config_sel=1). 000b - 2Mbps 001b - 1Mbps

Table continues on the next page...

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Field	Function
	010b - 500Kbps 011b - 250Kbps 1xxb - Reserved
10-8 DATA_RATE	Radio data rate setting This register selects the data rate for TXDIG when the primary data rate is selected (Bluetooth LE sel_2mbps=0, or Generic LL datarate_config_sel=0). 000b - 2Mbps 001b - 1Mbps 010b - 500Kbps 011b - 250Kbps 1xxb - Reserved
7-6 DEMOD_SEL	Demodulator Selector This bit selects the demodulator used during reception 00b - No demodulator selected 01b - Use NXP Multi-standard PHY demodulator 10b - Use Legacy 802.15.4 demodulator 11b - Reserved
5-4 —	Reserved
3 SDCLK_OUT_EN	sdclk out control 0b - no sdclk out 1b - enable sdclk out
2 —	Reserved
1 LPPS_ENABLE	Transceiver lpps enable control 0b - no lpps feature 1b - enable lpps feature
0 XCVR_SOFT_RESET	Transceiver soft reset control 0b - no soft reset 1b - enable soft reset on transceiver

52.4.4.2.6.2.3 TRANSCEIVER STATUS (XCVR_STATUS)

Offset

Register	Offset
XCVR_STATUS	4h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	TX_MODE	RX_MODE	TSM_BUSY	0	0		TSM_IRQ1	TSM_IRQ0	TSM_COUNT							
W							W1C	W1C								
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-16 —	Reserved
15 TX_MODE	Transmit Mode Indicates an TX transceiver operation is in progress.
14 RX_MODE	Receive Mode Indicates an RX transceiver operation is in progress.
13 TSM_BUSY	tsm busy status Indicates TSM is busy or not, active high
12 —	Reserved
11-10 —	Reserved
9 TSM_IRQ1	TSM Interrupt #1 0b - TSM Interrupt #1 is not asserted. 1b - TSM Interrupt #1 is asserted. Write '1' to this bit to clear it.

Table continues on the next page...

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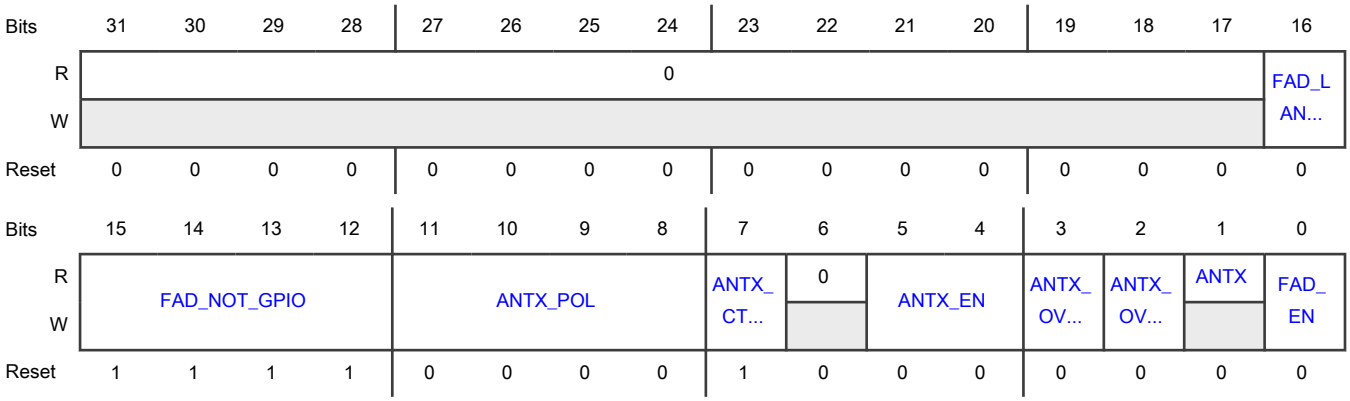
Field	Function
8 TSM_IRQ0	TSM Interrupt #0 0b - TSM Interrupt #0 is not asserted. 1b - TSM Interrupt #0 is asserted. Write '1' to this bit to clear it.
7-0 TSM_COUNT	TSM_COUNT Reflects the instantaneous value of the TSM counter.

52.4.4.2.6.2.4 FAD CONTROL (FAD_CTRL)

Offset

Register	Offset
FAD_CTRL	8h

Diagram



Fields

Field	Function
31-17 —	Reserved
16 FAD_LANT_SEL	FAD versus LANT_LUT_GPIO Selector Controls the mux which select whether the LANT_LUT_GPIO[3:0] or the FAD control signals are output to RF_GPO[11:8]. Refer also to the figure in the Coexistence/FEM/LANT connections section of the Radio Control chapter. 0b - LANT_LUT_GPIO[3:0] 1b - {ANT_B, ANT_A, RX_SWITCH, TX_SWITCH}

Table continues on the next page...

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Field	Function
15-12 FAD_NOT_GPIO	FAD versus GPIO Mode Selector **xxx1** : The ANT_A pad is controlled by the antenna-selection algorithm, modified by the register settings above {ANTX_CTRLMODE, ANTX_EN, ANTX_POL} **xxx0** : The ANT_A pad is controlled directly by the TSM output gpio0_trig_en **xx1x** : The ANT_B pad is controlled by the antenna-selection algorithm, modified by the register settings above {ANTX_CTRLMODE, ANTX_EN, ANTX_POL} **xx0x** : The ANT_B pad is controlled directly by the TSM output gpio1_trig_en **x1xx** : The TX_SWITCH pad is controlled by the antenna-selection algorithm, modified by the register settings above {ANTX_CTRLMODE, ANTX_EN, ANTX_POL} **x0xx** : The TX_SWITCH pad is controlled directly by the TSM output gpio2_trig_en **1xxx** : The RX_SWITCH pad is controlled by the antenna-selection algorithm, modified by the register settings above {ANTX_CTRLMODE, ANTX_EN, ANTX_POL} **0xxx** : The RX_SWITCH pad is controlled directly by the TSM output gpio3_trig_en
11-8 ANTX_POL	FAD Antenna Controls Polarity Control the polarity of the FAD pins: ANTX_POL<0> : This bit currently has no functionality ANTX_POL<1> : This bit currently has no functionality ANTX_POL<2>=1 : invert the TX_SWITCH output ANTX_POL<3>=1 : invert the RX_SWITCH output
7 ANTX_CTRLMODE	Antenna Diversity Control Mode When ANTX_CTRLMODE=1 (dual mode): ANT_A=NOT(ANTX) AND (GPIO3_TRIG_EN OR GPIO2_TRIG_EN) ANT_B=ANTX AND (GPIO3_TRIG_EN OR GPIO2_TRIG_EN) TX_SWITCH=GPIO2_TRIG_EN RX_SWITCH=GPIO3_TRIG_EN When ANTX_CTRLMODE=0 (single mode): ANT_A=NOT(ANTX) AND (GPIO3_TRIG_EN OR GPIO2_TRIG_EN) ANT_B=ANTX AND (GPIO3_TRIG_EN OR GPIO2_TRIG_EN) TX_SWITCH=GPIO2_TRIG_EN RX_SWITCH=(GPIO3_TRIG_EN OR GPIO2_TRIG_EN) GPIO2_TRIG_EN and GPIO3_TRIG_EN are outputs of the Transceiver Sequence Manager (TSM). The TSM timing registers associated with GPIO2_TRIG_EN and GPIO3_TRIG_EN should be programmed with the desired TX_SWITCH and RX_SWITCH timing , before enabling Fast Antenna Diversity.

Table continues on the next page...

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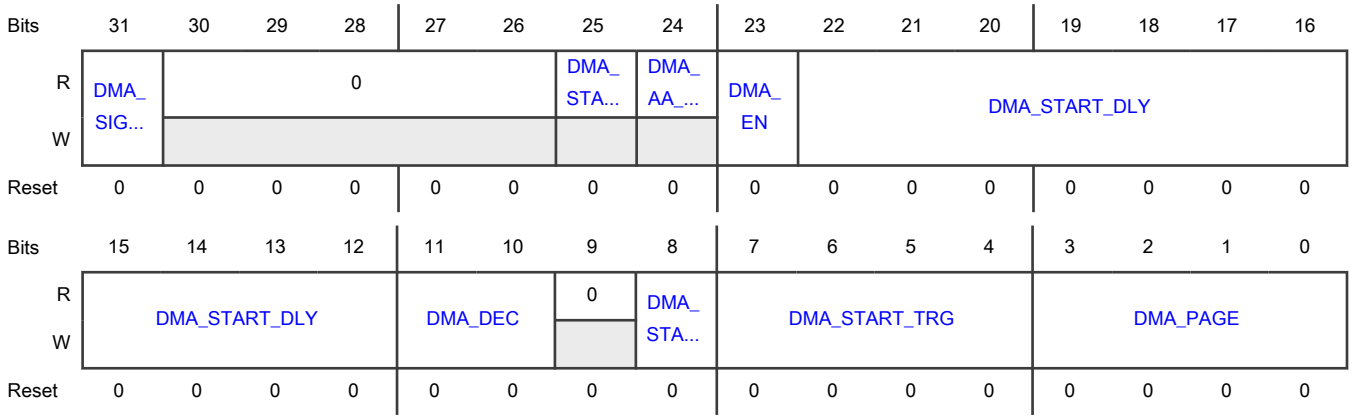
Field	Function
6 —	Reserved
5-4 ANTX_EN	FAD Antenna Controls Enable For any of the 4 FAD-related outputs {ANT_B, ANT_A, RX_SWITCH, TX_SWITCH}, when the associated register control bit (FAD_NOT_GPIO[x]=1) puts that output in FAD mode, ANTX_EN[1:0] determines which pairs of FAD related outputs are enabled: 00b - all disabled (held low) 01b - only RX/TX_SWITCH enabled 10b - only ANT_A/B enabled 11b - all enabled
3 ANTX_OVRD	Antenna State Override Value When ANTX_OVRD_EN=1, the FAD antenna state (ANTX) is overridden by the value of this register; otherwise, antenna state is determined by Ithe 802.15.4 FAD state machine, if XCVR_CTRL[DEMOD_SEL]=0b10, or the FSK PHY FAD state machine if XCVR_CTRL[DEMOD_SEL]=0b01.
2 ANTX_OVRD_EN	Antenna State Override Enable When ANTX_OVRD_EN=1, the FAD antenna state (ANTX) is overridden by the value of the ANTX_OVRD register; otherwise, antenna state is determined by the 802.15.4 FAD state machine, if XCVR_CTRL[DEMOD_SEL]=0b10, or the FSK PHY FAD state machine if XCVR_CTRL[DEMOD_SEL]=0b01.
1 ANTX	Antenna Selection State The ANTX bit reflects the state of antx_out signal.
0 FAD_EN	Fast Antenna Diversity Enable 0b - Fast Antenna Diversity disabled 1b - Fast Antenna Diversity enabled

52.4.4.2.6.2.5 TRANSCEIVER DMA CONTROL (DMA_CTRL)

Offset

Register	Offset
DMA_CTRL	Ch

Diagram



Fields

Field	Function
31 DMA_SIGNAL_VALID_MASK_EN	DMA Signal Valid Mask Enable 0b - Disable use of dma_signal_valid_mask. 1b - Enable use of dma_signal_valid_mask.
30-26 —	Reserved
25 DMA_START_TRIGGERED	DMA Start Trigger Occurred This read-only status bit becomes set, when, during a DMA session (DMA_PAGE > 0), the trigger source selected by DMA_START_TRG[2:0] occurs, with the edge sensitivity selected by DMA_START_EDGE. This bit is cleared when the DMA is re-armed by programming DMA_PAGE to 0 and then to a non-zero value.
24 DMA_AA_TRIGGERED	DMA Access Address triggered This status bit becomes set when the PHY indicates that a Network Address match has occurred. In some cases it may be desirable to delay the start of DMA transfers until such a match occurs; in such cases, software can poll this bit, and once it becomes set, immediately select the desired DMA_PAGE to initiate DMA transfers. This bit is intended for use with DMA_PAGE=GEN4-PHY, but is available on all pages. Its usage is optional.
23 DMA_EN	DMA Enable Setting DMA_EN=1 enables clock gating to the Transceiver DMA engine. This bit should be set prior to the start of a DMA session, and remain set for the duration of the session.
22-12 DMA_START_DLY	DMA Start Trigger Delay When a start trigger is used (DMA_START_TRG not equal to 0), the DMA transfers will be delayed by DMA_START_DLY microseconds after the trigger occurs.
11-10 DMA_DEC	DMA Decimation Rate

Table continues on the next page...

Table continued from the previous page...

Field	Function
	Controls whether every data is captured on every data valid strobe, or only every 2nd, 4th or 8th data valid strobe. 00b - Data is captured on every data valid 01b - Data is captured on every 2nd data valid 10b - Data is captured on every 4th data valid 11b - Data is captured on every 8th data valid
9 ——	Reserved
8 DMA_START_EDGE	DMA Start Trigger Edge Selector DMA_START_EDGE selects the edge sensitivity (rising or falling) of the selected start-trigger. 0b - Trigger fires on a rising edge of the selected trigger source 1b - Trigger fires on a falling edge of the selected trigger source
7-4 DMA_START_TRG	DMA Start Trigger Selector The DMA Start Trigger, if desired, can be selected from the sources as shown below 0000b - no trigger 0001b - PHY: pd found 0010b - PHY: aa found 0011b - Zigbee_PHY: pd found 0100b - Zigbee_PHY: sfd detect 0101b - RXDIG: agc_gain_chg 0110b - TSM: rx_dig_en 0111b - TSM: tsm_irq0_start_trig 1000b - CRC pass 1001b - CRC done (Not used for 15.4LL) 1010b - Localization control: pattern match 1011b - GenericLL: cte_present, Bluetooth LE: cte_en 1100b - Ranging sequence manager: dma_trigger
3-0 DMA_PAGE	Transceiver DMA Page Selector Selects the page of receiver data for storage to system memory when using Transceiver DMA Debug Mode. Setting this register to a non-zero value enables the DMA interface logic. Setting this register to zero disables the interface. 0000b - DMA idle

Table continues on the next page...

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Field	Function
	0001b - RXDIG-IQ: Select from (mixer, decimator, pd channel filter, src, cfo-mixer, demod chan filter) in RXDIG. 11bit signed data, MSB aligned 0010b - RXDIG-IQ-ALT: Same as above + signals on unused LSBs : {antenna switch, GenLL or 802.15.4LL CRC_FAIL} on "Q" LSBs, {preamble_found, aa_sfd_matched} on "I" LSBs. 0011b - ADC-IQ: 11bit samples are MSB aligned in each 16bit half-word 0100b - PHASE: Select from (sync phase, demod phase) within RXDIG. MSB aligned 0101b - RSSI-PHASE: select from 8bit Narrowband (rssi, rssi raw, lqi, snr, noise) and Wideband(rssi, rssi raw) + 8bit high-resolution PHASE 0110b - MAG-PHASE: RSSI magnitude + 8bit high-resolution PHASE 0111b - GEN4-PHY 1000b - DETERMINISTIC

52.4.4.2.6.2.6 DBG Ram control register (DBG_RAM_CTRL)

Offset

Register	Offset
DBG_RAM_CTRL	10h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	DBG_STOP_TRG				DBG_RAM...	DBG_STO...	DBG_STA...	DBG_AA_...	DBG_EN	DBG_START_DLY						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	DBG_START_DLY				DBG_DEC		DBG_STO...	DBG_STA...	DBG_START_TRG				DBG_SIG...	DBG_PAGE		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 DBG_STOP_TRG	Packet RAM Debug Stop Trigger Selector The Packet RAM Debug Stop Trigger, if desired, can be selected from the sources as shown below

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0000b - no trigger 0001b - PHY: pd found 0010b - PHY: aa found 0011b - Zigbee_PHY: pd found 0100b - Zigbee_PHY: sfd detect 0101b - RXDIG: agc_gain_chg 0110b - TSM: rx_dig_en 0111b - TSM: tsm_irq1_stop_trig 1000b - CRC fail 1001b - CRC done (Not used for 15.4LL) 1010b - RBME: error 1011b - GenericLL header fail 1100b - PLL unlock
27 DBG_RAM_FULL	DBG_RAM_FULL Status Bit indicating that logic has written to the DBG_RAM_LAST address when a Stop Trigger is not being use. In this case, any subsequent data will not alter the contents of the RAM. Set DBG_PAGE=0 to clear the DBG_RAM_FULL bit. 0b - Packet RAM is not full 1b - Packet RAM is full
26 DBG_STOP_TRIGGERED	DBG Stop Trigger Occurred This read-only status bit becomes set, when, during a DBG session (DBG_PAGE > 0), the trigger source selected by DBG_START_TRG[2:0] occurs, with the edge sensitivity selected by DBG_STOP_EDGE. This bit is cleared when the DBG is re-armed by programming DBG_PAGE to 0 and then to a non-zero value.
25 DBG_START_TRIGGERED	DBG Start Trigger Occurred This read-only status bit becomes set, when, during a DBG session (DBG_PAGE > 0), the trigger source selected by DBG_START_TRG[2:0] occurs, with the edge sensitivity selected by DBG_START_EDGE. This bit is cleared when the DBG is re-armed by programming DBG_PAGE to 0 and then to a non-zero value.
24 DBG_AA_TRIGGERED	DBG Access Address triggered This status bit becomes set when the PHY indicates that a Network Address match has occurred. In some cases it may be desirable to delay the start of DBG transfers until such a match occurs; in such cases, software can poll this bit, and once it becomes set, immediately select the desired DBG_PAGE to initiate DBG transfers. This bit is intended for use with DBG_PAGE=GEN4-PHY, but is available on all pages. Its usage is optional.
23	DBG Enable

Table continues on the next page...

Table continued from the previous page...

Field	Function
DBG_EN	Setting DBG_EN=1 enables clock gating to the Transceiver DBG engine. This bit should be set prior to the start of a DBG session, and remain set for the duration of the session.
22-12 DBG_START_DLY	DBG Start Trigger Delay When a start trigger is used (DBG_START_TRG not equal to 0), the Packet RAM Debug transfers will be delayed by DBG_START_DLY microseconds after the trigger occurs.
11-10 DBG_DEC	DBG Decimation Rate Controls whether every data is captured on every data valid strobe, or only every 2nd, 4th or 8th data valid strobe. 00b - Data is captured on every data valid 01b - Data is captured on every 2nd data valid 10b - Data is captured on every 4th data valid 11b - Data is captured on every 8th data valid
9 DBG_STOP_EDGE	DBG Stop Trigger Edge Selector DBG_STOP_EDGE selects the edge sensitivity (rising or falling) of the selected start-trigger. 0b - Trigger stops on a rising edge of the selected trigger source 1b - Trigger stops on a falling edge of the selected trigger source
8 DBG_START_EDGE	DBG Start Trigger Edge Selector DBG_START_EDGE selects the edge sensitivity (rising or falling) of the selected start-trigger. 0b - Trigger fires on a rising edge of the selected trigger source 1b - Trigger fires on a falling edge of the selected trigger source
7-4 DBG_START_TRG	DMA Start Trigger Selector The DMA Start Trigger, if desired, can be selected from the sources as shown below 0000b - no trigger 0001b - PHY: pd found 0010b - PHY: aa found 0011b - Zigbee_PHY: pd found 0100b - Zigbee_PHY: sfd detect 0101b - RXDIG: agc_gain_chg 0110b - TSM: rx_dig_en 0111b - TSM: tsm_irq0_start_trig 1000b - CRC pass 1001b - CRC done (Not used for 15.4LL) 1010b - Localization control: pattern match

Table continues on the next page...

Table continued from the previous page...

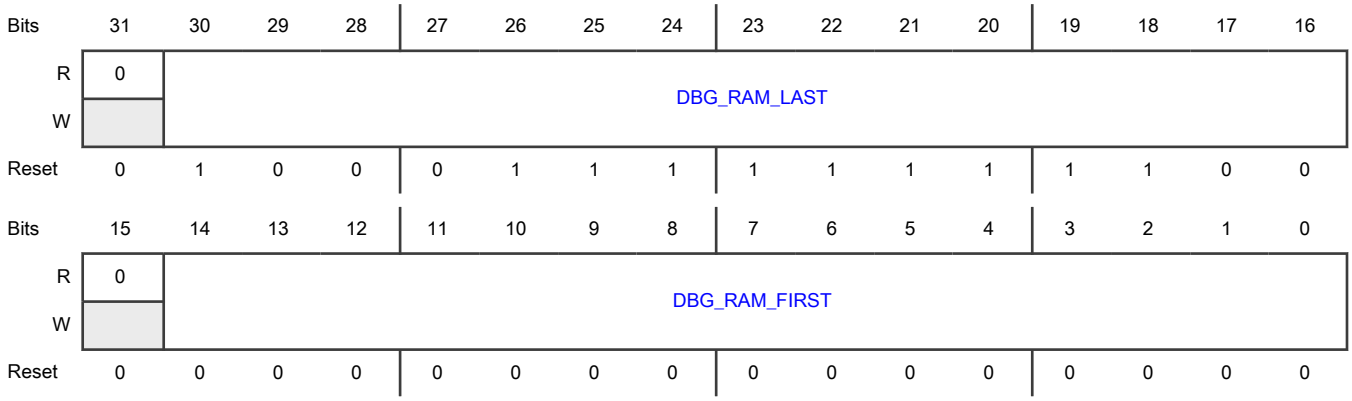
Field	Function
	1011b - GenericLL: cte_present, Bluetooth LE: cte_en 1100b - Ranging sequence manager: dma_trigger
3 DBG_SIGNAL_VALID_MASK_EN	DBG Signal Valid Mask Enable 0b - Disable use of dbg_signal_valid_mask. 1b - Enable use of dbg_signal_valid_mask.
2-0 DBG_PAGE	Packet RAM Debug Page Selector Selects the page of receiver data for storage to Packet RAM using Transceiver Packet RAM Debug Mode. Setting this register to a non-zero value enables the Packet RAM Debug Mode interface logic. Setting this register to zero disables the interface. 000b - DMA idle 001b - RXDIG-IQ: Select from (mixer, decimator, pd channel filter, src, cfo-mixer, demod chan filter) in RXDIG. 11bit signed data, MSB aligned 010b - RXDIG-IQ-ALT: Same as above + signals on unused LSBs : {antenna switch, GenLL or 802.15.4LL CRC_FAIL} on "Q" LSBs, {preamble_found, aa_sfd_matched} on "I" LSBs. 011b - ADC-IQ: 11bit samples are MSB aligned in each 16bit half-word 100b - PHASE: Select from (sync phase, demod phase) within RXDIG. MSB aligned 101b - RSSI-PHASE: select from 8bit Narrowband (rssi, rssi raw, lqi, snr, noise) and Wideband(rssi, rssi raw) + 8bit high-resolution PHASE 110b - MAG-PHASE: RSSI magnitude + 8bit high-resolution PHASE 111b - GEN4-PHY

52.4.4.2.6.2.7 DBG RAM ADDRESS (DBG_RAM_ADDR)

Offset

Register	Offset
DBG_RAM_ADDR	14h

Diagram



Fields

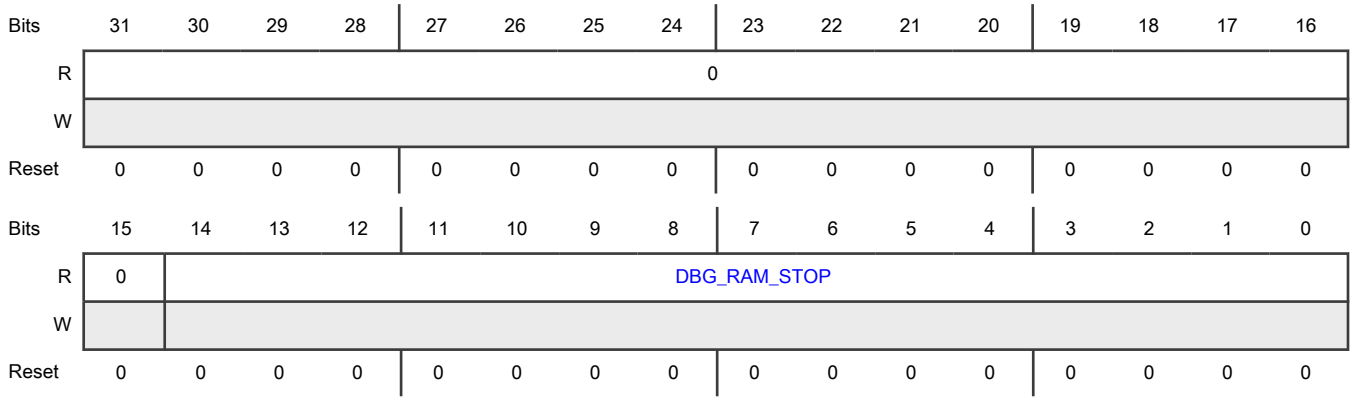
Field	Function
31 —	Reserved
30-16 DBG_RAM_LAST	DBG RAM Last Address Represents the last valid RAM address which can be written. The 2 LSBs should always be 0. The TX_PACKET_RAM is accessed from address 0x0000 to 0x0FFC, and the RX_PACKET_RAM from address 0x1000 to 0x17FC. Through programming of DBG_RAM_FIRST and DBG_RAM_LAST, data can be captured solely to the TX_PACKET_RAM, solely to the RX_PACKET_RAM, or it can span the TX_PACKET_RAM and RX_PACKET_RAM spaces. The only restrictions are that DBG_RAM_LAST should be greater than DBG_RAM_FIRST, and DBG_RAM_LAST should be no larger than the last address of the RX_PACKET_RAM (0x17FC).
15 —	Reserved
14-0 DBG_RAM_FIRST	DBG RAM First Address Represents the first RAM address which will be written. The 2 LSBs should always be 0. The TX_PACKET_RAM is accessed from address 0x0000 to 0x0FFC, and the RX_PACKET_RAM from address 0x1000 to 0x17FC. Through programming of DBG_RAM_FIRST and DBG_RAM_LAST, data can be captured solely to the TX_PACKET_RAM, solely to the RX_PACKET_RAM, or it can span the TX_PACKET_RAM and RX_PACKET_RAM spaces. The only restrictions are that DBG_RAM_LAST should be greater than DBG_RAM_FIRST, and DBG_RAM_LAST should be no larger than the last address of the RX_PACKET_RAM (0x17FC).

52.4.4.2.6.2.8 DBG RAM STOP ADDRESS (DBG_RAM_STOP_ADDR)

Offset

Register	Offset
DBG_RAM_STOP_ADDR	18h

Diagram



Fields

Field	Function
31-15 —	Reserved
14-0 DBG_RAM_STOP	DBG RAM Stop Address After a Packet RAM Debug Mode acquisition, RAM_STOP_ADDR represents the last (most recent) RAM location filled with sample data before the acquisition terminated. The acquisition terminates when a stop-trigger occurs, or due to a manual termination by setting DBG_PAGE=0.

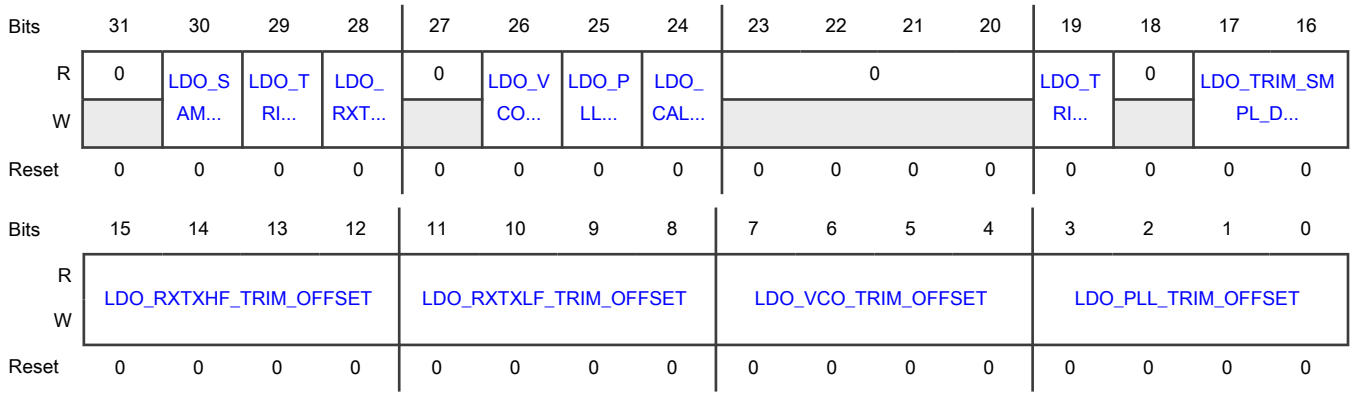
52.4.4.2.6.2.9 LDO TRIM Configuration 0 (LDO_TRIM_0)

Offset

Register	Offset
LDO_TRIM_0	1Ch

Function
LDO_TRIM_0

Diagram



Fields

Field	Function
31 —	Reserved
30 LDO_SAMPLE_TRIMSEL_OVRD_EN	LDO SAMPLE TRIMSEL Override Enable If set, the sample and trimsel signals are overridden with values in LDO_TRIM_SAMPLE_OVRD, LDO_RXTXHF_TRIMSEL_OVRD, LDO_PLL_TRIMSEL_OVRD, LDO_VCO_TRIMSEL_OVRD, and LDO_CAL_TRIMSEL_OVRD bits.
29 LDO_TRIM_SAMPLE_OVRD	LDO_TRIM_SAMPLE Override Value If LDO_SAMPLE_TRIMSEL_OVRD_EN is set, the LDO_TRIM_SAMPLE signal is overridden with this value.
28 LDO_RXTXHF_TRIMSEL_OVRD	LDO_RXTXHF_TRIMSEL Override Value If LDO_SAMPLE_TRIMSEL_OVRD_EN is set, the LDO_RXTXHF_TRIMSEL signal is overridden with this value.
27 —	Reserved
26 LDO_VCO_TRIMSEL_OVRD	LDO_VCO_TRIMSEL Override Value If LDO_SAMPLE_TRIMSEL_OVRD_EN is set, the LDO_VCO_TRIMSEL signal is overridden with this value.
25 LDO_PLL_TRIMSEL_OVRD	LDO_PLL_TRIMSEL Override Value If LDO_SAMPLE_TRIMSEL_OVRD_EN is set, the LDO_PLL_TRIMSEL signal is overridden with this value.
24 LDO_CAL_TRIMSEL_OVRD	LDO_CAL_TRIMSEL Override Value If LDO_SAMPLE_TRIMSEL_OVRD_EN is set, the LDO_CAL_TRIMSEL signal is overridden with this value.
23-20 —	Reserved
19 LDO_TRIM_CMPOUT_INV	LDO TRIM CMPOUT Invert If set, the LDO trim comparator output signal from the analog is inverted before it is used by the calibration logic.
18 —	Reserved
17-16	LDO TRIM Sample Delay Specifies when the LDO trim comparator output signal from the analog is captured.

Table continues on the next page...

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Field	Function
LDO_TRIM_SMPL_DLY	
15-12 LDO_RXTXHF_TRIM_OFFSET	LDO RXTXHF TRIM Offset Signed offset applied to the RXTXHF trim calculated by the calibration logic
11-8 LDO_RXTXLF_TRIM_OFFSET	LDO RXTXLF TRIM Offset Signed offset applied to the RXTXLF trim calculated by the calibration logic.
7-4 LDO_VCO_TRIM_OFFSET	LDO VCO TRIM Offset Signed offset applied to the VCO trim calculated by the calibration logic. The resolution of this offset is 4 codes: this signed value is arithmetically left-shifted by 2bits before it is added to VCO trim calculated by the calibrated logic.
3-0 LDO_PLL_TRIM_OFFSET	LDO PLL TRIM Offset Signed offset applied to the PLL trim calculated by the calibration logic.

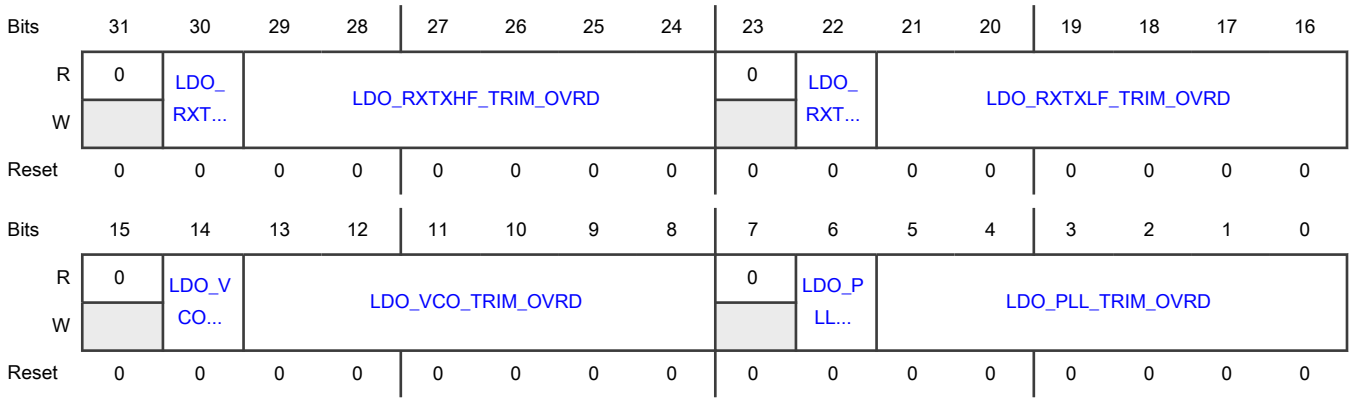
52.4.4.2.6.2.10 LDO TRIM Configuration 1 (LDO_TRIM_1)

Offset

Register	Offset
LDO_TRIM_1	20h

Function
LDO_TRIM_1

Diagram



Fields

Field	Function
31 —	Reserved
30 LDO_RXTXHF_TRIM_OVRD_EN	LDO RXTXHF TRIM Override Enable If set, the LDO_RXTXHF_TRIM_OVRD is used for the RXTXHF TRIM instead of the value determined by the calibration logic
29-24 LDO_RXTXHF_TRIM_OVRD	LDO RXTXHF TRIM Override Value If LDO_RXTXHF_TRIM_OVRD_EN=1, this value is used for the LDO RXTXHF TRIM.
23 —	Reserved
22 LDO_RXTXLF_TRIM_OVRD_EN	LDO RXTXLF TRIM Override Enable If set, the LDO_RXTXLF_TRIM_OVRD is used for the RXTXLF TRIM instead of the value determined by the calibration logic
21-16 LDO_RXTXLF_TRIM_OVRD	LDO RXTXLF TRIM Override Value If LDO_RXTXLF_TRIM_OVRD_EN=1, this value is used for the LDO RXTXLF TRIM.
15 —	Reserved
14 LDO_VCO_TRIM_OVRD_EN	VCO TRIM Override Enable If set, the VCO_TRIM_OVRD is used for the VCO TRIM instead of the value determined by the calibration logic.
13-8 LDO_VCO_TRIM_OVRD	LDO VCO TRIM Override Value If LDO_VCO_TRIM_OVRD_EN=1, this value is used for the LDO VCO TRIM.
7 —	Reserved
6 LDO_PLL_TRIM_OVRD_EN	LDO PLL TRIM Override Enable If set, the LDO_PLL_TRIM_OVRD is used for the PLL TRIM instead of the value determined by the calibration logic.
5-0 LDO_PLL_TRIM_OVRD	LDO PLL TRIM Override Value If LDO_PLL_TRIM_OVRD_EN=1, this value is used for the LDO PLL TRIM.

52.4.4.2.6.2.11 RF Analog LDO Trim Res Control 0 (LDO_TRIM_RES_0)

Offset

Register	Offset
LDO_TRIM_RES_0	24h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		LDO_RXTXHF_TRIM						0		LDO_RXTXLF_TRIM					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		LDO_VCO_TRIM						0		LDO_PLL_TRIM					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30 —	Reserved
29-24 LDO_RXTXHF_TRIM	LDO_RXTXHF_TRIM Result LDO RXTXHF Trim value
23-22 —	Reserved
21-16 LDO_RXTXLF_TRIM	LDO_RXTXLF_TRIM Result LDO Rxtxlf Trim value
15-14 —	Reserved
13-8 LDO_VCO_TRIM	LDO_VCO_TRIM Result LDO Vco Trim value
7-6	Reserved

Table continues on the next page...

Table continued from the previous page...

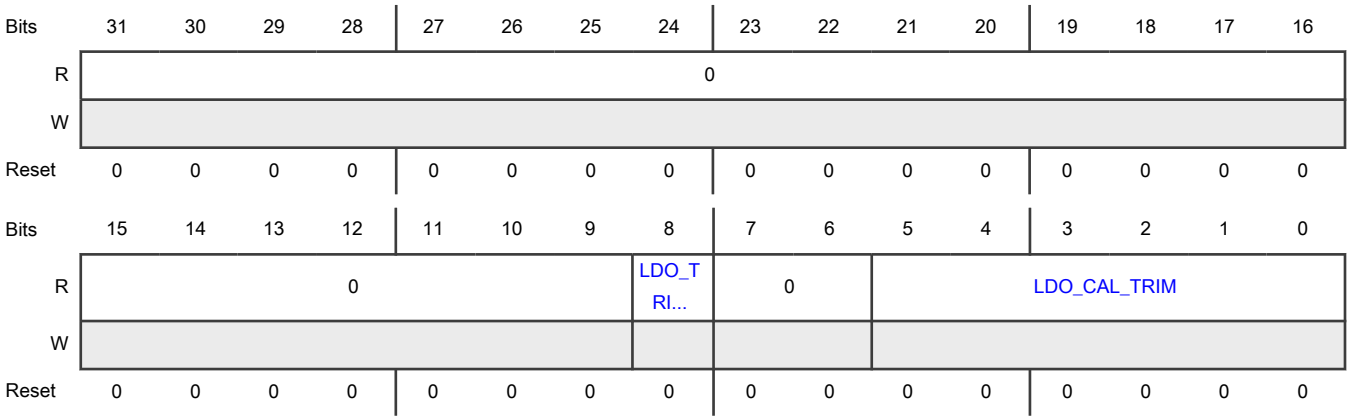
Field	Function
—	
5-0 LDO_PLL_TRIM	LDO_PLL_TRIM Result LDO Pll Trim value

52.4.4.2.6.2.12 RF Analog LDO Trim Res Control 1 (LDO_TRIM_RES_1)

Offset

Register	Offset
LDO_TRIM_RES_1	28h

Diagram



Fields

Field	Function
31-9 —	Reserved
8 LDO_TRIM_CMPOUT	LDO TRIM CMPOUT Instantaneous value of the LDO_TRIM_CMPOUT signal
7-6 —	Reserved
5-0	LDO_CAL_TRIM Result

Table continues on the next page...

Table continued from the previous page...

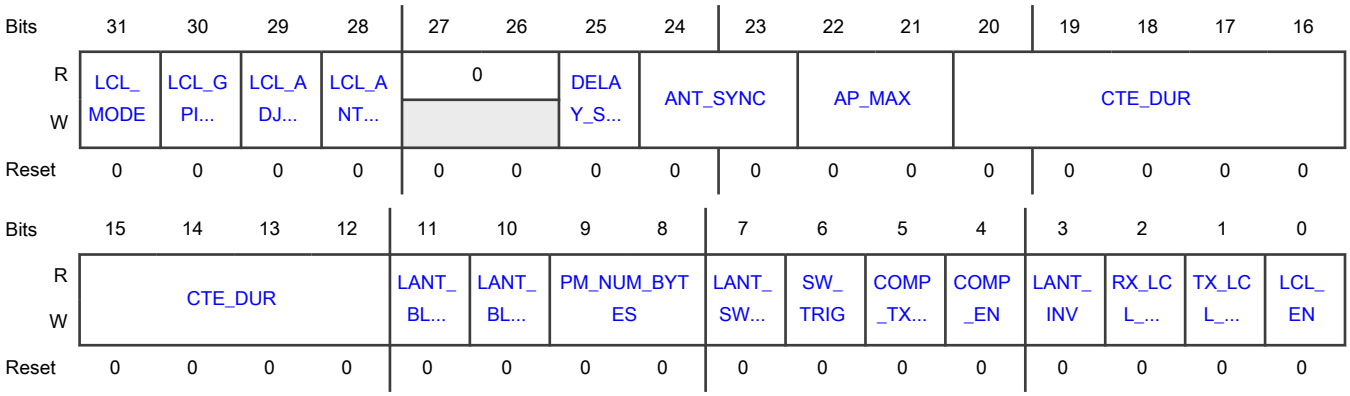
Field	Function
LDO_CAL_TRIM	LDO Cal Trim Value

52.4.4.2.6.2.13 LCL CTRL CFG 0 (LCL_CFG0)

Offset

Register	Offset
LCL_CFG0	2Ch

Diagram



Fields

Field	Function
31 LCL_MODE	Localization Mode Configure localization control module for GenLL or Bluetooth LE LL. 0b - GenLL configuration. 1b - Bluetooth LE LL configuration.
30 LCL_GPIO_SEL	Localization GPIO Select Reserved. This bit should be programmed to 0
29 LCL_ADJ_END_MASK	This field manages the tone_extension in LCL bloc, must be set to 1 in localization context. This must be set to 0 for other context as AoA/AoD.
28	Enable antenna permutation for mode 2 and 3 Enable hardware antenna permutation for mode 2 and 3

Table continues on the next page...

Table continued from the previous page...

Field	Function
LCL_ANT_PERMUT_EN	
27-26 —	Reserved
25 DELAY_SIGNED	Delay signed feature When set to 1, we can use rx_delay and tx_delay as signed register, which mean we can set a negative value. It can be useful for accuracy in antenna alignment for localization.
24-23 ANT_SYNC	Reserved This field is not used.
22-21 AP_MAX	Max number of Antenna paths Maximum antenna path possible. From 1 to 4 path (register 0..3) , we can use it in generalized context N:M antenna,we can use 1:4 for instance and set max_path to 3 (4 AP).
20-12 CTE_DUR	Total Switching Duration LCL antenna switching will continue for this many doublets, where a doublet is (RX/TX_HI_PER + RX/TX_LO_PER).
11 LANT_BLOCK_RX	Block LANT_SW for RX Setting this bit will cause the Localization Control Module to block its LANT_SW output, for RX. NOTE: the PHY's ant_out will still pass through on the LANT_SW output.
10 LANT_BLOCK_TX	Block LANT_SW for TX Setting this bit will cause the Localization Control Module to block its LANT_SW output, for TX. NOTE: the PHY's ant_out will still pass through on the LANT_SW output.
9-8 PM_NUM_BYTES	Number of Bytes to Match This field indicates how many bytes are used to compare in the bit stream for a pattern match. 00b - 4 bytes 01b - 5 bytes 10b - 6 bytes 11b - 8 bytes
7 LANT_SW_WIGGLE	LANT_SW Wiggle If set, 3 clock pulses will be driven on LANT_SW after the localization control module is triggered, to initialize the SOC TPM.
6 SW_TRIG	Software Trigger. Can be used with either RX or TX Setting this bit will cause a trigger event in RX and TX, depending on the trigger select configuration.

Table continues on the next page...

Table continued from the previous page...

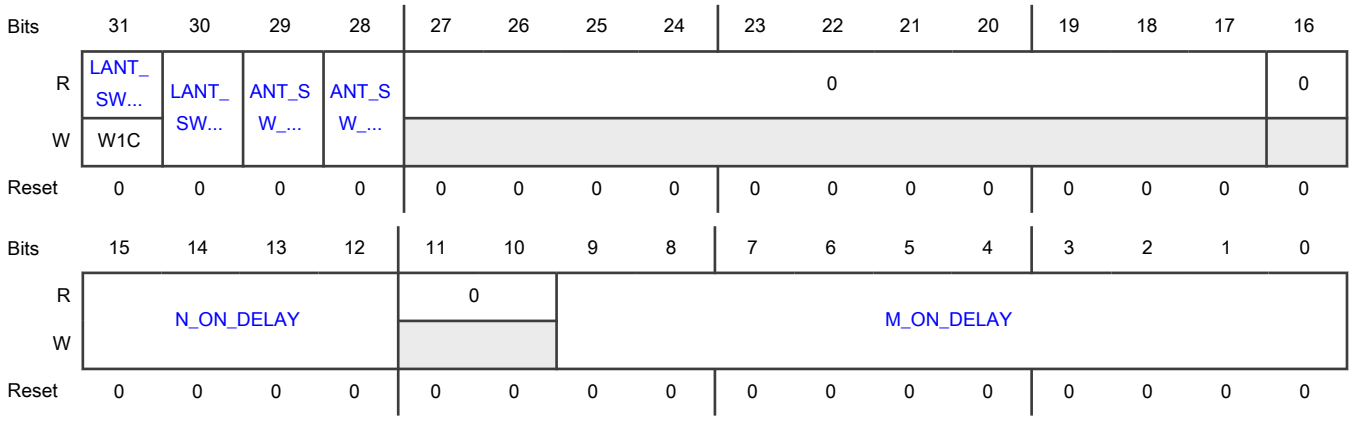
Field	Function
5 COMP_TX_EN	Pattern Matching Enable in TX Normally, pattern matching is used for RX. If it is desired for TX, as well, this bit should be set.
4 COMP_EN	Pattern Matching Enable This enables the pattern matching feature.
3 LANT_INV	Invert Antenna Switch Output
2 RX_LCL_EN	Enable Switching in RX
1 TX_LCL_EN	Enable Switching in TX
0 LCL_EN	Localization Control Module Enable Note: This bit, when 0, will still allow the PHY FAD antenna switch signal to propagate.

52.4.4.2.6.2.14 LCL CTRL CFG 1 (LCL_CFG1)

Offset

Register	Offset
LCL_CFG1	30h

Diagram



Fields

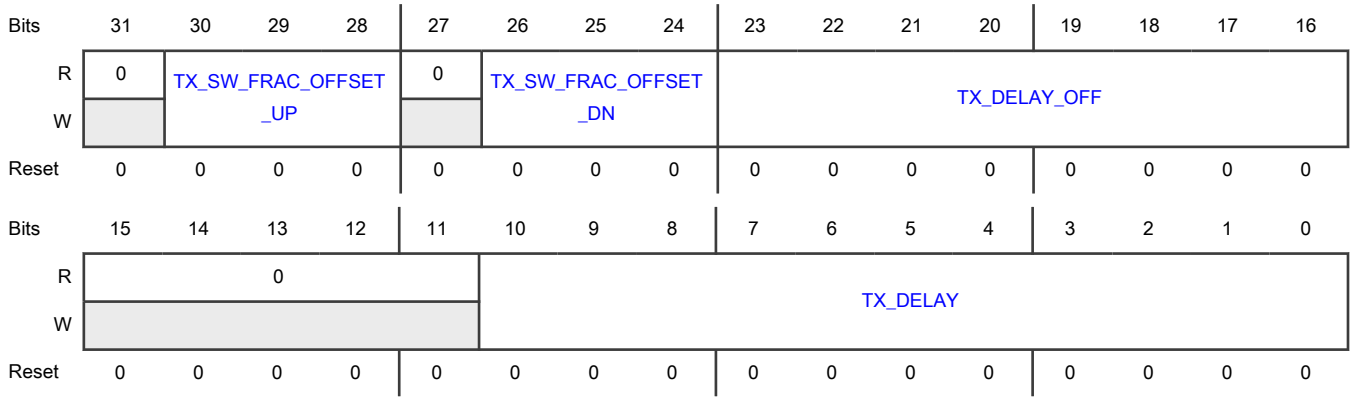
Field	Function
31 LANT_SW_FLAG	Localization Antenna Switch Flag The bit is set when a rising-edge on lant_sw occurs. Write 1 to clear the bit.
30 LANT_SW_IE	Localization Antenna Switch Interrupt Enable Configures the radio to generate an interrupt when the LANT_SW_FLAG is set. 0b - Localization Antenna Switch interrupt disabled 1b - Localization Antenna Switch interrupt enabled
29 ANT_SW_RF	Antenna switch trigger mode It means that a ramp down and ramp up on Tx will be managed when toggling antenna whatever the case in localisation mode 2 or 3 , even outside the t_pm when switching to antenna_sync.
28 ANT_SW_MODE3	Antenna switch for mode 3 PM to DT transition When antenna switch with PA ramp up/down is needed, the transitions t_pm-t_dt and t_dt-t_pm need to be managed, this bit will ensure this feature.
27-17 —	Reserved
16 —	Reserved
15-12 N_ON_DELAY	N on Delay rx/tx_lcl_on will de-assert M_ON_DELAY intervals + N_ON_DELAY doublets earlier than the antenna switching stops.
11-10 —	Reserved
9-0 M_ON_DELAY	M on Delay rx/tx_lcl_on will de-assert M_ON_DELAY intervals + N_ON_DELAY doublets earlier than the antenna switching stops.

52.4.4.2.6.2.15 LCL CTRL TX CONFIG0 (LCL_TX_CFG0)

Offset

Register	Offset
LCL_TX_CFG0	34h

Diagram



Fields

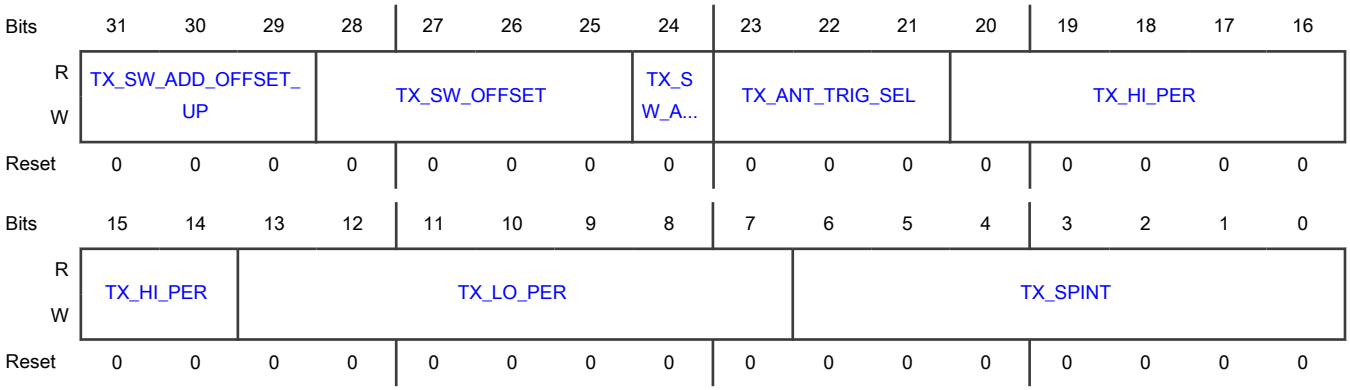
Field	Function
31 —	Reserved
30-28 TX_SW_FRAC_OFFSET_UP	TX_SW_FRAC_OFFSET_UP Fractional unsigned offset that adds to TX_SW_OFFSET for ramp up phase. It adjusts low power duration after 'lant_sw' by steps of a fraction of us.
27 —	Reserved
26-24 TX_SW_FRAC_OFFSET_DN	TX_SW_FRAC_OFFSET_DN Fractional unsigned offset that adds to TX_SW_OFFSET for ramp down phase. It adjusts low power duration before 'lant_sw' by steps of a fraction of us. Will shift as well ramp up phase.
23-16 TX_DELAY_OFF	Fine sample delay after TX_DELAY. This field allows for fine tuning the switching start point by several samples after TX_DELAY. Interval depends on TX filter selection (from 62.5 ns for datarate 2Mbps to 500 ns for datarate 250 Kbps).
15-11 —	Reserved
10-0 TX_DELAY	Interval delay before TX switching begins. After a legitimate trigger event in TX, antenna switching will begin this many intervals later, where an interval is defined as TX_SPINT samples.

52.4.4.2.6.2.16 LCL CTRL TX CONFIG1 (LCL_TX_CFG1)

Offset

Register	Offset
LCL_TX_CFG1	38h

Diagram



Fields

Field	Function
31-29 TX_SW_ADD_OFFSET_UP	TX_SW_ADD_OFFSET_UP Additional unsigned offset for ramp up phase. If TX_SW_OFFSET is negative then it shortens low power duration after lant_sw by steps of 1us. If TX_SW_OFFSET>0, then it widens low power duration after lant_sw (opposite direction as previous case).
28-25 TX_SW_OFFSET	TX_SW_OFFSET Sets a 4bit signed offset of N us, for automatic ramp down and up of PA during antenna switch. N expected negative most of the time meaning ramp down will end (-N) us before effective switch and ramp up will start MAX(-N,0) us after effective switch. If N is positive, provided ramp down and up duration is higher than N us, ramp down and up phases duration will be shortened of N us. Meaning complete power off will not be obtained during switch phase. Do not use values that do not respect above condition. See TX_SW_FRAC_OFFSET* and TX_SW_ADD_OFFSET_UP for further options.
24 TX_SW_ACTIVE	TX_SW_ACTIVE Enables automatic ramp down and up of PA during antenna switch. When this field is disabled, PA remains active during antenna switch.
23-21 TX_ANT_TRIG_SEL	Selects Trigger for TX 000b - Software Trigger 001b - LCL Pattern Found 010b - CRC Complete 011b - PA Warm-up complete

Table continues on the next page...

Table continued from the previous page...

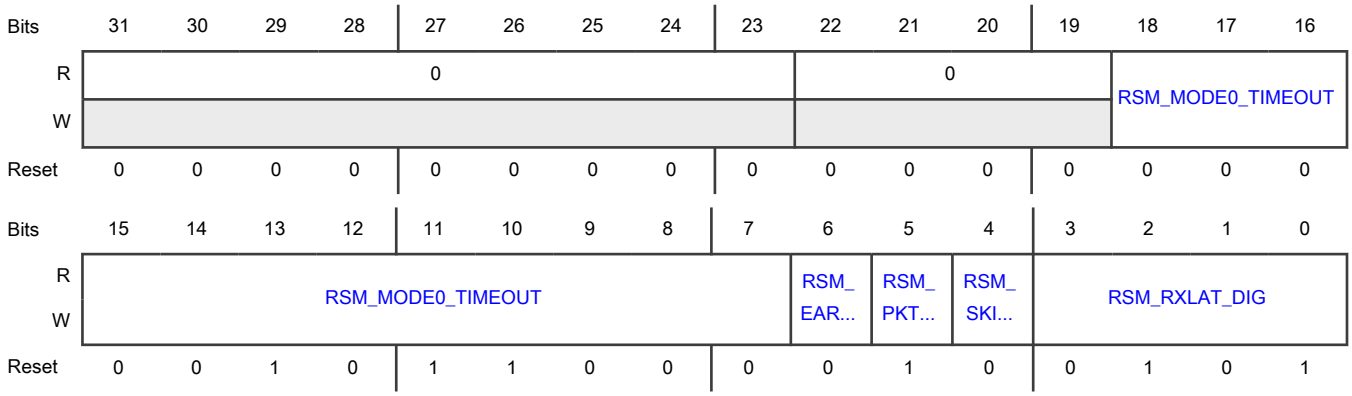
Field	Function
	100b - RBME Tx Done 101b - cte_en from NBU 110b - Ranging sequence manager lcl_tx_trigger
20-14 TX_HI_PER	Primary Number of intervals for antenna HIGH Number of intervals for which lant_sw should be 1, when switching is active. A value of 0 is not recommended when TX switching is enabled.
13-7 TX_LO_PER	Primary Number of intervals for antenna LOW Number of intervals for which lant_sw should be 0, when switching is active. A value of 0 is not recommended when TX switching is enabled.
6-0 TX_SPINT	Number of TX Samples that define the length of an Interval, where 0=1sample, 1=2sample, etc.

52.4.4.2.6.2.17 RSM CTRL 6 (RSM_CTRL6)

Offset

Register	Offset
RSM_CTRL6	3Ch

Diagram



Fields

Field	Function
31-23 —	Reserved

Table continues on the next page...

Table continued from the previous page...

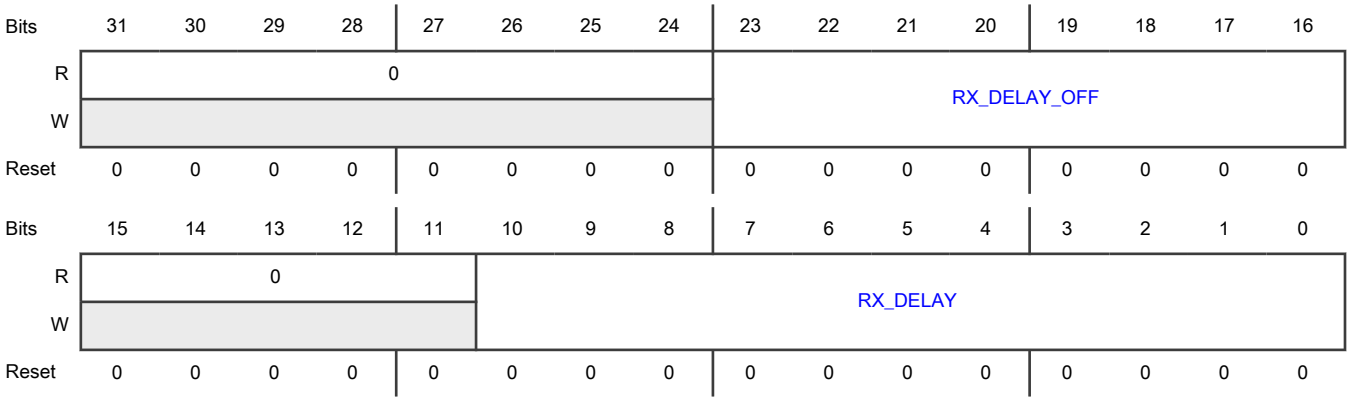
Field	Function
22-19 —	Reserved
18-7 RSM_MODE0_TIMEOUT	RSM TIMEOUT IN MODE0 This defines the timeout value +1 in microseconds to wait for Packet synchronization before switching to next step.
6 RSM_EARLY_MOD_DIS	Early Mod Disable Setting this bit avoid a toggling of modulation_disable during rx2rx in localization context, and so avoid PLL reconverge time. This is useful for a fast and good transition between tone/packets.
5 RSM_PKTRAM_EXTEND	Packet Ram Extend Information In localization we need more information in pktram and need to extend (compared to KW45). Always set to 1 in MCXW72. When set to 0, we come back to a legacy behavior limited to the KW45 information. In the KW45 configuration, Tone Extension is always set whatever the t_ext_sel bitfield in Packet RAM
4 RSM_SKIP_RECYCLE_R2R	RECYCLE R2R When set to 1, this skip the recycle during rx2rx and avoid rx_init pulse which reset the phy. It secure the good hartt detection for localization.
3-0 RSM_RXLAT_DIG	Digital Latency Extra rx latency time in microseconds needed to keep PHY activated after end of dt_rx in localization. It will let time for HARTT block to finish properly his detection.

52.4.4.2.6.2.18 LCL CTRL RX CONFIG0 (LCL_RX_CFG0)

Offset

Register	Offset
LCL_RX_CFG0	40h

Diagram



Fields

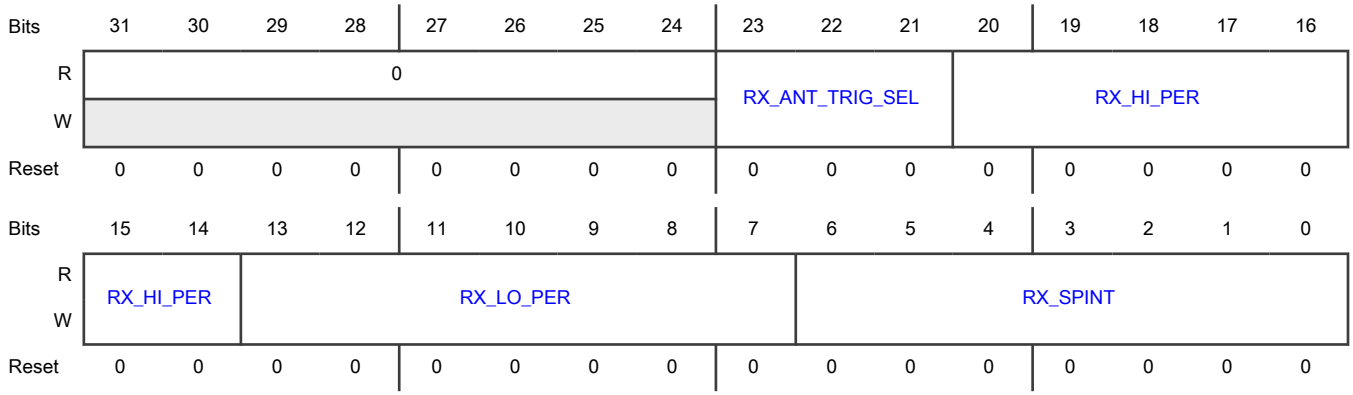
Field	Function
31-24 —	Reserved
23-16 RX_DELAY_OFF	Fine sample delay after RX_DELAY. This field allows for fine tuning the switching start point by several samples after RX_DELAY. Interval of 250 ns in 1Mbps, 125 ns in 2 Mbps.
15-11 —	Reserved
10-0 RX_DELAY	Interval delay before RX switching begins. After a legitimate trigger event in RX, antenna switching will begin this many intervals later, where an interval is defined as RX_SPINT samples.

52.4.4.2.6.2.19 LCL CTRL RX CONFIG1 (LCL_RX_CFG1)

Offset

Register	Offset
LCL_RX_CFG1	44h

Diagram



Fields

Field	Function
31-24 —	Reserved
23-21	Selects Trigger for RX

Table continues on the next page...

Table continued from the previous page...

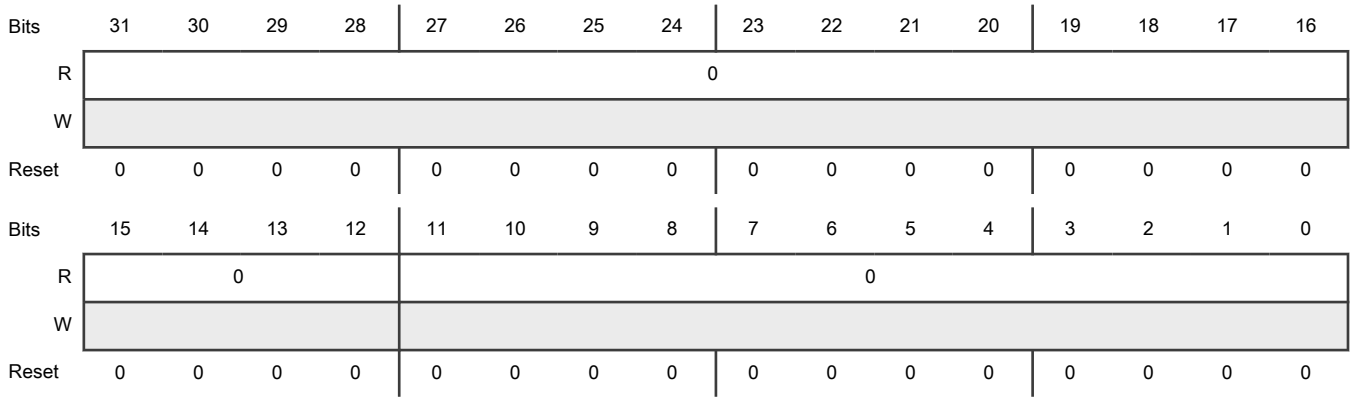
Field	Function
RX_ANT_TRIG_SEL	000b - Software Trigger 001b - LCL Pattern Found 010b - CRC Complete 011b - CRC Pass 100b - GenericLL: cte_present, Bluetooth LE: cte_en 101b - aa_fnd_to_ll 110b - Ranging sequence manager lcl_rx_trigger
20-14 RX_HI_PER	Primary Number of intervals for antenna HIGH Number of intervals for which lant_sw should be 1, when switching is active. It also indicates the number of intervals that the dma_mask should be 1. A value of 0 is not recommended when RX switching is enabled.
13-7 RX_LO_PER	Primary Number of intervals for antenna LOW Number of intervals for which lant_sw should be 0, when switching is active. It also indicates the number of intervals that the dma_mask should be 0. A value of 0 is not recommended when RX switching is enabled.
6-0 RX_SPINT	Number of RX Samples that define the length of an Interval, where 0=1sample, 1=2sample, etc.

52.4.4.2.6.2.20 LCL CTRL RX CONFIG2 (LCL_RX_CFG2)

Offset

Register	Offset
LCL_RX_CFG2	48h

Diagram



Fields

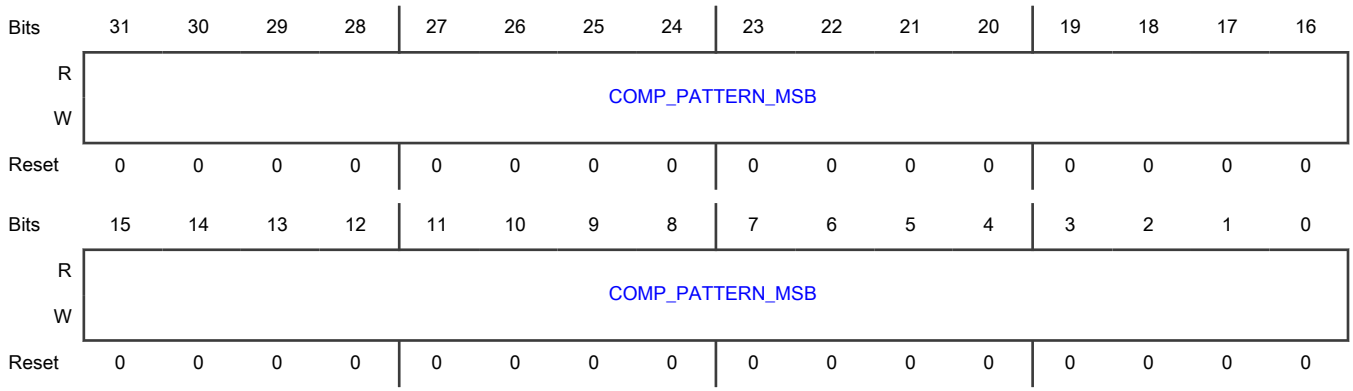
Field	Function
31-12 —	Reserved
11-0 —	Reserved

52.4.4.2.6.2.21 LCL CTRL PM MSB (LCL_PM_MSB)

Offset

Register	Offset
LCL_PM_MSB	4Ch

Diagram



Fields

Field	Function
31-0 COMP_PATTERN_MSB	Upper bytes of pattern to be matched, bits 63:32

52.4.4.2.6.2.22 LCL CTRL PM LSB (LCL_PM_LSB)

Offset

Register	Offset
LCL_PM_LSB	50h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	COMP_PATTERN_LSB															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	COMP_PATTERN_LSB															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 COMP_PATTERN_LSB	Lower bytes of pattern to be matched, bits 31:0

52.4.4.2.6.2.23 LCL GPIO CTRL 0 (LCL_GPIO_CTRL0)

Offset

Register	Offset
LCL_GPIO_CTRL0	54h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	LUT_7				LUT_6				LUT_5				LUT_4			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	LUT_3				LUT_2				LUT_1				LUT_0			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28	GPIO antenna state LUT entry

Table continues on the next page...

Table continued from the previous page...

Field	Function
LUT_7	Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
27-24 LUT_6	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
23-20 LUT_5	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
19-16 LUT_4	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
15-12 LUT_3	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
11-8 LUT_2	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
7-4 LUT_1	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
3-0 LUT_0	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).

52.4.4.2.6.2.24 LCL GPIO CTRL 1 (LCL_GPIO_CTRL1)

Offset

Register	Offset
LCL_GPIO_CTRL1	58h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	LUT_15				LUT_14				LUT_13				LUT_12			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	LUT_11				LUT_10				LUT_9				LUT_8			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 LUT_15	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
27-24 LUT_14	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
23-20 LUT_13	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
19-16 LUT_12	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
15-12 LUT_11	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
11-8 LUT_10	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
7-4 LUT_9	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
3-0 LUT_8	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).

52.4.4.2.6.2.25 LCL GPIO CTRL 2 (LCL_GPIO_CTRL2)

Offset

Register	Offset
LCL_GPIO_CTRL2	5Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	LUT_23				LUT_22				LUT_21				LUT_20			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	LUT_19				LUT_18				LUT_17				LUT_16			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 LUT_23	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
27-24 LUT_22	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
23-20 LUT_21	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
19-16 LUT_20	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
15-12 LUT_19	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
11-8 LUT_18	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).

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Field	Function
7-4 LUT_17	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
3-0 LUT_16	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).

52.4.4.2.6.2.26 LCL GPIO CTRL 3 (LCL_GPIO_CTRL3)

Offset

Register	Offset
LCL_GPIO_CTRL3	60h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	LUT_31				LUT_30				LUT_29				LUT_28			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	LUT_27				LUT_26				LUT_25				LUT_24			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 LUT_31	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
27-24 LUT_30	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
23-20 LUT_29	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).

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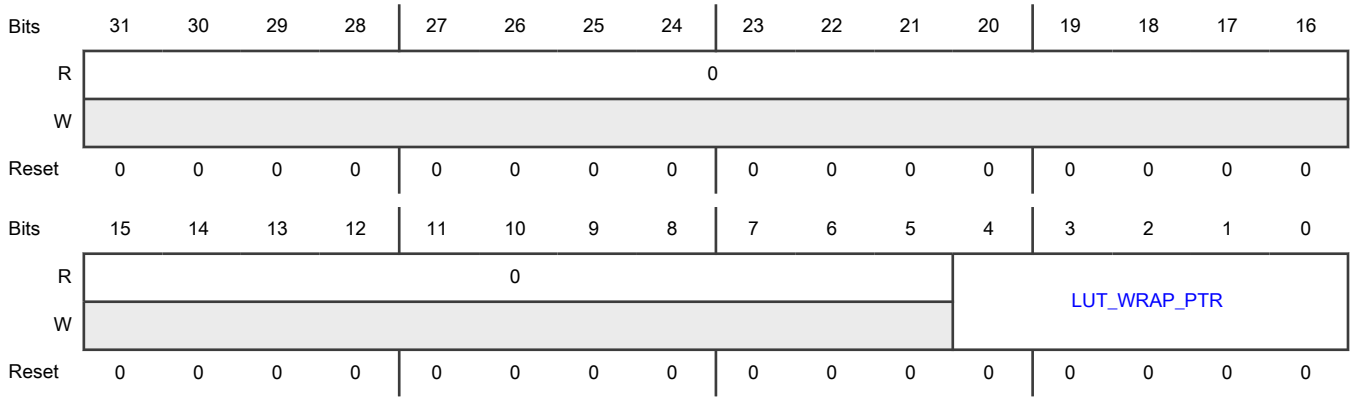
Field	Function
19-16 LUT_28	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
15-12 LUT_27	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
11-8 LUT_26	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
7-4 LUT_25	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).
3-0 LUT_24	GPIO antenna state LUT entry Each entry corresponds to a state of the 4 GPIOs, set at the beginning of each switch period (each doublet).

52.4.4.2.6.2.27 LCL GPIO CTRL 4 (LCL_GPIO_CTRL4)

Offset

Register	Offset
LCL_GPIO_CTRL4	64h

Diagram



Fields

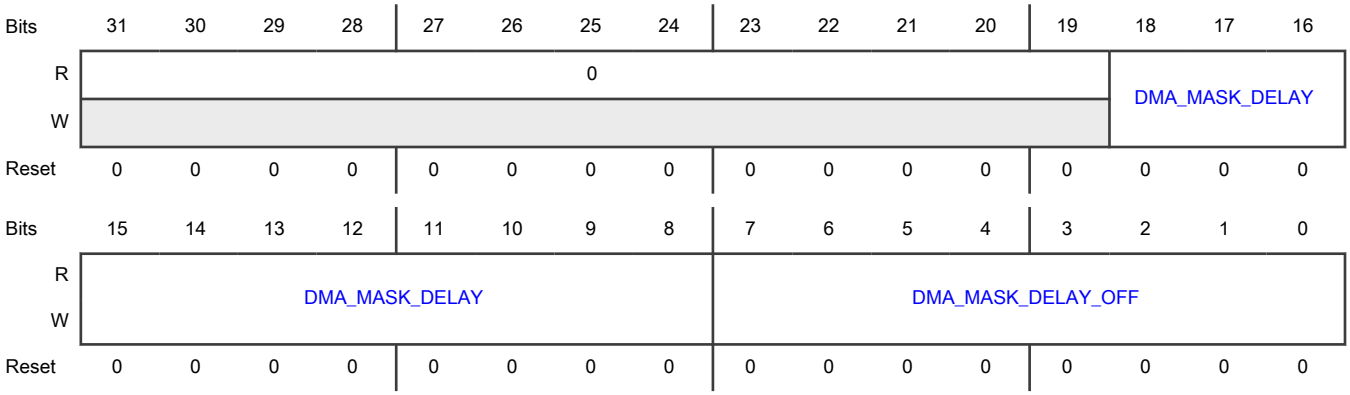
Field	Function
31-5 —	Reserved
4-0 LUT_WRAP_PTR	Wrap point for the LUT table in generating the 4 antenna GPIO wire states. The programmed value represents the last LUT entry that will be used before wrapping back to use LUT_0; if programmed to value "N", when the LCL_CTRL is triggered the output will be LUT_0, ..., LUT_N, LUT_0, ... etc. If programmed to "0", only LUT_0 will be used.

52.4.4.2.6.2.28 LCL_DMA_MASK_DELAY (LCL_DMA_MASK_DELAY)

Offset

Register	Offset
LCL_DMA_MASK_DELAY	68h

Diagram



Fields

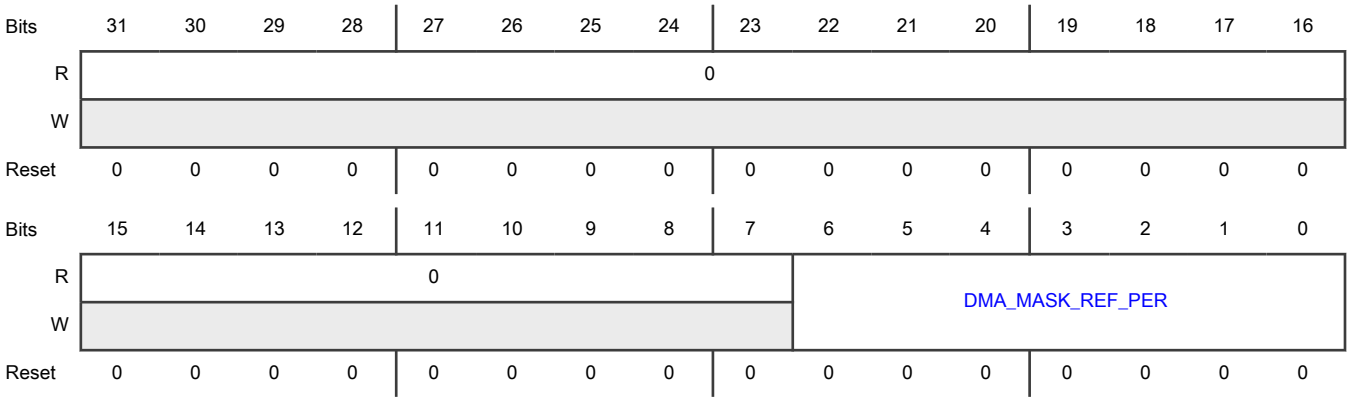
Field	Function
31-19 —	Reserved
18-8 DMA_MASK_DELAY	DMA_MASK_DELAY Coarse (intervals) offset delay from the trigger to the time at which DMA mask asserts.
7-0 DMA_MASK_DELAY_OFF	DMA_MASK_DELAY_OFF Fine (samples) offset delay from the trigger to the time at which DMA mask asserts.

52.4.4.2.6.2.29 LCL_DMA_MASK_PERIOD (LCL_DMA_MASK_PERIOD)

Offset

Register	Offset
LCL_DMA_MASK_PERIOD	6Ch

Diagram



Fields

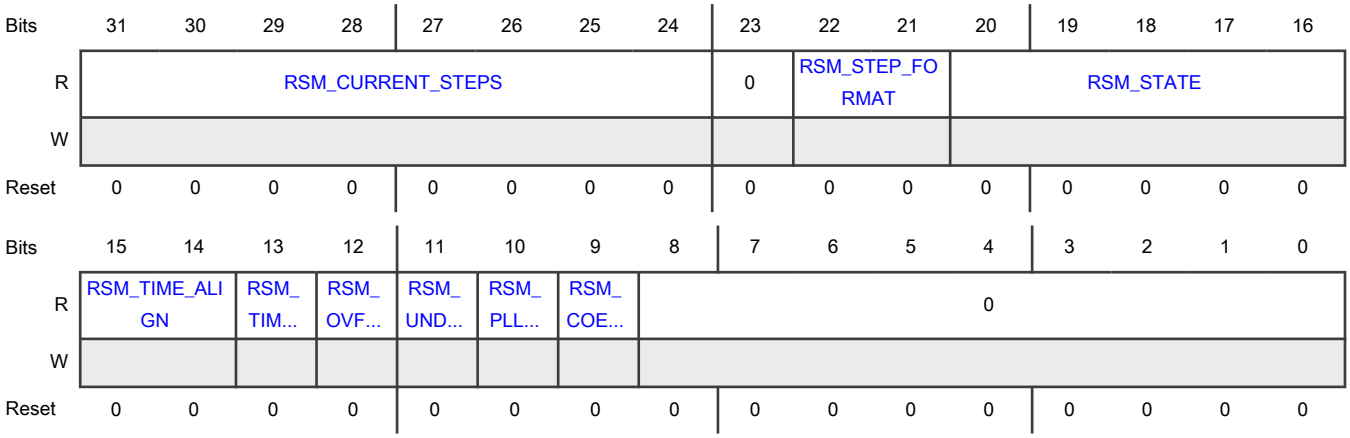
Field	Function
31-7 —	Reserved
6-0 DMA_MASK_REF_PER	DMA_MASK_REF_PER Duration (intervals) of the reference period, during which dma_mask remains asserted.

52.4.4.2.6.2.30 Ranging Sequence Manager Control and Status (RSM_CSR)

Offset

Register	Offset
RSM_CSR	70h

Diagram



Fields

Field	Function
31-24 RSM_CURRENT_STEPS	RSM_CURRENT_STEPS Indicates the current frequency step.
23 —	Reserved
22-21 RSM_STEP_FORMAT	RSM_STEP_FORMAT Indicates the current step format.
20-16 RSM_STATE	RSM_STATE Indicates the current state of the module. 0_0000b - IDLE 0_0001b - DELAY. Used only for the trigger delay in SQTE 0_0010b - EXT_TX (Extend TX). Used only for PDE 0_0011b - EXT_RX (Extend RX). Used only for PDE 0_0100b - WU (Warmup). Used only for SQTE 0_0101b - DT_TX (Packet TX). Used only for SQTE 0_0110b - DT_RX (Packet RX). Used only for SQTE 0_0111b - DT_RX_SYNC (Packet RX Sync). Used only for SQTE 0_1000b - FM_TX (Frequency Measurement TX). Used only for SQTE 0_1001b - FM_RX (Frequency Measurement RX). Used only for SQTE 0_1010b - PM_TX (Phase Measurement TX). 0_1011b - PM_RX (Phase Measurement RX).

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Field	Function
	0_1100b - IP1_RX2TX (Interlude Period 1 RX2TX). Used only for SQTE 0_1101b - IP1_TX2RX (Interlude Period 1 TX2RX). Used only for SQTE 0_1110b - S_RX2RX (Short Period RX2RX). Used only for SQTE 0_1111b - S_TX2TX (Short Period TX2TX). Used only for SQTE 1_0000b - IP2_RX2TX (Interlude Period 2 RX2TX). 1_0001b - IP2_TX2RX (Interlude Period 2 TX2RX). 1_0010b - FC_RX2TX (Frequency Change RX2TX). 1_0011b - FC_TX2RX (Frequency Change TX2RX). 1_0100b - WD (Warmdown) 1_0110b - TX_OFF 1_0111b - RX_OFF
15-14 RSM_TIME_ALIGN	RSM_TIME_ALIGN In case of Initiator and register RSM_TIME_CORR is set to 2, then this status is used to check the time drift and indicates the current localization time adjustment offset applied at the end of latest FC state in Radio CGM. The reference time is delayed or anticipated from 8*xcvr_ref_clk period (250ns) depending on previous register value. In case of Reflector and register RSM_TIME_ALIGN_MODE is set to 1, then this status indicates the position of the adjustment between 0us to 1us with a granularity of 250ns.
13 RSM_TIMEOUT0_ABORT	RSM_TIMEOUT0_ABORT This bit is set when Timeout condition occurs in all modes 0. This bit is reset automatically when RSM is activated. It indicates if the RSM Abort interrupt has been asserted due to timeout0_abort status
12 RSM_OVF_ERR	RSM OVERFLOW ERROR Indicates a RSM Overflow error occurs on Result circular Buffer. This bit is reset automatically when RSM is activated. It indicates if the RSM Abort interrupt has been asserted due to a buffer overflow error.
11 RSM_UNDR_ERR	RSM UNDERRUN ERROR Indicates a RSM Underrun error occurs on Config circular Buffer. This bit is reset automatically when RSM is activated. It indicates if the RSM Abort interrupt has been asserted due to a buffer underrun error.
10 RSM_PLL_ABORT	RSM PLL ABORT This bit is set when PLL_ABORT condition occurs. It indicates if the RSM Abort interrupt has been asserted due to PLL abort status
9 RSM_COEX_ABORT_ST	RSM COEX ABORT STATUS This bit is set when COEX_ABORT condition occurs. This bit is reset automatically when RSM is activated. It indicates if the RSM Abort interrupt has been asserted due to coexistence abort status
8-0 —	Reserved

Table continues on the next page...

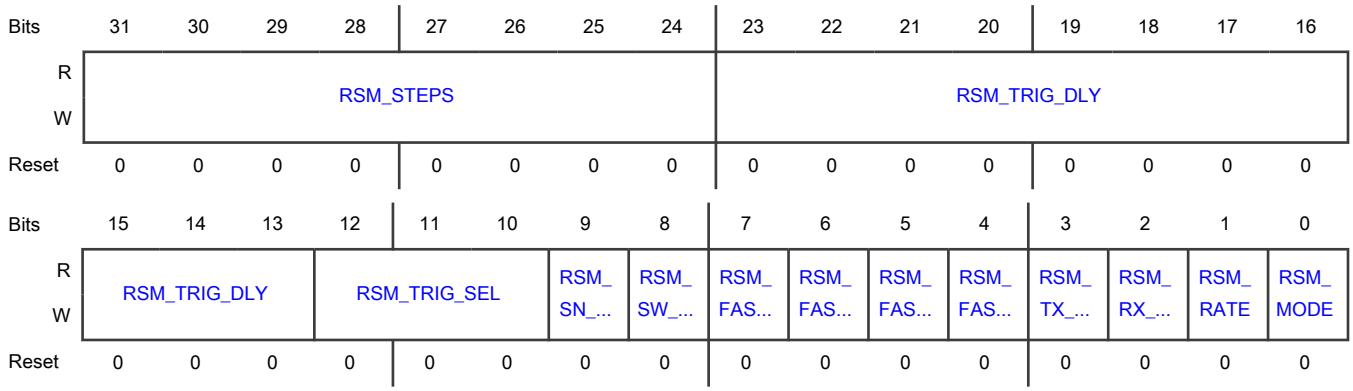
Field	Function

52.4.4.2.6.2.31 Ranging Sequence Manager Control (RSM_CTRL0)

Offset

Register	Offset
RSM_CTRL0	74h

Diagram



Fields

Field	Function
31-24 RSM_STEPS	RSM_FREQUENCY_STEP Number of frequency steps. (For SQTE this also includes the FCS.) The maximum number supported is 255.
23-13 RSM_TRIG_DLY	RSM_TRIG_DLY • SQTE mode: delay in microseconds from trigger to the beginning of the warm-up sequence. • PDE mode: delay in microseconds from trigger to when the first rx2tx or tx2rx occurs. For PDE mode, this should be programmed to a value greater than 0.
12-10 RSM_TRIG_SEL	RSM_TRIG_SEL This bit selects the trigger source to start the RSM sub-event processing. 000b - software trigger 001b - crc_vld 010b - aa_fnd_to_ll 011b - tx_dig_en 100b - seq_spare3 101b - lcl pattern_match

Table continues on the next page...

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Field	Function
	110b - nbu trigger 111b-111b - Reserved
9 RSM_SN_EN	RSM_SN_EN Arms the module for only RX operation to enable the sniffer mode. Once set, this bit should remain set until the RSM has returned to the IDLE state at the end of the sequence.
8 RSM_SW_ABORT	RSM_SW_ABORT Used to gracefully shut down the module prior to normal end of sequence. Once set, this bit should remain set until the RSM has returned to the IDLE state at the end of the sequence.
7 RSM_FAST_FC_TX_WU	RSM_FAST_FC_TX_WU Forces TSM to fast TX wu during FC_RX2TX and WU state (ipr_tx_en=1).
6 RSM_FAST_FC_RX_WU	RSM_FAST_FC_RX_WU Forces TSM to fast RX wu during FC_TX2RX and WU state (ipr_rx_en=1).
5 RSM_FAST_IP_TX_WU	RSM_FAST_IP_TX_WU Forces TSM to fast TX wu during IP1_RX2TX and IP2_RX2TX.
4 RSM_FAST_IP_RX_WU	RSM_FAST_IP_RX_WU Forces TSM to fast RX wu during IP1_TX2RX and IP2_TX2RX.
3 RSM_TX_EN	RSM_TX_EN Arms the module for operation starting with TX. Set this bit for SQTE Initiator/PDE MD. Once set, this bit should remain set until the RSM has returned to the IDLE state at the end of the sequence.
2 RSM_RX_EN	RSM_RX_EN Arms the module for operation starting with RX. Set this bit for SQTE Reflector/Sniffer /PDE RD. Once set, this bit should remain set until the RSM has returned to the IDLE state at the end of the sequence.
1 RSM_RATE	RSM_RATE Only used for SQTE. Indicates how the transceiver is configured, and the transfer rate for packets. 0b - 1Mbps 1b - 2Mbps
0 RSM_MODE	RSM_MODE Selects the RSM operation mode between SQTE (Secure Quick Tone Exchange) and PDE (Phase-based Distance Estimation).

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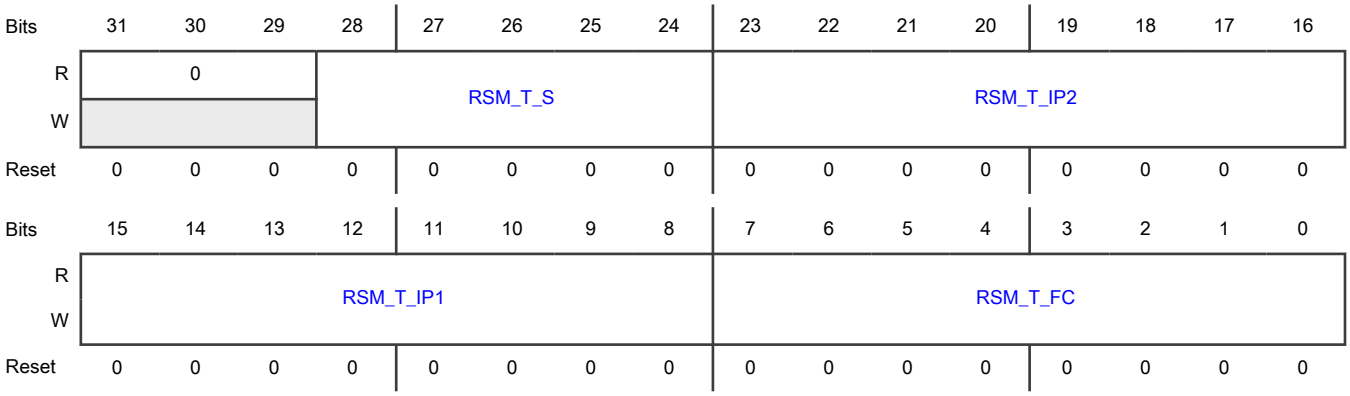
Field	Function
	0b - SQTE 1b - PDE

52.4.4.2.6.2.32 Ranging Sequence Manager Control (RSM_CTRL1)

Offset

Register	Offset
RSM_CTRL1	78h

Diagram



Fields

Field	Function
31-29 —	Reserved
28-24 RSM_T_S	RSM_T_GD Only applies to SQTE. S or GD (Time for Guard period) duration, in microseconds. This field should be programmed to 10us.
23-16 RSM_T_IP2	RSM_T_IP2 IP2 (interlude period 2 during CS packets) duration, in microseconds. This field should be programmed between 30us to 150us.
15-8 RSM_T_IP1	RSM_T_IP1 Only applies to SQTE. IP1 (interlude period 1 during CS packets) duration, in microseconds. This field should be programmed between 30us to 150us.

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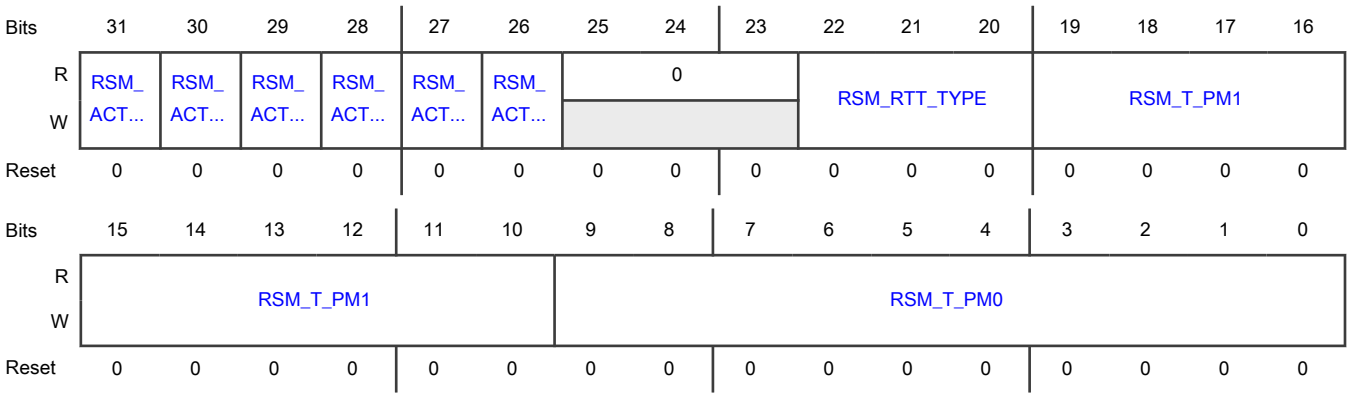
Field	Function
7-0 RSM_T_FC	RSM_T_FC Only applies to SQTE. FC (frequency Change Period) duration between CS steps, in microseconds. (For example : 0x96=150us). This field should be programmed between 40us to 150us.

52.4.4.2.6.2.33 Ranging Sequence Manager Control (RSM_CTRL2)

Offset

Register	Offset
RSM_CTRL2	7Ch

Diagram



Fields

Field	Function
31 RSM_ACTIVE_OVRD_EN_RXDIG	RSM_ACTIVE_OVRD_EN_RXDIG Enable signal used to override rsm_active to RXDIG module with RSM_ACTIVE_OVRD_RXDIG value. 0b - Disable override rsm_active of RXDIG module. 1b - Enable override rsm_active of RXDIG module.
30 RSM_ACTIVE_OVRD_RXDIG	RSM_ACTIVE_OVRD_RXDIG When RSM_ACTIVE_OVRD_EN_RXDIG is set to 1, override rsm_active to RXDIG module with RSM_ACTIVE_OVRD_RXDIG value.
29 RSM_ACTIVE_OVRD_EN_TXDIG	RSM_ACTIVE_OVRD_EN_TXDIG Enable signal used to override rsm_active to TXDIG module with RSM_ACTIVE_OVRD_TXDIG value. 0b - Disable override rsm_active of TXDIG module.

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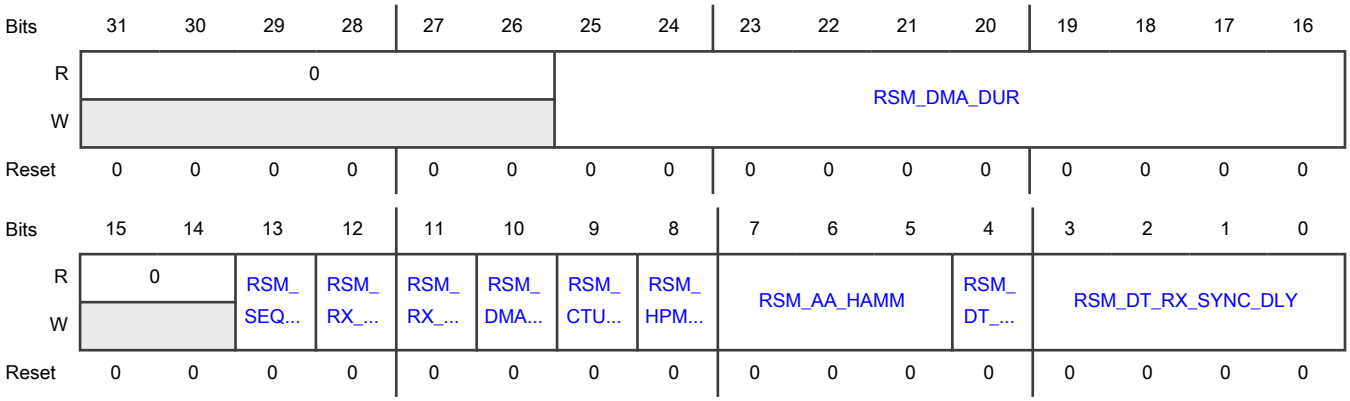
Field	Function
	1b - Enable override rsm_active of TXDIG module.
28 RSM_ACTIVE_OVRD_TXDIG	RSM_ACTIVE_OVRD_TXDIG When RSM_ACTIVE_OVRD_EN_TXDIG is set to 1, override rsm_active to TXDIG module with RSM_ACTIVE_OVRD_TXDIG value.
27 RSM_ACTIVE_OVRD_EN_LCL	RSM_ACTIVE_OVRD_EN_LCL Enable signal used to override rsm_active to LCL_CTRL module with RSM_ACTIVE_OVRD_LCL value 0b - Disable override rsm_active of LCL_CTRL module. 1b - Enable override rsm_active of LCL_CTRL module.
26 RSM_ACTIVE_OVRD_LCL	RSM_ACTIVE_OVRD_LCL When RSM_ACTIVE_OVRD_EN_LCL is set to 1, override rsm_active to LCL_CTRL module with RSM_ACTIVE_OVRD_LCL value.
25-23 —	Reserved
22-20 RSM_RTT_TYPE	RSM_RTT_TYPE Only used for SQTE. Indicates the payload packet length. Once set, this field should remain set until the RSM has returned to the IDLE state at the end of the sequence. 000b - no payload 001b - 32-bit payload 010b - 96-bit payload 011b - 32-bit payload 100b - 64-bit payload 101b - 96-bit payload 110b - 128-bit payload
19-10 RSM_T_PM1	RSM_T_PM1 PM (phase measurement) tone duration, in microseconds. For SQTE, this is the T_PM*N_AP duration. The T_PM(T_PM0, T_PM1) which is used depends on t_pm_sel field fetched from Packet RAM configuration buffer. The minimum value is 10us.
9-0 RSM_T_PM0	RSM_T_PM0 PM (phase measurement) tone duration, in microseconds. For SQTE, this is the T_PM*N_AP duration. The T_PM(T_PM0, T_PM1) which is used depends on t_pm_sel field fetched from Packet RAM configuration buffer. The minimum value is 10us.

52.4.4.2.6.2.34 Ranging Sequence Manager Control (RSM_CTRL3)

Offset

Register	Offset
RSM_CTRL3	80h

Diagram



Fields

Field	Function
31-26 —	Reserved
25-16 RSM_DMA_DUR	DMA Duration Duration of the dma_mask signal, in microseconds. Used in PM_RX state. NOTE: If used in conjunction with the RXDIG's window averager, to ensure that the same number of samples are captured during each time the dma_mask asserts, the duration must be a multiple of the window averager's duration.
15-14 —	Reserved
13 RSM_SEQ_RCCAL_PUP_MASK_DIS	RSM_SEQ_RCCAL_PUP_MASK_DIS If set, disables the seq_rccal_pup_mask output (seq_rccal_pup_mask output will always be 1).
12 RSM_RX_SIGNALS_MASK_DIS	RSM_RX_SIGNALS_MASK_DIS If set, disables the rx_signals_mask output (rx_signals_mask output will always be 1).

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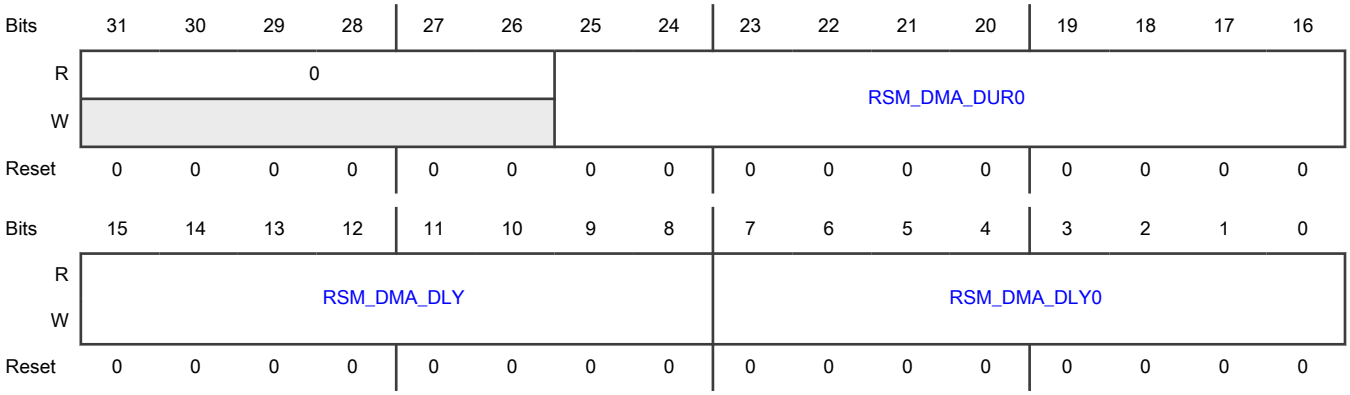
Field	Function
11 RSM_RX_PHY_EN_MASK_DIS	RSM_RX_PHY_EN_MASK_DIS Only applies to SQTE. If set, the rx_phy_en_mask output is always asserted. If clear, when the RSM is active the rx_phy_en_mask output is only asserted for packet reception.
10 RSM_DMA_RX_EN	RSM_DMA_RX_EN Enables dma_mask to assert in PM_RX state. (this bit should be cleared if antenna switching / LCL is being used). dma_mask always asserts in SQTE FCS FM state.
9 RSM_CTUNE	RSM_CTUNE If set, RSM will send coarse tune values read from the Packet RAM to the PLL. If clear, the PLL will perform coarse tune calibration
8 RSM_HPM_CAL	RSM_HPM_CAL If set, RSM will send HPM cal values read from the Packet RAM to the PLL. If clear, the PLL will perform HPM calibration
7-5 RSM_AA_HAMM	RSM_AA_HAMM Only applies to SQTE. AA hamming distance to PHY.
4 RSM_DT_RX_SYNC_DIS	RSM_DT_RX_SYNC_DIS Only applies to SQTE. Disables the auto-sync feature for Reflector in FCS RX packet.
3-0 RSM_DT_RX_SYNC_DLY	RSM_DT_RX_SYNC_DLY Only applies to SQTE, and only used by the Reflector device (RX_EN=1) when DT_RX_SYNC_DIS=0. In this configuration the RSM uses the PHY's AA_MATCHED output to sync the Reflector device to the Initiator device's timing. This corresponds to the delay in microseconds from the PHY's AA_MATCHED to the end of DT_RX duration (the packet duration including preamble and trailer, plus RX_SETTLING_LATENCY).

52.4.4.2.6.2.35 Ranging Sequence Manager Control (RSM_CTRL4)

Offset

Register	Offset
RSM_CTRL4	84h

Diagram



Fields

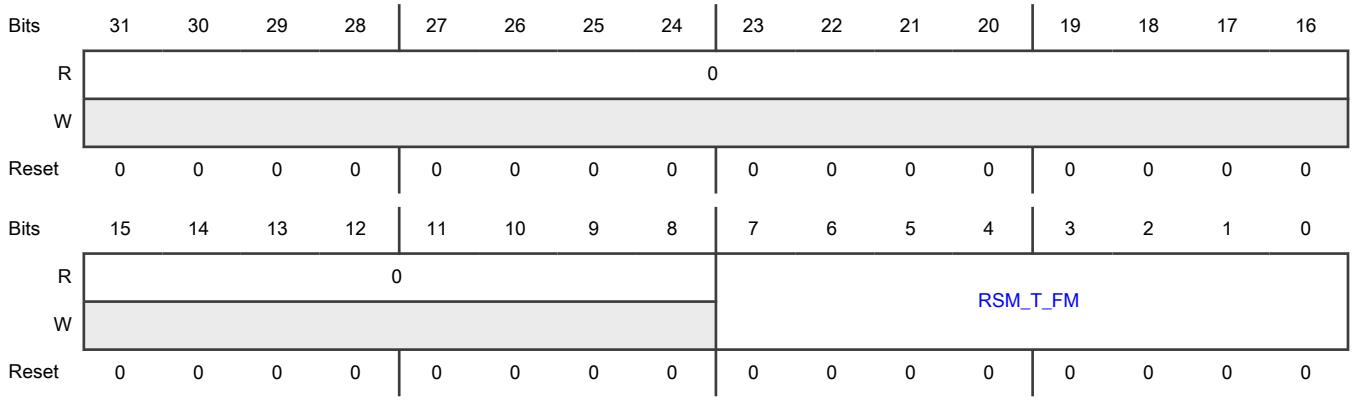
Field	Function
31-26 —	Reserved
25-16 RSM_DMA_DUR0	DMA Duration 0 Duration of the dma_mask signal, in microseconds. Used in FM_RX state (SQTE) and EXT_RX state (PDE). NOTE: If used in conjunction with the RXDIG's window averager, to ensure that the same number of samples are captured during each time the dma_mask asserts, the duration must be a multiple of the window averager's duration.
15-8 RSM_DMA_DLY	DMA Delay Delay from end of RX warmup to assertion of dma_mask signal, in microseconds. Used in PM_RX state.
7-0 RSM_DMA_DLY0	DMA Delay 0 Delay from end of RX warmup to assertion of dma_mask signal, in microseconds. Used in FM_RX state (SQTE) and EXT_RX state (PDE).

52.4.4.2.6.2.36 Ranging Sequence Manager Control (RSM_CTRL5)

Offset

Register	Offset
RSM_CTRL5	88h

Diagram



Fields

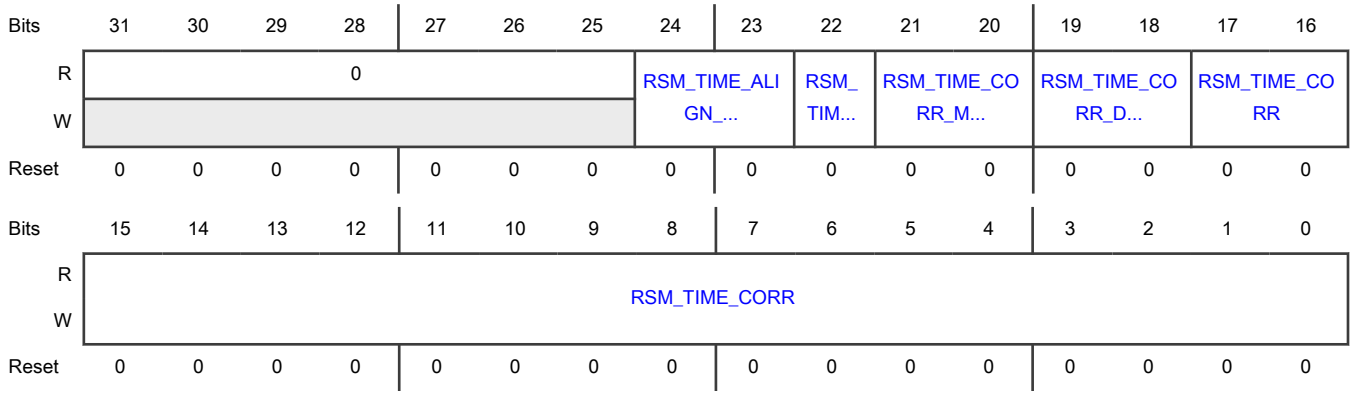
Field	Function
31-8 —	Reserved
7-0 RSM_T_FM	T_FM time Time for Frequency Measurement time in us. Should be set to 80us during normal operation.

52.4.4.2.6.2.37 Ranging Sequence Manager Control (RSM_CTRL7)

Offset

Register	Offset
RSM_CTRL7	8Ch

Diagram



Fields

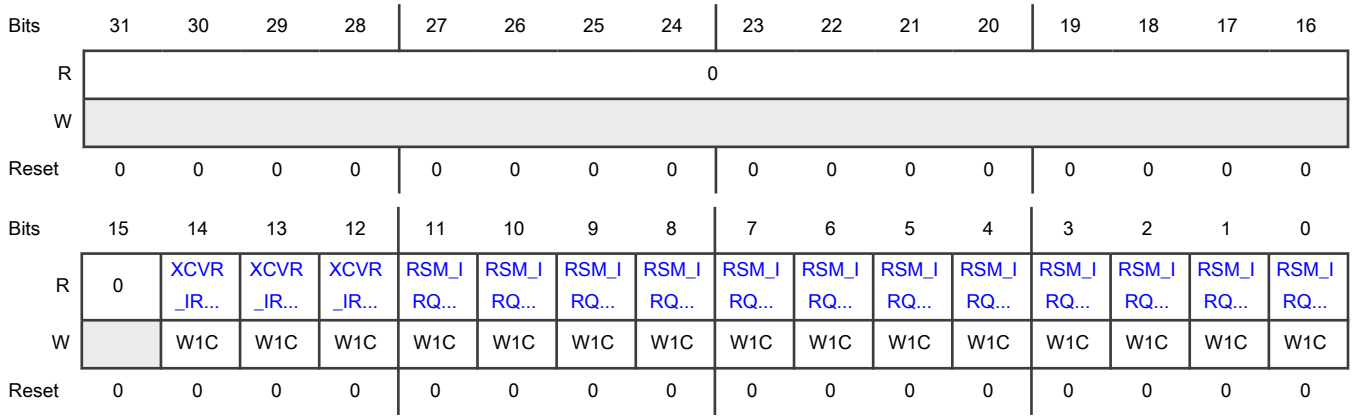
Field	Function
31-25 —	Reserved
24-23 RSM_TIME_ALIGN_OFFSET	Timing alignment correction offset offset to be applied on fine alignment (250 us granularity)
22 RSM_TIME_ALIGN_MODE	Timing alignment correction 0: disable, 1 : enable automatic adjustment in CGM clk counter based on RSM AA detection from rx_init
21-20 RSM_TIME_CORR_MODE	Timing drift correction 0: disable , 1: enable drift mode with 1us RSM counter adjustment , 2: enable drift mode with cgm clk adjustment
19-18 RSM_TIME_CORR_DELTA	Timing drift delta value Signed value. 00b - 0 us 01b - +1 us 11b - -1 us
17-0 RSM_TIME_CORR	Timing drift correction counter value Adjust drift time in us

52.4.4.2.6.2.38 Ranging Sequence Manager interrupt status (RSM_INT_STATUS)

Offset

Register	Offset
RSM_INT_STATUS	90h

Diagram



Fields

Field	Function
31-15 —	Reserved
14 XCVR_IRQ_RF_DENY_BTA	RSM_IRQ_RF_DENY_BTA The bit is set at the rising edge of rf_active signal while rf_not_allowed coexistence signal is already set. This interrupt is valid for all standards (Zigbee/BLE/CS/generic_FSK LL). Write 1 to clear the bit. This interrupt line is only routed to NBU processor.
13 XCVR_IRQ_RF_DENY_FALL	RSM_IRQ_RF_DENY_FALL The bit is set at the deassertion of rf_deny coexistence signal. This interrupt line is valid for all standards (Zigbee/BLE/CS/generic_FSK LL). Write 1 to clear the bit. This interrupt line is only routed to NBU processor.
12 XCVR_IRQ_RF_DENY_RISE	RSM_IRQ_RF_DENY_RISE The bit is set at the assertion of rf_deny coexistence signal. This interrupt line is valid for all standards (Zigbee/BLE/CS/generic_FSK LL). Write 1 to clear the bit. This interrupt line is only routed to NBU processor.
11 RSM_IRQ_STEP	RSM_IRQ_STEP The bit is set every N steps processed by RSM. Write 1 to clear the bit. Note that RSM_RX_EN or RSM_TX_EN must be set in order to clear this bit, so it is recommended that software ensures this W1C bit is cleared at the end of each RSM sequence before clearing RSM_RX_EN or RSM_TX_EN to disable the module.
10 RSM_IRQ_DT_TX	RSM_IRQ_DT_TX Flag The bit is set on entry to DT_TX states. Write 1 to clear the bit. Note that RSM_RX_EN or RSM_TX_EN must be set in order to clear this bit, so it is recommended that software ensures this W1C bit is cleared at the end of each RSM sequence before clearing RSM_RX_EN or RSM_TX_EN to disable the module.
9	RSM_IRQ_DT_RX Flag

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Field	Function
RSM_IRQ_DT_RX	The bit is set on entry to DT_RX states. Write 1 to clear the bit. Note that RSM_RX_EN or RSM_TX_EN must be set in order to clear this bit, so it is recommended that software ensures this W1C bit is cleared at the end of each RSM sequence before clearing RSM_RX_EN or RSM_TX_EN to disable the module.
8 RSM_IRQ_PM_TX	RSM_IRQ_PM_TX Flag The bit is set on entry to PM_TX states. Write 1 to clear the bit. Note that RSM_RX_EN or RSM_TX_EN must be set in order to clear this bit, so it is recommended that software ensures this W1C bit is cleared at the end of each RSM sequence before clearing RSM_RX_EN or RSM_TX_EN to disable the module.
7 RSM_IRQ_PM_RX	RSM_IRQ_PM_RX Flag The bit is set on entry to PM_RX state. Write 1 to clear the bit. Note that RSM_RX_EN or RSM_TX_EN must be set in order to clear this bit, so it is recommended that software ensures this W1C bit is cleared at the end of each RSM sequence before clearing RSM_RX_EN or RSM_TX_EN to disable the module.
6 RSM_IRQ_FM_TX	RSM_IRQ_FM_TX Flag The bit is set on entry to FM_TX state. Write 1 to clear the bit. Note that RSM_RX_EN or RSM_TX_EN must be set in order to clear this bit, so it is recommended that software ensures this W1C bit is cleared at the end of each RSM sequence before clearing RSM_RX_EN or RSM_TX_EN to disable the module.
5 RSM_IRQ_FM_RX	RSM_IRQ_FM_RX Flag The bit is set on entry to FM_RX state. Write 1 to clear the bit. Note that RSM_RX_EN or RSM_TX_EN must be set in order to clear this bit, so it is recommended that software ensures this W1C bit is cleared at the end of each RSM sequence before clearing RSM_RX_EN or RSM_TX_EN to disable the module.
4 RSM_IRQ_FC	RSM_IRQ_FC Flag The bit is set on entry to FC_RX2TX or FC_TX2RX states. Write 1 to clear the bit. Note that RSM_RX_EN or RSM_TX_EN must be set in order to clear this bit, so it is recommended that software ensures this W1C bit is cleared at the end of each RSM sequence before clearing RSM_RX_EN or RSM_TX_EN to disable the module.
3 RSM_IRQ_IP2	RSM_IRQ_IP2 Flag The bit is set on entry to IP2_TX2RX or IP2_RX2TX states. Write 1 to clear the bit. Note that RSM_RX_EN or RSM_TX_EN must be set in order to clear this bit, so it is recommended that software ensures this W1C bit is cleared at the end of each RSM sequence before clearing RSM_RX_EN or RSM_TX_EN to disable the module.
2 RSM_IRQ_IP1	RSM_IRQ_IP1 Flag The bit is set on entry to IP1_RX2TX or IP1_TX2RX states. Write 1 to clear the bit. Note that RSM_RX_EN or RSM_TX_EN must be set in order to clear this bit, so it is recommended that software ensures this W1C bit is cleared at the end of each RSM sequence before clearing RSM_RX_EN or RSM_TX_EN to disable the module.
1 RSM_IRQ_ABORT	RSM_IRQ_ABORT Flag The bit is set when the sequence is aborted due to pll_abort. This condition can occur during any RSM state except for the IDLE or WD states. Write 1 to clear the bit. Note that RX_EN or TX_EN must be set in order to clear this bit, so it is recommended that software ensures this W1C bit is cleared at the end of each RSM sequence before clearing RX_EN or TX_EN.

Table continues on the next page...

Table continued from the previous page...

Field	Function
0 RSM_IRQ_EOS	RSM_IRQ_EOS Flag The bit is set to indicate that the sequence is complete. It sets when the RSM transitions from the WD to the IDLE state. Write 1 to clear the bit. Note that RSM_RX_EN or RSM_TX_EN must be set in order to clear this bit, so it is recommended that software ensures this W1C bit is cleared at the end of each RSM sequence before clearing RSM_RX_EN or RSM_TX_EN to disable the module.

52.4.4.2.6.2.39 Ranging Sequence Manager interrupt enable (RSM_INT_ENABLE)

Offset

Register	Offset
RSM_INT_ENABLE	94h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	XCVR_IR...	XCVR_IR...	XCVR_IR...	RSM_IRQ...	RSM_IRQ...	RSM_IRQ...	RSM_IRQ...	RSM_IRQ...	RSM_IRQ...	RSM_IRQ...	RSM_IRQ...	RSM_IRQ...	RSM_IRQ...	RSM_IRQ...	RSM_IRQ...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-15 —	Reserved
14 XCVR_IRQ_RF_DENY_BTA_EN	XCVR_IRQ_RF_DENY_BTA Enable an interrupt asserted on the rising edge of rf_active signal while rf_not_allowed coexistence signal is already set.
13 XCVR_IRQ_RF_DENY_FALL_EN	XCVR_IRQ_RF_DENY_FALL_EN Enable an interrupt asserted on the deassertion of rf_not_allowed coexistence signal.

Table continues on the next page...

Table continued from the previous page...

Field	Function
12 XCVR_IRQ_RF_DENY_RISE_EN	XCVR_IRQ_RF_DENY_RISE_EN Enable an interrupt asserted on the assertion of rf_not_allowed coexistence signal.
11 RSM_IRQ_STEP_EN	RSM_IRQ_STEP_EN Enable an interrupt asserted every N steps where N value is defined in RSM_INT_NBSTEP register
10 RSM_IRQ_DT_TX_EN	RSM_IRQ_DT_TX_EN Enable an interrupt asserted on entry to DT_TX state.
9 RSM_IRQ_DT_RX_EN	RSM_IRQ_DT_RX_EN Enable an interrupt asserted on entry to DT_RX state.
8 RSM_IRQ_PM_TX_EN	RSM_IRQ_PM_TX_EN Enable an interrupt asserted on entry to PM_TX state.
7 RSM_IRQ_PM_RX_EN	RSM_IRQ_PM_RX_EN Enable an interrupt asserted on entry to PM_RX state.
6 RSM_IRQ_FM_TX_EN	RSM_IRQ_FM_TX_EN Enable an interrupt asserted on entry to FM_TX state.
5 RSM_IRQ_FM_RX_EN	RSM_IRQ_FM_RX_EN Enable an interrupt asserted on entry to FM_RX state.
4 RSM_IRQ_FC_EN	RSM_IRQ_FC_EN Enable an interrupt on entry to FC_RX2TX or FC_TX2RX states.
3 RSM_IRQ_IP2_EN	RSM_IRQ_IP2_EN Enable an interrupt asserted on entry to IP2_TX2RX or IP2_RX2TX states.
2 RSM_IRQ_IP1_EN	RSM_IRQ_IP1_EN Enable an interrupt asserted on entry to IP1_RX2TX or IP1_TX2RX states.

Table continues on the next page...

Table continued from the previous page...

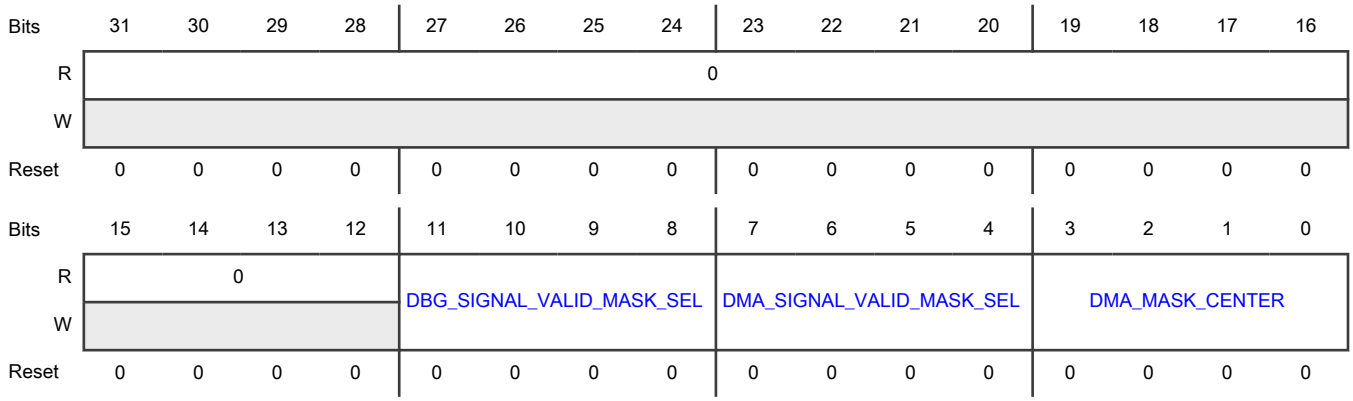
Field	Function
1 RSM_IRQ_ABORT_EN	RSM_IRQ_ABORT_EN Enable an interrupt when the sequence is aborted due to pll_abort.
0 RSM_IRQ_EOS_EN	RSM_IRQ_EOS_EN Enable an interrupt when the sequence is complete.

52.4.4.2.6.2.40 DMA_MASK management (DMA_MASK_CTRL)

Offset

Register	Offset
DMA_MASK_CTRL	98h

Diagram



Fields

Field	Function
31-16 —	Reserved
15-12 —	Reserved
11-8	MASK selection for DBG engine during RX data capture DMA MASK can be composed of different data types. The selection of them and any of their combination can be made with this registers.

Table continues on the next page...

Table continued from the previous page...

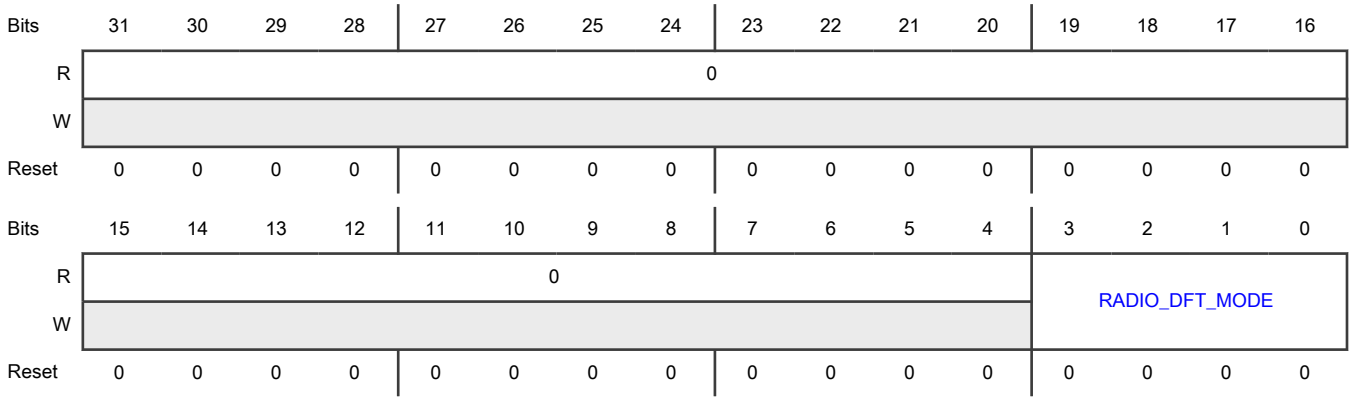
Field	Function
DBG_SIGNAL_VALID_MASK_SEL	bit 0 - mask for PCTs bit 1 - mask for RX frequency compensation data (FM_RX) bit 2 - mask for RX tones (PM_RX) bit 3 - mask for RX packets (DT_RX)
7-4 DMA_SIGNAL_VALID_MASK_SEL	MASK selection for DMA engine during RX data capture DMA MASK can be composed of different data types. The selection of them and any of their combination can be made with this registers. bit 0 - mask for PCTs bit 1 - mask for RX frequency compensation data (FM_RX) bit 2 - mask for RX tones (PM_RX) bit 3 - mask for RX packets (DT_RX)
3-0 DMA_MASK_CENTER	DMA_MASK centering Register to center DMA_MASK length with a power of 2 us within the window formed by LO_PER and HI_PER. A value of 0 in this field will not affect DMA_MASK window. If this field is programmed to a window wider than HI_PER, no alteration also will be performed. 0000b - No centering 0001b - 1 us centered window 0010b - 2 us centered window 0011b - 4 us centered window 0100b - 8 us centered window 0101b - 16 us centered window 0110b - 32 us centered window 0111b - 64 us centered window 1000b - 128 us centered window 1001b - 256 us centered window 1010b - 512 us centered window 1011b - 1024 us centered window

52.4.4.2.6.2.41 RF DFT CTRL (RF_DFT_CTRL)

Offset

Register	Offset
RF_DFT_CTRL	9Ch

Diagram



Fields

Field	Function
31-4 —	Reserved
3-0 RADIO_DFT_MODE	Radio DFT mode control These bits control Radio DFT mode used by TXDIG and PLL. Values other than those shown below are Reserved. 0000b - Normal Mode 0001b - Carrier Only 0010b - Pattern Register 0011b - LFSR 0100b - RAM Modulation 1010b - Coarse Tune BIST, no modulation 1011b - PLL Locking BIST, no modulation 1100b - HPM DAC Cal BIST, no modulation

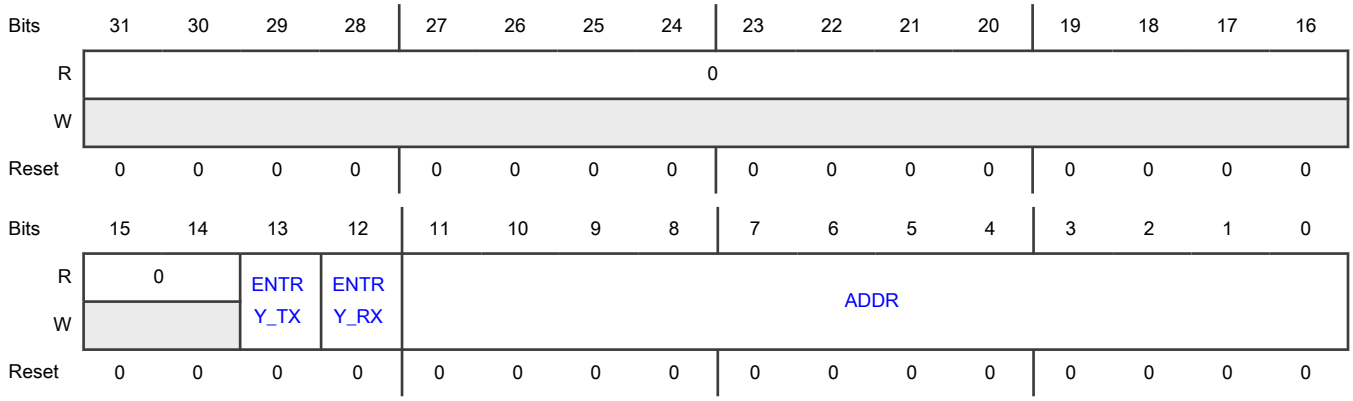
52.4.4.2.6.2.42 IPS FAST OVERWRITE ADDRESS (IPS_FO_ADDR0 - IPS_FO_ADDR7)

Offset

For a = 0 to 7:

Register	Offset
IPS_FO_ADDRa	A0h + (a × 4h)

Diagram



Fields

Field	Function
31-14 —	Reserved
13 ENTRY_TX	Enable Entry for TX If set, the Nth fast overwrite entry is enabled for TX
12 ENTRY_RX	Enable Entry for RX If set, the Nth fast overwrite entry is enabled for RX
11-0 ADDR	IPS Address This specifies the address associated with the Nth fast overwrite entry

52.4.4.2.6.2.43 IPS FAST OVERWRITE DRS0 DATA (IPS_FO_DRS0_DATA0 - IPS_FO_DRS0_DATA7)

Offset

For a = 0 to 7:

Register	Offset
IPS_FO_DRS0_DATAa	C0h + (a × 4h)

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	DRS0_DATA															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	DRS0_DATA															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 DRS0_DATA	Fast Overwrite DRS0 data This specifies the 32bit data associated with the Nth fast overwrite entry, for DRS0.

52.4.4.2.6.2.44 IPS FAST OVERWRITE DRS1 DATA (IPS_FO_DRS1_DATA0 - IPS_FO_DRS1_DATA7)

Offset

For a = 0 to 7:

Register	Offset
IPS_FO_DRS1_DATAa	E0h + (a × 4h)

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	DRS1_DATA															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	DRS1_DATA															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

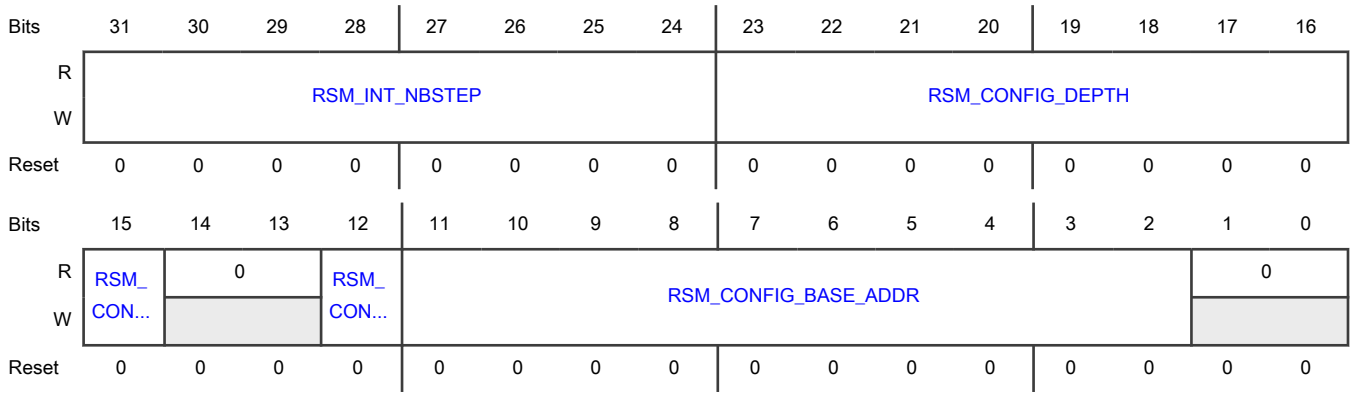
Field	Function
31-0 DRS1_DATA	Fast Overwrite DRS1 data This specifies the 32bit data associated with the Nth fast overwrite entry, for DRS1.

52.4.4.2.6.2.45 Ranging Sequence Manager Configuration Buffer (RSM_CONFIG_BUFF)

Offset

Register	Offset
RSM_CONFIG_BUFF	100h

Diagram



Fields

Field	Function
31-24 RSM_INT_NBSTEP	RSM INTERRUPT STEP NUMBER Indicates the number of steps to process before generating an RSM STEP interrupt. An interrupt is then generated every RSM_INT_NBSTEP steps. If this field is set to 0, RSM STEP interrupt is never asserted.
23-15 RSM_CONFIG_DEPTH	RSM CONFIG BUFFER DEPTH Indicates the exact depth in word of the circular RSM config buffer. Max depth is 511 words. The minimum allowed depth depends on the required configuration step size in mode3 and the FW latency to ensure that step information is always available in configuration buffer before the beginning of this step. Depth must be tuned to avoid RSM underrun error.
14-13 —	Reserved
12	RSM CONFIG BUFFER LOCATION Indicates if the config buffer is mapped in TX or RX Packet RAM.

Table continues on the next page...

Table continued from the previous page...

Field	Function
RSM_CONFIG_BUFF_LOC	0b - located in Tx Packet RAM 1b - located in Rx Packet RAM
11-2 RSM_CONFIG_BASE_ADDR	RSM CONFIG BUFFER BASE ADDRESS This register indicates the offset address of the circular RSM config buffer from RX or TX packet RAM base address. This address is in word aligned
1-0 —	Reserved

52.4.4.2.6.2.46 Ranging Sequence Manager Config Pointer (RSM_CONFIG_PTR)

Offset

Register	Offset
RSM_CONFIG_PTR	104h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				RSM_CONFIG_START_PTR										0	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0			RSM_CON...	RSM_CONFIG_WR_PTR										0	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-28 —	Reserved
27-18 RSM_CONFIG_START_PTR	RSM CONFIG START POINTER Indicates the first address to read in the RSM config circular buffer upon a new sub-event. This address is in word aligned.

Table continues on the next page...

Table continued from the previous page...

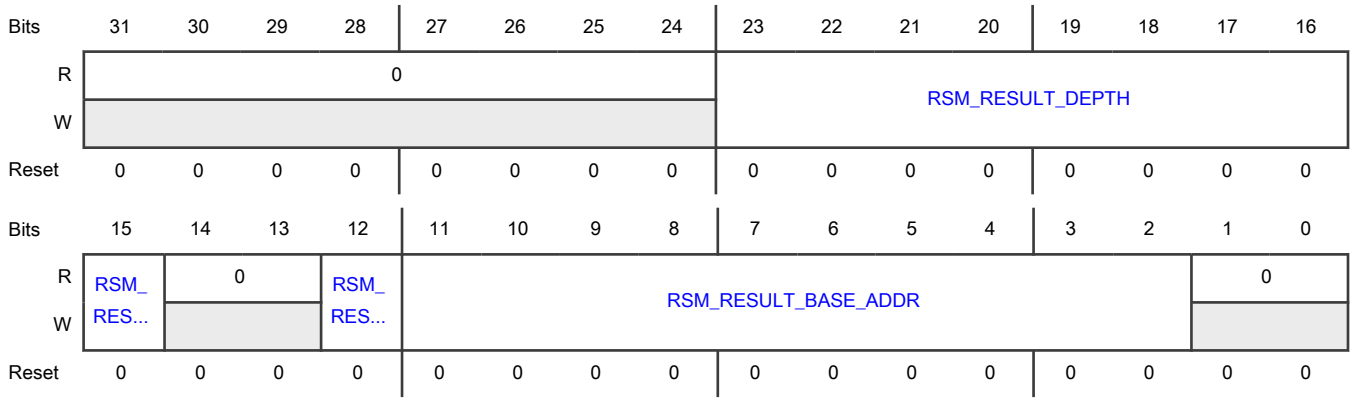
Field	Function
17-13 —	Reserved
12 RSM_CONFIG_WR_PAGE	RSM CONFIG WRITE PAGE Indicates the page number (0 or 1) associated to the config write pointer. At the beginning of a sub-event, the page number is always set to 0 and then FW toggles this bit each time the write pointer wraps to the beginning of the config buffer.
11-2 RSM_CONFIG_WR_PTR	RSM CONFIG WRITE POINTER Indicates the current FW write pointer of the RSM config circular buffer. This address is in word aligned. This field has to be updated by FW each time new step configuration data is written in config buffer. HW uses this field only to check a potential underrun error.
1-0 —	Reserved

52.4.4.2.6.2.47 Ranging Sequence Manager Result Buffer (RSM_RESULT_BUFF)

Offset

Register	Offset
RSM_RESULT_BUFF	108h

Diagram



Fields

Field	Function
31-24 —	Reserved

Table continues on the next page...

Table continued from the previous page...

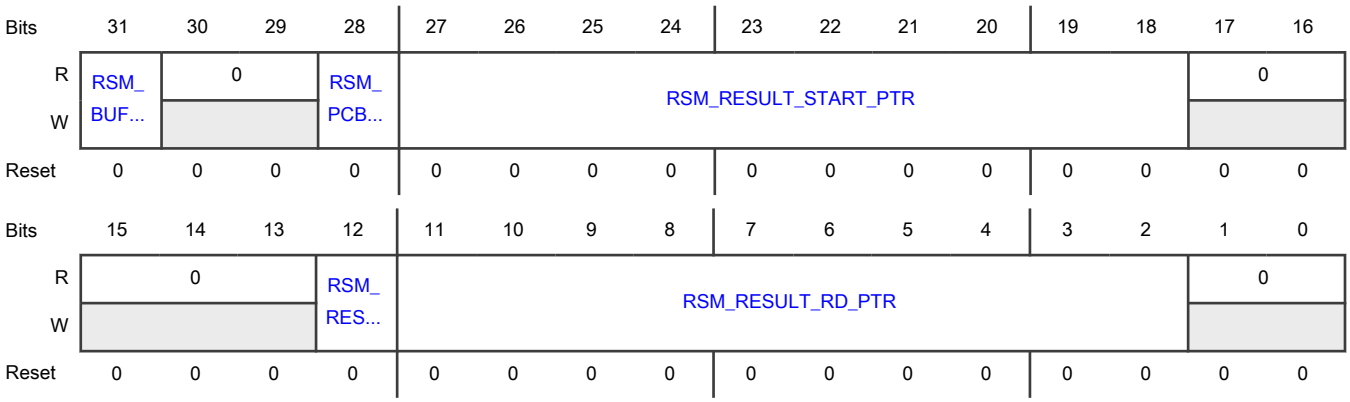
Field	Function
23-15 RSM_RESULT_DEPTH	RSM RESULT BUFFER DEPTH Indicates the exact depth in word of the circular RSM result buffer. Max depth is 511 words. The minimum allowed depth depends on the required status step size in mode3 and the FW latency to ensure that step statuses can always be written by HW without overriding the previous step information not yet fetched by FW. Depth must be tuned to avoid RSM override error.
14-13 —	Reserved
12 RSM_RESULT_BUFF_LOC	RSM RESULT BUFFER LOCATION Indicates if the result buffer is mapped in TX or RX Packet RAM. 0b - located in TX Packet RAM 1b - located in RX Packet RAM
11-2 RSM_RESULT_BASE_ADDR	RSM RESULT BUFFER BASE ADDRESS Indicates the offset address of the circular RSM result buffer from RX or TX packet RAM base address. This address is in word aligned
1-0 —	Reserved

52.4.4.2.6.2.48 Ranging Sequence Manager Config Pointer (RSM_RESULT_PTR)

Offset

Register	Offset
RSM_RESULT_PTR	10Ch

Diagram



Fields

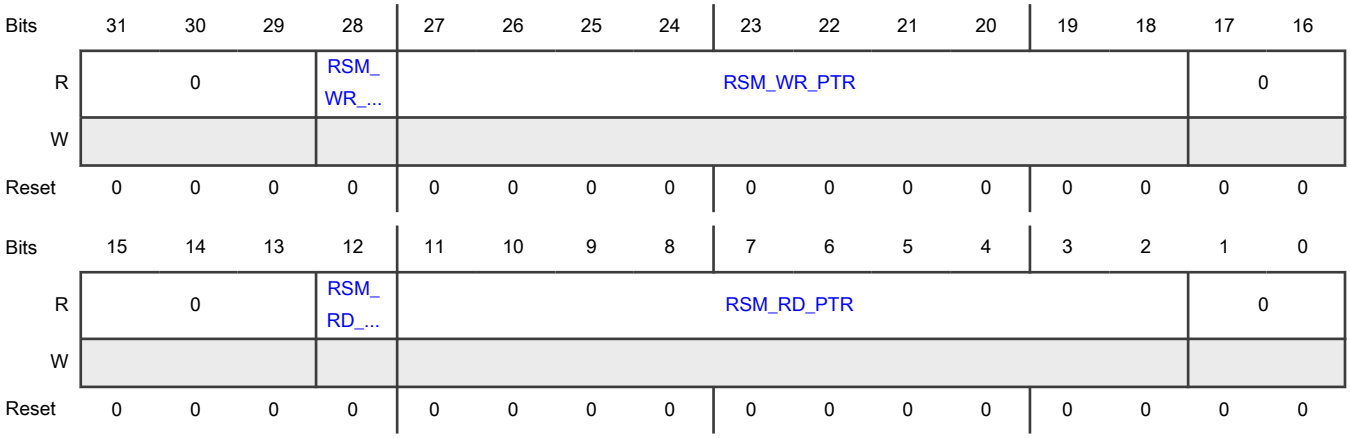
Field	Function
31 RSM_BUFFER_ABORT_EN	RSM BUFFER ABORT ENABLE This register is used to allow RSM to abort sub-event if a RSM buffer overflow/underrun error is detected
30-29 —	Reserved
28 RSM_PCBD_CTUNE_SEL	RSM PCBD CTUNE SELECT Selects the type of data to store in result buffer. '0': pll_ctune_best_diff '1':vco_ctune
27-18 RSM_RESULT_START_PTR	RSM RESULT START POINTER Indicates the address to write the first step result in the circular RSM result buffer upon a new sub-event. This address is in word aligned.
17-13 —	Reserved
12 RSM_RESULT_RD_PAGE	RSM RESULT READ PAGE Indicates the page number (0 or 1) associated to the result read pointer. At the beginning of a sub-event, the page number is always 0 and then FW toggles this bit each time the read pointer wraps to the beginning of the result buffer
11-2 RSM_RESULT_RD_PTR	RSM RESULT READ POINTER Indicates the current FW read pointer of the circular RSM result buffer. This address is in word aligned. This field has to be updated by FW each time new step results are read in the result buffer. HW uses this field only to check a potential overflow error.
1-0 —	Reserved

52.4.4.2.6.2.49 Ranging Sequence Manager Pointer (RSM_PTR)

Offset

Register	Offset
RSM_PTR	110h

Diagram



Fields

Field	Function
31-29 —	Reserved
28 RSM_WR_PAGE	RSM RESULT WRITE PAGE This register indicates the page number (0 or 1) associated to the result write pointer. At the beginning of a sub-event, the page number is always 0 and then HW toggles this bit each time the write pointer wraps to the beginning of the result buffer
27-18 RSM_WR_PTR	RSM RESULT WRITE POINTER Indicates the current write pointer of the circular RSM result buffer. This address is in word aligned.
17-13 —	Reserved
12 RSM_RD_PAGE	RSM CONFIG READ PAGE This register indicates the page number (0 or 1) associated to the config read pointer. At the beginning of a sub-event, the page number is always 0 and then HW toggles this bit each time the write pointer wraps to the beginning of the config buffer
11-2 RSM_RD_PTR	RSM CONFIG READ POINTER This register indicates the current read pointer of the circular RSM circular buffer. This address is in word aligned.
1-0 —	Reserved

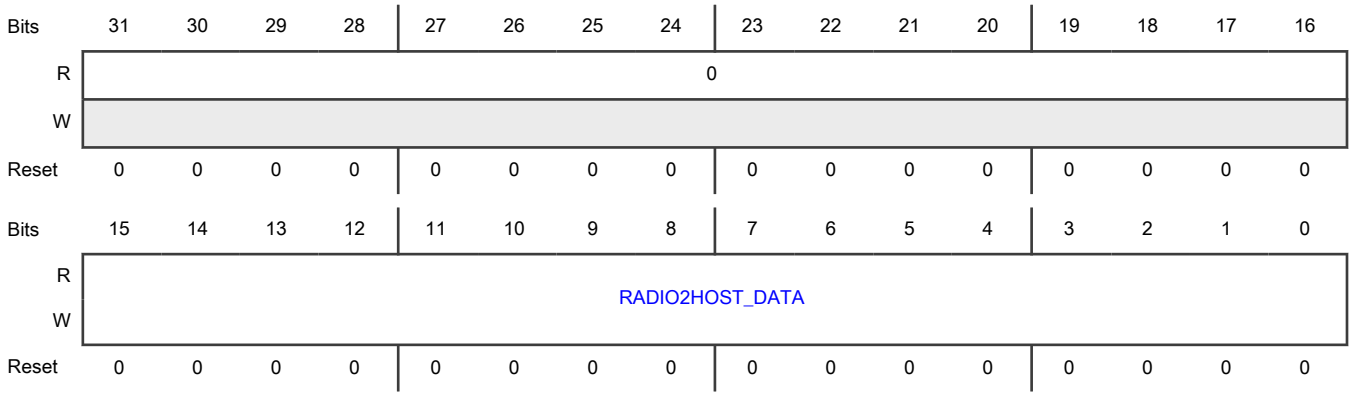
52.4.4.2.6.2.50 Radio to Host Buffer (RADIO2HOST)

Offset

Register	Offset
RADIO2HOST	120h

Function
This buffer allows communication between CPU cores without the need for one core to wakeup the other core.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 RADIO2HOST_DATA	Data of Buffer0 This register field is mirrored in a RFMC module register.

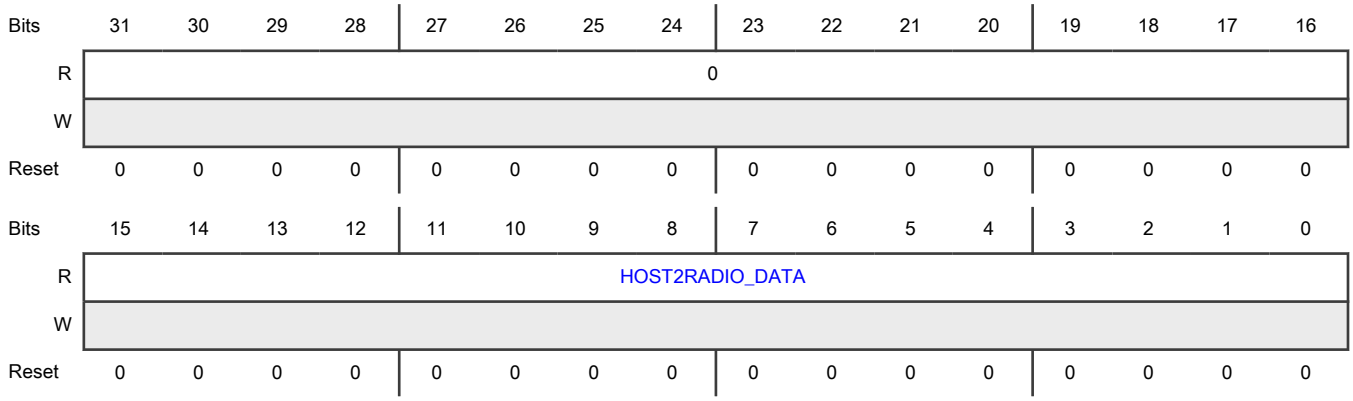
52.4.4.2.6.2.51 Host to Radio Buffer (HOST2RADIO)

Offset

Register	Offset
HOST2RADIO	124h

Function
This buffer allows communication between CPU cores without the need for one core to wakeup the other core.

Diagram



Fields

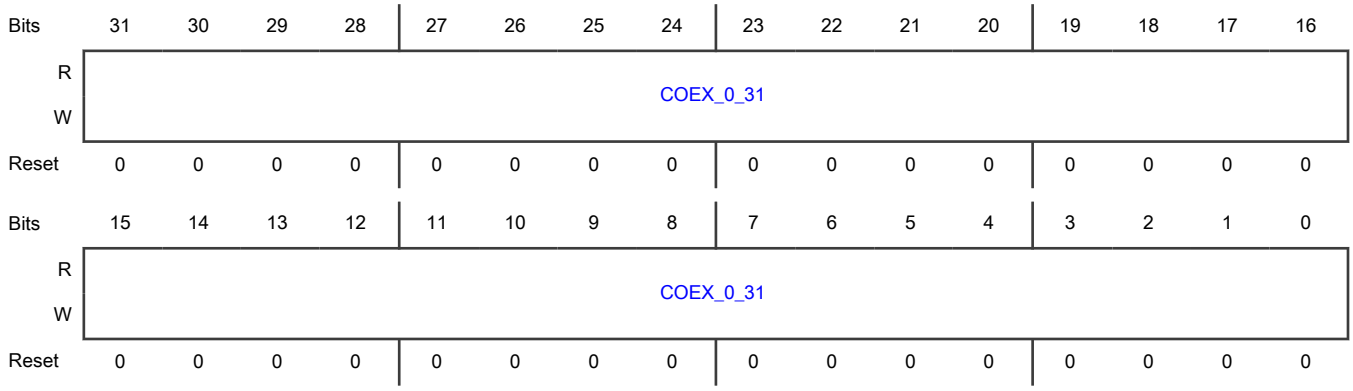
Field	Function
31-16 —	Reserved
15-0 HOST2RADIO_DATA	Data of Buffer0 This register field is mirrored from a RFMC module register.

52.4.4.2.6.2.52 skip coex rf_denied for channel 0 to 31 (COEX_CHANNEL0)

Offset

Register	Offset
COEX_CHANNEL0	128h

Diagram



Fields

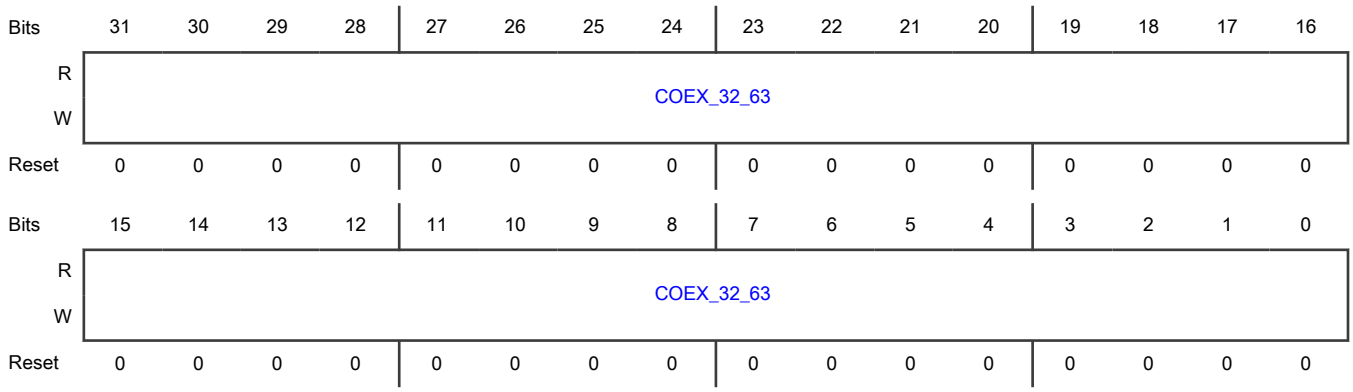
Field	Function
31-0 COEX_0_31	Coexistence Allowed Channel Table0 Indicates the list of RF channels from 0 to 31 which can be used even if coexistence rf_not_allowed signal is set.

52.4.4.2.6.2.53 skip coex rf_denied for channel 32 to 63 (COEX_CHANNEL1)

Offset

Register	Offset
COEX_CHANNEL1	12Ch

Diagram



Fields

Field	Function
31-0 COEX_32_63	Coexistence Allowed Channel Table1 Indicates the list of RF channels from 32 to 63 which can be used even if coexistence rf_not_allowed signal is set.

52.4.4.2.6.2.54 skip coex rf_denied for channel 64 to 95 (COEX_CHANNEL2)

Offset

Register	Offset
COEX_CHANNEL2	130h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	COEX_64_95															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	COEX_64_95															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 COEX_64_95	Coexistence Allowed Channel Table2 Indicates the list of RF channels from 64 to 95 which can be used even if coexistence rf_not_allowed signal is set.

52.4.4.2.6.2.55 skip coex rf_denied for channel 96 to 127 (COEX_CHANNEL3)

Offset

Register	Offset
COEX_CHANNEL3	134h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	COEX_96_127															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	COEX_96_127															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0	Coexistence Allowed Channel Table3

Table continues on the next page...

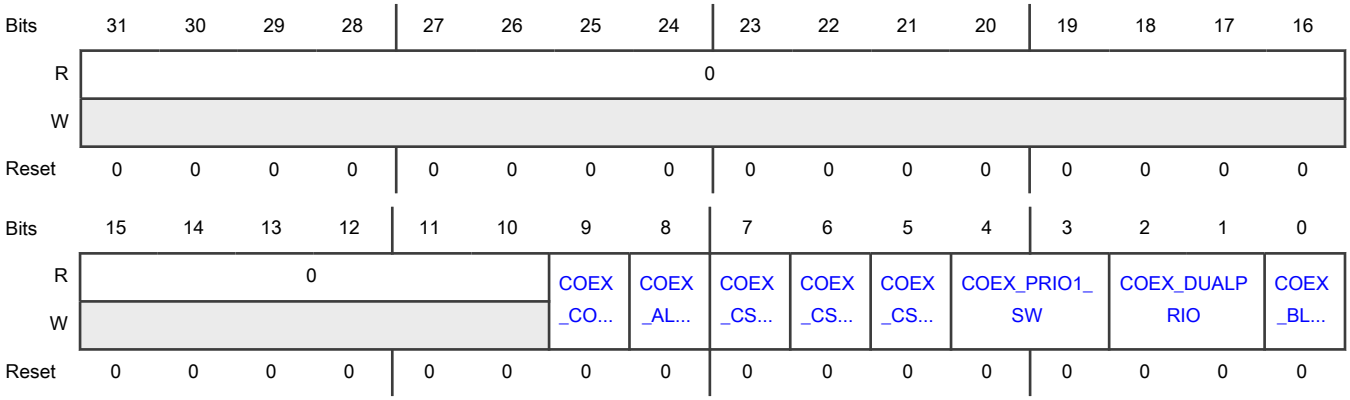
Field	Function
COEX_96_127	Indicates the list of RF channels from 96 to 127 which can be used even if coexistence rf_not_allowed signal is set.

52.4.4.2.6.2.56 Coexistence mode (COEX_MODE)

Offset

Register	Offset
COEX_MODE	138h

Diagram



Fields

Field	Function
31-10 —	Reserved
9 COEX_CONFLICT_CHANNEL_EN	Coexistence conflict channel enable This bit enables the management of PTA priority outside radio IP. When set to 1, the information that channel is in conflict or not with WIFI is sent to external via rf_status pin - Send 0 to external via rf_status pin if channel is not in conflict with WIFI - Send 1 to external via rf_status pin if channel is in conflict with WIFI
8 COEX_ALLOW_CHANNEL_EN	Coexistence allow channel enable This bit enables the management of PTA priority inside radio IP. When set to 1, RF activity is not stopped upon rf_not_allowed assertion if the current channel is in the allowed channel list(COEX_CHANNEL0/1/2/3 registers)
7 COEX_CS_DUALPHASE	Coexistence cs dual phase mode

Table continues on the next page...

Table continued from the previous page...

Field	Function
	When set to 1 and register COEX_CS_DUAL_REQ is set to 0, then bt_active/prio/status is sent at beginning CS and in case of rf_deny , abort is done during mode 0 else mask tx_en after mode 0 to preserve localization.
6 COEX_CS_DUALREQ	Coexistence cs dual req mode 0 : only one req bt_active/prio/status is sent at beginning CS 1 : on req bt_active bt_active/prio/status is sent at beginning CS and another one after mode 0 ; abort is done during mode 0, but only tx_en is masked after mode 0 to preserve localization.
5 COEX_CS_EN	Coexistence cs rf_deny enable When set to 1, the tx_en will be masked when rf_not_allowed occur in channel_sounding only (rsm_active)
4-3 COEX_PRIO1_SW	Coexistence dual priority bit 0 -> 0 :disable control by SW; 1 :enable control of rf_priority[1] by SW bit 1 -> value of rf_priority[1] if bit 0 is set
2-1 COEX_DUALPRIO	Coexistence dual priority bit 0 -> 0 :priority managed as in KW45; 1 :2 priorities managed bit 1 -> 0 :status is constant; 1: status follow rx_en/tx_en
0 COEX_BLE_EARLY_EVENT	Coexistence early start btle enable When set to 1, this enable allows to start TSM counter upon btle_early_event signal assertion for coexistence constraint. In that case, ble_early_event signal, driven by NBU is used to anticipate the tsm counter activation without waiting for the first rx_en/tx_en assertion

52.4.4.2.6.2.57 Coexistence status (COEX_STATUS)

Offset

Register	Offset
COEX_STATUS	13Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												COEX_STATUS			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-4 —	Reserved
3-0 COEX_STATUS	Coexistence status Bit 0 indicates the status of btle_early_event signal from NBU which anticipates the TSM counter activation for coexistence. Bit 1 indicates the status of rsm_arb_grant signal. This signal is set when Coexistence doesn't block RSM to use RF interface

52.4.4.3 Radio RAM

52.4.4.3.1 TX Packet Ram

52.4.4.3.1.1 RADIO_PACKET_RAM register descriptions

The Radio Packet RAM is directly accessed by various logic blocks in the radio. If software performs an access to Packet RAM concurrently with an access by the radio logic, software reads will be wait-stated but software writes will be ignored. Therefore it the Packet RAM is written by software at a time when the radio logic might be accessing the Packet RAM, it is advisable that software verify the writes were completed successfully by reading the Packet RAM values at the addresses written.

52.4.4.3.1.1.1 RADIO_PACKET_RAM_ADDR memory map

RADIO.TX_PACKET_RAM base address: 48A0_8000h

Offset	Register	Width (In bits)	Access	Reset value
0h - FFCh	Shared Packet RAM for multiple Link Layer usage. (PACKET_RAM_0 - PACKET_RAM_1023)	32	RW	See section

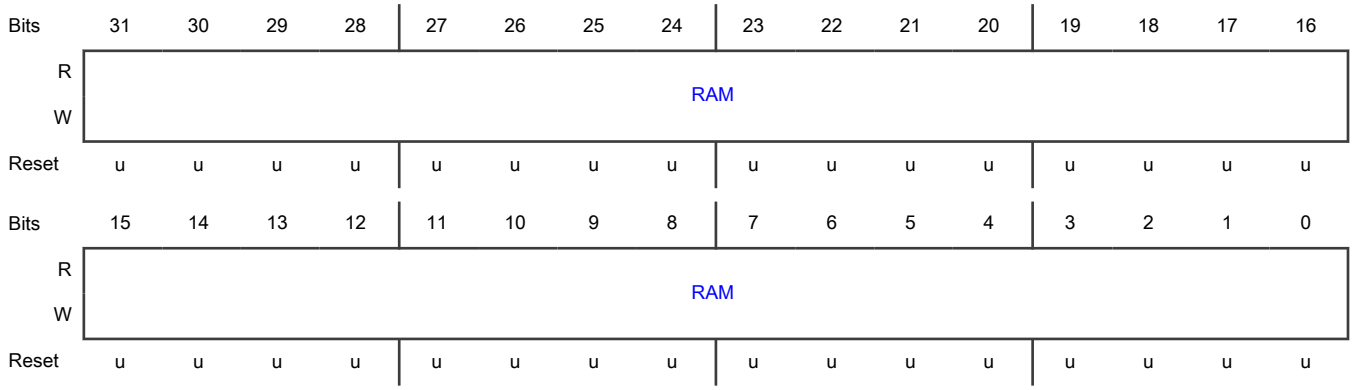
52.4.4.3.1.1.2 Shared Packet RAM for multiple Link Layer usage. (PACKET_RAM_0 - PACKET_RAM_1023)

Offset

For a = 0 to 1023:

Register	Offset
PACKET_RAM_a	0h + (a × 4h)

Diagram



Fields

Field	Function
31-0 RAM	One entry in the packet RAM One word of the packet RAM, whatever the defined width is.

52.4.4.3.2 RX Packet Ram

52.4.4.3.2.1 RADIO_PACKET_RAM register descriptions

The Radio Packet RAM is directly accessed by various logic blocks in the radio. If software performs an access to Packet RAM concurrently with an access by the radio logic, software reads will be wait-stated but software writes will be ignored. Therefore it the Packet RAM is written by software at a time when the radio logic might be accessing the Packet RAM, it is advisable that software verify the writes were completed successfully by reading the Packet RAM values at the addresses written.

52.4.4.3.2.1.1 RADIO_PACKET_RAM_ADDR memory map

RADIO.RX_PACKET_RAM base address: 48A0_9000h

Offset	Register	Width (In bits)	Access	Reset value
0h - 7FCh	Shared Packet RAM for multiple Link Layer usage. (PACKET_RAM_0 - PACKET_RAM_511)	32	RW	See section

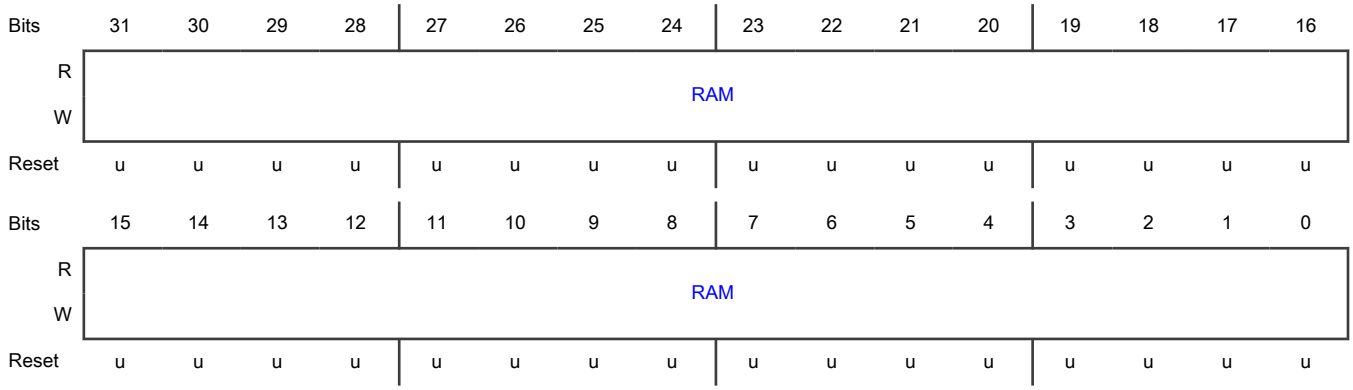
52.4.4.3.2.1.2 Shared Packet RAM for multiple Link Layer usage. (PACKET_RAM_0 - PACKET_RAM_511)

Offset

For a = 0 to 511:

Register	Offset
PACKET_RAM_a	0h + (a × 4h)

Diagram



Fields

Field	Function
31-0 RAM	One entry in the packet RAM One word of the packet RAM, whatever the defined width is.

52.4.4.3.3 Radio Packet RAM memory map

NOTE

The RAM entries shown for Bluetooth LE LL are not actually part of the "Packet RAM" but are included in the table for reference.

RAM	Start Address	Size(Byte)
Bluetooth LE LL		
Bluetooth LE LL IMEM	0xA0100000(CPU2)/0x48900000(SoC)	2K
Bluetooth LE LL DMEM	0xA0140000(CPU2)	80K
Bluetooth LE LL EBRAM	0xA9024000(CPU2)	8928
Bluetooth LE LL SMU2	0xB0000000(CPU2)/489C0000(SoC)	80K
Generic LL		
Generic LL TX_RAM Buffer	TX_RAM_BASE_ADDR	2048+256
Generic LL IE	TX_RAM_BASE_ADDR+0xAC0	64
Generic LL SAM	TX_RAM_BASE_ADDR+0xB00	256
Generic LL PIRK	TX_RAM_BASE_ADDR+0xB00	128
Generic LL LIRK	TX_RAM_BASE_ADDR+0xB80	128
Generic LL RPA-ID	TX_RAM_BASE_ADDR+0xC00	64
Generic LL PRPA	TX_RAM_BASE_ADDR+0xC40	64
Generic LL LRPA	TX_RAM_BASE_ADDR+0xC80	64

Table continues on the next page...

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Generic LL WL0	TX_RAM_BASE_ADDR+0xD00	256
Generic LL WL1	TX_RAM_BASE_ADDR+0xE00	256
Generic LL RX_RAM Buffer	RX_RAM_BASE_ADDR	2048
Zigbee LL		
Zigbee LL TX_RAM Buffer	TX_RAM_BASE_ADDR	128
Zigbee LL RX_RAM Buffer	TX_RAM_BASE_ADDR+0x80	128
Zigbee LL SAM	TX_RAM_BASE_ADDR+0x100	256
Wake on Radio		
WOR_HOP	TX_RAM_BASE_ADDR+0x900	256
WOR_TIME	TX_RAM_BASE_ADDR+0xA00	160
Ranging sequence manager		
RSM_CONFIG_BUFFER	RX_RAM_BASE_ADDR	1024
RSM_RESULT_BUFFER	RX_RAM_BASE_ADDR+0x400	1024

52.4.4.4 Link Layer Blocks

52.4.4.4.1 802.15.4 Link Layer

52.4.4.4.1.1 802.15.4 Link Layer Controller

####### 52.4.4.4.1.1.1 Introduction

The 802.15.4 Link Layer Controller implements all hardware functionality of the 802.15.4 Link Layer.

####### 52.4.4.4.1.1.2 Overview

The 802.15.4 Link Layer implementation is divided into software and hardware components. The 802.15.4 Link Layer Controller represents the hardware component of the link layer. Link Layer hardware functionality is further sub-divided into functional blocks. These blocks include:

- Packet Processor block.
- Sequence Manager block.
- Packet Storage block.
- Event Timer block.
- Interrupts block.
- Clear Channel Assessment/Energy Detect/Link Quality Indication block.
- Bit Streaming Mode block.

Together, these blocks implement and accelerate critical functions of the 802.15.4 Link Layer. The non-timing critical functions are implemented in software on a MCU.

52.4.4.4.1.1.3 Block Diagram

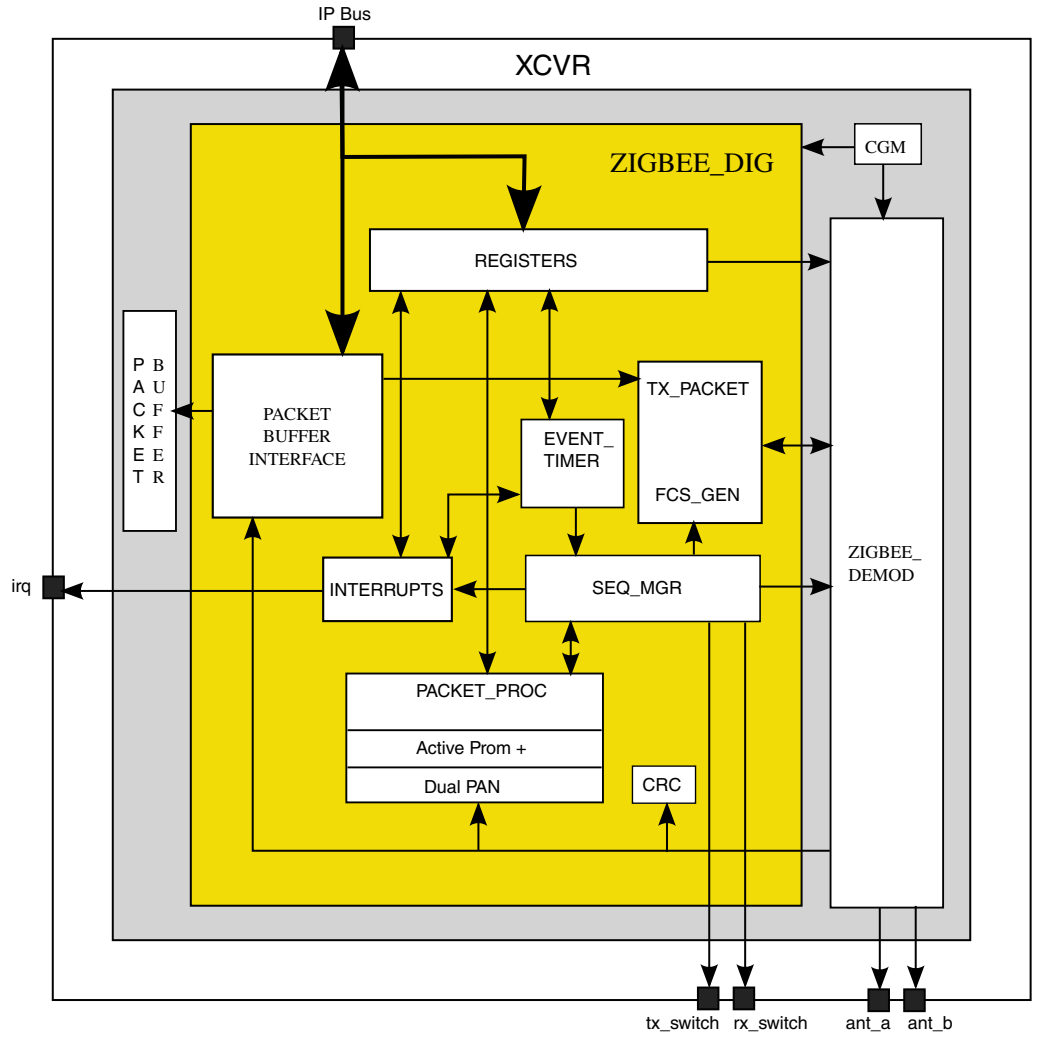

Figure 407. 802.15.4 Link Layer Controller Block Diagram

52.4.4.4.1.2 Functional Description

52.4.4.4.1.2.1 Submodules sections

52.4.4.4.1.2.1.1 Packet Processor

52.4.4.4.1.2.1.1.1 Introduction

The 802.15.4 Packet Processor performs sophisticated hardware filtering of the incoming received packet, to determine whether the packet is both PHY- and MAC-compliant, whether the packet is addressed to this device, and if the device is a PAN Coordinator, whether a message is pending for the sending device. The packet processor greatly reduces the packet filtering burden on software, allowing software to tend to higher-layer tasks with a lower latency and smaller software footprint.

Table 542. References

Revision	Title
IEEE Std 802.15.4 -2003	Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)

Table continues on the next page...

Table 542. References (continued)

Revision	Title
IEEE Std 802.15.4 -2006	802.15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs)
IEEE Std 802.15.4 -2011	Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)
IEEE Std 802.15.4e™-2012	Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) (Amendment to IEEE Std 802.15.4™-2011)
IEEE Std 802.15.4 -2015	Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) (Amendment to IEEE Std 802.15.4-2011)

52.4.4.4.1.2.1.1.1.1 Overview

The 802.15.4 Packet Processor performs aggressive hardware filtering of the incoming packet as it is being received, to increase battery life by not awakening the MCU to process packets which are non-compliant or not addressed to the device, or that violate the 802.15.4 MAC Frame structure. The advanced frame parsing enables the sequence manager to handle complex sequences, by, for example, determining whether a receive frame requires an acknowledge, and generating the Sequence Number for that acknowledge, so that the transmit/receive combination sequence can be executed without any MCU intervention. Finally, the packet processor includes a hardware accelerator that allows the device to handle a critical timing requirement that had been problematic for 8-bit MCU's in the past: the quick-turnaround requirement for an indirect queue-lookup to determine the correct response to an end device sending a data polling request. The packet processor contains a register-based table of end devices which have messages pending, allowing a single-cycle hardware table lookup to be performed, and a minimum-turnaround-time acknowledge packet to be sent to the end device without MCU intervention. The packet processor also includes support for Dual PAN mode, which allows the device to simultaneously reside on 2 networks, with 2 separate IEEE addresses. And the packet processor also supports Active Promiscuous mode, which allows address filtering rules to be bypassed, while still enabling the device to automatically acknowledge packets which are addressed to the device.

52.4.4.4.1.2.1.1.1.2 Features

- Aggressive packet filtering to enable long, uninterrupted MCU sleep periods
- Fully compliant with both 2003 and 2006 versions of the 802.15.4 wireless standard
- Supports all Frame Types, including reserved types
- Supports all valid 802.15.4 Frame Lengths
- Enables auto-Tx Acknowledge frames (no MCU intervention) by parsing of Frame Control Field and Sequence Number
- Supports all Source and Destination Address modes, and also PAN ID Compression
- Supports Broadcast address for PAN ID and short address mode
- Supports "Promiscuous" mode, to receive all packets regardless of address- and rules-checking
- Allows Frame Type-specific filtering (e.g., reject all but Beacon frames)
- Supports SLOTTED and non-SLOTTED modes
- Includes special filtering rules for PAN Coordinator devices
- Enables minimum-turnaround TX-Acknowledge frames for data-polling requests by automatically determining message-pending status
- Assists MCU in locating pending messages in its indirect queue for data-polling end devices
- Assists MCU in determining if a poll request originated from a valid child end device
- Makes available to MCU detailed status of frames which fail address- or rules-checking
- Supports Dual PAN mode, allowing the device to exist on 2 PAN's simultaneously

- Supports 2 IEEE addresses for the device
- Supports Active Promiscuous Mode
- Includes provisions to enable software support of 802.15.4e and 802.15.4-2015 frame types and versions

52.4.4.4.1.2.1.1.1.3 Block diagram

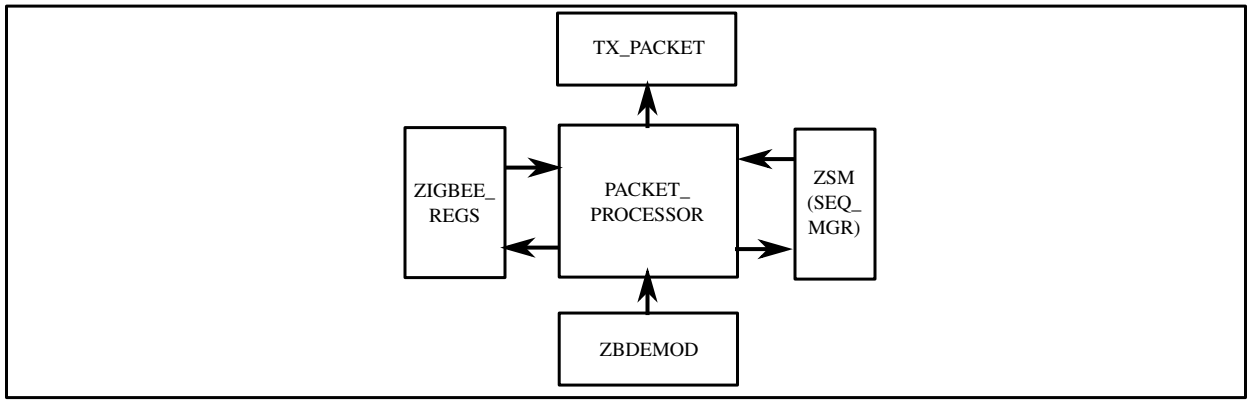

Figure 408. Block diagram

52.4.4.4.1.2.1.1.2 Memory Map and register definition

Numerous registers exist to provide configuration and status for the 802.15.4 Packet Processor.

The memory-mapped registers which affect the Packet Processor are described in the table below.

Field	R/W	Description
PI	r	Poll Indication: 1: the received packet was a data request, regardless of whether a source-address table-match occurred, and regardless of whether source-address matching is enabled (see SRCADDR_EN bit); 0: the received packet was not a data request PI is a read-only bit.
SRCADDR	r	If Source Address Management is engaged, meaning at least one of the following bits is set: • SAP0_EN • SAA0_EN • SAP1_EN • SAA1_EN then SRCADDR will be set to 1 if the packet just received is a poll request (PI=1), and at least one of the following conditions is met: • SAP0_EN && SAP0_ADDR_PRESENT • SAA0_EN && SAA0_ADDR_ABSENT

Table continues on the next page...

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Field	R/W	Description
		• SAP1_EN && SAP1_ADDR_PRESENT • SAA1_EN && SAA1_ADDR_ABSENT If SRCADDR=1, this indicates to SW that the Packet Processor has determined that an auto-TxACK frame must be transmitted with the FramePending subfield of the FrameControlField set to 1. HW will assemble and transmit this Ack packet. If the above conditions are not met, SRCADDR will be cleared to 0.
SAP0_EN	rw	1: Enables SAP0 Partition 0: Disables SAP0 Partition
SAA0_EN	rw	1: Enables SAA0 Partition 0: Disables SAA0 Partition
SAP1_EN	rw	1: Enables SAP1 Partition 0: Disables SAP1 Partition
SAA1_EN	rw	1: Enables SAA1 Partition 0: Disables SAA1 Partition
SAA0_START[6:0]	rw	First Index of SAA0 partition.
SAP1_START[6:0]	rw	First Index of SAP1 partition.
SAA1_START[6:0]	rw	First Index of SAA1 partition.
SAM_CHECKSUM[15:0]		Software-computed source address checksum, to be installed into a table index
SAM_INDEX[6:0]		Contains the table index to be enabled or invalidated. Software must ensure that the index is within the range of the desired partition.
SAM_INDEX_WR	w	For 32-bit writes, SAM_INDEX_WR must be set to indicate that the table entry specified by SAM_INDEX[6:0] is to be written; if SAM_INDEX_WR=0, the table entry is not written, but the SAM_INDEX[6:0] register is updated. For 8-bit writes, this bit is ignored.
SAM_INDEX_EN	w	Enable the index selected by SAM_INDEX[6:0] for searching.
SAM_INDEX_INV	w	Invalidate the index selected by SAM_INDEX[6:0]
FIND_FREE_IDX	w	After modifying Valid bits (enabling or invalidating), write this bit to 1 to force HW to update the “First Free Index” registers to account for the changed Valid bits. This HW update process takes 4us. SW can poll SAM_BUSY to determine when the table update is complete. Write-only bit. Writing 0 to this bit has no effect. Readback value is indeterminate.
SAM_BUSY	r	HW is in the process of updating the Source Address table, either in response to a poll indication from the packet processor, or due to SW setting FIND_FREE_IDX=1. In the latter case, SW should poll

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Field	R/W	Description
		SAM_BUSY until low before accessing the “First Free Index” registers. Read-only bit.
INVALIDATE_ALL	w	Writing a 1 to this bit clears all 128 Valid bits. Invalidates the entire table. Write-only bit. Writing 0 to this bit has no effect. Readback value is indeterminate.
SAP0_1ST_FREE_IDX[6:0]	r	First non-enabled (invalid) index in the SAP0 partition. Read-only.
SAA0_1ST_FREE_IDX[6:0]	r	First non-enabled (invalid) index in the SAA0 partition. Read-only.
SAP1_1ST_FREE_IDX[6:0]	r	First non-enabled (invalid) index in the SAP1 partition. Read-only.
SAA1_1ST_FREE_IDX[6:0]	r	First non-enabled (invalid) index in the SAA1 partition. Read-only
PROMISCUOUS	rw	Bypasses most packet filtering. 1: all packet filtering except frame length checking (FrameLength>=5 and FrameLength<=127) is bypassed. 0: normal mode **Note:** Promiscuous Mode is not intended for Sequence TR with RXACKRQD=1 (auto-RXACK mode), because the contents of auto-RXACK packets are not stored in the Packet Buffer. If auto-RXACK packets are to be stored in the PB, use ACTIVE_PROMISCUOUS instead.
PANCORDNTR0	rw	Device is a PAN Coordinator on PAN0. Allows device to receive packets with no destination address, if Source PAN ID matches.
MACPANID0[15:0]	rw	MAC PAN ID for PAN0. The packet processor compares the incoming packet's Destination PAN ID against the contents of this register to determine if the packet is addressed to this device; or if the incoming packet is a Beacon frame, the packet processor compares the incoming packet Source PAN ID against this register. Also, if PANCORDNTR0=1, and the incoming packet has no Destination Address field, and if the incoming packet is a Data or MAC Command frame, the packet processor compares the incoming packet Source PAN ID against this register.
MACSHORTADDRS0[15:0]	rw	MAC Short Address for PAN0, for 16-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.
MACLONGADDRS0[63:0]	rw	MAC Long Address for PAN0, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.
BEACON_FT	rw	1: Beacon frame type enabled. 0: reject all Beacon frames

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Field	R/W	Description
ACK_FT	rw	1: Acknowledge frame type enabled. 0: reject all Acknowledge frames
DATA_FT	rw	1: Data frame type enabled. 0: reject all Data frames
CMD_FT	rw	1: MAC Command frame type enabled. 0: reject all MAC Command frames
LLDN_FT	rw	1: LLDN frame type enabled (Frame Type 4). 0: reject all MAC Command frames
MULTIPURPOSE_FT	rw	1: MULTIPURPOSE frame type enabled (Frame Type 5). 0: reject all MAC Command frames
EXTENDED_FT	rw	1: EXTENDED frame type enabled (Frame Type 7). 0: reject all MAC Command frames
NS_FT	rw	1: Not-specified (reserved) frame type enabled. No packet filtering is performed, except for frame length checking (FrameLength>=5 and FrameLength<=127). 0: reject all reserved frame types
EXTENDED_FCS_CHK	rw	Verify FCS on Frame Type Extended 1: Packet Processor will check FCS at end-of-packet based on packet length derived from PHR, for Frame Type EXTENDED 0: Packet Processor will not check FCS for Frame Type EXTENDED (default)
ACTIVE_PROMISCUOUS	rw	1: Provide Data Indication on all received packets under the same rules which apply in PROMISCUOUS mode, however acknowledge those packets under rules which apply in non-PROMISCUOUS mode 0: normal operation (Default)
FRM_VER_FILTER[3:0]	rw	The incoming packet's Frame Control Field is parsed to obtain the FrameVersion subfield, and that value is compared against this register, in accordance with the following: xxx1: Accept received packets with FrameVersion=00 xx1x: Accept received packets with FrameVersion=01 x1xx: Accept received packets with FrameVersion=10 1xxx: Accept received packets with FrameVersion=11

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Field	R/W	Description
		These filtering rules apply to Beacon, Acknowledge, Data, and MAC Command Frame Types, since these frame types require a 2-octet Frame Control Field which embeds a 2-bit FrameVersion subfield. Later frame types introduced in the 802.15.4e addendum (LLDN, Multipurpose) don't guarantee a FrameVersion subfield with the original meaning, so these filtering rules do not apply to these frame types. See registers LLDN_FT and MULTIPURPOSE_FT. For Acknowledge frames, FrameVersion bits are ignored by the Packet Processor, irrespective of FRM_VER_FILTER.
MACPANID1[15:0]	rw	MAC PAN ID for PAN1. The packet processor compares the incoming packet's Destination PAN ID against the contents of this register to determine if the packet is addressed to this device; or if the incoming packet is a Beacon frame, the packet processor compares the incoming packet Source PAN ID against this register. Also, if PANCORDNTR1=1, and the incoming packet has no Destination Address field, and if the incoming packet is a Data or MAC Command frame, the packet processor compares the incoming packet Source PAN ID against this register.
MACSHORTADDRS1[15:0]	rw	MAC Short Address for PAN1, for 16-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.
MACLONGADDRS1[63:0]	rw	MAC Long Address for PAN1, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.
ACTIVE_NETWORK	rw	Selects the PAN on which to transceive, by activating a PAN parameter set (PAN0 or PAN1). In Manual Dual PAN mode (or Single PAN mode), this bit selects the active PAN parameter set (channel and addressing parameters) which governs all autosequences. In Auto Dual PAN mode, this bit selects the PAN on which to begin transceiving, latched at the point at which DUAL_PAN_DWELL register is written. 1: Select PAN1 0: Select PAN0 (Default)
DUAL_PAN_AUTO	rw	Activates automatic Dual PAN operating mode. In this mode, PAN-switching is controlled by hardware at a pre-programmed rate, determined by DUAL_PAN_DWELL. 1: Auto Dual PAN Mode 0: Manual Dual PAN mode (or Single PAN mode). Default. Whenever DUAL_PAN_AUTO=0, CURRENT_NETWORK=ACTIVE_NETWORK at all times. In other words, software directly controls which PAN is selected.

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<table>
<tr><th>Field</th><th>R/W</th><th>Description</th></tr>
<tr><td></td><td></td><td>Whenever DUAL_PAN_AUTO=1, CURRENT_NETWORK is controlled by hardware</td></tr>
<tr><td>PANCORDNTR1</td><td>rw</td><td>Device is a PAN Coordinator on PAN1. Allows device to receive packets with no destination address, if Source PAN ID matches.</td></tr>
<tr><td>CURRENT_NETWORK</td><td>r</td><td>This read-only bit indicates which PAN is currently selected by hardware in automatic Dual PAN mode
1: PAN1 is selected
0: PAN0 is selected</td></tr>
<tr><td>DUAL_PAN_DWELL[7:0]</td><td>rw</td><td>Channel Frequency Dwell Time. In Auto Dual PAN mode, hardware will toggle the PAN, after dwelling on the current PAN for the interval described below (assuming Preamble/SFD not detected). A write to DUAL_PAN_DWELL, always re-initializes the DWELL TIMER to the programmed value. If a write to DUAL_PAN_DWELL occurs during an autosequence, the DWELL TIMER will begin counting down immediately. If a write to DUAL_PAN_DWELL occurs when there is no autosequence underway, the DWELL TIMER will not begin counting until the next autosequence begins; it will begin counting at the start of the sequence warmup.
<table>
<tr><th>PRESCALER (bits [1:0])</th><th>TIMEBASE (bits [7:2])</th><th>RANGE (min) - (max)</th></tr>
<tr><td>00</td><td>0.5ms</td><td>0.5 - 32ms</td></tr>
<tr><td>01</td><td>2.5ms</td><td>2.5 - 160ms</td></tr>
<tr><td>10</td><td>10ms</td><td>10 - 640ms</td></tr>
<tr><td>11</td><td>50ms</td><td>50ms - 3.2seconds</td></tr>
</table>
A write to DUAL_PAN_DWELL also causes the value of ACTIVE_NETWORK to get latched into the hardware. This latched value will be the starting point for the automatic dual-pan mode (i.e., start on PAN0 or on PAN1). The starting value takes effect immediately (if sequence is underway and DUAL_PAN_AUTO=1), or is otherwise delayed until sequence starts and DUAL_PAN_AUTO=1.</td></tr>
<tr><td>DUAL_PAN_REMAIN[5:0]</td><td></td><td>This read-only register indicates time remaining before next PAN switch in auto Dual PAN mode. The units for this register, depend on the PRESCALER setting (bits [1:0]) in the DUAL_PAN_DWELL register, according to the following table:</td></tr>
</table>

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<table>
<tr><th>Field</th><th>R/W</th><th>Description</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><th>DUAL_PAN_DWELL PRESCALER</th><th>DUAL_PAN_REMAIN UNITS</th></tr>
<tr><td>00</td><td>0.5ms</td></tr>
<tr><td>01</td><td>2.5ms</td></tr>
<tr><td>10</td><td>10ms</td></tr>
<tr><td>11</td><td>50ms</td></tr>
</table>

The readback value indicates that between N-1 and N timebase units remain until the next PAN switch. For example, a DUAL_PAN_REMAIN readback value of 3, with a DUAL_PAN_DWELL PRESCALER setting of 2 (10ms), indicates that between 20ms (2*10ms) and 30ms (3*10ms), remain until the next automatic PAN switch.</td></tr>
<tr><td>RECD_ON_PAN0</td><td>r</td><td>Indicates the packet which was just received, was received on PAN0.

In Dual PAN mode operating on 2 different channels, RECD_ON_PAN0 will be set if CURRENT_NETWORK=0 when the packet was received, regardless of FILTERFAIL status.

In DUAL PAN mode operating with same channel on both networks, CURRENT_NETWORK will be ignored and RECD_ON_PAN0 will be set only if a valid packet was received on PAN0 (PAN0’s FILTERFAIL_FLAG is deasserted).</td></tr>
<tr><td>RECD_ON_PAN1</td><td>r</td><td>Indicates the packet which was just received, was received on PAN1.

In Dual PAN mode operating on 2 different channels, RECD_ON_PAN1 will be set if CURRENT_NETWORK=1 when the packet was received, regardless of FILTERFAIL status.

In DUAL PAN mode operating with same channel on both networks, CURRENT_NETWORK will be ignored and RECD_ON_PAN1 will be set only if a valid packet was received on PAN1 (PAN1’s FILTERFAIL_FLAG is deasserted).</td></tr>
<tr><td>FILTERFAIL_CODE[9:0]</td><td>r</td><td>Status of packet processor filtering. For incoming packets which have been rejected by the packet processor, FILTERFAIL_CODE will indicate which violated packet-filtering rule(s) led to the rejection. This is intended for debug only. The contents of this register are valid at the FILTERFAIL_IRQ interrupt. The packet processor maintains 2 independent copies of FILTERFAIL_CODE[9:0], one for each PAN. When reading this register, software can select for which PAN the FILTERFAIL_CODE applies, using the FILTERFAIL_PAN_SEL bit. See Appendix A.</td></tr>
<tr><td>FILTERFAIL_PAN_SEL</td><td>rw</td><td>1: FILTERFAIL_CODE[9:0] will report the FILTERFAIL status of PAN1

0: FILTERFAIL_CODE[9:0] will report the FILTERFAIL status of PAN0</td></tr>
</table>

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Field	R/W	Description
LENIENCY[42:0]	rw	The LENIENCY register allows individual packet filtering rules to be overridden, on a rule-by-rule basis. In other words, a specific packet filtering rule, such as an address-mode check, which would result in an incoming packet being rejected, can be overridden by setting the corresponding bit in the LENIENCY register, which would then result in the packet being accepted. This is similar to PROMISCUOUS mode, except that it allows checks to be overridden individually. This will facilitate debug, and potentially allow the device to communicate with devices which may not be 100% MAC-compliant. The mapping of LENIENCY register bits to rules is shown in Appendix B of this document.

52.4.4.4.1.2.1.1.3 Functional Description

The packet processor is responsible for receiving symbols from the demodulator, combining them into octets, assembling the octets into packets, filtering the packets in compliance with the 802.15.4 wireless MAC standard, and storing the packets into the Packet Buffer (Packet RAM).

The packet processor parses the incoming packets on-the-fly to determine:

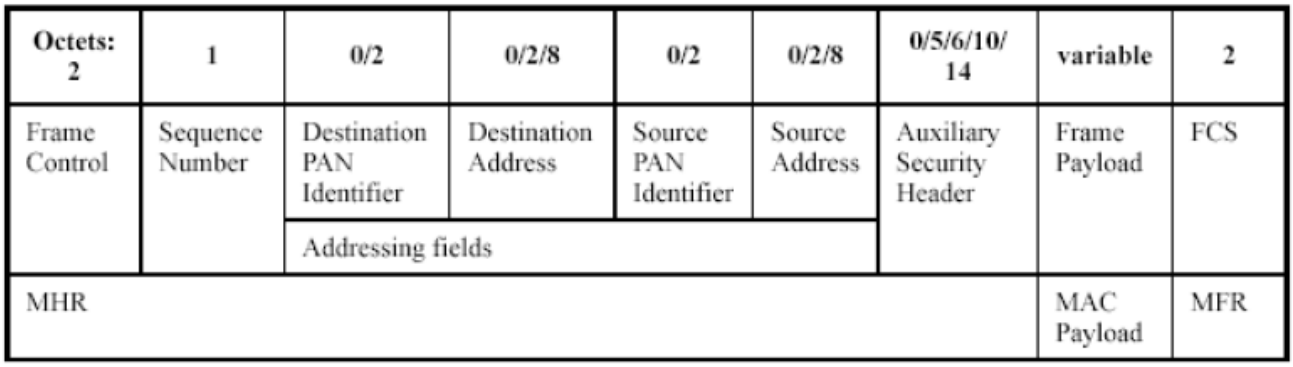
1. whether the packet is MAC-compliant, and if it is,
2. whether the packet is addressed to the end device.

The packet processor performs aggressive filtering on incoming packets, in order to reduce unnecessary MCU wake-ups, to allow longer MCU sleep durations, and to provide sufficient hardware automation so as to enable complex sequences to be executed by the sequence manager. The packet processor also includes hardware support for Dual PAN operation (allowing the device to reside on two networks simultaneously), and for Active Promiscuous mode (allowing the device to receive all packets, but acknowledging only those addressed to the device).

The 802.15.4 packet processor also includes functionality to allow a critical-timing requirement to be met, which in the past has been problematic for low-MIPS 802.15.4 receiving devices: the ability of a coordinator device to respond to a MAC Command data request from an end device, with an Acknowledge frame containing a FramePending bit accurately reflecting the presence of a message for the end device in the coordinator's indirect queue, or the absence of the end device in the coordinator's neighbor table, within the prescribed 192us window. This functionality is described in more detail in the Source Address Matching section.

52.4.4.4.1.2.1.1.3.1 Packet Filtering Background

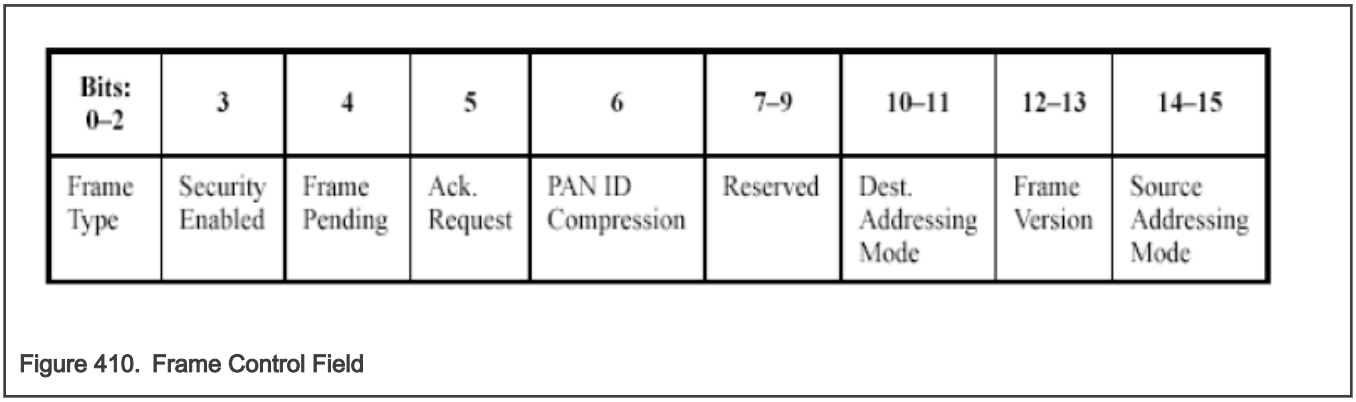
The packet processor parses packets to verify compliance with the 802.15.4 MAC frame format. The basic MAC frame format is shown in the figure below.



Octets: 2	1	0/2	0/2/8	0/2	0/2/8	0/5/6/10/14	variable	2
Frame Control	Sequence Number	Destination PAN Identifier	Destination Address	Source PAN Identifier	Source Address	Auxiliary Security Header	Frame Payload	FCS
		Addressing fields						
MHR							MAC Payload	MFR

Figure 409. MAC Frame Format

The packet processor parses the incoming octets on the fly, as they are received. The Frame Control Field, two octets in length, contains subfields which encode “instructions” on how to parse the remainder of the MHR (MAC Header). The structure of the Frame Control Field is shown in the figure below.



Bits: 0–2	3	4	5	6	7–9	10–11	12–13	14–15
Frame Type	Security Enabled	Frame Pending	Ack. Request	PAN ID Compression	Reserved	Dest. Addressing Mode	Frame Version	Source Addressing Mode

Figure 410. Frame Control Field

The packet processor utilizes the Frame Control Fields subfields in the following manner:

FCF Subfield	Utilization by Packet Processor
FrameType	Interprets the remaining MHR as specific to Beacon, Ack, Data, Command, or Reserved frame types. Each frame type has a unique MHR structure, and so different parsing rules apply.
SecurityEnabled	If SecurityEnabled=1 and FrameVersion>0 (frame versions 2006 and later), an Auxiliary Security Header field will be present in the MHR and will need to be further parsed by the packet processor if this is a MAC Command frame (see Section Source Address Management below). There is no other use of SecurityEnabled by the packet processor.
FramePending	ignored by packet processor
Ack. Request	will be copied into the **pp_ack_request** signal to the sequence manager. An auto-TxAck frame will follow the incoming receive frame if necessary conditions are met
PAN ID Compression	used for addressing mode rules-checking and addressing field parsing.

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FCF Subfield	Utilization by Packet Processor
Reserved	ignored by packet processor
Destination Addressing Mode	used for addressing mode rules-checking and addressing field parsing
FrameVersion	For Beacon, Data, and MAC Command frames, FrameVersion is checked against the allowed frame versions according to FRM_VER_FILTER For Acknowledge frames, FrameVersion is ignored. If SecurityEnabled=1 and FrameVersion>0 (frame versions 2006 and later), an Auxiliary Security Header field will be present in the MHR and the MHR will need to be further parsed by the packet processor if this is a MAC Command frame (see Section Source Address Management).
Source Addressing Mode	used for addressing mode rules-checking and addressing field parsing

The Packet Processor parses the FrameType field of the Frame Control Field per the following table:

Frame type value b_2 b_1 b_0	Description
000	Beacon
001	Data
010	Acknowledgment
011	MAC command
100–111	Reserved

Figure 411. Frame Type Field

Directly following the Frame Control Field is the Sequence Number field. The Sequence Number field of the MHR is captured by the packet processor. If an auto-TxAck frame follows the incoming receive frame, the captured Sequence Number will be copied to the transmitted Acknowledge packet, and the Packet Processor will insert FrameVersion=00 into the Frame Control Field of the transmitted frame, regardless of the received FrameVersion subfield of the original frame.

The Addressing Fields follow the Sequence Number. The format of the Addressing Fields depends upon the Source and Destination Addressing Mode subfields of the Frame Control Field. The Addressing Modes are defined in the table below:

Addressing mode value b_1 b_0	Description
00	PAN identifier and address fields are not present.
01	Reserved.
10	Address field contains a 16-bit short address.
11	Address field contains a 64-bit extended address.

Figure 412. Addressing Mode Fields

The packet processor uses these Source and Destination Address Modes shown above, to extract the Source PAN ID and Address (if present), and the Destination PAN ID and Address (if present), from the MHR, according to the table below:

FrameType	Destination Addressing Mode	Source Addressing Mode	PanID-Compression	Addressing Fields
Acknowledge only (reject all other frame types)	0	0	0	None
Data or Command (reject Ack and Beacon frames)	2 or 3	0	0	DstPanID + DstAddr
Beacon (all devices), or Data or Command (PAN Coord Only) (reject Ack frames)	0	2 or 3	0	SrcPanID + SrcAddr
Data or Command (reject Ack and Beacon frames)	2 or 3	2 or 3	0	DstPanID + DstAddr + SrcPanId + SrcAddr
Reject all frames (Illegal as per Section 7.2.2.1.5)	0	0	1	-
Reject all frames (Illegal as per Section 7.2.2.1.5)	2 or 3	0	1	-
Reject all frames	0	2 or 3	1	-

Table continues on the next page...

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FrameType	Destination Addressing Mode	Source Addressing Mode	PanID-Compression	Addressing Fields
(Illegal as per Section 7.2.2.1.5)				
Data or Command (reject Ack or Beacon frames)	2 or 3	2 or 3	1	DstPanID + DstAddr + SrcAddr
Reject all frames (Illegal as per Section 7.2.2.1.6)	1	-	-	-
Reject all frames (Illegal as per Section 7.2.2.1.8)	-	1	-	-

The Source PAN ID and Address, and Destination PAN ID and Address, extracted by the packet processor, are then checked against the MACPANID, MACSHORTADDRS, and MACLONGADDRS register settings, depending on the FrameType of the incoming packet, to determine:

1. Is the addressing mode combination valid for this frame type?
2. Do the address fields indicate that the packet is indeed addressed to the end device?

The details on how the packet processor answers those 2 questions, are described in the following sections.

52.4.4.4.1.2.1.1.3.2 Packet Filtering Detail

The figure below is a high-level representation of the packet filtering performed by the 802.15.4 packet processor. The sections which follow provide more detail on the packet filter implementation.

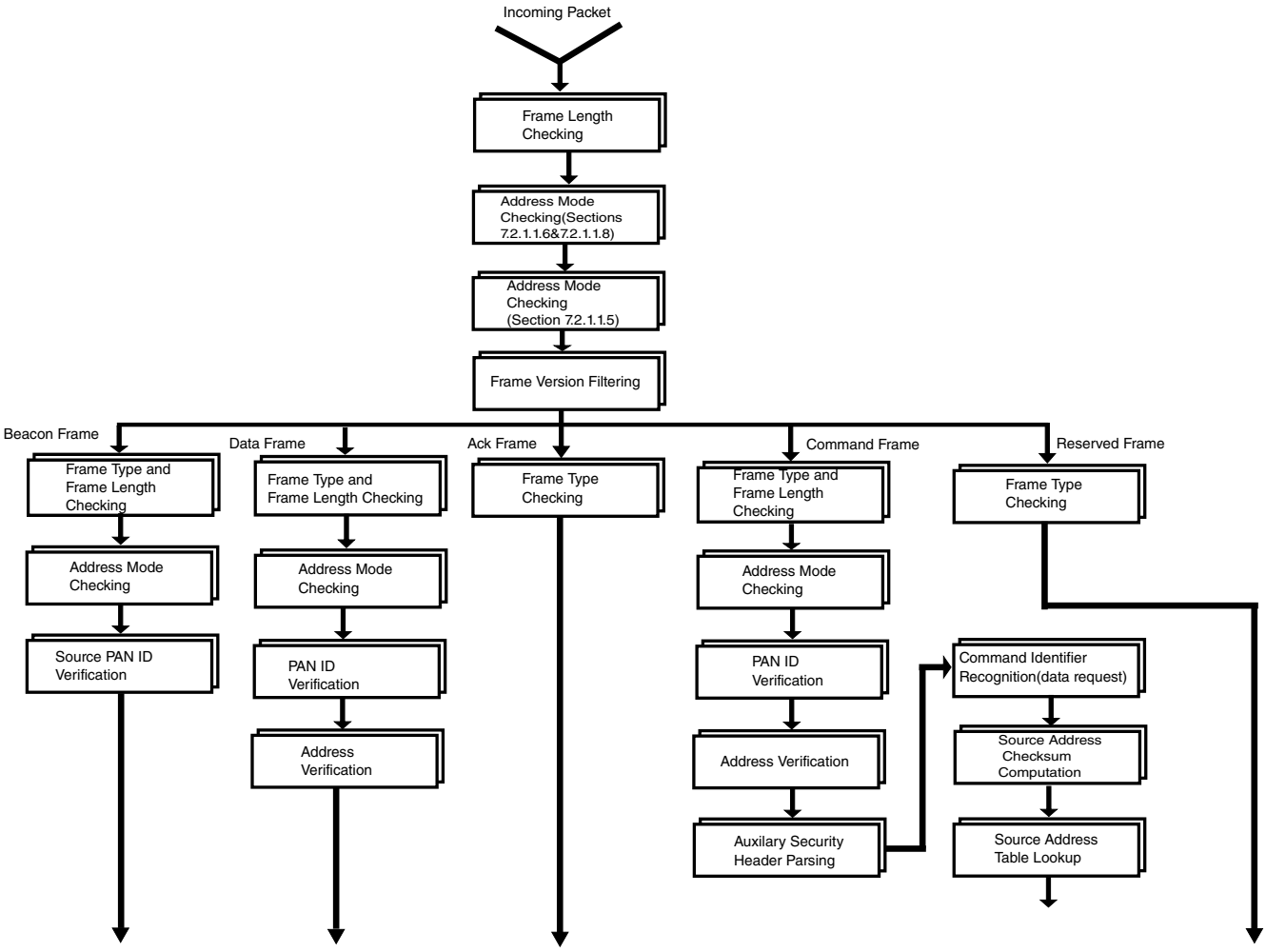

Figure 413. Packet Filtering Flow Diagram

First-Stage Packet Filtering

The first stage of packet filtering examines the incoming packet, and implements basic rule-checking, based on the 2006 version of the 802.15.4 standard, and is applied to *all* frame types. First stage rule-checking is described in the table below:

	Filtering Step	Description
1	Frame Length Checking	Check that all frames are at least 5 octets long (minimum frame length required by the standard), and no longer than 127 octets long (maximum frame length allowed by the standard).
2	Address Mode Checking (Sections 7.2.1.1.6 and 7.2.1.1.8)	Check that neither Source nor Destination Address Mode set to 1 (illegal addressing mode)
3	Address Mode Checking	Check for PAN ID Compression enabled, with either Source or Destination Address Mode set to 0 (illegal addressing mode)

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	Filtering Step	Description
	(Section 7.2.1.1.5)	
4	FrameVersion Checking	Check that incoming packet's Frame Version is allowed based on FRM_VER_FILTER setting. (FRM_VER_FILTER is a programmable register, see Register Descriptions Section).

Packets which pass first stage filtering, proceed to the second stage of packet filtering, which is *frame type-specific* filtering. Packets which fail initial rule checking are marked as rejected.

Second-Stage Packet Filtering

The second stage of packet filtering is *frame type-specific*. Different variations of the MAC Header (MHR) apply to different frame types, so different parsing mechanisms apply to each.

Note: In the following section, the following references are to register bits; see Register Description Section for register descriptions: BEACON_FT, ACK_FT, DATA_FT, CMD_FT, NS_FT, PANCORDNTR, MACPANID, MACSHORTADDRS, and MACLONGADDRS.

1) For Beacon frames, these are the basic filtering steps:

- Check that Beacon frames are enabled by software (BEACON_FT)
- Check that FrameLength >= 9
- Check for illegal combinations of PAN ID Compression and Source/Destination Address Modes
- Verify the Source PAN ID matches MACPANID, or that MACPANID = 0xffff.

2) For Acknowledge frames, these are the basic filtering steps:

- Check that Ack frames are enabled by software (ACK_FT)
- If Sequence TR is active and RXACKRQD = 1, check the received Sequence Number matches the transmitted Sequence Number; FrameVersion bits are ignored, as per section 7.2.2.3.1 of the 802.15.4 standard.

Note: It is recommended to use Sequence TR to receive Acknowledge frames, not Sequence R. See Chapter ZSM Sequence Manager, Section Sequence TR (Transmit/Receive).

3) For Data frames, these are the basic filtering steps:

- Check that Data frames are enabled by software (DATA_FT)
- Check that FrameLength >= 9
- Check for illegal combinations of Source and Destination Address Modes
- If PANCORDNTR=0, check for missing Destination Address field or present Source Address field
- If no Destination Address field (PANCORDNTR=1 only), check Source PAN ID matches MACPANID
- If Destination Address present, check Destination PAN ID matches MACPANID or broadcast (0xffff)
- If Short Destination Address field, check address matches MACSHORTADDRS or broadcast (0xffff)
- If Long Destination Address field, check address matches MACLONGADDRS.

4) For MAC Command frames, these are the basic filtering steps:

- Check that Command frames are enabled by software (CMD_FT)
- Check that FrameLength >= 9
- Check for illegal combinations of Source and Destination Address Modes
- If PANCORDNTR=0, check for missing Destination Address field or present Source Address field
- If no Destination Address field (PANCORDNTR=1 only), check Source PAN ID matches MACPANID
- If no Destination Address field (PANCORDNTR=1 only), capture Source PAN ID and Source Address for later use
- If Destination Address present, check Destination PAN ID matches MACPANID or broadcast (0xffff)
- If Short Destination Address field, check address matches MACSHORTADDRS or broadcast (0xffff)
- If Long Destination Address field, check address matches MACLONGADDRS.
- At end of the addressing field, if incoming packet's FrameVersion=0 or SecurityEnabled=0, capture the next octet (Command Identifier)
- At end of the addressing field, if incoming packet's FrameVersion!=0 and SecurityEnabled=1, parse the Auxiliary Security Header, then capture the next octet (Command Identifier)
- If Command Identifier indicates the MAC Command is a data request, compute a "Source Address Checksum" to uniquely identify the sending device.

52.4.4.4.1.2.1.1.3.3 Source Address Management

The 802.15.4 wireless MAC standard envisions a scenario whereby an end device may interrogate a coordinator as to whether the coordinator is storing data (i.e., a pending message) for the end device. The situation arises in a beacon-enabled network, when a coordinator includes in its transmitted beacon frame the MAC address of the end device in its "Pending Address Fields". The "Pending Address Fields" are part of the required MAC payload of the beacon frame. The "Pending Address Fields" contain a list of end device addresses for which messages are pending. In this scenario, an end device which finds its address included in the "Pending Address Fields" of the received beacon frame, must respond to the beacon (coordinator) with a MAC Command of type "data request". Alternatively, in non-beacon-enabled networks, an end device may periodically wake up and "poll" a coordinator, to determine if a message is pending for the end device. In either case, the coordinator stores messages for its end devices in its "indirect queue". The coordinator must respond to an incoming MAC Command data request (which *must* have AckRequest=1 in its Frame Control Field), with an Acknowledge frame containing a FramePending subfield indicating the presence (or absence) of a message for the requesting end device, in the coordinator's indirect queue. For a coordinator built around a low-MIPS MCU, a significant amount of MCU time is typically required, simply to ascertain whether a given end device has a message pending or not; the indirect queue can be quite large, and for 8-bit MCU's, the queue must be searched byte-by-byte. This makes it difficult, or impossible, for an underpowered MCU to establish frame-pending status within the 192us RX-to-TX turnaround time required by the standard.

Also, coordinators may include, in software, a "Neighbor Table", the contents of which consist of all the end devices with which the coordinator is in communication. The neighbor table requires periodic maintenance by coordinator (parent) software, as end devices (children) come and go within the network, join different parents, or simply never return. Child tables have limited capacity and parents need to create space for new devices that may show up. A timeout mechanism is the only way that can guarantee that child tables will eventually be cleaned up. Coordinator software must "age out" end devices with which there has not been recent communication. In order for an end device to refresh its status within its parent's Neighbor Table, the end device may periodically send a "keepalive" message in the form of a MAC Data Poll Request. Upon receipt of such a poll request, the parent must search its neighbor table to determine if the source address of the end device is a valid table entry. If the end device exists in the table, an Acknowledgment packet must be transmitted to the end device, with the FramePending subfield set to 0, and coordinator software resets that end device's timeout counter; if the child is not present in the table, an Acknowledgment packet must be transmitted to the end device, with the FramePending subfield set to 1, and the parent device will follow up by transmitting a "Leave Packet" to the end device, instructing the end device to sever its child status with the parent. The end device may opt to rejoin at a later time. Due to the size of the parent's Neighbor table, the search a child's source address can be time consuming, and may not always be possible within the 192us RX-to-TX turnaround time required by the standard.

To alleviate both of these problems, the 802.15.4 packet processor includes hardware acceleration to expedite the source address table search, greatly relieving the software bottleneck during the critical 192us turnaround time. The table search acceleration

consists of 2 components: 1) a search for the *presence* of a specific end device's source address, which expedites the process of determining whether a message is pending for the device; and 2) a search for the *absence* of a specific end device's source address, which expedites the process of determining whether the end device is a valid child of the parent.

The packet processor maintains a register table (128 deep, 16-bit wide). The table is divided into multiple partitions, one to perform the "Source Address Present" (SAP) search, and another to perform the "Source Address Absent" (SAA) search. In the SAP partition of the table, coordinator software will store the address of end devices for which it has a message pending; in the SAA partition of the table, coordinator software will store the address of end devices for which it is the parent. To reduce area, the address information is stored in a "compressed" format. Software compresses the address information, and stores it into the table partitions, during a non-critical time. Then, when the coordinator's packet processor receives a MAC Command data request, it extracts the source address information from the incoming packet, and compresses it using the *same* compression algorithm used by software to populate the source address table. The packet processor performs 2 steps simultaneously:

1. it compares the just-received, compressed source address information, or "checksum", against all of the enabled entries in the SAP partition of the table. If a match is found in the SAP partition, the packet processor *asserts* the **rx_frame_pending** signal to the transmit block (TX_PACKET), so that an auto-TxAck packet can be sent to the requesting end device, with the FramePending subfield set to 1, indicating that the end device has a message pending in the coordinator's indirect queue. A message packet from the coordinator to the end device will follow.
2. it compares the just-received, compressed source address information, or "checksum", against all of the enabled entries in the SAA partition of the table. If *no* match is found in the SAA partition, the packet processor *asserts* the **rx_frame_pending** signal to the transmit block (TX_PACKET), so that an auto-TxAck packet can be sent to the requesting end device, with the FramePending subfield set to 1, indicating that the end device is not a valid child of this parent, and a "Leave Packet" from the coordinator to the end device, will follow.

If neither condition is met, i.e, there is no address match in the SAP partition, and a positive match in the SAA partition, the packet processor *deasserts* the **rx_frame_pending** signal, so that an auto-TxAck packet can be sent indicating to the end device that it has no data pending, and that it remains a valid child of this parent; the end device may then deactivate its receiver immediately. For the packet processor, the entire table lookup occurs in 128 clock cycles, once the last source address octet has been received. The SAP and SAA lookups are performed simultaneously. The checksum is also computed on-the-fly by hardware as the source address octets are received, taking no more than 1 clock cycle per octet. Finally, table-search status is reported to the MCU:

1. after the packet processor completes its SAP table search, the status bit SAP0_ADDR_PRESENT will be set to 1 if a match is found in the SAP partition, and the table index which matched will be indicated in the SAP0_MATCH[6:0] register, to further assist software in locating the relevant message within its indirect queue; if no match is found in the SAP partition, the status bit SAP0_ADDR_PRESENT will be set to 0.
2. after the packet processor completes its SAA table search, the status bit SAA0_ADDR_ABSENT will be set to 1 if *no* match is found in the SAA partition; if a positive match is found in the SAA partition, the status bit SAA0_ADDR_ABSENT will be set to 0, and the table index which matched will be indicated in the SAA0_MATCH[6:0] register, to further assist software in locating the child device within its neighbor table.

Both features, SAP and SAA acceleration, are optional, and functionally independent. Coordinator software can elect to enable both, either, or neither feature. The control bit SAP0_EN enables SAP acceleration. The control bit SAA0_EN enables SAA acceleration. If either feature is disabled, that table partition (SAP or SAA) is not searched, and so is not a factor in determining FramePending status for the transmitted Acknowledge frame. If *both* features are disabled, FramePending status defaults to software control, and merely tracks the state of the ACK_FRM_PND register bit; in this case software must manage FramePending status for all auto-TxAck frames.

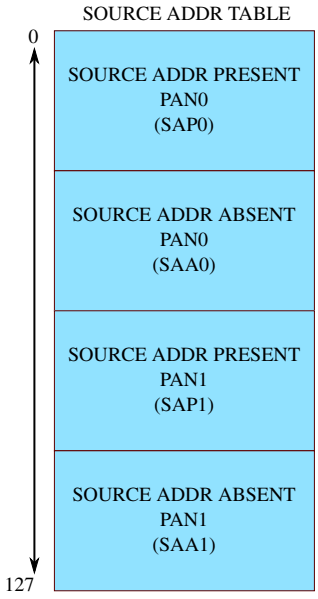
Software can also take direct control of FramePending status for the next auto-TxAck frame at any time (regardless of whether SAP or SAA acceleration is enabled), by setting the ACK_FRM_PND_CTRL bit; in this case, hardware FramePending status will track the state of ACK_FRM_PND.

In order to support Dual PAN mode, a device could theoretically be a PAN Coordinator on both networks. Thus, a coordinator device may need to maintain distinct message pending lists and/or neighbor tables for the 2 PANs. Accordingly, the packet processor further subdivides the Source Address Management table into 4, instead of 2, partitions:

1. SAP0: Source Address Present Partition for PAN0
2. SAA0: Source Address Absent Partition for PAN0

3. SAP1: Source Address Present Partition for PAN1
4. SAA1: Source Address Absent Partition for PAN1

SOURCE ADDRESS TABLE PARTITIONS



Four register control bits enable each partition individually. If a partition is enabled, and a MAC poll request is received on the corresponding PAN (e.g. SAP0 or SAA0 partitions on PAN0), then the partition is searched by the packet processor, looking for a source address match (or absence), and the result of the search affects the FramePending status; if a partition is disabled, the partition is not searched, and will not influence FramePending status. The register bits are described in the table below.

REGISTER NAME	DESCRIPTION
SAP0_EN	Enables SAP0 Partition
SAA0_EN	Enables SAA0 Partition
SAP1_EN	Enables SAP1 Partition
SAA1_EN	Enables SAA1 Partition

For maximum flexibility in supporting all combinations of message-pending status, neighbor-table status, and dual PAN mode, the dividing-line between all the partitions is fully programmable. The SAP0 partition always starts at table index 0. Three registers control the starting point for the other 3 partitions. The starting point is defined the first table index (0-127) of that partition. The registers are described below, along with some software restrictions to ensure table consistency.

REGISTER NAME	DESCRIPTION	RESTRICTIONS
SAA0_START[6:0]	First Index of SAA0 partition.	If SAA0_START=0, then there is no SAP0 partition (SAP0_EN should be set to 0)
SAP1_START[6:0]	First Index of SAP1 partition.	Software must ensure that: **SAP1_START ≥ SAA0_START**

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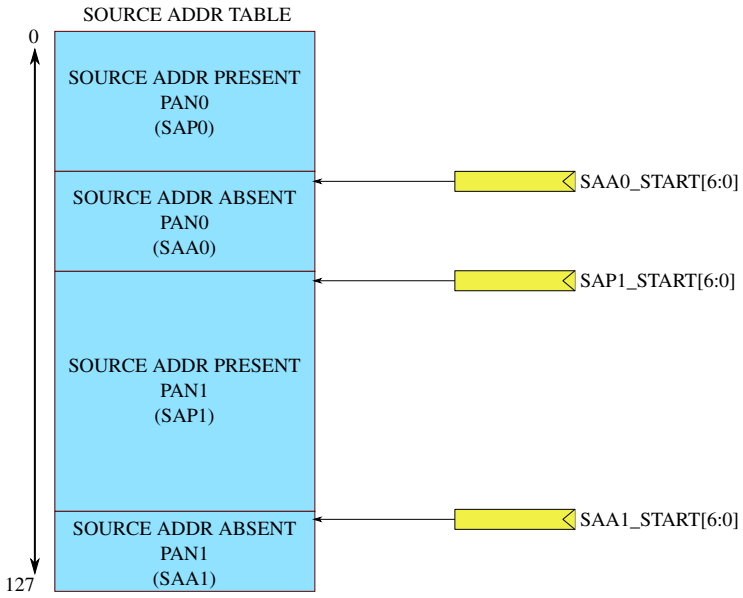
REGISTER NAME	DESCRIPTION	RESTRICTIONS
		If SAP1_START = SAA0_START, then there is no SAA0 partition (SAA0_EN should be set to 0)
SAA1_START[6:0]	First Index of SAA1 partition.	Software must ensure that: **SAA1_START ≥ SAP1_START** If SAA1_START = SAP1_START, then there is no SAP1 partition (SAP1_EN should be set to 0)

A diagram which depicts one example of how the dividing-line registers affect partitioning of the table, is shown below.

SOURCE ADDRESS TABLE PARTITIONS -- NON-EQUAL SIZES (EXAMPLE)



Each table partition consists of one or more indices, which can be used to store source address checksums. The first index for any partition, is defined by the aforementioned *PARTITION*_START[6:0] register, where *PARTITION*_ is one of {SAP0, SAP1, SAA0, SAA1}. The last index for any partition, is defined by the next higher partition's *PARTITION*_START[6:0] register, minus 1. When populating the table with source address information, software must be sure to select an index that is within the defined range for the partition. For example, when installing a checksum in the SAP1 partition:

SAP1_START ≤ Selected_Index ≤ (SAA1_START – 1)

To populate the table partitions, a 7-bit register SAM_INDEX[6:0] is provided, as well as a "index enable bit", and a "index invalidate" bit. A 16-bit SAM_CHECKSUM[15:0] is provided, into which software will write the computed checksum. Installing a checksum into any partition is referred to as "Enabling an Index", and removing a checksum from any partition is referred to as "Invalidating an Index". A description of the registers is provided in the following table:

REGISTER NAME	DESCRIPTION
SAM_CHECKSUM[15:0]	Software-computed source address checksum, to be installed into a table index

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REGISTER NAME	DESCRIPTION
SAM_INDEX[6:0]	Contains the table index to be enabled or invalidated. Software must ensure that the index is within the range of the desired partition.
SAM_INDEX_WR	For 32-bit writes, this must be set to indicate that the table entry specified by SAM_INDEX[6:0] is to be written; if SAM_INDEX_WR=0, the table entry is not written, but the SAM_INDEX[6:0] register is updated. For 8-bit writes, this bit is ignored.
SAM_INDEX_EN	Enable the index selected by SAM_INDEX[6:0] for searching.
SAM_INDEX_INV	Invalidate the index selected by SAM_INDEX[6:0]
FIND_FREE_IDX	After modifying Valid bits (enabling or invalidating), write this bit to 1 to force HW to update the “First Free Index” registers to account for the changed Valid bits. This HW update process takes 4us. SW can poll SAM_BUSY to determine when the table update is complete. Write-only bit. Writing 0 to this bit has no effect. Readback value is indeterminate.
SAM_BUSY	HW is in the process of updating the Source Address table, either in response to a poll indication from the packet processor, or due to SW setting FIND_FREE_IDX=1. In the latter case, SW should poll SAM_BUSY until low before accessing the “First Free Index” registers. Read-only bit.
INVALIDATE_ALL	Writing a 1 to this bit clears all 128 Valid bits. Invalidates the entire table. Write-only bit. Writing 0 to this bit has no effect. Readback value is indeterminate.

All the index-control registers reside within a single 32-bit word, so that a single 32-bit write can store a new checksum in the table, and simultaneously enable, or invalidate, the index. For 32-bit writes, SAM_INDEX_WR must be set to 1 to cause the SAM_CHECKSUM[15:0] to be loaded into the table at the address specified by SAM_INDEX[6:0]. For 32-bit reads, it is necessary first to update SAM_INDEX[6:0] to the desired table index, if it is not already set to the desired index; this requires a write to SAM_INDEX[6:0] with SAM_INDEX_WR=0, so as to not update the table contents. Then, a subsequent 32-bit read will return the table contents at the desired index.

For systems that don’t support 32-bit writes, the register fields should be written in the following order:

1. SAM_INDEX[6:0]
2. SAM_CHECKSUM (the 2 bytes can be written in either order)
3. SAM_INDEX_EN (to enable), or SAM_INDEX_INV (to invalidate)

During operation, when a packet is received and the packet processor searches the table for a source address match, only enabled indices within each partition are searched. Invalidated indices are ignored.

To assist software in finding an available index to store the next source address checksum, the packet processor makes available the following 4 read-only registers:

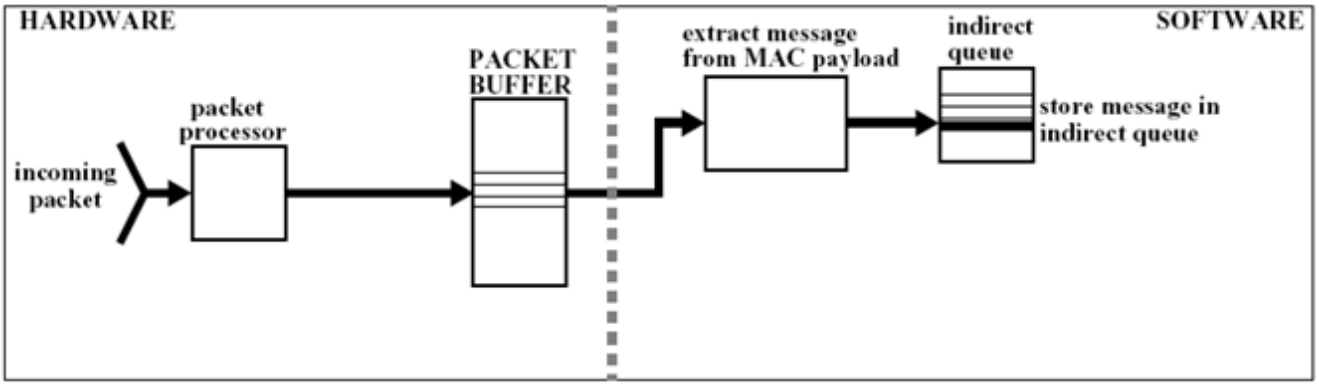
REGISTER NAME	DESCRIPTION
SAP0_1ST_FREE_IDX[6:0]	First non-enabled (invalid) index in the SAP0 partition
SAA0_1ST_FREE_IDX[6:0]	First non-enabled (invalid) index in the SAA0 partition
SAP1_1ST_FREE_IDX[6:0]	First non-enabled (invalid) index in the SAP1 partition
SAA1_1ST_FREE_IDX[6:0]	First non-enabled (invalid) index in the SAA1 partition

Operational Use

The following flow description illustrates how hardware and software interact to utilize the Source Addressing Management feature to facilitate pending-message handling and neighbor table management. This flow assumes both SAP and SAA acceleration are enabled, and Dual PAN mode is in effect. There are 11 sequential steps.

Step 1: Message Packet Reception, Extracting the Message, Indirect Queue Management

A message (data frame) is received by a coordinator. The message is received from one end device, and is intended for another end device. The coordinator's packet processor receives the packet, and stores it in the packet buffer. Coordinator software downloads the packet data from the packet buffer, extracts the message from the MAC payload, and stores the message in its indirect queue.



Step 2: Software computes address checksum

Coordinator software also extracts the destination information (Destination PANID and Destination Address), from the data packet stored in the packet buffer. Software uses this information to compute a 16-bit checksum. This checksum uniquely identifies the sending device, with a high degree of reliability. The checksum is computed according to the following rules:

Destination Addressing Mode	Rule
Mode 2 (short address)	Checksum = (Destination PAN ID + DstAddr[15:0]) % 65536
Mode 3 (long address)	Checksum = (Destination PAN ID + DstAddr[15:0]) % 65536 Checksum = (Checksum + DstAddr[31:16]) % 65536 Checksum = (Checksum + DstAddr[47:32]) % 65536 Checksum = (Checksum + DstAddr[63:48]) % 65536

Step 3: Software populates the address table

Coordinator software chooses an index in the Source Address Table in which it will store the just-computed checksum. If the data packet was received on PAN0, an index in the SAP0 partition should be chosen. Software may consult the register SAP0_1ST_FREE_IDX[6:0] to find the first available index in this partition. If the data packet was received on PAN1, an index in the SAP1 partition should be chosen. Software may consult the register SAP1_1ST_FREE_IDX[6:0] to find the first available index in this partition.

If an index is chosen which is already valid, software should first invalidate the index with the following procedure:

1. Set SAM_INDEX[6:0] to the selected index
2. Set SAM_INDEX_EN=0 and SAM_INDEX_INV=1

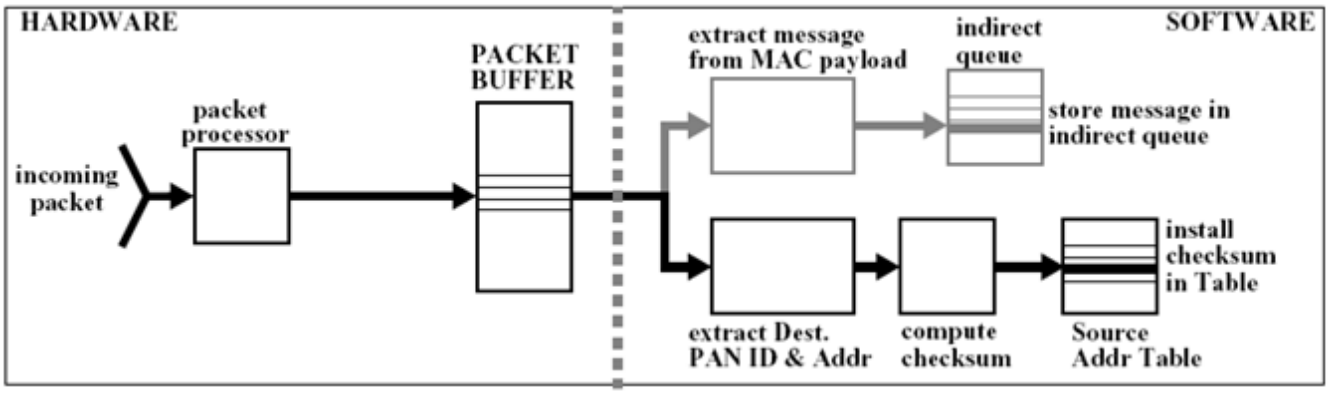
These steps can be performed in a single, 32-bit register write.

To install the source address checksum into the index and enable the index, the following procedure should be used:

1. Program SAM_CHECKSUM[15:0] to the computed checksum
2. Set SAM_INDEX[6:0] to the selected index
3. Set SAM_INDEX_EN=1 and SAM_INDEX_INV=0

These steps can be performed in a single, 32-bit register write.

The index is now enabled, and the packet processor will include it in its search when the next MAC Poll Request is received.



Step 4: Incoming Poll request, Packet Processor parses the Auxiliary Security Header

An incoming packet is received. The packet processor performs routine packet filtering. After determining that the packet is type 'MAC Command', the packet processor must perform additional packet parsing in order to locate the packet's Command Frame Identifier. This is the octet that distinguishes this command as being of type "data request", from other MAC Command types. For the packet processor, this extra parsing is more complex, because the Command Frame Identifier is part of the MAC payload; this is the only scenario where the packet processor is required to parse the payload. This is further complicated by the fact that the revision 2006 (and subsequent) of the 802.15.4 wireless MAC standard, includes a variable-length "Auxiliary Security Header", prior to the MAC payload. This header is only present for FrameVersion > 0, and SecurityEnabled = 1. The packet processor must conditionally parse this header in order to locate the start of the MAC payload, where the Command Frame Identifier is located. The packet processor uses 2 subfields of the Frame Control Field to parse the Auxiliary Security Header (A.S.H.): FrameVersion, and SecurityEnabled. The packet processor parses the Auxiliary Security Header (A.S.H.) according to the following table:

Length of Auxiliary Security Header (Octets)	SecurityEnabled (Frame Control Field)	FrameVersion (Frame Control Field)	KeyIdentifierMode (Security Control Field)	Remarks
0	0	00 or 01	-	If !SecurityEnabled, no ASH regardless of FrameVersion
0	1	00	0	If packet is 2003-compliant, no ASH
5 Security Control (1 octet) + Frame Counter (4 octet)	1	01	0x00	ASH present. Length of ASH computed by HW.

Table continues on the next page...

Table continued from the previous page...

Length of Auxiliary Security Header (Octets)	SecurityEnabled (Frame Control Field)	FrameVersion (Frame Control Field)	KeyIdentifierMode (Security Control Field)	Remarks
6 Security Control (1 octet) + Frame Counter (4 octet) + Key Identifier (1 octet)	1	01	0x01	ASH present. Length of ASH computed by HW.
10 Security Control (1 octet) + Frame Counter (4 octet) + Key Identifier (5 octet)	1	01	0x2	ASH present. Length of ASH computed by HW.
14 Security Control (1 octet) + Frame Counter (4 octet) + Key Identifier (9 octet)	1	01	0x3	ASH present. Length of ASH computed by HW.
-	-	10 or 11	-	HW will handle these FrameVersion's indentically to FrameVersion 01

The contents of the A.S.H. are irrelevant to the packet processor; only its length is important. This is because the octet which immediately follows the A.S.H. is the Command Frame Identifier. This is all the packet processor needs to know.

Step 5: Hardware extracts the Command Frame Identifier

After parsing the A.S.H. (if present), the next octet in the MAC payload, in accordance with the 802.15.4 standard, is the Command Frame Identifier.

Command frame identifier	Command name	RFD		Subclause
		Tx	Rx	
0x01	Association request	X		5.3.1
0x02	Association response		X	5.3.2
0x03	Disassociation notification	X	X	5.3.3
0x04	Data request	X		5.3.4
0x05	PAN ID conflict notification	X		5.3.5
0x06	Orphan notification	X		5.3.6
0x07	Beacon request			5.3.7
0x08	Coordinator realignment		X	5.3.8
0x09	GTS request			5.3.9
0x0a–0xff	Reserved			—

The packet processor checks to see if the Command Frame Identifier = 0x4. If it is not, packet processing for this frame is complete, the remainder of the packet is received, without inspection by the packet processor, and is stored the packet buffer. If the Command Frame Identifier = 0x4, then this is a data request, and assuming the prior rules-checking and address-checking on this packet have already passed, then the Source Address Matching function will be applied to this packet, continuing in STEP 6. Source address matching function can be applied to Frame Version 1 data packets also for supporting Enhanced Frame Pending feature by setting ENABLE_FV1_ DATA_PKT_IND to 0x1.

Step 6: Hardware Computes the Source Address Checksum

The packet processor uses the received Source PAN ID and Source Address for this packet to compute a 16-bit Source Address checksum. This checksum uses precisely the same algorithm that software uses to compute its Address checksum (see STEP 2), except that the *Source* PAN ID and address are used, rather than the Destination PAN ID and address. This checksum uniquely identifies the sending device, with a high degree of reliability. Note if the incoming packet's Frame Control Field has the PANIDCompression subfield asserted, the packet processor will substitute "Destination PAN ID" for "Source PAN ID" in the computation, since Source PAN ID will not be present under these circumstances.

Step 7: Hardware performs "Source Address Present" Table Search

If the MAC poll request was received on PAN0, and SAP0_EN=1 to enable searches of the PAN0 "Source Address Present" partition, the packet processor uses its Source Address checksum to look for a match in the SAP0 partition of the table. Only table entries that are enabled, are compared against (see STEP 3); table indices which are not enabled, are ignored in the search.

If a single table match is found (i.e., 1 software-computed checksum in SAP0 partition matches the hardware-computed checksum for the incoming packet), this means that there is a message for this requestor in the coordinator's message queue. For a SAP0 match, the packet processor takes these 2 steps:

1. Set SAP0_ADDR_PRESENT=1
2. Set SAP0_MATCH[6:0] to the index which matched

If multiple table matches are found (i.e., more than 1 software-computed checksum in the SAP0 partition matches the hardware-computed checksum for the incoming packet), this means that there are multiple messages for this requestor in

the coordinator's message queue. In this case, the packet processor takes the same steps as for a single match, with the SAP0_MATCH[6:0] register being set to the lowest-value matching index (i.e., the smallest number) within the SAP0 partition.

If no source address match is found in the SAP0 table search, the packet processor will set SAP0_ADDR_PRESENT=0.

If, on the other hand, the MAC poll request was received on PAN1, and SAP1_EN=1 to enable searches of the PAN1 "Source Address Present" partition, the packet processor uses its Source Address checksum to look for a match in the SAP1 partition of the table. Only table entries that are enabled, are compared against (see STEP 3); table indices which are not enabled, are ignored in the search.

If a single table match is found (i.e., 1 software-computed checksum in SAP1 partition matches the hardware-computed checksum for the incoming packet), this means that there is a message for this requestor in the coordinator's message queue. For a SAP1 match, the packet processor takes these 2 steps:

1. Set SAP1_ADDR_PRESENT=1
2. Set SAP1_MATCH [6:0] to the index which matched

If multiple table matches are found (i.e., more than 1 software-computed checksum in the SAP1 partition matches the hardware-computed checksum for the incoming packet), this means that there are multiple messages for this requestor in the coordinator's message queue. In this case, the packet processor takes the same steps as for a single match, with the SAP1_MATCH[6:0] register being set to the lowest-value matching index (i.e., the smallest number) within the SAP1 partition.

If no source address match is found in the SAP1 table search, the packet processor will set SAP1_ADDR_PRESENT=0.

Step 8: Hardware performs "Source Address Absent" Table Search

If the MAC poll request was received on PAN0, and SAA0_EN=1 to enable searches of the PAN0 "Source Address Absent" partition, the packet processor uses its Source Address checksum to look for a match in the SAA0 partition of the table. Only table entries that are enabled, are compared against (see STEP 3); table indices which are not enabled, are ignored in the search.

If one (or more) table match is found (i.e., a software-computed checksum in SAA0 partition matches the hardware-computed checksum for the incoming packet), this means that the end device which sent the poll request is a valid child of this parent. For a SAA0 match, the packet processor takes these 2 steps:

1. Set SAA0_ADDR_ABSENT=0
2. Set SAA0_MATCH[6:0] to the first index which matched

If *no* source address match is found in the SAA0 table search, the packet processor will set SAA0_ADDR_ABSENT=1.

If, on the other hand, the MAC poll request was received on PAN1, and SAA1_EN=1 to enable searches of the PAN1 "Source Address Absent" partition, the packet processor uses its Source Address checksum to look for a match in the SAA1 partition of the table. Only table entries that are enabled, are compared against (see STEP 3); table indices which are not enabled, are ignored in the search.

If one (or more) table match is found (i.e., a software-computed checksum in SAA1 partition matches the hardware-computed checksum for the incoming packet), this means that the end device which sent the poll request is a valid child of this parent. For a SAA1 match, the packet processor takes these 2 steps:

1. Set SAA1_ADDR_ABSENT=0
2. Set SAA1_MATCH[6:0] to the first index which matched

If *no* source address match is found in the SAA1 table search, the packet processor will set SAA0_ADDR_ABSENT=1.

Step 9: Hardware determines FramePending status

The packet processor maintains an internal flag called **rx_frame_pending**, which is sent to the TX_PACKET block after every received packet, to directly control the state of the FramePending subfield of the Frame Control Field in the upcoming auto-TxAck frame (if enabled with AUTOACK=1).

If the Source Address Management feature is completely disabled, i.e.,

SAP0_EN = SAA0_EN = SAP1_EN = SAA1_EN = 0

then the packet processor will set the **rx_frame_pending flag** to the value of the ACK_FRM_PND register, putting the state of FramePending under direct software control.

Otherwise, if *any* of the following conditions are met, the packet processor will set its **rx_frame_pending** flag to 1:

1. The MAC Poll Request was received on PAN0, SAP0_EN=1, and SAP0_ADDR_PRESENT=1
2. The MAC Poll Request was received on PAN1, SAP1_EN=1, and SAP1_ADDR_PRESENT=1
3. The MAC Poll Request was received on PAN0, SAA0_EN=1, and SAA0_ADDR_ABSENT=1
4. The MAC Poll Request was received on PAN1, SAA1_EN=1, and SAA1_ADDR_ABSENT=1

If none of the conditions are met, **rx_frame_pending** flag will be set to 0.

Step 10: Receive interrupt RXIRQ

The packet processor receives the remainder of the packet, and verifies the FCS. Assuming the CRC check passes, the RXIRQ interrupt is issued. In the coordinator software's RXIRQ Interrupt Service Routine, software can determine if the received packet was a MAC Poll Request by reading the PI bit of the IRQSTS register. If PI=0, the received packet was not a poll request, and no action relating to Source Address Matching need be taken.

Otherwise, if *either* SAP0_ADDR_PRESENT=1 or SAP1_ADDR_PRESENT=1, an auto-TxAck packet is being sent with the FramePending subfield set to 1, so software should follow up by constructing a data packet (or packets) for the requesting end device, with a payload consisting of the message for this device which had been stored in the coordinator's indirect queue.

Also, if *either* SAA0_ADDR_ABSENT=1 or SAA1_ADDR_ABSENT=1, an auto-TxAck packet is being sent with the FramePending subfield set to 1, so software should follow up by constructing a "Leave Message" for the requesting end device.

Step 11: Software disables the spent index

In the final step, coordinator software must disable (invalidate) the index which was just used to locate and send the stored message to the requesting end device. To disable the index:

1. Set SAM_INDEX[6:0] to the selected index
2. Set SAM_INDEX_EN=0 and SAM_INDEX_INV=1

At this point, the disabled index is now an available table entry, which can be used to install a new Address checksum for another message in the indirect queue.

52.4.4.4.1.2.1.1.3.4 Dual PAN Mode

In the past, radio transceivers designed for 802.15.4 applications allow a device to associate to one and only one PAN (Personal Area Network), at any given time. The Packet Processor includes hardware support for a device to reside on two networks simultaneously. In optional Dual PAN mode, the device will alternate between the 2 PAN's, under hardware or software control. Hardware support for Dual PAN operation consists of 2 sets of PAN and IEEE addresses for the device, 2 different channels (one for each PAN), a programmable timer to automatically switch PAN's (including on-the-fly channel-changing) without software intervention, control bits to configure and enable Dual PAN mode, and read-only bits to monitor status in Dual PAN mode. A device can be configured to be a PAN Coordinator on either network, both networks, or neither.

For the purpose of defining a "PAN" in the context of Dual PAN mode, two sets of network parameters are maintained. In this document, "PAN0" and "PAN1" will be used to refer to the 2 PAN's. Each parameter set uniquely identifies a PAN for Dual PAN mode. These parameters are:

PAN0	PAN1
CHANNEL_NUM0	CHANNEL_NUM1
MACPANID0 (16-bit register)	MACPANID1 (16-bit register)
MACSHORTADDRS0 (16-bit register)	MACSHORTADDRS1 (16-bit register)
MACLONGADDRS0 (64-bit registers)	MACLONGADDRS1 (64-bit registers)
PANCORDNTR0 (1-bit register)	PANCORDNTR1 (1-bit register)

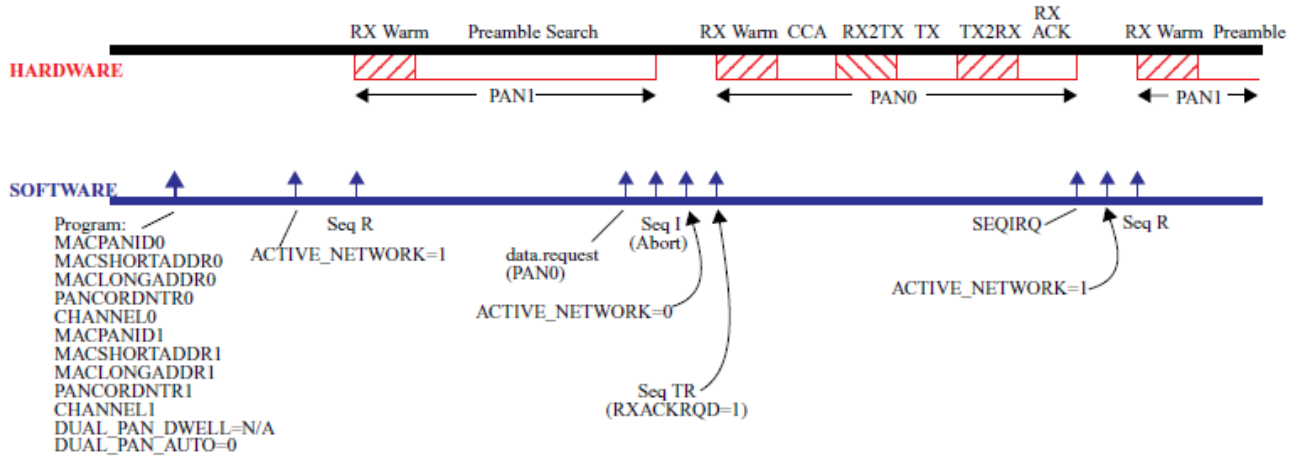
During device initialization, if Dual PAN mode is to be utilized, software will program both parameters sets, to configure the hardware for operation on two networks.

Two modes are available for Dual PAN operation: manual and automatic.

Manual Dual PAN

In manual Dual PAN mode, software controls which PAN is selected for transmission and reception, at all times. Software populates both PAN network parameter-set registers listed above. Software then selects a PAN to begin transmission or reception. A single control bit **ACTIVE_NETWORK**, selects the PAN. To select PAN0, **ACTIVE_NETWORK** should be set to 0; to select PAN1, **ACTIVE_NETWORK** should be set to 1. Software then initiates an autosequence by writing the appropriate value to XCVSEQ (PHY_CTRL1 Register). At any point, software can elect to switch to the alternate PAN. To do so, software aborts the sequence (if one is active) by writing XCVSEQ=IDLE. Software then toggles **ACTIVE_NETWORK**, and restarts a new sequence with XCVSEQ. Software is responsible for aborting and initiating sequences. Hardware is responsible for warming up the transceiver on the selected channel (CHANNEL_NUM0 or CHANNEL_NUM1), and performing address-filtering on the selected network's address parameters (PANCORDNTR, MacPanID, Short Address, and/or IEEE address). Software overhead is significantly reduced in this mode, since there is no need to re-program all of the PAN-select registers every time the PAN is toggled in Dual PAN mode; only a single bit (**ACTIVE_NETWORK**) need be written. For manual Dual PAN operation, **DUAL_PAN_AUTO** should be set to 0.

The following diagram depicts Dual PAN operation in manual mode. In this example, software populates both PAN parameters sets during initialization. In this example, software elects to initiate packet reception on PAN1, so **ACTIVE_NETWORK** is set to 1. Software initiates the Sequence R by writing to XCVSEQ. Hardware warms up the receiver on CHANNEL_NUM1 and enters preamble-search. In this example, no packet is received, but a data request from higher-level software requires a switch to PAN0. Software responds by aborting the reception by writing Sequence I to XCVSEQ. Software then sets **ACTIVE_NETWORK** to 0 to select PAN0. In the example, software initiates a Sequence TR. Hardware warms up the receiver for CCA on CHANNEL_NUM0, performs CCA (channel is idle), warms down the receiver, and warms up the transmitter on CHANNEL_NUM0, transmits the requested packet, warms down the transmitter and warms up the receiver again (as per the autosequence) on CHANNEL_NUM0, to receive the acknowledge packet. The acknowledge packet is received and the autosequence completes successfully with RXIRQ and SEQIRQ. Software elects to resume packet reception on PAN1 (which was in progress before the data request). Software toggles **ACTIVE_NETWORK** back to 1, and re-initiates Sequence R.



Auto Dual PAN

In automatic Dual PAN mode, hardware is responsible for alternating the selected PAN, at a pre-programmed interval. Software programs a "PAN dwell time", which determines the amount of time during which the hardware will receive on a given PAN. This is done by programming the **DUAL_PAN_DWELL** register. Software sets the **DUAL_PAN_AUTO** bit to 1 for automatic Dual PAN operation, and sets **ACTIVE_NETWORK** to correspond to the PAN on which it desires packet reception to begin. Software then initiates a Sequence R. Hardware warms up the receiver on the selected PAN, and begins preamble search. When the dwell time expires, assuming preamble and SFD have not been detected, hardware will switch to the alternate PAN. This includes an on-the-fly channel change. Once switched to the alternate PAN, hardware will use the address filtering parameters (PANCORDNTR, MacPanID, Short Address, and/or IEEE address) programmed for the alternate PAN. Once the dwell time expires on the alternate PAN, assuming preamble and SFD have not been detected, hardware will switch back to the original PAN. This process will repeat indefinitely, until one of the following occurs:

1. A packet is successfully received (address match and CRC valid).
2. Software aborts the Sequence R
3. A TMR3 RX timeout, which automatically aborts the Sequence R
4. A PLL unlock automatically aborts the Sequence R (if unlock aborting is enabled)

If the hardware PAN dwell timer expires *during* a packet reception (i.e., preamble and SFD have been detected during a Sequence R), the PAN-switch will be delayed until the packet is completely received. If the packet is received successfully (address match and CRC valid), the receive sequence will terminate with RXIRQ and SEQIRQ (if an auto-Acknowledge was requested and enabled, the sequence will complete after the Acknowledge packet was transmitted, and TXIRQ will also be set, in addition to RXIRQ and SEQIRQ); the PAN switch will occur at this point, after the Sequence has returned to IDLE.

If the received packet fails FCS (CRC check), or, if the packet was not intended for the device (address mismatch), the hardware will toggle the PAN, and return to preamble-search on the new PAN.

If the hardware PAN dwell timer expires during a state *other* than RX preamble search during Sequence R (i.e., if expiration occurs during TX, CCA, ED, Sequence TR, or any warmup or transitional state), PAN-switch will be delayed until either:

1. Preamble Search state is reached during a Sequence R (not Sequence TR)
2. Sequence returns to IDLE.

At any point, software can elect to interrupt the automatic Dual PAN operation, by aborting the sequence with a XCVSEQ=IDLE, and the setting the **DUAL_PAN_AUTO** bit to 0. In response, hardware will freeze the current state of the dwell timer, and capture the currently-selected PAN, so that hardware-controlled PAN alternation can resume where it left off, later. Software can then tend to that tasks that caused the Dual PAN interruption. When software wants to resume Dual PAN operation, it then sets **DUAL_PAN_AUTO**=1, and re-initiates Sequence R. Hardware will resume the dwell timer from the point it was

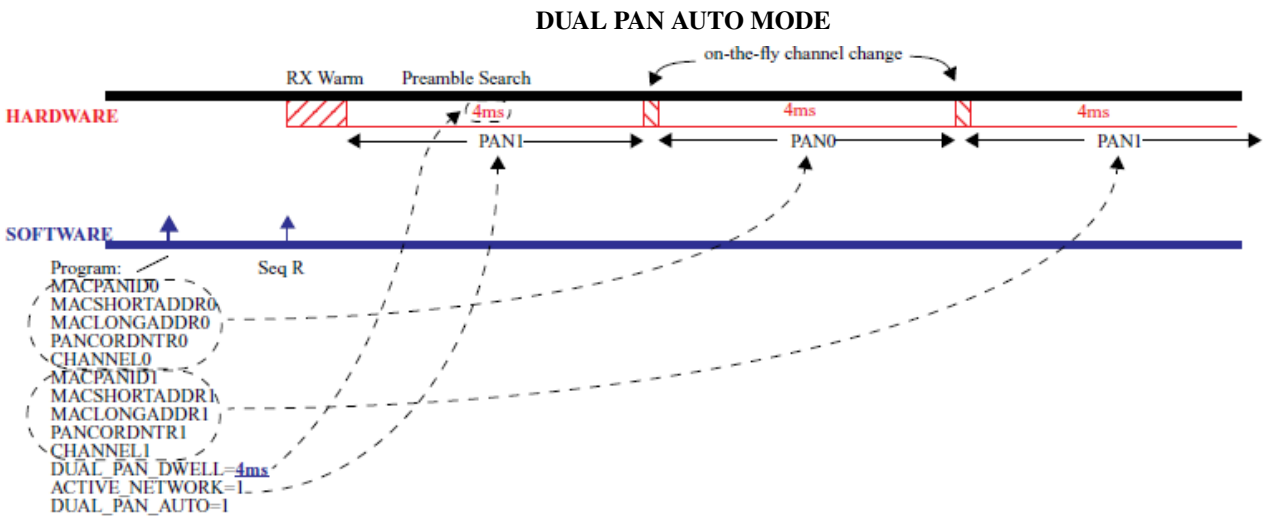
frozen earlier, on the same PAN, and will warmup the receiver to receive on the PAN which was being monitored before the interruption. Hardware will dwell on that PAN until the timer expires, and then switch PAN's (assuming no preamble and SFD detected, subject to the conditions listed above). Software can always determine the selected PAN at any time, in any mode, by reading **CURRENT_NETWORK** bit. If **DUAL_PAN_AUTO**=0, then **CURRENT_NETWORK** = **ACTIVE_NETWORK**. If **DUAL_PAN_AUTO**=1, then **CURRENT_NETWORK** is controlled by hardware.

To initiate auto Dual PAN operation for the first time, or to reset the dwell timer to its programmed value and allow software to select the initial PAN for auto Dual PAN operation, software should program the desired initial PAN to **ACTIVE_NETWORK** (0 for PAN0, 1 for PAN1), and then program the desired dwell time into the **DUAL_PAN_DWELL** register. Hardware always responds to a write to **DUAL_PAN_DWELL**, by resetting the dwell timer to its programmed value, and selecting the initial PAN for auto Dual PAN operation, based on the state of **ACTIVE_NETWORK**. A write to **DUAL_PAN_DWELL**, always re-initializes the DWELL TIMER to the programmed value. If a write to **DUAL_PAN_DWELL** occurs during an autosequence, the DWELL TIMER will begin counting down immediately. If a write to **DUAL_PAN_DWELL** occurs when there is no autosequence underway, the DWELL TIMER will not begin counting until the next autosequence begins; it will begin counting at the start of the autosequence warmup. Under all circumstances, **DUAL_PAN_AUTO** must be asserted to allow the DWELL TIMER to count. If **DUAL_PAN_AUTO**=0, the DWELL TIMER will freeze and hold its state, until **DUAL_PAN_AUTO**=1. However, a write to **DUAL_PAN_DWELL** will still initialize the DWELL TIMER to its programmed value, regardless of the state of **DUAL_PAN_AUTO**.

At any point during auto Dual PAN mode, software can ascertain the PAN currently being serviced by hardware, by reading the **CURRENT_NETWORK** bit. Software can also determine the time-remaining in the current dwell, by reading the **DUAL_PAN_REMAIN** Register.

In auto Dual PAN mode, software retains responsibility for initiating and aborting sequences. There is no provision for hardware-initiated sequences. TMR2 may be used to initiate an autosequence at a future time. TMR3 may be used as an RX hardware-abort mechanism.

The following diagram depicts Dual PAN operation in automatic mode. In this example, software populates both PAN parameters sets during initialization. In this example, software wants to initiate packet reception in auto Dual PAN mode, on PAN1, so **ACTIVE_NETWORK** is set to 1. For auto Dual PAN operation, software programs the desired PAN-switching interval into **DUAL_PAN_DWELL** register, in this case, 4ms. Software initiates the Sequence R by writing to XCVSEQ. The dwell timer begins counting as soon as the receiver warmup begins. Hardware warms up the receiver on CHANNEL_NUM1 (since PAN1 was selected as the initial PAN in this example), and begins preamble search. If a packet is received during this interval, hardware applies PAN1 address filtering. In this example, no preamble is detected at the point at which the dwell timer expires. So, at this point, hardware executes a PAN-switch to PAN0. which includes an on-the-fly channel change. The on-the-fly channel change requires approximately 93us and no preamble detection is possible during this "blind spot". (For more details on how the hardware executes the Dual PAN on-the-fly channel change, see Chapter ZSM Sequence Manager, Section Dual PAN Mode.) After the PAN switch, hardware resumes preamble search on CHANNEL_NUM0, and applies PAN0 address filtering if a packet is received. In this example, no preamble is detected at the point at which the dwell timer expires. So, at this point, hardware performs a PAN-switch back to PAN1. And so on and so forth.



Two-PAN-one-channel

A special case occurs if a device is operating in Dual PAN mode (either Auto or Manual mode), and both PAN's occupy the same channel; in other words, CHANNEL_NUM0=CHANNEL_NUM1. In this case, hardware will detect this condition automatically, and apply both sets of address-filtering parameters simultaneously. Hardware will provide Data Indication if the received packet matches either the PAN0 address parameter set {**MACPANID0, MACSHORTADDRS0, MACLONGADDRS0, PANCORDNTR0**}, or the PAN1 address parameter set {**MACPANID1, MACSHORTADDRS1, MACLONGADDRS1, PANCORDNTR1**}. At Data Indication, two status bits can be queried by software to quickly determine on which PAN the packet was received, **RECD_ON_PAN0** or **RECD_ON_PAN1**. In the "Two-PAN-one-channel" scenario, it is possible for a packet to satisfy both sets of addressing parameters (PAN0 and PAN1). When this happens, both **RECD_ON_PAN0** and **RECD_ON_PAN1** will be set. In the "Two-PAN-one-channel" scenario, the **CURRENT_NETWORK** bit should be ignored, since both networks are simultaneously active.

If Dual PAN mode is not to be utilized, **ACTIVE_NETWORK** should be maintained at 0 (default) to select the PAN0 parameters for transceiving. In single PAN operation, the PAN1 parameter registers need not be programmed, and can be used as scratchpad. CHANNEL_NUM1 should not be programmed, and should instead be left in its default state, if Dual PAN mode is not in use.

Dual PAN Channel Override

In Dual PAN mode, in case there is a need to generate a frequency which may be offset from the 16 prescribed 5MHz-spaced channels, to, for example, avoid interference on one of the Dual PAN channels, a method has been provided to do that, by designating one of the two PAN channels to use the transceiver's set of direct frequency-programming registers, instead of CHANNEL_NUMx. Programming the direct frequency-programming registers – integer, numerator, and denominator, allows an RF frequency to be selected with much more precision than the 5MHz granularity of the 802.15.4 mapped-channel registers, CHANNEL_NUM0 and CHANNEL_NUM1. This is referred to as "Dual PAN Channel Override". For more details on this feature, see Chapter ZSM Sequence Manager, Section Dual PAN Channel Override.

52.4.4.4.1.2.1.1.3.5 Active Promiscuous Mode

Functional description

The 802.15.4 Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs) defines the following behavior for Promiscuous Mode operation:

> "In promiscuous mode, the MAC sublayer shall pass all frames received after the first filter directly to the upper layers without applying any more filtering or processing."

Where first level filtering is described as:

> "For the first level of filtering, the MAC sublayer shall discard all received frames that do not contain a correct value in their FCS field in the MFR (see 7.2.1.9)"

Promiscuous mode allows a device to receive and process all 802.15.4 frames which pass FCS check (CRC), regardless of whether or not they are addressed to the device. This allows a device to receive and process all valid traffic on a network. In Promiscuous mode, the Packet Processor will provide a Data Indication on all such packets. This capability allows a simple network sniffer to be constructed, which can display comprehensive packet data for all packets transmitted on a network within receiving range of the device.

Since a device operating in promiscuous mode is designed to do so discreetly, automatic acknowledgement of all received packets is inhibited, regardless of the state of the Ack Request field in the Frame Control Field of the received packet; otherwise, the sniffing device would be acknowledging received frames for which it was not the addressee.

The Packet Processor features an "Active Promiscuous Mode". In this mode, the Packet Processor will process packets according to the same rules that it applies to Promiscuous mode, except that it will automatically transmit an acknowledgement packet *for frames that are addressed to the device*. In other words, in Active Promiscuous mode, if the received frame meets all the address and packet filtering requirements that would have applied in non-promiscuous mode, an acknowledgement packet will be transmitted; a Data Indication will still be provided for all valid packets (those which pass FCS check). Note that all existing packet processor rules governing transmission of acknowledge packets, are still in effect; i.e., AUTOACK bit of the PHY_CTRL1 Register must be set to 1, and the Ack Request field in the Frame Control Field of the received packet must be set to 1.

The Packet Processor can be also programmed to provide a Data Indication for packets which fail FCS check, by setting CRC_MSK=0. Received packets which fail FCS check are never acknowledged, under any circumstances.

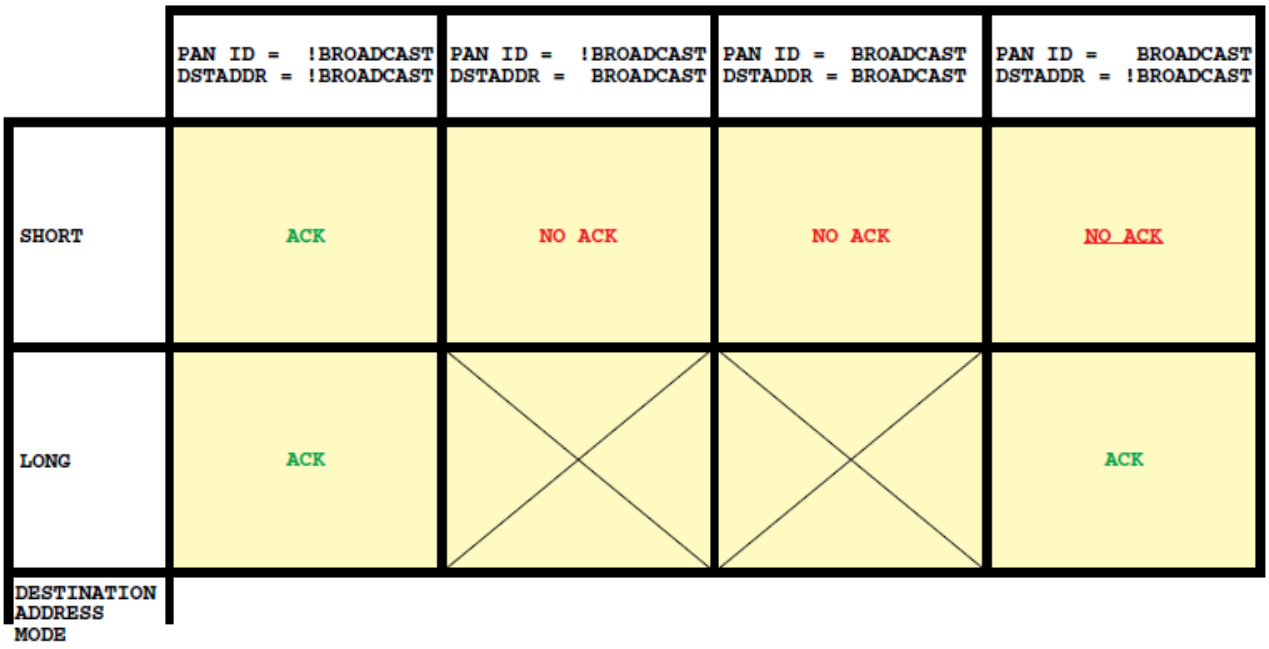
Special Handling for Broadcast Packets

Special rules apply to received packets which contain a broadcast PAN Identifier (0xffff), and/or a broadcast short address (0xffff). According to the 802.15.4 standard,

> “For valid frames that are not broadcast, if the Frame Type subfield indicates a data or MAC command frame and the Acknowledgment Request subfield of the Frame Control field is set to one, the MAC sublayer shall send an acknowledgment frame."

An exception is made for received packets which contain a broadcast PAN Identifier, and a long address which matches the device’s IEEE address. Such packets are acknowledged, because the IEEE address uniquely identifies the device, regardless of PAN. This special case will apply also in Active Promiscuous mode; such packets will be acknowledged. The following diagram describes the packet processor’s "acknowledgement decision" for all permutations of broadcast indicators in the received packet’s addressing fields.

ACKNOWLEDGE-ON-BROADCAST (ALL PERMUTATIONS)



Special Handling for Broadcast Packets

The Packet Processor features an autosequence to automatically receive, and verify, Acknowledge Frames after a Transmit frame has been sent by the device. This is accomplished by programming a Sequence TR with RXACKRQD=1. During normal operation, these receive Acknowledge Frames are not stored in the Packet Buffer. They are merely checked for matching Sequence Number and Frame Version, with a Data Indication issued for a valid match on both. In Active Promiscuous Mode, receive Acknowledge frames *will* be stored into the Packet Buffer, just like any other received frame. This saves software from having to re-construct the contents of the Acknowledge packet, from the contents of the packet which was originally transmitted. Ordinary Promiscuous Mode should therefore not be used with Sequence TR with RXACKRQD=1. Use Active Promiscuous instead.

52.4.4.4.1.2.1.1.3.6 Provisions to Enable Software Support for 802.15.4e and 802.15.4-2015

Addendum 802.15.4e to the 802.15.4-2011 standard introduces 3 new variations on the 802.15.4 MAC Frame Structure:

1. FrameVersion=2 (Frame Types: Beacon, Acknowledge, Data, and MAC Command)
2. LLDN Frame Type
3. Multipurpose Frame Type

In addition, the 802.15.4-2015 revision to the standard introduces a new Frame Type: Extended (Frame Type = 0b111).

All three of the “4e-compliant packets”, as well as the Extended Frame Type, modify the format and definition of the Frame Control Field in such a way as to render parsing of the MHR by the packet processor impossible, without major upgrades to the hardware. For example, the packet processor hardware does not support 8-bit (simple) addressing, nor Sequence Number Suppression.

As in interim solution, provisions have been added to the packet processor to allow these new packet variations to be recognized and conditionally admitted (Data Indication to software). Three new Frame Type control bits, and a modification of the Frame Version Filtering bits, are included in the Packet Processor, and affect hardware packet parsing as indicated in the following table:

REGISTER	DEFINITION
FRM_VER_FILTER[3:0]	Frame Version selector. The incoming packet's Frame Control Field is parsed to obtain the FrameVersion subfield, and that value is compared against this register, in accordance with the following: xxx1: Accept received packets with FrameVersion=00 xx1x: Accept received packets with FrameVersion=01 x1xx: Accept received packets with FrameVersion=10 1xxx: Accept received packets with FrameVersion=11 These filtering rules apply to Beacon, Acknowledge, Data, and MAC Command Frame Types, since these frame types require a 2-octet Frame Control Field which embeds a 2-bit FrameVersion subfield. Later frame types introduced in the 802.15.4e addendum (LLDN, Multipurpose) don't guarantee a FrameVersion subfield with the original meaning, so these filtering rules do not apply to those frame types. See registers LLDN_FT and MULTIPURPOSE_FT.
LLDN_FT	1: LLDN frame type enabled (Frame Type 4) 0: reject all LLDN frames
MULTIPURPOSE_FT	1: Multipurpose frame type enabled (Frame Type 5) 0: reject all Multipurpose frames
EXTENDED_FT	1: Extended frame type enabled (Frame Type 7) 0: reject all Extended frames

The Extended Frame Type does not comply with the General MAC Frame Format, which is shown in the following diagram:

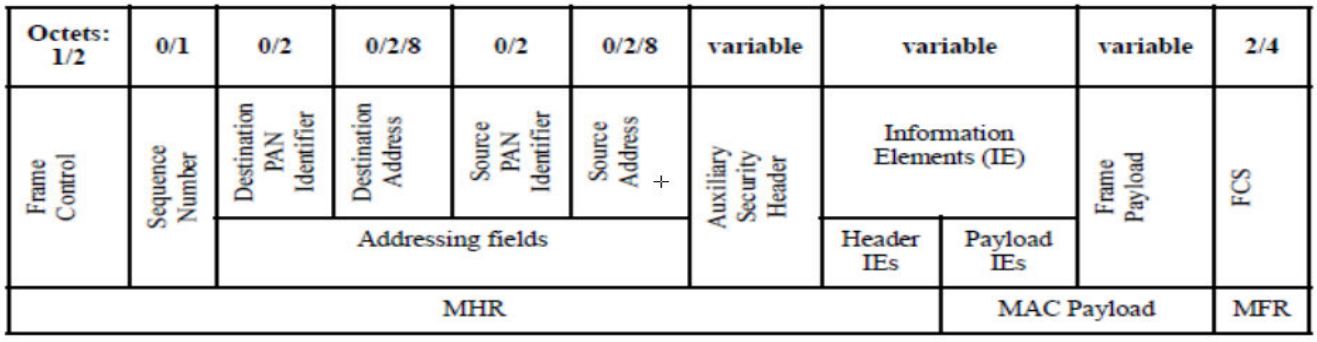


Figure 414. General MAC Frame Format

Instead, the Extended Frame has its own unique format, which is shown in the following diagram:

Bits: 0-2	3-5	variable
Frame Type	Extended Frame Type	Extended Frame Payload

Figure 415. Extended Frame Format

Because the Extended Frame Payload, which is not defined in the 802.15.4-2015 revision to the standard, would be intended to contain and fully specify the FCS, the Packet Processor will not be able to verify FCS on received packets with Frame Type Extended. FCS checking will need to be implemented in software.

Note: If the EXTENDED_FT bit is set to enable Data Indication on packets of Frame Type Extended, software should expect a substantial increase in the frequency of notifications, as a consequence of the lack of hardware verification of FCS, which will have implications for software workload as well as power consumption in the SoC.

When the packet processor receives any of the 4e-compliant frames, if the corresponding control bit is set, the hardware will skip Stage 2 filtering, and merely verify FCS. If FCS passes, the packet processor will notify software of the packet, without inspection of the addressing fields or payload. For such packets, software will be responsible for parsing the MHR and payload sections of the frame. If the corresponding control bit is not set, the packet processor will reject the received packet and there will be no Data Indication.

When the packet processor receives a packet of Frame Type Extended, if the EXTENDED_FT bit is set, the hardware will skip Stage 2 filtering, and after the entire packet is received, the packet processor will merely notify software of the packet, without inspection of the Extended Frame Type bits or the Extended Frame Payload. For such packets, software will be responsible for parsing the Extended Frame Type and the Extended Frame Payload sections of the frame. If the corresponding control bit is not set, the packet processor will reject the received packet and there will be no Data Indication.

Like all existing frames prior to 802.15.4e and 802.15.4-2015, a received frame may require an acknowledgement. In the case of the new 802.15.4e and 802.15.4-2015 frames, the required timing for the acknowledge frame transmission, has been modified. The acknowledgement no longer immediately follows the packet reception. For this reason, upon reception of any of these 4e-compliant 2015-compliant packets, the packet processor will cancel any auto-ACK transmission, regardless of the state of the PHY_CTRL[AUTOACK] bit and AR field of the received packet's Frame Control Field. Software will be responsible for constructing the acknowledgment packet and transmitting it at the appropriate time using a Sequence T.

To help expedite software processing of the 4e- and 2015-compliant Frame Types and Versions, additional status bits have been added to the 802.15.4 register set, which are described in the following table:

STATUS BIT	RESIDES IN REGISTER	DEFINITION
ENH_PKT_STATUS	IRQSTS	1: The last packet received was 4e- or 2015-compliant (SW should query the RX_FRAME_FILTER register for additional status bits) 0: The last packet received was neither 4e- nor 2015-compliant
BEACON_FV2_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType Beacon with FrameVersion 2 0: The last packet received was not a FrameType Beacon with FrameVersion 2
DATA_FV2_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType Data with FrameVersion 2

Table continues on the next page...

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		0: The last packet received was not a FrameType Data with FrameVersion 2
ACK_FV2_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType Acknowledge with FrameVersion 2 0: The last packet received was not a FrameType Acknowledge with FrameVersion 2
CMD_FV2_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType MAC Command with FrameVersion 2 0: The last packet received was not a FrameType MAC Command with FrameVersion 2
LLDN_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType LLDN 0: The last packet received was not a FrameType LLDN
MULTIPURPOSE_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType Multipurpose with FrameVersion 2 0: The last packet received was not a FrameType Multipurpose
EXTENDED_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType Extended 0: The last packet received was not a FrameType Extended

The new status bits are mapped into the 802.15.4 Address space as shown in the diagram below:

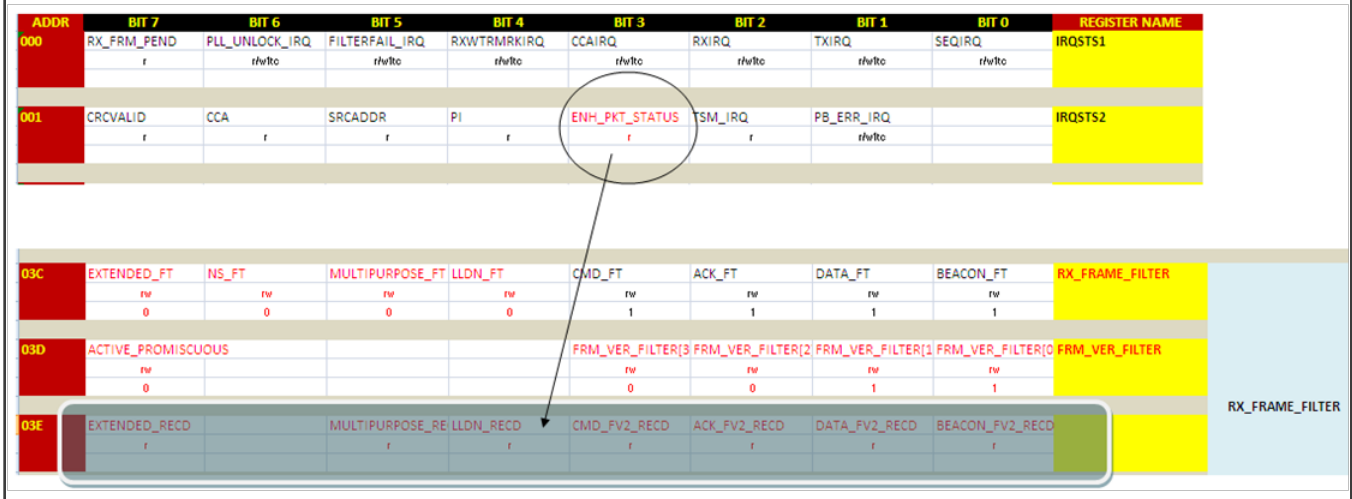

Figure 416. Enhanced Packet Status Bits

52.4.4.4.1.2.1.1.3.7 Clocks

Packet Processor is a fully synchronous module. It has a single clock input **clk_250khz**. The clock frequency, 250KHz, is the 802.15.4 bit rate. This clock input is driven by a divide-down of the RF Oscillator, generated in the CRM (Clocks and Resets module). The Packet Processor has no asynchronous interfaces.

52.4.4.4.1.2.1.1.3.8 Reset

The Packet Processor has a single, active-low, asynchronous reset input: **rst_b** . At integration, this reset should be tied to the master reset for the entire transceiver. There are no special reset requirements.

52.4.4.4.1.2.1.1.3.9 Interrupts

The Packet Processor does not generate any interrupts.

52.4.4.4.1.2.1.1.3.10 Appendix A

FILTERFAIL CODES

A description of the FILTERFAIL codes can be found in the following table.

FILTERFAIL CODE BIT	REASON FOR FILTERFAIL
[0]	Fails Stage 1 Frame Length Checking (FL < 5 or FL > MAXFRAMELENGTH) **Note:** FL < 3 will not generate an SFD, so this bit will not be set
[1]	Fails Stage 1 Section 7.2.1.1.6 or Section 7.2.1.1.8 Checking (DST_ADDR_MODE or SRC_ADDR_MODE = 1)
[2]	For frame version 0 or 1, fails Stage 1 Section 7.2.1.1.5 Checking (Illegal PAN_ID_COMPRESSION Usage); For frame version 2, fails Stage 1 checking not supported cases in 802.15.4-2015 Table 7-2, see leniency[40] for the not supported cases.
[3]	Fails Stage 1 Frame Version Checking
[4]	Fails Stage 2 Auto-RxAck Checking (Illegal Ack Frame Format in Sequence TR)
[5]	Fails Stage 2 Frame Type Checking (Incorrect Frame Filter Bit setting)
[6]	Fails Stage 2 Frame Length Checking (Illegal Beacon, Data, or Cmd FL)
[7]	Fails Stage 2 Addressing Mode Checking (Illegal Addressing Mode for Beacon, Data, OR Cmd)
[8]	Fails Stage 2 Sequence Number Matching (Sequence TR Only)
[9]	Fails Stage 2 PAN ID or Address Checking (Beacon, Data, or Cmd)

52.4.4.4.1.2.1.1.3.11 Appendix B

LENIENCY BITS

The Packet Processor performs filtering on all received packets, in order to determine whether the packet is intended for the device. The packet filtering is based on rules. In case any of the packet filtering rules need to be overridden, a 43-bit "leniency register" has been provided. When the leniency register is programmed to its default value (0), all hardware packet filtering rules are in effect, and if an incoming packet violates any rule, a "Filter Fail" will occur (packet will be rejected). When a given leniency register bit is asserted, the packet filtering rule assigned to that bit will not be in effect, and if any incoming packet violates that rule (but no other rules), then a "Filter Fail" will not occur, the packet will not be rejected, the packet will be treated as "intended for the device", and software will be notified of the incoming packet. The table below shows the assignment of leniency bits to packet filtering rules.

LENIENCY BIT	PACKET FILTERING RULE OVERRIDDEN
leniency[0]	Override Stage 1 Frame Length Checking (FL < 5 or FL > MAXFRAMELENGTH)

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LENIENCY BIT	PACKET FILTERING RULE OVERRIDDEN
leniency[1]	Override Stage 1 Section 7.2.1.1.6 Checking (DST_ADDR_MODE = 1)
leniency[2]	Override Stage 1 Section 7.2.1.1.8 Checking (SRC_ADDR_MODE = 1)
leniency[3]	Override Stage 1 Section 7.2.1.1.5 Checking (Illegal PAN_ID_COMPRESSION Usage)
leniency[4]	Override Stage 2 Auto-RxAck Checking (Illegal Ack Frame Format in Sequence TR)
leniency[5]	Override Stage 2 Frame Length Checking (Illegal Beacon, Data, or Cmd FL)
leniency[6]	Override Stage 2 Beacon Frame Address Mode Violations
leniency[7]	Override Stage 2 Data Frame Address Mode Violations
leniency[8]	Override Stage 2 MAC Command Frame Address Mode Violations
leniency[9]	Override Stage 2 Sequence Number Matching
leniency[10]	Override Stage 2 Filter for DST_ADDR_MODE_NONE/SRC_ADDR_MODE_SHORT (Beacon Only)
leniency[11]	Override Stage 2 Filter for DST_ADDR_MODE_NONE/SRC_ADDR_MODE_SHORT (Data and MAC Command Only)
leniency[12]	Override Stage 2 Dst PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_NONE (Data and MAC Command Only)
leniency[13]	Override Stage 2 Dst Short Addr Filter for DST_ADDR_MODE_SHORT/ SRC_ADDR_MODE_NONE (Data and MAC Command Only)
leniency[14]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_SHORT/ PAN_ID_COMPRESSION (Beacon Only)
leniency[15]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_SHORT/ PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[16]	Override Stage 2 Dst Short Addr Filter for DST_ADDR_MODE_SHORT/ SRC_ADDR_MODE_SHORT/PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[17]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_SHORT/ NO_PAN_ID_COMPRESSION (Beacon Only)
leniency[18]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_SHORT/ NO_PAN_ID_COMPRESS ION (Data and MAC Command Only)
leniency[19]	Override Stage 2 Dst Addr Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_SHORT/ NO_PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[20]	Override Stage 2 Src PAN ID Filter for DST_ADDR_MODE_NONE/SRC_ADDR_MODE_LONG/ NO_PAN_ID_COMPRESSION (Beacon Only)
leniency[21]	Override Stage 2 Src PAN ID Filter for DST_ADDR_MODE_NONE/SRC_ADDR_MODE_LONG/ NO_PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[22]	Override Stage 2 Dst PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_NONE (Data and MAC Command Only)
leniency[23]	Override Stage 2 Dst Long Addr Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_NONE (Data and MAC Command Only)

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LENIENCY BIT	PACKET FILTERING RULE OVERRIDDEN
leniency[24]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_LONG/ PAN_ID_COMPRESSION (Beacon Only)
leniency[25]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_LONG/ PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[26]	Override Stage 2 Dst Long Addr Filter for DST_ADDR_MODE_SHORT/ SRC_ADDR_MODE_LONG/PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[27]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_SHORT/ PAN_ID_COMPRESSION (Beacon Only)
leniency[28]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_SHORT/ PAN_ID_COMPRESSION (Data and Mac Command Only)
leniency[29]	Override Stage 2 Dst Long Addr Filter for DST_ADDR_MODE_LONG/ SRC_ADDR_MODE_SHORT/PAN_ID_COMPRESSION (Data and Mac Command Only)
leniency[30]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_LONG/ NO_PAN_ID_COMPRESSION (Beacon Only)
leniency[31]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_LONG/ NO_PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[32]	Override Stage 2 Short Addr Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_LONG/ NO_PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[33]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_SHORT/ NO_PAN_ID_COMPRESSION (Beacon Only)
leniency[34]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_SHORT/ NO_PAN_ID_COMPRESSI ON (Data and MAC Command Only)
leniency[35]	Override Stage 2 Long Addr Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_SHORT/ NO_PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[36]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_LONG (Beacon Only)
leniency[37]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_LONG (Data and MAC Command Only)
leniency[38]	Override Stage 2 Long Addr Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_LONG (Data and MAC Command Only)
leniency[39]	Allow an auto-TxAck frame to be sent, after a receive frame which has all of the following parameters: 1. Destination PAN ID = Broadcast (0xFFFF) 2. Destination Address = !Broadcast (not 0xFFFF) 3. Destination Address Mode = Short Nominally, the SEQ_MGR inhibits auto-TxAck on such frames.
leniency[40]	Override Stage 1 for frame version 2 not supported cases in 802.15.4-2015 Table 7-2. See detail in Chapter "Enhanced Acknowledgment (Enh-Ack) Support".

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LENIENCY BIT	PACKET FILTERING RULE OVERRIDDEN
leniency[41]	Override Stage 2 Auto-RxAck Checking (Illegal EnhAck Frame Format in Sequence TR). 1. The received PAN ID Compression matches the transmitted PAN ID Compression 2. The received Sequence Number Suppression matches the transmitted Sequence Number Suppression 3. The received Destination Address Mode matches the transmitted Source Address Mode
leniency[42]	Override Stage 2 Auto-RxAck Checking (Illegal EnhAck Frame Format in Sequence TR). 1. The Destination Address field, when present, shall contain the value of the Source Address field from the frame that is being acknowledged. 2. The Destination PAN ID, when present, contains the value from the Source PAN ID field from the frame that is being acknowledged.

52.4.4.4.1.2.1.2 Sequence Manager

52.4.4.4.1.2.1.2.1 Introduction

This Section describes the 802.15.4 Sequence Manager.

52.4.4.4.1.2.1.2.1.1 Overview

The 802.15.4 Sequence Manager (ZSM) is a hardware state machine which controls the timing of all transmit, receive, and CCA operations for the 802.15.4 Link Layer. The ZSM manages high-level 802.15.4 required timing (autosequences), and interfaces directly with a lower-level, protocol-neutral sequence manager called the Transceiver Sequence Manager (TSM), which manages the direct control of the digital, analog, and RF components of the 2.4GHz transceiver. See the TSM Chapter for more details.

For each digital and analog element in the 2.4GHz transceiver, the ZSM and TSM operate seamlessly and collaboratively, to perform some or all of the following functions:

- activation
- deactivation
- initialization
- mode transitions
- initiating calibration routines
- clock enabling and disabling
- interrupt triggering and status generation

Designed into the ZSM are a variety of complex sequences, called autosequences, which are sequential concatenations of simpler, building-block sequences. The hardware autosequences provide the following advantages:

- smaller SW memory footprint: HW automates operations previously done by SW
- increases MCU sleep times, reducing current consumption
- handles timing-critical sequences (rx-to-tx), e.g., data-polling, not possible in SW

Sequences can be initiated by software directly, or alternatively, can be initiated automatically at the expiration of a hardware timer. The general parameters of the sequences can be programmed by software prior to initiating the sequences. Such parameters allow software to select, for example:

- whether CCA is required ahead of a transmit sequence
- whether an automatic Ack frame should be transmitted after a receive sequence

- slotted vs. unslotted mode
- type of CCA (e.g., Energy Detect, CCA Mode 2)
- whether the device is a PAN Coordinator or not
- whether the device resides on 2 networks simultaneously (Dual PAN mode)

The ZSM also includes support for Dual PAN Mode, and Active Promiscuous Mode.

52.4.4.4.1.2.1.2.1.2 Features

- Supports complex sequences
- Unburdens software by automating many transceiver operations
- Data-polling accelerator hardware enables critical-timing sequences
- Includes Continuous CCA for low-latency-transmit applications
- Includes capability to conditionally perform CCA prior to every transmit operation
- Includes capability to conditionally transmit an Ack frame after every receive operation
- Supports software- or timer-initiated sequences
- Fully supports 2003 and 2006 versions of the 802.15.4 standard
- Supports slotted and unslotted modes
- Supports beacon-enabled and non-beacon-enabled networks
- Supports orderly transceiver shutdown on PLL unlock event
- Increases software visibility by making SEQ_STATE state readable
- Supports Dual PAN Mode, including on-the-fly channel changing
- Supports Active Promiscuous Mode

52.4.4.4.1.2.1.2.1.3 Modes and operations

The ZSM controls, coordinates, and automates all 802.15.4 transceiver operations within the 2.4GHz radio. Software selects the desired sequence, sets the general parameters, and (optionally) configures a hardware timer to trigger the sequence at a precise time in the future. Subsequently, the MCU can enter a low-power state, or tend to other activities, while the sequence manager state machine conducts the programmed transceiver operations. When the sequence completes, an interrupt alerts the MCU. At this point the MCU can check the completion status of the sequence, download received data from the packet buffer, and then prepare the next sequence. Sequences can be simple transceiver operations. For example, transmit one frame, or, perform a CCA on a channel. Alternatively, the sequence manager supports complex sequences, which use simple operations as building blocks, strung together in a back-to-back fashion, with precise timing intervals between operations. For example, a “TR” sequence calls for a transmit frame followed by a receive frame. For complex sequences, interrupts can optionally be generated at the completion of each stage of the sequence, providing greater visibility for the MCU into the timeline of the sequence. Software can determine the precise state of the sequence manager state machine at any time. Software can opt to abort a sequence at any time; when this happens, the sequence manager will return to its IDLE state in an orderly fashion.

52.4.4.4.1.2.1.2.1.4 Block diagram

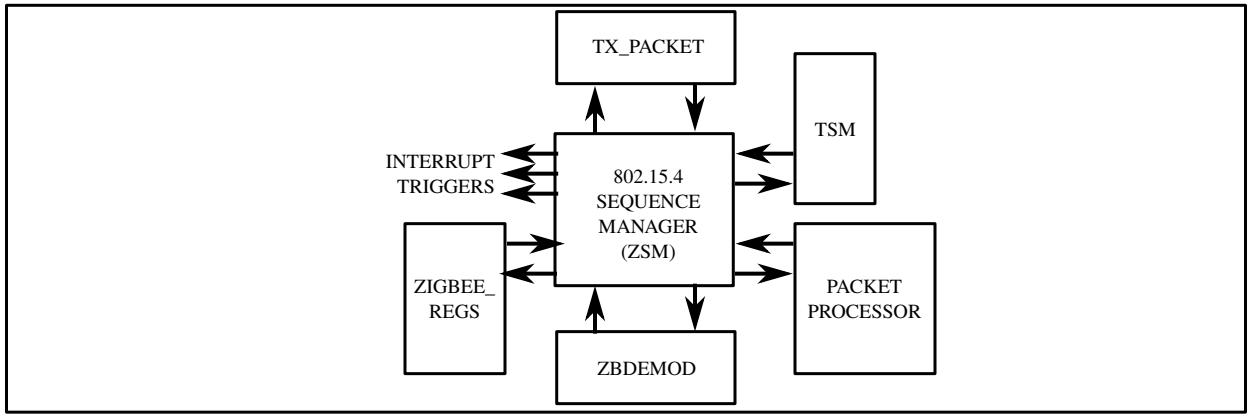

Figure 417. Block diagram

52.4.4.4.1.2.1.2.2 Memory Map and register definition

Numerous registers exist to provide configuration and status for the 802.15.4 Sequence Manager. See table below.

<table>
<tr><th>Field</th><th>R/W</th><th>Description</th></tr>
<tr><td>XCVSEQ</td><td>rw</td><td>The Transceiver Sequence Selector register selects a sequence for the sequence manager to execute. Sequence initiation can be immediate, or scheduled (see TMRTRIGEN). A write of XCVSEQ=IDLE will abort any ongoing sequence. A write of XCVSEQ=IDLE must always be performed after a sequence is complete, and before a new sequence is programmed. Any write to XCVSEQ other than XCVSEQ=IDLE during an ongoing sequence, shall be ignored. The mapping of XCVSEQ to sequence types is as follows:
<table>
<tr><th>XCVSEQ</th><th>SEQUENCE</th><th>DESCRIPTION</th></tr>
<tr><td>0</td><td>I</td><td>IDLE</td></tr>
<tr><td>1</td><td>R</td><td>RECEIVE</td></tr>
<tr><td>2</td><td>T</td><td>TRANSMIT</td></tr>
<tr><td>3</td><td>C</td><td>CCA</td></tr>
<tr><td>4</td><td>TR</td><td>TRANSMIT/RECEIVE</td></tr>
<tr><td>5</td><td>CCCA</td><td>CONTINUOUS CCA</td></tr>
</table></td></tr>
<tr><td>TMRTRIGEN</td><td>rw</td><td>Timer2 Trigger Enable.
1: allow timer TC2 (or TC2') to initiate a preprogrammed sequence (see XCVSEQ register).
0: programmed sequence initiates immediately upon write to XCVSEQ.</td></tr>
</table>

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Field	R/W	Description
CCABFRTX	rw	CCA Before TX. Applies only to Sequences T and TR, ignored during all other sequences. 1: at least one CCA measurement is required prior to the transmit operation (see also SLOTTED). 0: no CCA required, transmit operation begins immediately.
SLOTTED	rw	Slotted Mode, for beacon-enabled networks. Applies only to Sequences T, TR, and R, ignored during all other sequences. Used, in concert with CCABFRTX, to determine how many CCA measurements are required prior to a transmit operation. Also used during R sequence to determine whether the ensuing transmit acknowledge frame (if any) needs to be synchronized to a backoff slot boundary.
RXACKRQD	rw	Receive Acknowledge Frame required. Applies only to Sequence TR, ignored during all other sequences. 1: A receive Ack frame follows the transmit frame. 0: An ordinary receive frame (not an Ack frame) follows the transmit frame.
AUTOACK	rw	Auto Acknowledge Enable. Applies only to Sequence R and Sequence TR, ignored during other sequences. 1: sequence manager will follow a receive frame with an automatic hardware-generated Tx Ack frame, assuming other necessary conditions are met. 0: sequence manager will not follow a receive frame with a Tx Ack frame, under any conditions; the sequence will terminate after the receive frame.
CRC_MSK	rw	CRC Mask. 1: sequence manager requires CRCVALID=1 at the end of the received frame in order for the receive operation to complete successfully; if CRCVALID=0, sequence manager will return to preamble-detect mode after the last octet of the frame has been received. 0: sequence manager ignores CRCVALID and considers the receive operation complete after the last octet of the frame has been received.
PROMISCUOUS	rw	Prevents auto-TxAck on received packets 1: promiscuous mode, no auto-TxAck 0: auto-TxAck allowed, depending on other conditions.
CCATYPE[1:0]	rw	Clear Channel Assessment Type. Selects one of four possible functions for CCA or ED, per below. (See Chapter CCA/ED/LQI for more details). 00: ENERGY DETECT 01: CCA MODE 1

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Field	R/W	Description
		10: CCA MODE 2 11: CCA MODE 3
TC3TMOUT	rw	1: Allow a TMR3 timeout to abort any RX operation 0: Don't allow a TMR3 timeout to abort any RX operation See Appendix A for more details on how autosequences are affected by a TMR3 timeout
SEQ_STATE[4:0]	r	This read-only register reflects realtime 802.15.4 Sequence Manager (ZSM) state
ACTIVE_PROMISCUOUS	rw	1: Provide Data Indication on all received packets under the same rules which apply in PROMISCUOUS mode, however acknowledge those packets under rules which apply in non-PROMISCUOUS mode 0: normal operation (Default)
ACTIVE_NETWORK	rw	Selects the PAN on which to transceive, by activating a PAN parameter set (PAN0 or PAN1). In Manual Dual PAN mode (or Single PAN mode), this bit selects the active PAN parameter set (channel and addressing parameters) which governs all autosequences. In Auto Dual PAN mode, this bit selects the PAN on which to begin transceiving, latched at the point at which DUAL_PAN_DWELL register is written. 1: Select PAN1 0: Select PAN0 (Default)
DUAL_PAN_AUTO	rw	Activates automatic Dual PAN operating mode. In this mode, PAN-switching is controlled by hardware at a pre-programmed rate, determined by DUAL_PAN_DWELL. 1: Auto Dual PAN Mode 0: Manual Dual PAN mode (or Single PAN mode). Default. Whenever DUAL_PAN_AUTO=0, CURRENT_NETWORK=ACTIVE_NETWORK at all times. In other words, software directly controls which PAN is selected. Whenever DUAL_PAN_AUTO=1, CURRENT_NETWORK is controlled by hardware
CURRENT_NETWORK	r	This read-only bit indicates which PAN is currently selected by hardware in automatic Dual PAN mode 1: PAN1 is selected 0: PAN0 is selected
DUAL_PAN_DWELL[7:0]	rw	Channel Frequency Dwell Time. In Auto Dual PAN mode, hardware will toggle the PAN, after dwelling on the current PAN for the interval described below (assuming Preamble/SFD not detected). A write to

Table continues on the next page...

Table continued from the previous page...

<table>
<tr><th>Field</th><th>R/W</th><th>Description</th></tr>
<tr><td></td><td></td><td>DUAL_PAN_DWELL, always re-initializes the DWELL TIMER to the programmed value. If a write to DUAL_PAN_DWELL occurs during an autosequence, the DWELL TIMER will begin counting down immediately. If a write to DUAL_PAN_DWELL occurs when there is no autosequence underway, the DWELL TIMER will not begin counting until the next autosequence begins; it will begin counting at the start of the sequence warmup.

<table>
<tr><th>PRESCALER (bits [1:0])</th><th>TIMEBASE (bits [7:2])</th><th>RANGE (min) - (max)</th></tr>
<tr><td>00</td><td>0.5ms</td><td>0.5 - 32ms</td></tr>
<tr><td>01</td><td>2.5ms</td><td>2.5 - 160ms</td></tr>
<tr><td>10</td><td>10ms</td><td>10 - 640ms</td></tr>
<tr><td>11</td><td>50ms</td><td>50ms - 3.2seconds</td></tr>
</table>

A write to DUAL_PAN_DWELL also causes the value of ACTIVE_NETWORK to get latched into the hardware. This latched value will be the starting point for the automatic dual-pan mode (i.e., start on PAN0 or on PAN1). The starting value takes effect immediately (if sequence is underway and DUAL_PAN_AUTO=1), or is otherwise delayed until sequence starts and DUAL_PAN_AUTO=1.</td></tr>
<tr><td>DUAL_PAN_REMAIN[5:0]</td><td></td><td>This read-only register indicates time remaining before next PAN switch in auto Dual PAN mode. The units for this register, depend on the PRESCALER setting (bits [1:0]) in the DUAL_PAN_DWELL register, according to the following table:

<table>
<tr><th>DUAL_PAN_DWELL PRESCALER</th><th>DUAL_PAN_REMAIN UNITS</th></tr>
<tr><td>00</td><td>0.5ms</td></tr>
<tr><td>01</td><td>2.5ms</td></tr>
<tr><td>10</td><td>10ms</td></tr>
<tr><td>11</td><td>50ms</td></tr>
</table>

The readback value indicates that between N-1 and N timebase units remain until the next PAN switch. For example, a DUAL_PAN_REMAIN readback value of 3, with a DUAL_PAN_DWELL PRESCALER setting of 2 (10ms), indicates that between 20ms (2*10ms) and 30ms (3*10ms), remain until the next automatic PAN switch.</td></tr>
<tr><td>RECD_ON_PAN0</td><td>r</td><td>Indicates the packet which was just received, was received on PAN0.</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	R/W	Description
		In Dual PAN mode operating on 2 different channels, RECD_ON_PAN0 will be set if CURRENT_NETWORK=0 when the packet was received, regardless of FILTERFAIL status. In DUAL PAN mode operating with same channel on both networks, CURRENT_NETWORK will be ignored and RECD_ON_PAN0 will be set only if a valid packet was received on PAN0 (PAN0's FILTERFAIL_FLAG is deasserted).
RECD_ON_PAN1	r	Indicates the packet which was just received, was received on PAN1. In Dual PAN mode operating on 2 different channels, RECD_ON_PAN1 will be set if CURRENT_NETWORK=1 when the packet was received, regardless of FILTERFAIL status. In DUAL PAN mode operating with same channel on both networks, CURRENT_NETWORK will be ignored and RECD_ON_PAN1 will be set only if a valid packet was received on PAN1 (PAN1's FILTERFAIL_FLAG is deasserted).
ACKDELAY[5:0]	rw	Provides a fine-tune adjustment of the time delay between Rx warmdown and the beginning of Tx warmup for an Tx Acknowledge packet. ACKDELAY register will apply to both SLOTTED and UNSLOTTED TxAck, but only to TxAck (not T sequences). This is a two's complement value. The minimum permissible value is -19 (0x2D). Values less than -19 will lead to unexpected results. Resolution = 2us. Range = +/- 62us. Default = 0x0. Max ACKDELAY = 0x1F. Min ACKDELAY = 0x2d.
TXDELAY[5:0]	rw	Provides a fine-tune adjustment of the time delay between post-CCA Rx warm-down and the beginning of Tx warm-up for an Tx (non-Ack) packet. TXDELAY register will apply in both SLOTTED and UNSLOTTED modes, but only to T sequences (e.g., T, TR, and T(R)), not TxAck operations. This is a two's complement value. The minimum permissible value is -19 (0x2D). Values less than -19 will lead to unexpected results. Resolution = 2us. Range = +/- 62us. Default = 0x0. Max TXDELAY = 0x1F. Min TXDELAY = 0x2d

Table continues on the next page...

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Field	R/W	Description
CLR_NEW_SEQ_INHIBIT	rw	when asserted, overrides the automatic hardware locking of the programmed XCVSEQ while an autosequence is underway. Asserting this feature will allow software to change the programmed autosequence “on-the-fly”, without aborting and returning to idle between sequences. Overriding the hardware lockout of XCVSEQ should be used with caution, since the Sequence Manager is not designed (or verified) for manual state transitions between one type of autosequence and other (i.e., Sequence T -> Sequence R).
NO_RX_RECYCLE	rw	when asserted, prevents the Sequence Manager from automatically re-starting the receiver when a packet is received which results in a FilterFail or CRC failure. Normally, the Sequence Manager jumps to the RX_CYC state, and then resumes from there with a new Rx warmup, in search of a new packet. When this bit is set, the Sequence Manager will instead return to idle state, and issue a SEQIRQ, after a FilterFail or CRC failure.
LATCH_PREAMBLE	rw	1: Make PREAMBLE_DET and SFD_DET bits of PHY_STS Register “sticky”, i.e., occurrences of preamble and SFD detection are latched and held until the start of the next autosequence 0: Don’t make PREAMBLE_DET and SFD_DET bits of PHY_STS Register “sticky”, i.e, these status bits reflect the realtime, dynamic state of preamble_detect and sfd_detect. (default)
XCVSEQ_ACTUAL[2:0]	r	indicates the programmed sequence that has been recognized by the Sequence Manager. Takes into account the fact that sequence-change commands from software are ignored while a sequence is underway (see new_seq_inhibit bit). Read-only bits.
SEQ_IDLE	r	when asserted, indicates that the Sequence Manager is in its idle state. Read-only bit.
NEW_SEQ_INHIBIT	r	when asserted, indicates that a new programmed autosequence has commenced (TMR2 match has occurred if TMRTRIGEN=1). Once this bit is asserted, software is blocked from commanding any new autosequences (other than Sequence I to abort the current sequence), until the current sequence completes. Hardware will ignore a sequence-change command from software while this bit is asserted. Hardware will automatically deassert this bit once the sequence completes. Read-only bit.
RX_TIMEOUT_PENDING	r	when asserted, indicates that a TMR3 timeout (RX timeout) flag has been set by Hardware, but the Sequence Manager has not yet aborted because an RX operation is not currently underway. This would be the case, for example, during a Sequence TR, if a TMR3 timeout were to occur during the transmit operation of this sequence; the sequence would not be aborted by Hardware until the receive operation begins. This bit will always be 0 if TC3TMOUT=0. Read-only bit.

Table continues on the next page...

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Field	R/W	Description
RX_MODE	r	indicates that an RX operation is in progress. CCA and ED operations are considered RX operations. Read-only bit.
TMR2_SEQ_TRIG_ARMED	r	when asserted, indicates that TMR2 has been programmed and is armed to trigger a new autosequence, when Sequence Manager timer-triggering mode is selected (i.e., TMRTRIGEN=1). When timer-triggering mode is selected, TMR2 must be re-programmed (using either T2CMP or T2), in advance of each new sequence. Once TMR2 is programmed, this bit will be asserted, and will remain asserted until the new sequence commences (at TMR2 match). Hardware will deassert this bit when the new sequence starts. When TMRTRIGEN=0, this bit should be ignored. Read-only bit.
SW_ABORTED	r	when asserted, indicates that the autosequence has terminated due to an Software abort. Software can abort any programmed autosequence by writing Sequence I to XCVSEQ. This bit is valid at the SEQIRQ interrupt. Hardware will maintain this bit asserted until the next autosequence commences. Read-only bit.
TC3_ABORTED	r	when asserted, indicates that the autosequence has terminated due to an TC3 (TMR3) timeout during a receive operation. This bit is valid at the SEQIRQ interrupt. Hardware will maintain this bit asserted until the next autosequence commences. Read-only bit.
PLL_ABORTED	r	when asserted, indicates that the autosequence has terminated due to an PLL unlock event. This bit is valid at the SEQIRQ interrupt. Hardware will maintain this bit asserted until the next autosequence commences. Read-only bit.
CCCA_BUSY_CNT[5:0]	r	For Sequence CCCA mode only, this register indicates the number of “busy” CCA attempts which occurred during the autosequence, before the channel was detected to be idle. This register can also be read in real-time (during the autosequence) to determine how many busy CCA attempts have occurred to that point. The register saturates at 63 (i.e, if there are more than 63 busy attempts, the register will continue to read 63). This register is automatically cleared to zero by hardware when the next autosequence commences. Read-only register.
SEQ_T_STATUS[5:0]	r	Status of the just-completed (or ongoing) Sequence T or Sequence TR autosequence. This register is valid at all times during, and after, the Sequence T or Sequence TR. Not valid for other types of autosequences. This is a read-only register. The bits of this register map to status, according to the following table: [0] 1st CCA complete (CCABFRTX=1) [1] 2nd CCA complete (SLOTTED=1) [2] Tx operation complete [3] Rx Recycle occurred (Sequence TR only)

Table continues on the next page...

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Field	R/W	Description
		[4] Rx operation complete (Sequence TR only) [5] TxAck operation complete(Sequence TR only)
CONTINUOUS_EN	rw	Enable Continuous TX or RX mode (testmode). See Appendix B.
SLOT_PRELOAD[7:0]	rw	This register represents the number that gets loaded into the slot_timer at SFD detect, which ultimately determines when the next slot boundary will occur. Due to processing delays within the analog front-end and digital modem, the point at which SFD is detected by the modem, is delayed relative to over-the-air timing. Since this timing may not be known prior to until actual silicon, and since this is such a critical timing parameter for slotted operations, it has been made programmable. The default value is 0x74. This timing parameter is critical for the Sequence R autosequence in slotted mode, when an automatic TxAck is required.

52.4.4.4.1.2.1.2.3 Functional description

This section describes the supported sequences in more detail. All sequences can be initiated by software directly (instantaneously) by writing the desired sequence to the XCVSEQ register, with the TMRTRIGEN bit deasserted. Alternatively, software can schedule the initiation of a sequence at a precise time in the future, by programming the desired start time into the T2CMP (or T2PRIMECMP) timer compare register, and setting the TMRTRIGEN bit. The XCVSEQ register field is writable and readable, so software can read this register to determine which sequence it had programmed earlier. After the sequence completes (SEQIRQ interrupt), software should set the XCVSEQ to IDLE (0x0), before initiating a new sequence. If the sequence-complete interrupt (SEQIRQ) is masked, software can determine when the sequence is complete by polling the SEQ_STATE register, until it returns to SEQ_IDLE (0x0). While a sequence is ongoing, software can abort the sequence at any time by writing IDLE (0x0) to XCVSEQ; the sequence manager state machine will respond with an orderly return to the SEQ_IDLE state, and a SEQIRQ will be generated. While a sequence is underway, software should not attempt to change XCVSEQ (other than aborting the sequence as previously described); the sequence manager will ignore all mid-sequence attempts to change XCVSEQ. As mentioned previously, software should write the IDLE value to XCVSEQ before changing sequences. If TMR2 triggering is enabled (TMRTRIGEN=1), after the scheduled sequence is automatically launched at TMR2 match, and then completes, software must re-arm TMR2 triggering by writing to either T2CMP, or T2PRIMECMP. At least the LS byte of one of these registers must be written to re-arm. This hardware interlock is designed to prevent the inadvertent re-triggering of sequences, which would otherwise occur after the 24-bit Event Timer rolls over.

The supported sequences are shown in the following table.

Table 543. Supported Sequences

XCVSEQ	Sequence	Description
0	I	Idle
1	R	Receive Sequence - conditionally followed by a TxAck
2	T	Transmit Sequence
3	C	Standalone CCA
4	TR	Transmit /Receive Sequence - transmit unconditionally followed by either an R or RxAck

Table continues on the next page...

Table 543. Supported Sequences (continued)

XCVSEQ	Sequence	Description
5	CCCA	Continuous CCA - sequence completes when channel is idle
6	Reserved	
7	Reserved	

All sequences can be aborted by a PLL unlock detection. The unlock detection is qualified by the sequence manager; in other words, an unlock detection during the early stages of the PLL warmup is expected, and is not allowed to abort the sequence at that point. The primary rationale for the PLL unlock abort, is to prevent transmission on an incorrect, or unstable, frequency during a transmit operation, or to increase battery life by not prolonging a receive or CCA operation that is bound to fail. Software can disable the PLL unlock auto-abort. See Sequence Aborting.

52.4.4.4.1.2.1.2.3.1 Supported Sequences

52.4.4.4.1.2.1.2.3.1.1 Sequence I (Idle)

When the IDLE value is written to XCVSEQ, the sequence manager goes to its SEQ_IDLE state. If not already in SEQ_IDLE, the sequence manager executes an orderly warmdown to return to SEQ_IDLE. A SEQIRQ interrupt is then issued. Writing IDLE value to XCVSEQ is the proper way to abort a sequence.

When a sequence is aborted in this way (called a software abort), the SW_ABORTED bit of the ABORT_STS register in 802.15.4 space, will become set. This bit will be self-cleared at the start of the next autosequence.

52.4.4.4.1.2.1.2.3.1.2 Sequence R (Receive)

Sequence R is the basic receive sequence. Sequence R can be used to receive all types of 802.15.4 PHY- and MAC-compliant frames, including reserved frame types. However, reception of Acknowledge frames is not recommended using Sequence R. This is because reception of an Acknowledge frame, usually follows a transmitted frame, with a designated Sequence Number, so that the received Acknowledge frame can be verified for the matching Sequence Number. In a standalone Sequence R, there is no Sequence Number to verify against, so any Acknowledge frame is merely transferred to the Packet Buffer. (Note: the appropriate way to receive Acknowledge frames is with Sequence TR, with the RXACKRQD bit asserted). Using Sequence R, *all* frames which pass frame-filtering rules and CRC check, are transferred to the Packet Buffer.

The basic execution of a successful Sequence R is as follows:

- MCU writes TC2 compare value to the desired initiation time, and sets TMRTRIGEN (optional)
- MCU writes XCVSEQ=R
- Wait for TC2 match (if TMRTRIGEN=1)
- SEQ_MGR executes RxWarmup
- Preamble Detected
- SFD Detected
- FrameLength octet received, transferred to Packet Buffer
- *N* additional octets received (*N* = FrameLength), transferred to Packet Buffer. *Note if (FrameLength > 127), then N = 127.*
- If frame-filtering rules and CRC check pass:
- ---> RXIRQ interrupt issued
- ---> SEQ_MGR executes RxWarmdown
- ---> If received Frame Control Field indicates AckRequest=1
- ---- ---> SEQ_MGR executes TxWarmup

- ---- ---> an Ack frame is transmitted using the received Sequence Number
- ---- ---> SEQ_MGR executes TxWarmdown
- SEQIRQ interrupt issued

When Sequence R is initiated, the ZSM sequence manager warms up the receiver (analog and digital elements), via the TSM (Transceiver Sequence Manager). After warmup is complete, timer TMR3 can be enabled as a “bracketing” timer (software option). If a TMR3 timer match occurs, and software has asserted the TC3TMOUT bit, the sequence manager will warm down the receiver and return to SEQ_IDLE state. Assuming no TMR3 timeout, reception proceeds in preamble-search mode. Once a preamble is detected, reception continues in SFD-search mode. At this point, the sequence manager’s slot timer is activated. This is because a slotted “transmit acknowledge” frame (TxAck) may be required later in this sequence. The slot timer is loaded with the following value (in us):

Slot Timer Preload = 160 + TXWARMUPTIME + (2*ACKDELAY).

The 160 term arises because, at the point of SFD detection, we are exactly 10 symbols into the backoff slot, and the symbol period is 16us. The slot timer will count up and eventually rollover at 319, to 0. (There are 320us in a backoff slot). The receiver receives the next octet (FrameLength). Starting with this octet, and continuing through the remainder of the frame, each octet that is received is transferred to Packet Buffer. After each octet is transferred to Packet Buffer, the Packet Buffer address is incremented by 1. The next 2 octets (Frame Control Field) are then received, which are parsed to obtain the AckRequest field, and the FrameVersion field. The next octet is then received (SequenceNumber), and stored. The remainder of the frame, determined by FrameLength, is then received. As the octets are received, the packet data is parsed and subjected to packet-filtering rules (see Chapter Packet Processor). If any of the packet-filtering rules fail, or if the CRC check on the FCS field fails, the sequence manager will return the receiver to preamble-search mode, after the last octet has been received and transferred to Packet Buffer. Assuming the packet-filtering rules and CRC pass, an interrupt (RXIRQ) is issued to the MCU. At this point, the sequence manager must determine if a TxAck is required. A TxAck is required if the following 3 conditions are all met:

- AUTOACK=1 (register bit)
- PROMISCUOUS=0 (register bit)
- The received FrameControlField has AckRequest=1

If these conditions are met, and SLOTTED mode is not in effect, the sequence manager loads its TxAck timer with the following value (in us):

TxAck Timer Preload = 192 - TXWARMUPTIME - 2*ACKDELAY

The 192us is the non-slotted RX-to-TX turnaround requirement in the 802.15.4 standard. The TXWARMUPTIME takes into account the fact that the TxAck timer must expire early for the Tx warmup to be complete at exactly the 192us point. The ACKDELAY is a signed, fine-tune adjustment to the TxAck transmission time (+/- 62us).

If SLOTTED mode is in effect, the slot timer was previously loaded (at SFD detect), but the sequence manager needs to determine how much time is left in the current backoff slot. If less than 192us remain, the sequence manager must wait an *additional* backoff slot before initiating the Ack transmission. So it sets a flag indicating it must allow the slot counter to rollover an additional iteration.

Finally, at TxAck timer expiration (in non-SLOTTED mode), or at the qualified rollover of the slot timer (in SLOTTED mode), a Tx warmup is initiated. The conclusion of the Tx warmup will coincide precisely with a backoff slot boundary if SLOTTED mode is in effect. The sequence manager will then initiate the transmission of the Ack frame. The entire Ack frame will be built up by hardware; the Packet Buffer is not used for the auto-TxAck feature. The hardware will insert the following parameters into the Ack frame’s Frame Control Field:

Table 544. Frame Control Field for Hardware-generated Auto-TxAck Frame

FCF Field	Value
FrameType	Acknowledge
SecurityEnabled	0
FramePending	Determined by the Packet Processor.

Table continues on the next page...

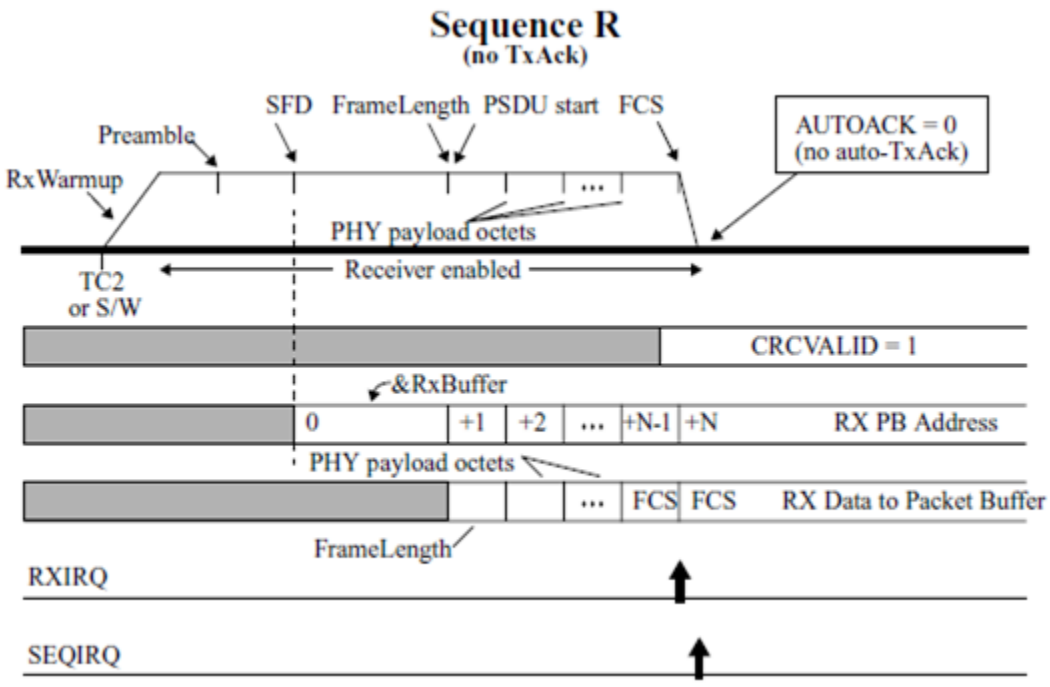
Table 544. Frame Control Field for Hardware-generated Auto-TxAck Frame (continued)

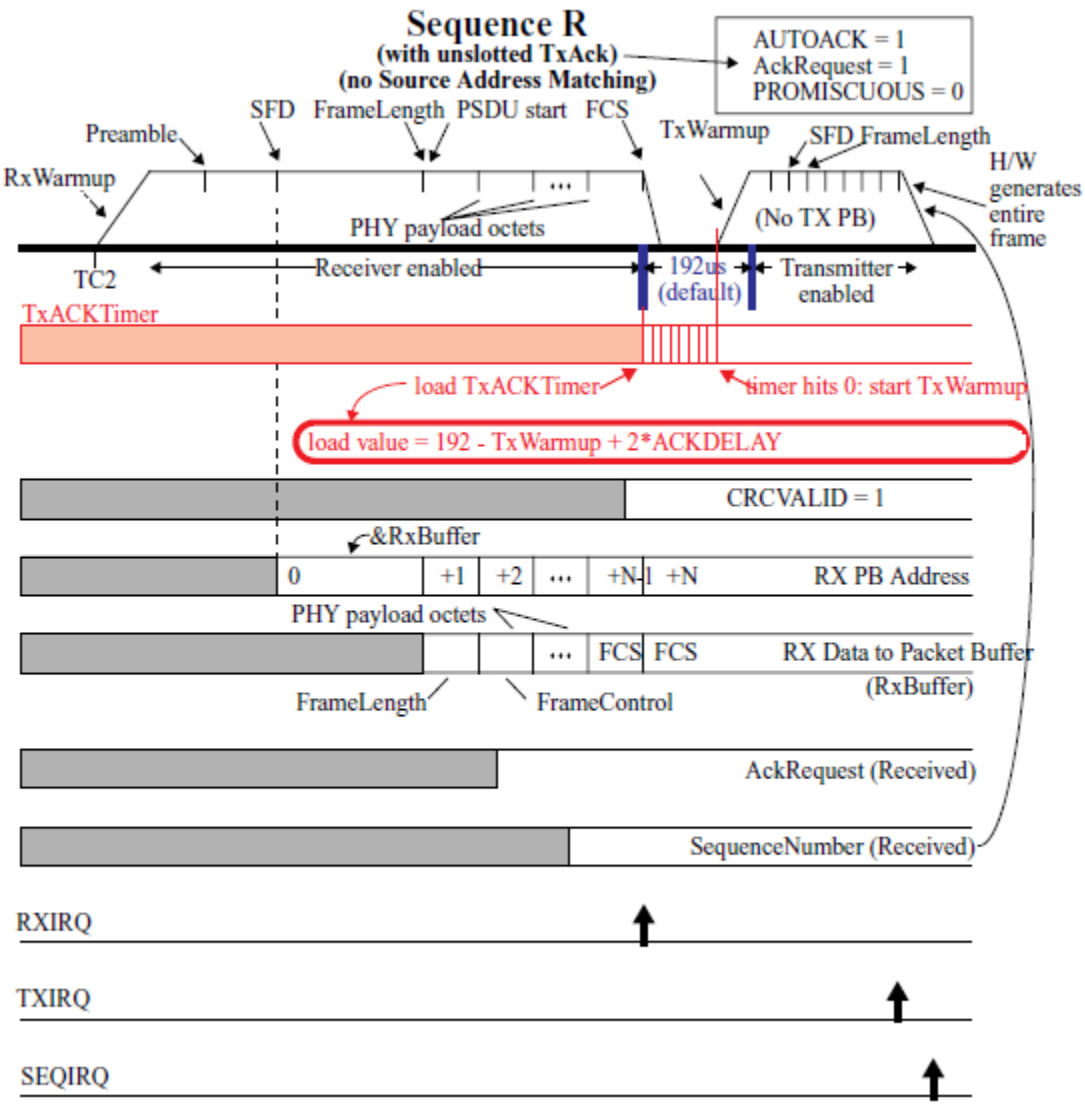
FCF Field	Value
	(see Packet Processor Chapter, Source Address Management.)
AckRequest	0
PanIDCompression	0
Reserved (bits 7-9)	000
DstAddrMode	0
FrameVersion	0
SrcAddrMode	0

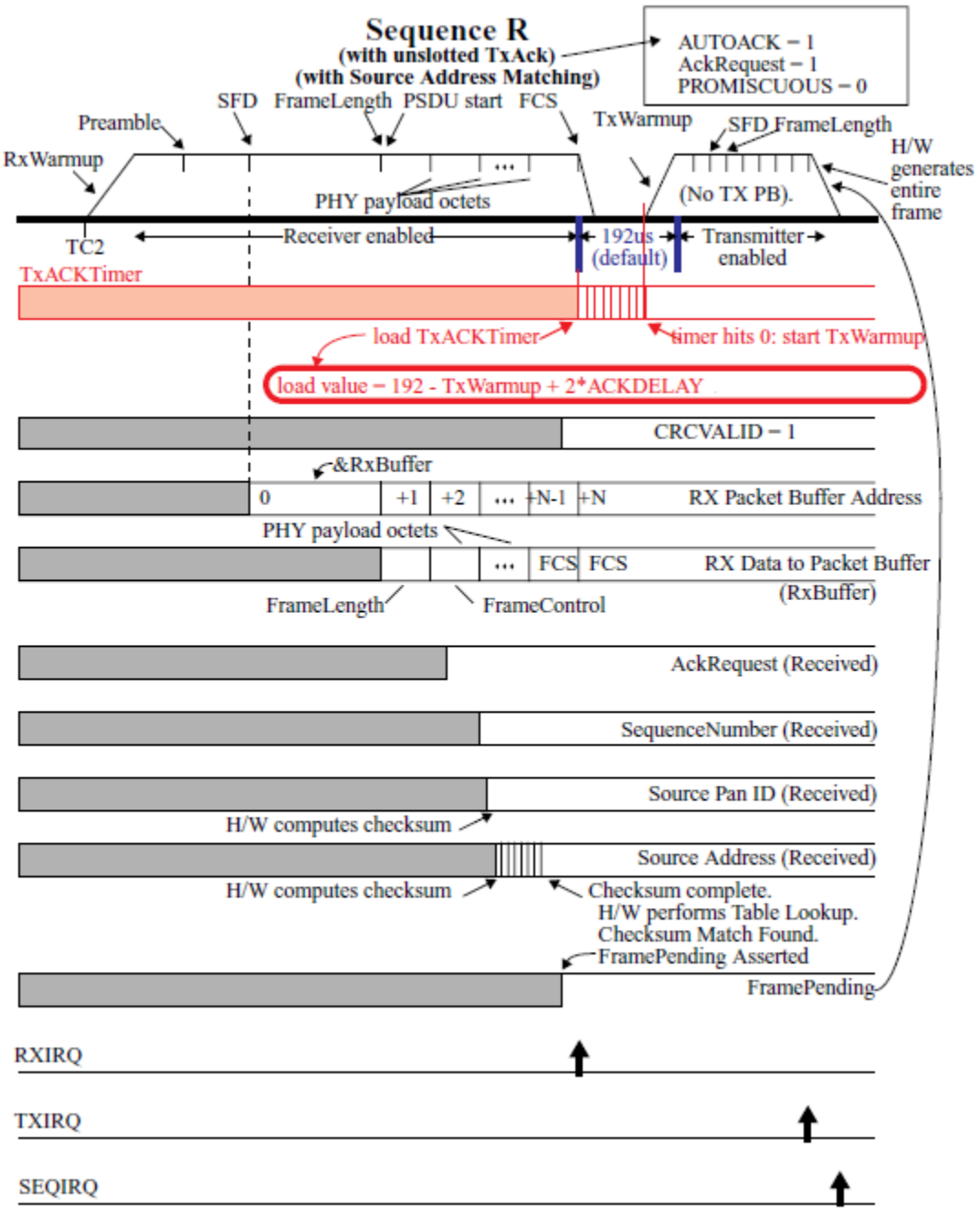
The Sequence Number for the Ack packet, will be the Sequence Number obtained from the previously received frame.

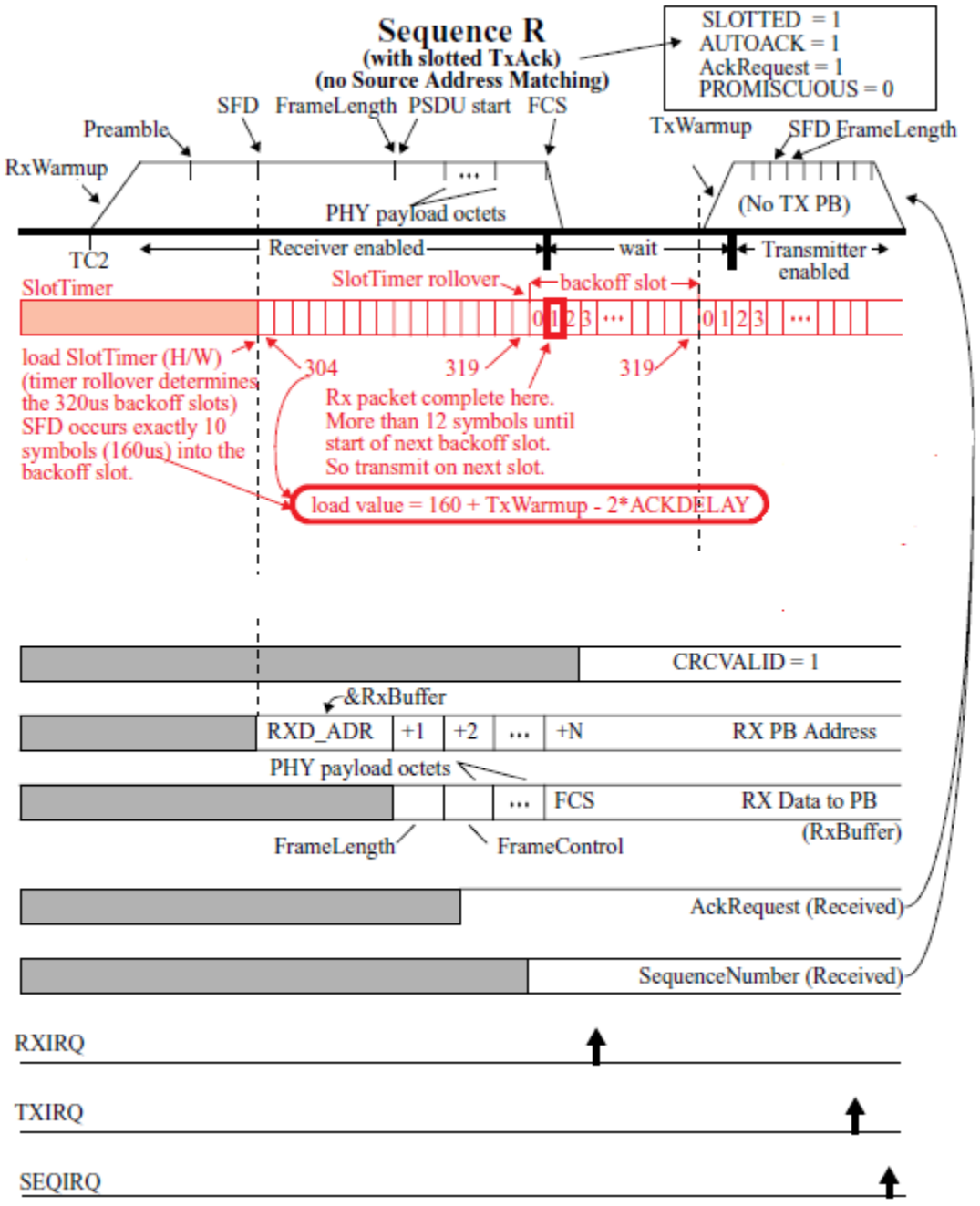
After the Ack frame has been transmitted, the sequence manager will issue a TXIRQ interrupt, and then perform a Tx warmdown. Finally, a SEQIRQ interrupt will be issued, and the sequence manager returns to SEQ_IDLE state.

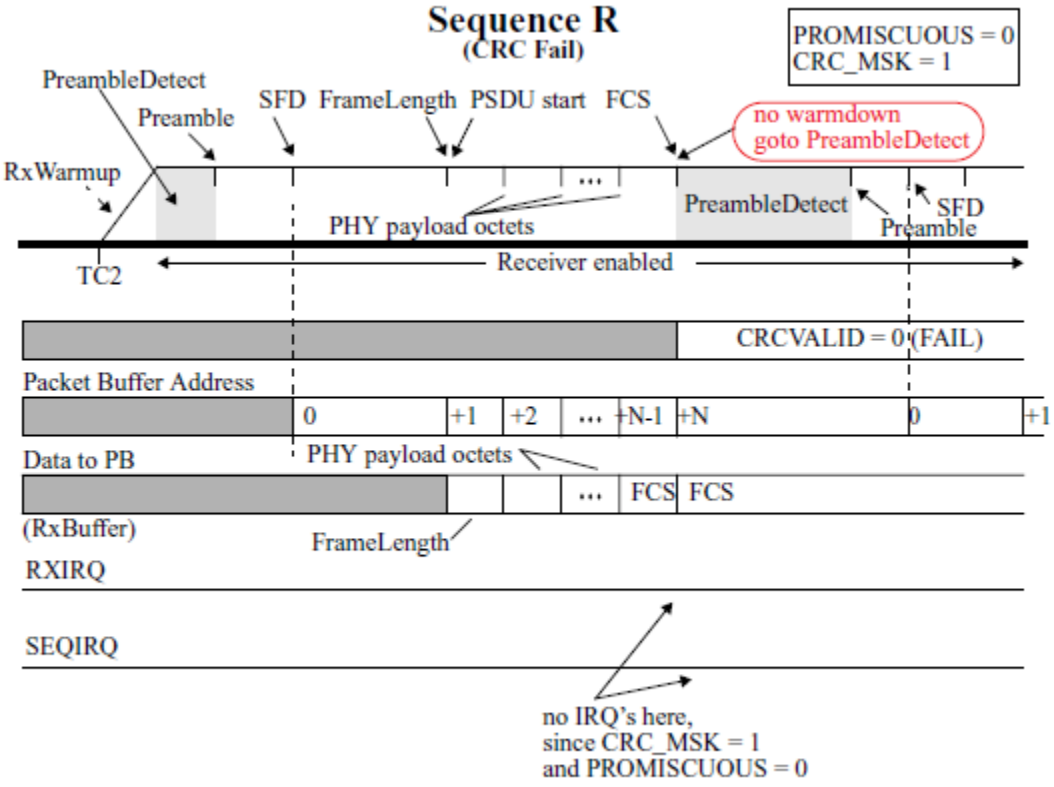
Sequence R Timing Diagrams

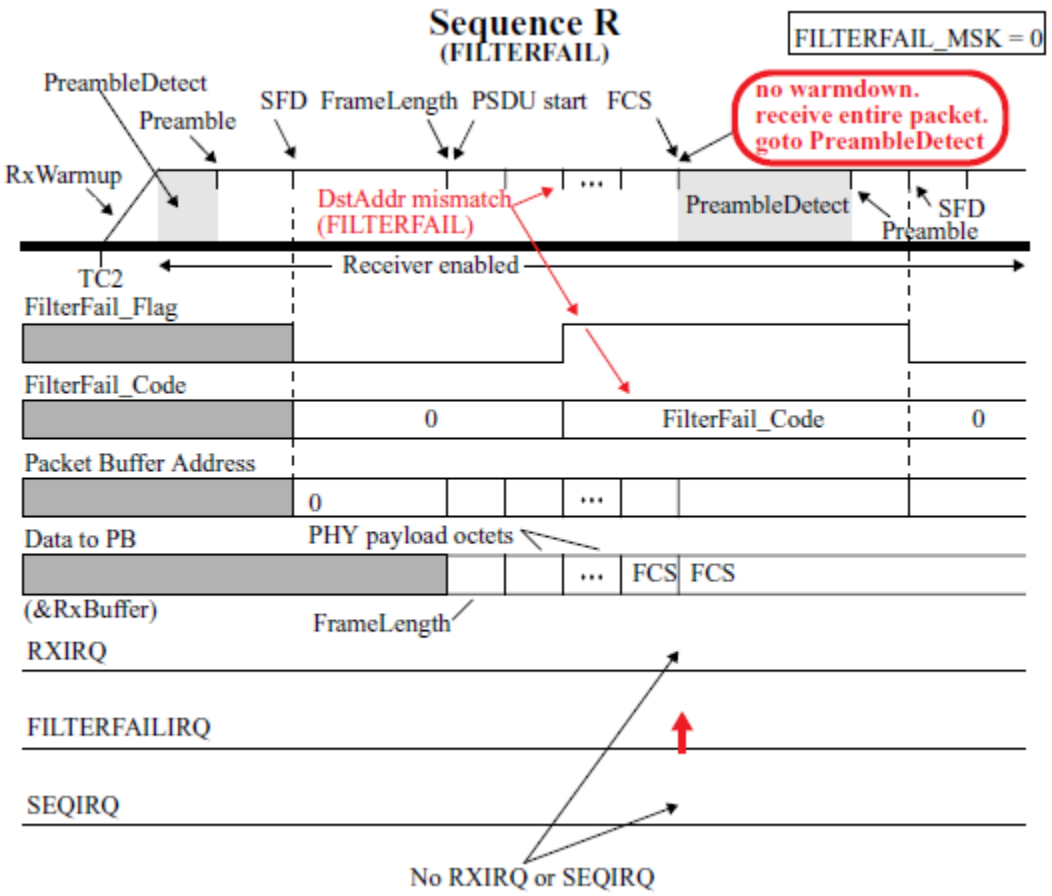



Sequence R
(with unslotted TxAck)
(no Source Address Matching)
AUTOACK = 1
AckRequest = 1
PROMISCUOUS = 0
Preamble
SFD
FrameLength
PSDU start
FCS
TxWarmup
SFD
FrameLength
H/W generates entire frame
RxWarmup
PHY payload octets
(No TX PB)
TC2
Receiver enabled
192us (default)
Transmitter enabled
TxACKTimer
load TxACKTimer
timer hits 0: start TxWarmup
load value = 192 - TxWarmup + 2*ACKDELAY
CRCVALID = 1
&RxBuffer
0
+1
+2
...
+N-1
+N
RX PB Address
PHY payload octets
FCS
FCS
RX Data to Packet Buffer (RxBuffer)
FrameLength
FrameControl
AckRequest (Received)
SequenceNumber (Received)
RXIRQ
TXIRQ
SEQIRQ


Sequence R
(with unslotted TxAck)
(with Source Address Matching)
AUTOACK = 1
AckRequest = 1
PROMISCUOUS = 0
SFD
FrameLength
PSDU start
FCS
TxWarmup
SFD FrameLength
Preamble
RxWarmup
H/W generates entire frame
PHY payload octets
(No TX PB).
TC2
Receiver enabled
192us (default)
Transmitter enabled
TxACKTimer
load TxACKTimer
timer hits 0: start TxWarmup
load value = 192 - TxWarmup + 2*ACKDELAY
CRCVALID = 1
&RxBuffer
0
+1
+2
...
+N-1
+N
RX Packet Buffer Address
PHY payload octets
FCS
FCS
RX Data to Packet Buffer (RxBuffer)
FrameLength
FrameControl
AckRequest (Received)
SequenceNumber (Received)
Source Pan ID (Received)
H/W computes checksum
Source Address (Received)
H/W computes checksum
Checksum complete.
H/W performs Table Lookup.
Checksum Match Found.
FramePending Asserted
FramePending
RXIRQ
TXIRQ
SEQIRQ


Sequence R
(with slotted TxAck)
(no Source Address Matching)
SLOTTED = 1
AUTOACK = 1
AckRequest = 1
PROMISCUOUS = 0
Preamble
SFD
FrameLength
PSDU start
FCS
TxWarmup
SFD
FrameLength
RxWarmup
PHY payload octets
(No TX PB)
TC2
Receiver enabled
wait
Transmitter enabled
SlotTimer
SlotTimer rollover
backoff slot
load SlotTimer (H/W) (timer rollover determines the 320us backoff slots) SFD occurs exactly 10 symbols (160us) into the backoff slot.
304
319
319
Rx packet complete here. More than 12 symbols until start of next backoff slot. So transmit on next slot.
load value = 160 + TxWarmup - 2*ACKDELAY
CRCVALID = 1
&RxBuffer
RXD_ADR
+1
+2
+N
RX PB Address
PHY payload octets
FCS
RX Data to PB (RxBuffer)
FrameLength
FrameControl
AckRequest (Received)
SequenceNumber (Received)
RXIRQ
TXIRQ
SEQIRQ


Sequence R
(CRC Fail)
PROMISCUOUS = 0
CRC_MSK = 1
PreambleDetect
Preamble
SFD
FrameLength
PSDU start
FCS
no warmdown
goto PreambleDetect
RxWarmup
PHY payload octets
PreambleDetect
SFD
Preamble
TC2
Receiver enabled
CRCVALID = 0 (FAIL)
Packet Buffer Address
0
+1
+2
+N-1
+N
0
+1
Data to PB
PHY payload octets
FCS
FCS
(RxBuffer)
FrameLength
RXIRQ
SEQIRQ
no IRQ's here,
since CRC_MSK = 1
and PROMISCUOUS = 0



52.4.4.4.1.2.1.2.3.1.3 Sequence T (Transmit)

Sequence T is the basic, standalone transmit sequence. Sequence T can be used to transmit all types of 802.15.4 PHY- and MAC-compliant frames. However, transmission of Acknowledge frames is not recommended using Sequence T. This is because transmission of an Acknowledge frame, usually follows a received frame, with a designated Sequence Number. The ZSM sequence manager automates the transmission of an Ack frame which follows a received frame, using Sequence R with the AUTOACK bit asserted. This is the recommended method for transmitting an Ack frame. This is especially beneficial, because the transmitted Ack frame octets are generated by hardware, and so no setup of a transmit packet in Packet Buffer, is required. However, sequence manager hardware does not prohibit Ack frames using Sequence T.

Sequence T allows for the insertion of 1 or 2 CCA (clear channel assessment) measurements prior to transmission, to ensure that the selected channel is idle. The CCA-before-TX feature is governed by two register bits, CCABFRTX and SLOTTED. All CCA measurements must indicate channel-idle, in order for the sequence manager to proceed to transmission; if the channel is determined by CCA to be busy, the sequence manager will terminate the sequence without a transmission. The number of CCA measurements attempted by the sequence manager, and the timing of the measurements, is shown in the following table.

Table 545. Timing of CCA Operations for Sequence T

CCABFRTX	SLOTTED	Number of CCA measurements	Timing of Initiation of CCA measurement #1	Timing of Initiation of CCA measurement #2	Timing of First Bit of Transmitted Frame (assumes channel idle)
0	X	0	-	-	Immediately follows TxWarmup
1	0	1	Immediately follows RxWarmup	-	Immediately follows RxWarmdown and TxWarmup
1	1	2	Immediately follows RxWarmup	320us after Initiation of CCA measurement #1	320us after Initiation of CCA measurement #2

Any CCA mode can be used for Sequence T and Sequence TR (CCA Modes 1, 2, and 3 are available. See Chapter CCA/ED/LQI). Software must configure the CCATYPE bits prior to initiating the autosequence, to select the CCA Mode.

The basic execution of a successful Sequence T is as follows:

- MCU writes TC2 compare value to the desired initiation time, and sets TMRTRIGEN (optional)
- MCU sets CCABFRTX if one or more CCA's are required prior to transmit
- MCU sets SLOTTED if in slotted mode (2 CCA's will be attempted)
- MCU writes XCVSEQ=T
- Wait for TC2 match (if TMRTRIGEN=1)
- If CCABFRTX=1 :
- ---> SEQ_MGR executes RxWarmup
- ---> SEQ_MGR initiates CCA measurement (takes 128us)
- ---> if CCA indicates channel busy, sequence terminates, CCAIRQ & SEQIRQ issued
- ---> otherwise, if CCA indicates channel idle:
- ---- ---> if SLOTTED=0, SEQ_MGR executes a RxWarmdown, followed by a TxWarmup
- ---- ---> if SLOTTED=1, SEQ_MGR initiates a 2nd CCA, 320us after initiating 1st CCA.
- ---- ---> if SLOTTED=1, and channel busy, sequence terminates, CCAIRQ & SEQIRQ issued
- ---- ---> if SLOTTED=1, and channel idle, SEQ_MGR executes a RxWarmdown, followed by a TxWarmup
- if SLOTTED=1, SEQ_MGR waits until 320us elapse after 2nd CCA initiation
- SEQ_MGR executes TxWarmup
- Preamble transmitted
- SFD transmitted
- FrameLength octet is obtained from Packet Buffer Address 0, and transmitted
- CRC engine is reset
- *N* additional octets are obtained from Packet Buffer and transmitted (*N* = FrameLength - 2)
- Each octet that is transmitted, is shifted through the CRC engine

- After Mth octet transmitted, FCS is available from CRC engine.
- FCS lower octet transmitted
- FCS upper octet transmitted
- SEQ_MGR issues TXIRQ
- SEQ_MGR executes TxWarmdown
- SEQ_MGR issues SEQIRQ

When Sequence T is initiated, the sequence manager first must determine if one or more CCA measurements are required. If CCABFRTX bit is asserted, the sequence manager warms up the receiver (analog and digital elements), via the TSM (Transceiver Sequence Manager). Immediately after the conclusion of the warmup, a CCA measurement is initiated. The CCA measurement takes 128us. If CCA indicates the channel is busy, the sequence manager warms down the receiver, issues CCAIRQ and SEQIRQ interrupts, and terminates the sequence. If, however, CCA indicates the channel is idle, the sequence manager inspects the SLOTTED bit to determine what to do next. If the SLOTTED bit is clear, the sequence manager issues a CCAIRQ interrupt, and then executes a warmdown of the receiver. If, however, the SLOTTED bit is set, the sequence manager does not issue a CCAIRQ interrupt; instead, the sequence manager initiates a second CCA measurement, precisely 320us after the initiation of the first CCA. This 320us interval is timed by the slot timer, which had been preloaded with 320 (microseconds) at the instant that Rx warmup was complete. At the conclusion of the second CCA, the sequence manager issues a CCAIRQ. If the second CCA indicates the channel is busy, the sequence manager warms down the receiver, issues a SEQIRQ interrupt, and terminates the sequence. If, however, CCA indicates the channel is idle, the sequence manager executes a warmdown of the receiver. Prior to executing the warmdown, the sequence manager reloads the slot timer, in order to precisely schedule the ensuing transmission. This time, the slot timer is loaded with a smaller value, in order to account for the fact that the timer must expire early in order to trigger the Tx warmup, which must complete at precisely the next backoff slot boundary. Thus, this time the slot timer is preloaded with:

Slot Timer Preload = 320 - TXWARMUPTIME + (2*TXDELAY).

The 320us is the duration of the backoff slot. The TXWARMUPTIME takes into account the fact that the TxAck timer must expire early for the Tx warmup to be complete at exactly the 320us point. The TXDELAY is a signed, fine-tune adjustment to the TxAck transmission time (+/- 62us).

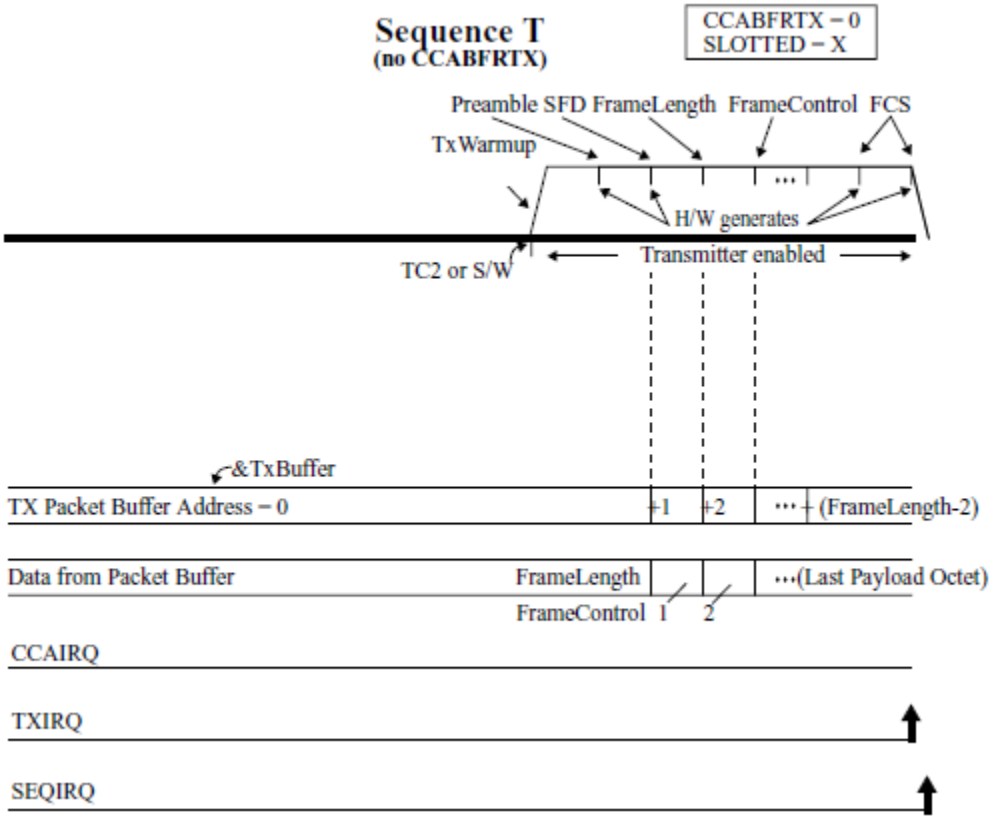
If the SLOTTED bit is asserted, once the slot timer expires, the sequence manager executes a Tx warmup. The conclusion of this warmup coincides with the backoff slot boundary. If the SLOTTED bit is deasserted, the sequence manager does not wait for the slot timer, and instead executes a Tx warmup immediately after the Rx warmdown.

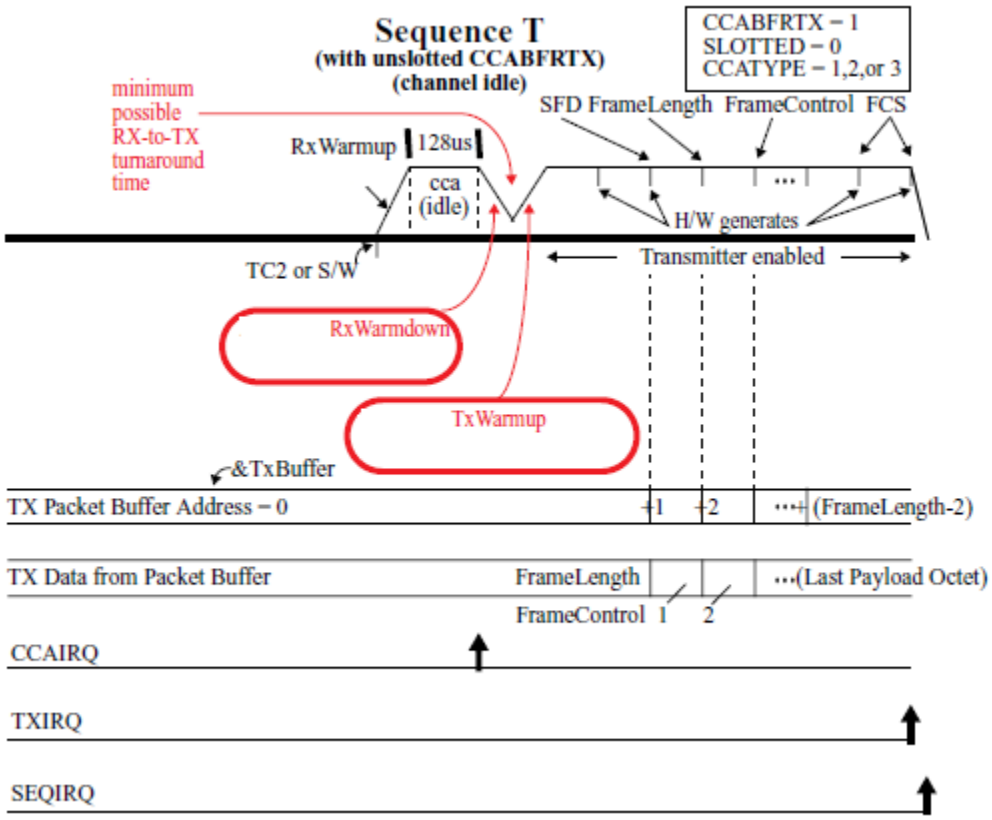
At this point, the sequence manager begins the transmit operation. The preamble and SFD are transmitted first. The preamble and SFD octets are generated by hardware, and are not included in the Packet Buffer. Then, the FrameLength octet is obtained from the Packet Buffer (address 0), and the buffer address pointer is incremented by one. The FrameLength octet is transmitted. The CRC engine is reset at this point. The FrameLength octet is used to determine how many more octets remain in the Packet Buffer. The number of remaining octets is:

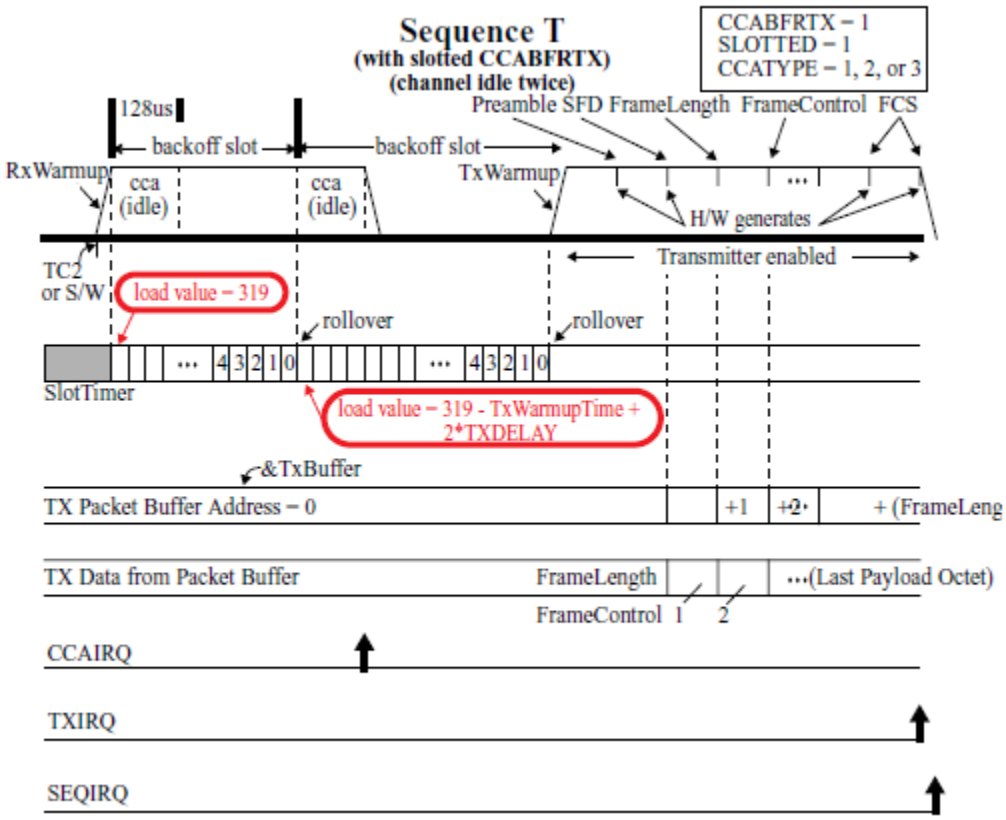
Number of octets remaining in Tx buffer = FrameLength - 2

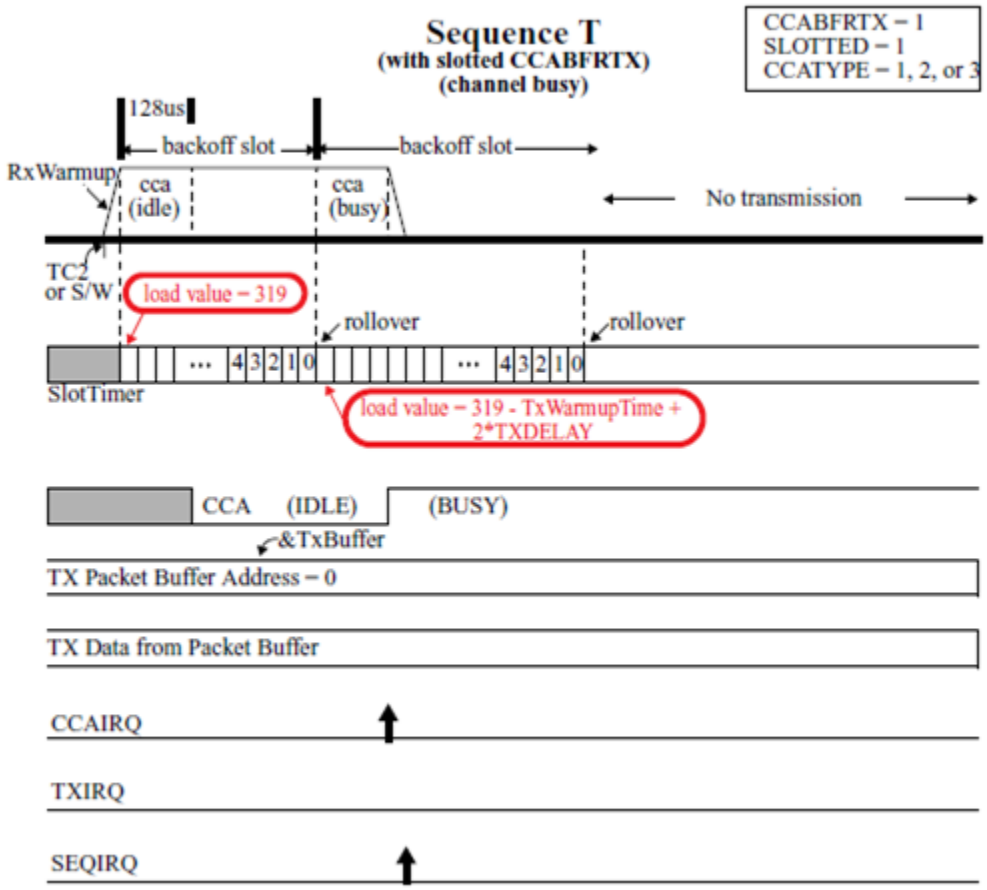
This is because the final 2 octets of the transmit frame constitute the FCS (Frame Check Sequence), and this value is hardware-computed. Thus, FCS is not part of the Tx buffer. Each of the octets in the Tx buffer is transmitted, and simultaneously shifted through CRC, to generate the FCS field. Once the Tx buffer is drained and all of its octets transmitted, the 2 FCS octets are transmitted, starting with the least significant octet. At this point, the transmit operation is complete. The sequence manager issues a TXIRQ interrupt. The sequence manager then executes a complete Tx warmdown, and follows up with a SEQIRQ interrupt. The sequence manager returns to SEQ_IDLE state.

Sequence T Timing Diagrams


Sequence T
(no CCABFRTX)
CCABFRTX = 0
SLOTTED = X
Preamble SFD FrameLength FrameControl FCS
TxWarmup
H/W generates
TC2 or S/W
Transmitter enabled
&TxBuffer
TX Packet Buffer Address = 0
+1
+2
(FrameLength-2)
Data from Packet Buffer
FrameLength
(Last Payload Octet)
FrameControl 1
2
CCAIRQ
TXIRQ
SEQIRQ


Sequence T
(with unslotted CCABFRTX)
(channel idle)
CCABFRTX = 1
SLOTTED = 0
CCATYPE = 1,2,or 3
minimum possible RX-to-TX turnaround time
RxWarmup
128us
cca (idle)
SFD FrameLength FrameControl FCS
H/W generates
Transmitter enabled
TC2 or S/W
RxWarmdown
TxWarmup
&TxBuffer
TX Packet Buffer Address = 0
+1
+2
(FrameLength-2)
TX Data from Packet Buffer
FrameLength
(Last Payload Octet)
FrameControl 1
2
CCAIRQ
TXIRQ
SEQIRQ


Sequence T
(with slotted CCABFRTX)
(channel idle twice)
CCABFRTX = 1
SLOTTED = 1
CCATYPE = 1, 2, or 3
128us
backoff slot
backoff slot
Preamble SFD FrameLength FrameControl FCS
RxWarmup
cca
(idle)
cca
(idle)
TxWarmup
H/W generates
Transmitter enabled
TC2
or S/W
load value = 319
rollover
rollover
SlotTimer
load value = 319 - TxWarmupTime +
2*TXDELAY
&TxBuffer
TX Packet Buffer Address = 0
+1
+2
+ (FrameLeng
TX Data from Packet Buffer
FrameLength
(Last Payload Octet)
FrameControl 1
2
CCAIRQ
TXIRQ
SEQIRQ



52.4.4.4.1.2.1.2.3.1.4 Sequence C (CCA)

Sequence C is the standalone CCA sequence. During Sequence C, the sequence manager executes a Clear Channel Assessment (CCA). The result of the CCA measurement is reported back to software in the CCA bit of the IRQSTS2 Register. The CCA bit indicates either a busy channel (1), or an idle channel (0).

The basic execution of a Sequence C is as follows:

- MCU writes TC2 compare value to the desired initiation time, and sets TMRTRIGEN (optional)
- MCU writes XCVSEQ=C
- Wait for TC2 match (if TMRTRIGEN=1)
- SEQ_MGR asserts one of {**cca1_en, cca2_en, cca3_en, ed_en** } to CCA_DIG
- SEQ_MGR executes RxWarmup, via Transceiver Sequence Manager
- SEQ_MGR initiates CCA measurement by asserting **rx_cca_en** to CCA_DIG
- SEQ_MGR waits for CCA to complete
- CCA bit is set to the CCA status (1=busy 0=idle)
- CCAIRQ interrupt issued
- SEQ_MGR executes RxWarmdown
- SEQIRQ interrupt issued

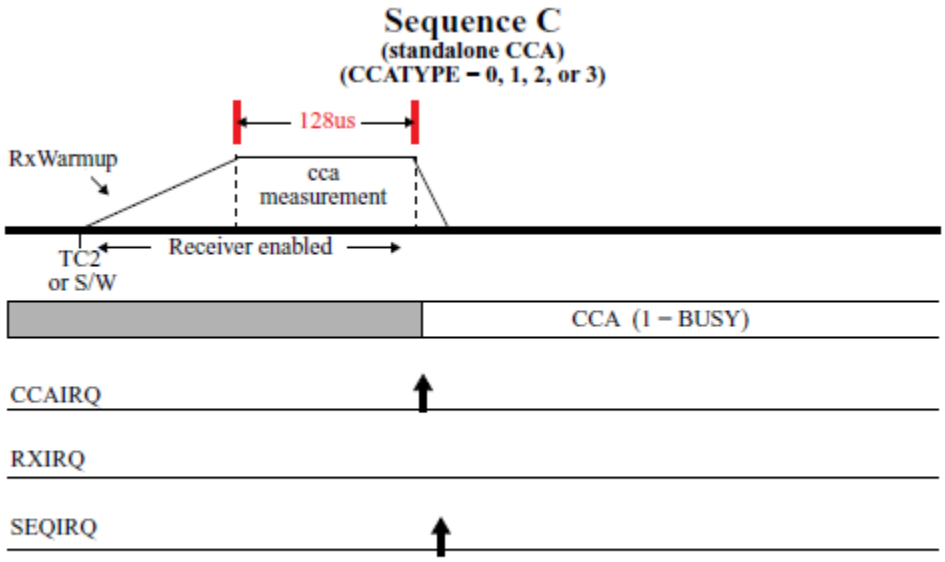
When Sequence C is initiated, the sequence manager asserts one of 4 control signals to CCA_DIG, based on which CCA or ED mode is programmed into CCATYPE[1:0]. The mapping of CCATYPE[1:0] to control signal is shown in the following table:

CCATYPE[1:0]	CCA_DIG CONTROL SIGNAL
00	ed_en
01	cca1_en
10	cca2_en
11	cca3_en

The asserted control signal will remain asserted for the duration of the Sequence C. The sequence manager warms up the receiver (analog and digital elements), via the Transceiver Sequence Manager (TSM). The TC3 “bracketing” timer has no effect on the sequence manager during Sequence C, so it cannot abort the sequence. At the completion of the warmup, the sequence manager initiates the CCA by asserting the **rx_cca_en** signal to CCA_DIG. While CCA is enabled, the CCA_DIG measures and averages the energy or signal on the channel. At the completion of the CCA process, the CCA bit is set to the status of the channel (idle or busy). The CCAIRQ is issued, the receiver is warmed down, the SEQIRQ is issued, and the sequence manager returns to SEQ_IDLE state.

Any CCATYPE setting may be used for Sequence C.

Sequence C Timing Diagrams



52.4.4.4.1.2.1.2.3.1.5 Sequence TR (Transmit/Receive)

Sequence TR is a combination Transmit/Receive sequence. The sequence is executed as a concatenation of 1 transmit operation followed by 1 receive operation, with a minimum TX-to-RX turnaround time in between. There are 2 permutations of Sequence TR, depending on the RXACKRQD bit. For both permutations, the Sequence T which constitutes the first half of a Sequence TR, is identical to the standalone Sequence T (XCVSEQ=2). This means that the transmit operation can be slotted or unslotted, and can be preceded by 1 or 2 CCA measurements, depending on the state of the CCABFRTX and SLOTTED bits.

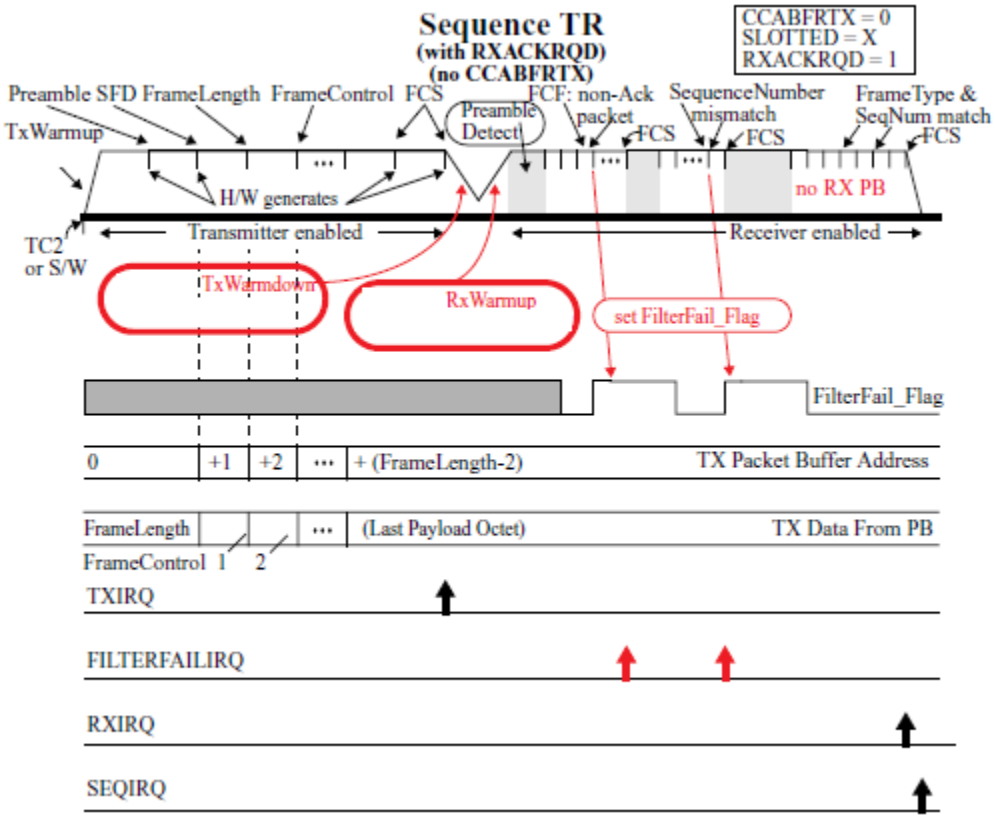
If RXACKRQD=0, then Sequence TR is executed as a Sequence T followed by a Sequence R, with a minimum TX-to-RX turnaround time in between. The Sequence R, which constitutes the second half of the Sequence TR, is identical to the standalone Sequence R (XCVSEQ=1). This means that the receive operation can be followed by an automatic, hardware-generated transmit Acknowledge frame, if all the necessary conditions are met. As with basic Sequence R, data for a successful receive operation is always transferred to Packet Buffer.

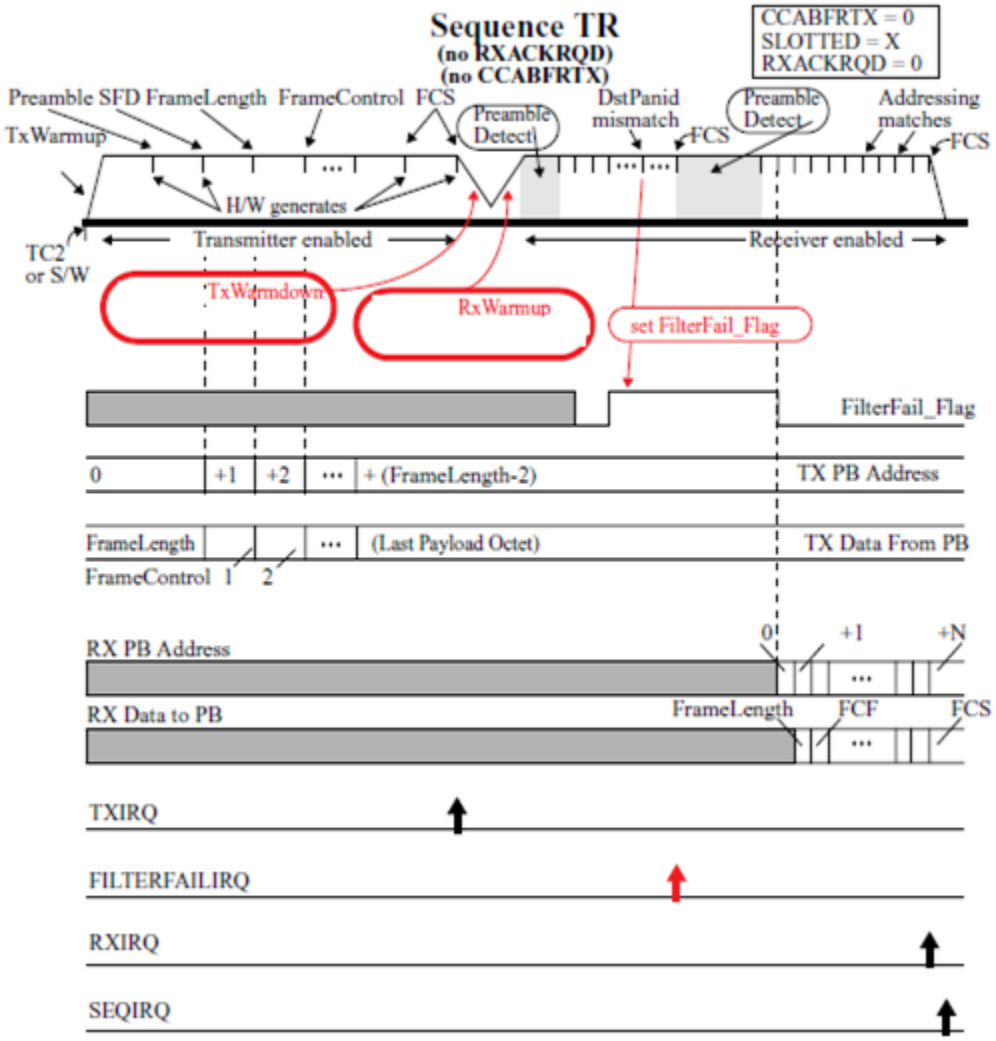
If RXACKRQD=1, then Sequence TR is executed as a Sequence T followed by a Receive-Acknowledge-Only frame. This type of receive operation is special, and not the same as a standalone Sequence R. The Ack-only receive operation filters all incoming frames, looking only for an Acknowledge frame whose Sequence Number matches the Sequence Number which was transmitted in the Sequence T portion of the sequence. All non-matching frames are discarded, and after each non-matching frame, the sequence manager will return the receiver to preamble-detect mode. This receive operation will continue until the matching Ack frame is received. Since this is a Receive-Acknowledge-Only operation, and not a Sequence R, there will be no receive octets transferred to Packet Buffer (an exception is made if ACTIVE_PROMISCUOUS=1; if so, all receive octets are transferred to the Packet Buffer, even for the Receive-Acknowledge-Only frame). The sequence will end with a RXIRQ interrupt, which indicates that the matching Ack frame was successfully received.

Needless to say, if during the transmit operation of a Sequence TR, an Acknowledge frame is being requested of the receiving end device (Frame Control Field: AckRequest=1), then Sequence TR with RXACKRQD=1 is the appropriate procedure. (Using Sequence TR with *RXACKREQ=0* is *not* recommended for this scenario, since there is no Sequence Number matching.)

Conversely, if during the transmit operation of a Sequence TR, an Acknowledge frame is *not* being requested of the receiving end device (Frame Control Field: AckRequest=0), then Sequence TR with RXACKRQD=1 should *never* be used, since a receive acknowledge frame will not be forthcoming. Instead, use Sequence TR with RXACKRQD=0, or simply Sequence T, if no followup receive frame is expected.

Sequence TR Timing Diagrams





52.4.4.4.1.2.1.2.3.1.6 Sequence CCCA (Continuous CCA)

Sequence CCCA is the Continuous CCA sequence. This sequence is designed to accommodate situations where channel availability may be infrequent, or low-duty-cycle, and a device needs to be able to transmit at the earliest available opportunity. During Sequence CCCA, the sequence manager repeats CCA measurements continuously until a channel-idle condition is found. The interval between the end of one CCA measurement, and the start of the next, is 63us. The actual interval between consecutive CCA measurements (i.e., from measurement-start to measurement-start), in the CCCA sequence, is 193us. After each CCA iteration, the CCA bit (IRQSTS2 Register) is set to the result of the measurement. As long as the CCA bit is high (busy) at the end of the iteration, the sequence manager will initiate a new measurement. Unlike Sequence C (standalone CCA), there is no CCAIRQ interrupt generated at the end of each CCA measurement, until the channel-idle condition is detected, at which point CCAIRQ is issued. The SLOTTED bit has no effect on this sequence. A Sequence CCCA will be aborted by the ZSM Sequence Manager if a TMR3 match occurs, and TC3TMOUT=1. CCA Modes 1, 2, or 3, can be used for Continuous CCA.

The basic execution of a Sequence CCCA is as follows:

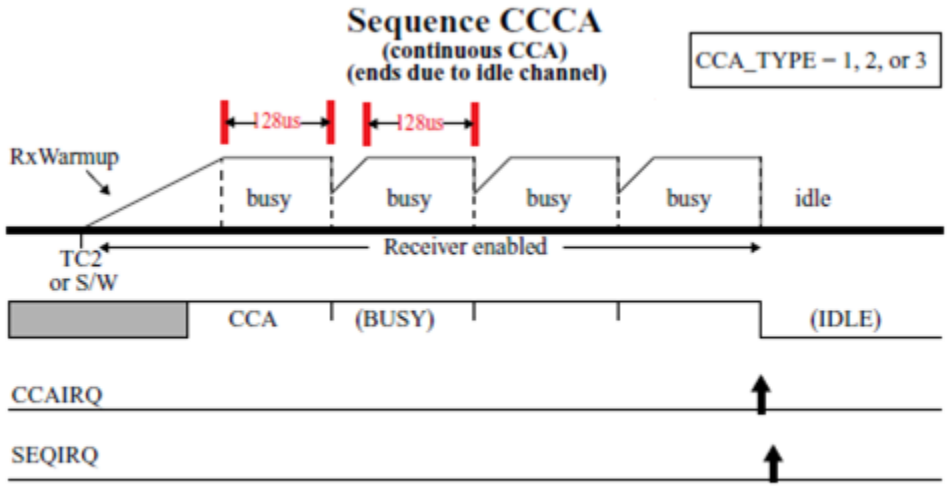
- MCU writes TC2 compare value to the desired initiation time, and sets TMRTRIGEN (optional)
- MCU writes XCVSEQ=CCCA
- Wait for TC2 match (if TMRTRIGEN=1)
- SEQ_MGR asserts one of {**cca1_en, cca2_en, cca3_en** } to CCA_DIG

- SEQ_MGR executes RxWarmup
- SEQ_MGR initiates CCA measurement by asserting **rx_cca_en** to CCA_DIG
- SEQ_MGR waits for CCA to complete
- CCA bit is set to the CCA status (1=busy 0=idle)
- If CCA=1, initiate a new CCA measurement immediately and repeat the previous 4 steps
- If CCA=0, CCAIRQ is issued
- SEQ_MGR executes RxWarmdown
- SEQIRQ interrupt issued

Note: The CCA bit (IRQSTS2 register) may change dynamically during the CCA measurement, and are only considered valid (and sampled by the Sequence Manager), at the end of the CCA measurement; therefore the user should not continuously poll CCA during CCCA and be expecting continuously-valid results

Note: The user can continuously monitor progress of the Sequence CCCA by reading the CCCA_BUSY_CNT register.

Sequence CCCA Timing Diagrams

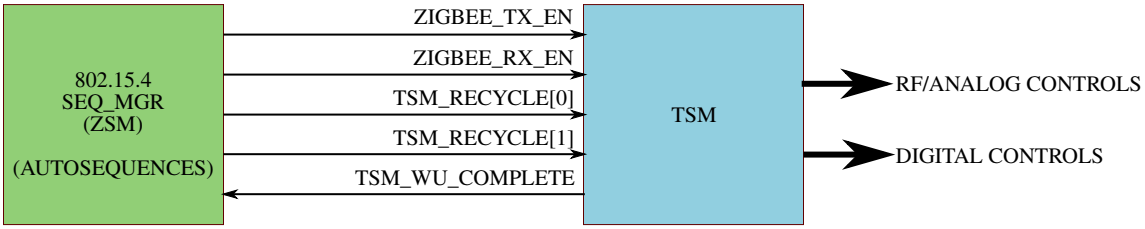


52.4.4.4.1.2.1.2.3.2 ZSM/TSM Interaction

The 802.15.4 Sequence Manager (ZSM) controls high-level autosequence timing, but offloads low level warmup and warmdown tasks to a dedicated, protocol-neutral Transceiver Sequence Manager, or TSM (see TSM Chapter). The ZSM initiates high-level functions, such as a CCA measurement operation or a transmit acknowledge operation, by commanding the TSM to execute an RX warmup, a TX warmup, a RX warmdown, a TX warmdown, or an RX recycle. Based on these commands, TSM generates the precise timing to control all of the digital, analog, and RF components of the TX and RX chains. The TSM is fully programmable, allowing all of the enabling and control signals to the transceiver components to be independently scheduled with 1us precision. TSM also allows all enable and control signals to be optionally overridden at any time, giving software complete control of each transceiver block, and ultimately the entire warmup/warmdown process if desired.

The ZSM and TSM sequence managers operate on the same clock domain, and both have 1us resolution. The TSM is fully programmable, while the ZSM is largely hardwired, with a few key exceptions. In the ZSM/TSM relationship, ZSM is the master and TSM is the slave. The key ZSM/TSM interface signaling is shown below:

ZSM/TSM INTERFACE SIGNALS



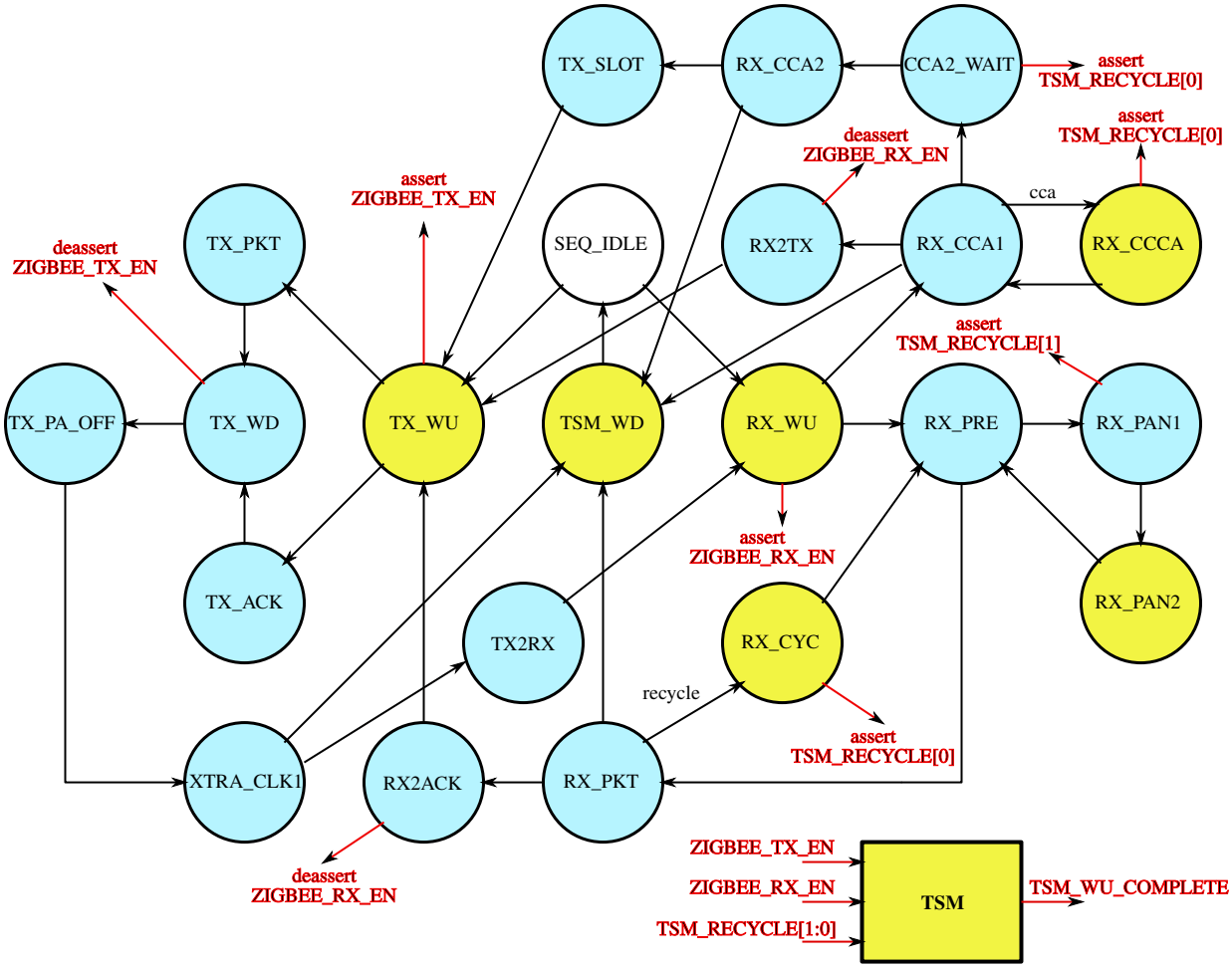
A description of the interface signals is provided in the table below.

ZSM/TSM INTERFACE SIGNAL	DESCRIPTION
ZIGBEE_TX_EN	A low-to-high transition initiates a TSM TX warmup, starting 1us after the transition. A high-to-low transition initiates a TSM TX warmdown, starting 1us after the transition.
ZIGBEE_RX_EN	A low-to-high transition initiates a TSM RX warmup, starting 1us after the transition. A high-to-low transition initiates a TSM RX warmdown, starting 1us after the transition.
TSM_RECYCLE[0]	This signal asserts in the ZSM RX_CYC state, and causes the TSM to jump from its “ON” phase, back to a point in the TSM RX warmup determined by the TSM’s RECYCLE_COUNT0[7:0] register in XCVR space. This process is used to execute an RX recycle. This signal is also asserted in the ZSM RX_CCCA state, with the same response by the TSM. This process is used to re-initialize the CCA function during Continuous CCA (CCCA) operations.
TSM_RECYCLE[1]	This signal asserts in the ZSM RX_PAN1 state, and causes the TSM to jump from its “ON” phase, back to a point in the TSM RX warmup determined by the TSM’s RECYCLE_COUNT1[7:0] register in XCVR space. This process is used to re-initialize the PLL digital on a new RF channel, during a Dual PAN mode on-the-fly channel change.
TSM_WU_COMPLETE	For the ZSM states which assert ZIGBEE_TX_EN or ZIGBEE_RX_EN, this 1us-wide signal from the TSM indicates that the warmup is complete, and the ZSM is now free to advance to its next state. The TSM_WU_COMPLETE is asserted 1us before the actual end of sequence, which is determined by the END_OF_TX_WU[7:0] register for TX warmup, and the END_OF_RX_WARMUP[7:0] register for RX warmup.

52.4.4.4.1.2.1.2.3.3 ZSM State Diagram

A ZSM state diagram is shown below. The states in yellow, are ZSM states which require interaction with the TSM. For example, a TSM control signal is asserted or deasserted, and/or a wait for warmup-complete from TSM is required; the assertions of the TSM control signals are shown in red. The states in blue have no interaction with TSM, so the timing of these states, and the transitions between such states, are governed by the ZSM itself.

802.15.4 SEQUENCE MANAGER AND TSM INTERACTION



Each ZSM state is represented in the hardware by a 5-bit state vector. The ZSM state can be monitored at any time by way of the read-only SEQ_STATE[4:0] register in 802.15.4 space. The mapping of ZSM state names to state vectors is shown in the table below:

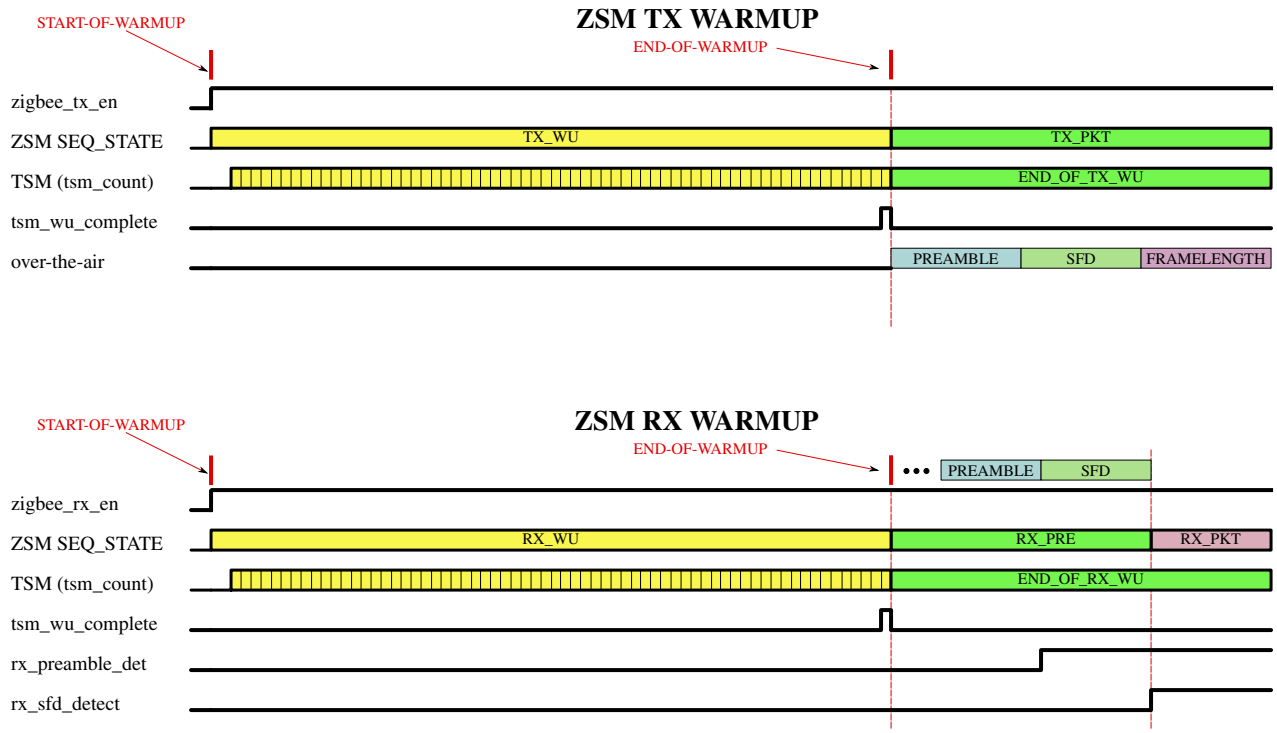
ZSM STATE	VECTOR
SEQ_IDLE	0x00
RX_WU	0x10
RX_PRE	0x14
RX_PKT	0x15
RX2ACK	0x16
RX_CYC	0x17
RX_PAN1	0x1D
RX_PAN2	0x1E
RX_CCA1	0x18

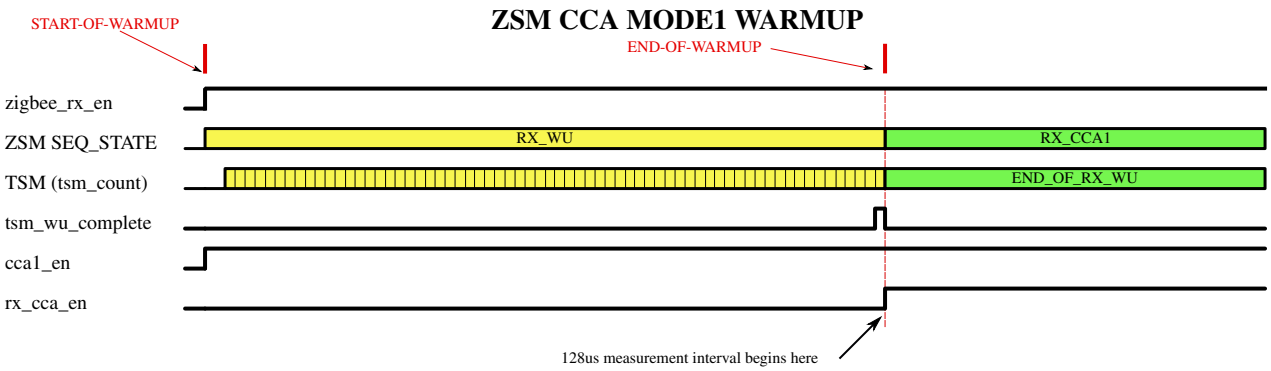
Table continues on the next page...

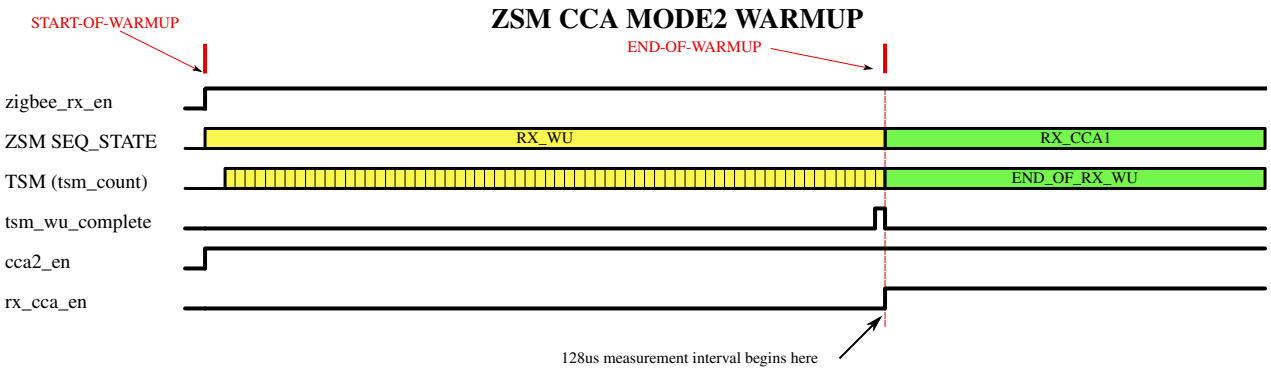
Table continued from the previous page...

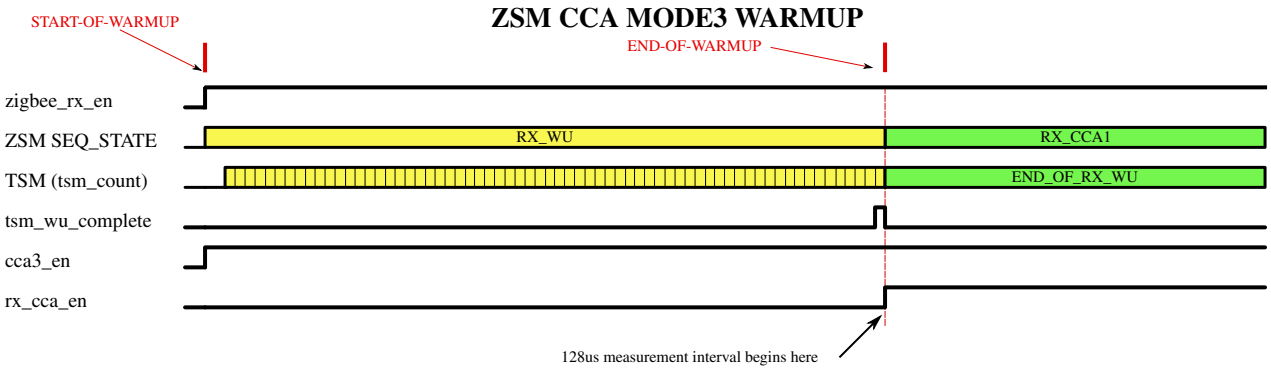
ZSM STATE	VECTOR
CCA2_WAIT	0x19
RX_CCA2	0x1A
RX_CCCA	0x1C
RX2TX	0x1B
TX_WU	0x01
TX_PKT	0x05
TX_ACK	0x06
TX_SLOT	0x07
TX_WD	0x08
TX_PA_OFF	0x09
XTRA_CLK1	0x0A
TX2RX	0x0B
TSM_WD	0x1F

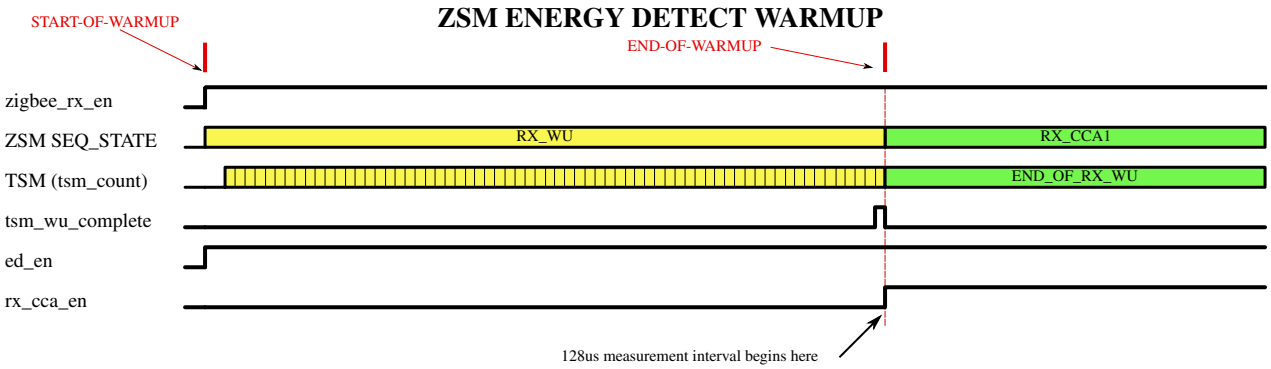
52.4.4.4.1.2.1.2.3.4 ZSM Warmup Timing




ZSM CCA MODE1 WARMUP
START-OF-WARMUP
END-OF-WARMUP
zigbee_rx_en
ZSM SEQ_STATE
RX_WU
RX_CCA1
TSM (tsm_count)
END_OF_RX_WU
tsm_wu_complete
cca1_en
rx_cca_en
128us measurement interval begins here


ZSM CCA MODE2 WARMUP
START-OF-WARMUP
END-OF-WARMUP
zigbee_rx_en
ZSM SEQ_STATE
RX_WU
RX_CCA1
TSM (tsm_count)
END_OF_RX_WU
tsm_wu_complete
cca2_en
rx_cca_en
128us measurement interval begins here


ZSM CCA MODE3 WARMUP
START-OF-WARMUP
END-OF-WARMUP
zigbee_rx_en
ZSM SEQ_STATE
RX_WU
RX_CCA1
TSM (tsm_count)
END_OF_RX_WU
tsm_wu_complete
cca3_en
rx_cca_en
128us measurement interval begins here


ZSM ENERGY DETECT WARMUP
START-OF-WARMUP
END-OF-WARMUP
zigbee_rx_en
ZSM SEQ_STATE
RX_WU
RX_CCA1
TSM (tsm_count)
END_OF_RX_WU
tsm_wu_complete
ed_en
rx_cca_en
128us measurement interval begins here

52.4.4.4.1.2.1.2.3.5 Dual PAN Mode

Dual PAN On-the-fly Channel Change

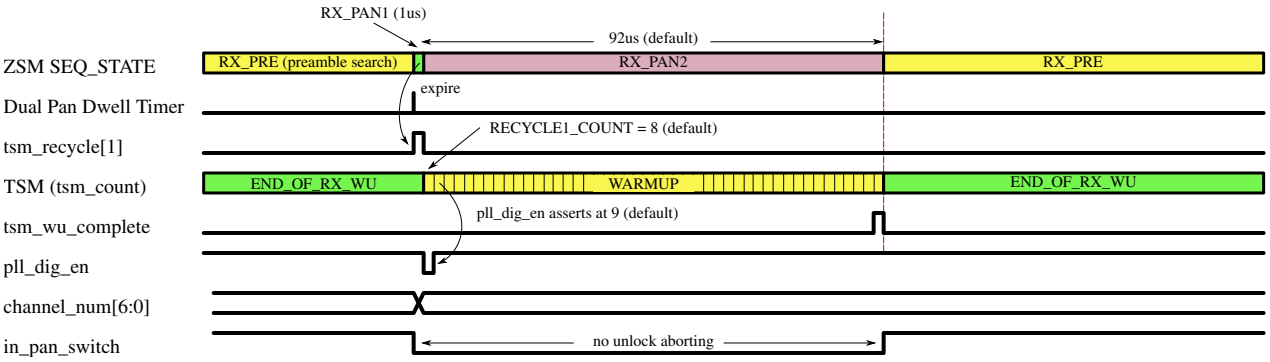
The 802.15.4 Sequence Manager (ZSM) supports Dual PAN mode, which allows the device to reside on 2 networks simultaneously, switching back and forth between the 2 networks under software, or hardware control. (See Packet Processor Chapter, Section Dual PAN Mode for more details on Dual PAN mode).

In Automatic Dual PAN Mode, the device must switch from one network to another under hardware control, at a software-programmed rate. Since the 2 networks often occupy different channels (frequencies), the sequence manager supports an "on-the-fly channel change", whereby, during a Sequence R, in preamble-search state (RX_PRE), the sequence manager will request the TSM to toggle **pll_dig_en** and switch to a new RF channel, wait out a PLL settling time, and then resume preamble search on the new channel. The entire on-the-fly channel change consumes 93us (based on default TSM programming), and consumes 2 ZSM states. The first state (RX_PAN1) issues **tsm_recycle[1]** to the TSM, which causes TSM to jump from its "ON" phase, back to the tsm_count value which is programmed into the RECYCLE_COUNT1[7:0] register in XCVR space. Based on the default programming for RECYCLE1_COUNT, along with the default programming for the TSM timing registers, this TSM recycle will cause the TSM to jump back to the point 1us before **pll_dig_en** is asserted, resulting in a 1us-long deassertion of **pll_dig_en**. The TSM will resume counting from that point, which will re-assert **pll_dig_en**, and the ZSM will simultaneously select the alternate Dual Pan channel. Meanwhile, the ZSM will advance to RX_PAN2 state and wait there pending **tsm_wu_complete** from the TSM. The TSM will resume counting until it once again until it reaches END_OF_RX_WU[7:0], and then will return to its ON phase. At the end of the TSM RX warmup, TSM will issue **tsm_wu_complete** to ZSM, which will return ZSM to RX_PRE (preamble search) state.

Normally, during RX sequences, the PLL is monitored for unlock conditions, and if such an unlock were to occur, the ZSM would abort the RX sequence by deasserting ZIGBEE_RX_EN to TSM. During RX_PAN1 and RX_PAN2 states, ZSM asserts **in_pan_switch** to the transceiver, which indicates that PLL unlock detection should be temporarily suspended while the channel change and subsequent PLL re-lock takes place. Once the ZSM transitions from RX_PAN2 state back to RX_PRE, ZSM will deassert **in_pan_switch** to resume PLL unlock monitoring.

As mentioned, the entire on-the-fly channel change consumes 93us, based on default TSM programming. This 93us represents a short "blind spot" during which preamble detection can't occur, while the device switches from one RF frequency to another. See diagram below.

ZSM DUAL PAN ON-THE-FLY CHANNEL CHANGE



Dual PAN Channel Override

When using Dual PAN mode, the channels are assigned to the 2 PAN's by programming the CHANNEL_NUM0[6:0] and CHANNEL_NUM1[6:0] registers in 802.15.4 space. This method allows a channel number, from 11 to 26, to be programmed into each register, and the channel number is processed downstream into the necessary Integer, Numerator, and Denominator components, required to generate the correct RF frequencies (see PLL Digital Chapter).

In Dual PAN mode, in case there is a need to generate a frequency which may be offset from the 16 prescribed 5MHz-spaced channels, to, for example, avoid interference on one of the Dual PAN channels, a method has been provided to do that, by designating one of the two PAN channels to use the transceiver's set of direct frequency-programming registers, instead of CHANNEL_NUMx. Programming the direct frequency-programming registers – integer, numerator, and denominator, allows an

RF frequency to be selected with much more precision than the 5MHz granularity of the 802.15.4 mapped-channel registers, CHANNEL_NUM0 and CHANNEL_NUM1.

Two bits have been provided in 802.15.4 space to realize this feature: ZB_DP_CHAN_OVRD_SEL and ZB_DP_CHAN_OVRD_EN. When ZB_DP_CHAN_OVRD_EN=1, this enables one of the Dual PAN channels to use the direct frequency programming. The ZB_DP_CHAN_OVRD_SEL bit determines *which* channel uses the direct programming, according to the following table:

ZB_DP_CHAN_OVRD_EN	ZB_DP_CHAN_OVRD_SEL	PAN0 Frequency Determined by …	PAN1 Frequency Determined by …
0	X	CHANNEL_NUM0[6:0]	CHANNEL_NUM1[6:0]
1	0	DIRECT FREQUENCY PROGRAMMING	CHANNEL_NUM1[6:0]
1	1	CHANNEL_NUM0[6:0]	DIRECT FREQUENCY PROGRAMMING

Direct Frequency Programming is accomplished by setting the PLL's Integer, Numerator, and Denominator registers to the appropriate values for the desired RF frequency. These registers are in XCVR address space, and are shown in the following table:

DIRECT FREQUENCY PROGRAMMING PARAMETER	REGISTER NAME (XCVR SPACE)	REGISTER MNEMONIC
Integer	LPM_INTG[6:0]	PLL_LP_SDM_CTRL1
Numerator	LPM_NUM[27:0]	PLL_LP_SDM_CTRL2
Denominator	LPM_DENOM[27:0]	PLL_LP_SDM_CTRL3

See the PLL Digital Chapter for RF frequency programming details.

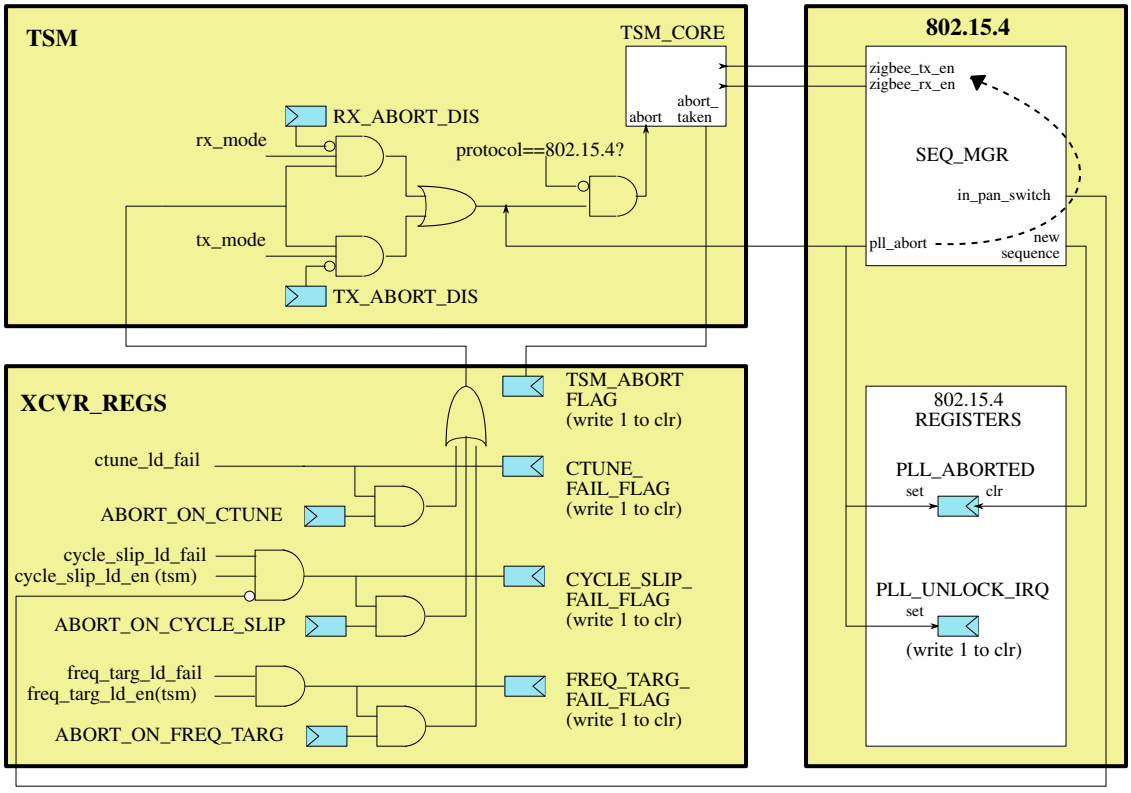
In Dual PAN automatic mode, if ZB_DP_CHAN_OVRD_EN=1, when the hardware switches to the PAN selected by ZB_DP_CHAN_OVRD_SEL as a direct-programming channel, the CHANNEL_NUMx[6:0] register is ignored and the directly programmed frequency is used instead; when the hardware switches back to the other channel, the CHANNEL_NUMx[6:0] register is used once again.

52.4.4.4.1.2.1.2.3.6 Sequence Aborting

All 802.15.4 sequences can be aborted by a PLL unlock detection. The unlock detection is qualified by the ZSM sequence manager; in other words, an unlock condition during the early stages of the PLL warmup is expected, and is not allowed to abort the sequence at that point. The primary rationale for the PLL unlock abort is to prevent transmission on an incorrect, or unstable, frequency during a transmit operation, or to increase battery life by not prolonging a receive or CCA operation that is bound to fail. Software can disable the PLL unlock auto-abort.

When a PLL unlock event occurs during a 802.15.4 autosequence, the TSM's abort facilities are not used, to allow the ZSM to handle the unlock condition directly, as shown in the following diagram:

802.15.4 PLL UNLOCK HANDLING



The combined-abort signal is blocked from reaching the TSM, and instead is routed to the 802.15.4 Sequence Manager (ZSM). This is due to the fact that the ZSM already includes abort-handling logic, which is being re-used from previous Freescale/NXP 802.15.4 products. Keeping the unlock handling intact, facilitates the porting of software from one NXP 802.15.4 product to the next.

For 802.15.4, the logic which determines which ZSM states allow aborting, is designed into the ZSM state machine. Not all states require an abort-on-unlock. When an unlock event occurs during a ZSM state that requires an abort, the ZSM will deassert its initiating signal to TSM (zigbee_tx_en or zigbee_rx_en), which results in a de facto abort, similar to a TSM-generated abort. For a ZSM abort, the PLL_UNLOCK_IRQ bit will become set, as will the PLL_ABORTED bit. The PLL_UNLOCK_IRQ bit is of type write-1-to-clear, and resides in the IRQSTS1 register of 802.15.4 space. The PLL_ABORTED bit is a read-only bit, and resides in the ABORT_STS register of 802.15.4 space; it will self-clear at the start of the next autosequence.

52.4.4.4.1.2.1.2.3.7 Clocks

The ZSM sequence manager use 2 clocks.

The main clock is **seq_mgr_clk**. This clock establishes the sequence manager timebase (1us), and runs the sequence manager state machine and auxiliary timers.

A secondary clock is “**ck”,** which is a gated 32mhz clock from the reference oscillator. This clock is used only for low-latency processing of a few incoming signals, such as the issuing of XCVSEQ sequence commands through the IPS bus interface, which can occur at a rate faster than 1us.

The **seq_mgr_clk** and **ck** derive from the same 32MHz source. Thus, these 2 clocks are in the same clock domain, and will be balanced (skew-controlled) during clock-tree synthesis. The **seq_mgr_clk** will be generated in the CRM. All inputs to the sequence manager are also in this same clock domain, including all the TSM interface signals, and the IPS bus-based control registers; there are no clock-domain-crossings or asynchronous interfaces in the ZSM sequence manager.

52.4.4.4.1.2.1.2.3.8 Reset

The 802.15.4 Sequence Manager has a single, active-low, asynchronous reset input: **rst_b** . At integration, this reset should be tied to the master reset for the entire transceiver. There are no special reset requirements.

52.4.4.4.1.2.1.2.3.9 Interrupts

The 802.15.4 Sequence Manager generates 4 interrupt "triggers":

1. rxirq_trig
2. txirq_trig
3. ccairq_trig
4. filterfail_irq_trig

These triggers are not a direct interrupts to the MCU, but are used to set individual 802.15.4 Interrupt Status bits to become 4 of the 12 802.15.4 Link Layer interrupt sources which, if enabled, will result in the 802.15.4 interrupt **ipi_int_zigbee** being asserted to the MCU. These 4 interrupt triggers will assert the 802.15.4 Interrupt Status Bits RXIRQ, TXIRQ, CCAIRQ, and FILTERFAIL_IRQ, respectively. All of these Interrupt Status Bits reside in the IRQSTS1 register of 802.15.4 Address Space. See Section Interrupts for more details on how the 802.15.4 Link Layer interrupt sources are consolidated into a single MCU interrupt line.

52.4.4.4.1.2.1.2.3.10 Appendix A

Effect of Timer TMR3 on Sequence Manager

Timer TMR3 can be used as a “bracketing” timer, to abort certain sequences after a software-determined timeout period. This timeout mechanism is enabled by setting the TC3TMOUT bit to 1. If TC3TMOUT=0, then the abort mechanism is disabled, and timer TMR3 functions merely as a software timer.

Timer TMR3’s hardware-abort functions are summarized in the following table.

Table 546. TMR3 Hardware Abort Functions

SEQUENCE	TC3TMOUT=0	TC3TMOUT=1
I	S/W timer	S/W timer
R	S/W timer	Abort sequence
T	S/W timer	S/W timer
C	S/W timer	S/W timer
TR	S/W timer	Abort sequence, (during receive operation only)
CCCA	S/W timer	Abort sequence

52.4.4.4.1.2.1.2.3.11 Appendix B

Continuous TX and RX Modes

Setting the bit CONTINUOUS_EN enables continuous transmission or reception, determined by which type of sequence is subsequently activated using the XCVSEQ register (i.e., Sequence T or Sequence R). Continuous TX and RX modes are designed to be used in tandem; i.e., two communicating devices, one serving as a continuous transmitter, and the other serving as a continuous receiver. The CONTINUOUS_EN resides in the SEQ_MGR_CTRL register of 802.15.4 address space. A description of the continuous TX and RX modes follows:

Continuous TX Mode

Continuous TX mode instructs the Sequence Manager to stay in a transmitting state forever (TX_PKT state), rather than shutting down the sequence after the 802.15.4 packet has been transmitted. In Continuous TX mode, data to be transmitted must be pre-established in the Packet Buffer prior to initiating a Sequence T. In Continuous TX mode, the first byte of the Packet Buffer

determines the length of the buffer, in bytes. In this mode, when the end of the buffer is reached, instead of transmitting FCS (CRC bytes), the TX modem circles back to the 2nd byte of the buffer (the byte after the length byte), and re-transmits the remainder of the buffer again, and this repeats continuously, until one of the following events occurs:

1) CONTINUOUS_EN is deasserted by SW

2) SW aborts the Sequence T by writing Sequence I to XCVSEQ

3) An PLL Unlock occurs, aborting the Sequence

To prepare for Continuous TX mode, the following steps should be taken:

1) Write the “length” byte to the first byte of the Packet Buffer

2) Write the remaining Packet Buffer contents (a total of “length” bytes)

3) Assert the CONTINUOUS_EN bit

4) Start the Transmit Sequence by writing Sequence T to XCVSEQ.

After Continuous TX mode has been entered, the SEQ_STATE register can be monitored to verify the Sequence Manager has reached the TX_PKT state, and remains in this state.

Continuous RX Mode

Continuous RX mode instructs the Sequence Manager to stay in a receiving state forever (RX_PKT state), rather than shutting down the sequence after a 802.15.4 packet has been received. For continuous RX mode, it is assumed that another device has been deployed as a continuous transmitter. The length of the continuous transmitter’s TX buffer, will also be the length of the continuous receiver’s RX buffer. For the receiver, in Continuous RX mode, the length of the buffer is determined by the DUAL_PAN_DWELL register. (Needless to say, Continuous RX mode should not be engaged simultaneously with Dual PAN mode, since DUAL_PAN_DWELL is serving an alternate purpose). For Continuous RX mode, DUAL_PAN_DWELL should be programmed to the same value as the “length” byte of the continuous transmitter’s TX buffer. See step 2) above, for Continuous TX mode. In Continuous RX mode, the first byte received (after Preamble and SFD), will be the “length” byte, which can be read from the RX_FRM_LEN register of the receiving device. (It is up to the user to guarantee that this length byte on the TX device matches the contents of the DUAL_PAN_DWELL register on the RX devices, by correctly programming the 2 devices). Each subsequent byte which is received, will be written to the next sequential address of the Packet Buffer, starting at PB address 0. When the number of received bytes matches the contents of DUAL_PAN_DWELL register, the Packet Buffer’s address generation logic will circle back to PB address 0, and store the next received byte to this location. Then, each subsequent received byte, will be written to the next sequential address of the Packet Buffer. In this way, the contents of TX buffer on the continuous transmitter, will be identical to the contents of the RX buffer on the continuous receiver (assuming no reception errors). To prepare for Continuous RX mode, the following steps should be taken:

1) Program DUAL_PAN_DWELL register with the contents of the “length” byte of the continuously-transmitting device’s TX Buffer

2) Assert the CONTINUOUS_EN bit

3) Start the Receive Sequence by writing Sequence R to XCVSEQ.

After Continuous RX mode has been entered, the SEQ_STATE register can be monitored to verify the Sequence Manager has reached the RX_PKT state, and remains in this state. The contents of the Packet Buffer can also be observed in realtime, to verify they match the contents of the TX device’s TX buffer. The Sequence Manager will remain in the RX_PKT state until one of the following events occurs:

1) CONTINUOUS_EN is deasserted by SW

2) SW aborts the Sequence R by writing Sequence I to XCVSEQ

3) An PLL Unlock occurs, aborting the Sequence

52.4.4.4.1.2.1.3 Packet Storage

The 802.15.4 Link Layer has access to a Packet Buffer to store data to be transmitted, and to receive incoming packet data. The 802.15.4 Link Layer software prepares data to be transmitted, by loading the octets, in order, into the Packet Buffer (Zigbee LL TX_RAM Buffer). After reception, the octets received over the air are stored into the Packet Buffer (Zigbee LL RX_RAM Buffer),

in the order they are received. The Packet Buffer contains separate spaces for TX and RX data, so incoming receive octets don't overwrite previously-loaded content intended for transmission. The Packet Buffer is large enough to accommodate the longest 802.15.4 packet, 127 bytes, for both transmit and receive.

The 802.15.4 Packet Buffer is contained within the multi-protocol Packet RAM. In the Packet RAM, space has been allocated for 802.15.4 packets, with separate spaces for TX and RX. The Packet RAM is 64 bits wide, so the 802.15.4 Link Layer controller hardware will address the RAM in an interleaved fashion as it stores octets to, or fetches octets from, the RAM-based packet buffer. The 802.15.4 TX buffer space begins at TX_RAM_BASE_ADDR, and 802.15.4 RX buffer space begins at RX_RAM_BASE_ADDR. Separate TX and RX spaces means that incoming RX packets don't overwrite TX packet data.

In addition, the 802.15.4 Link Layer controller includes acceleration for Source Address Matching (see Section Source Address Management). The hardware acceleration includes a Source Address Table, which is 128 entries by 16 bits wide. This table begins at TX_RAM_BASE_ADDR+0x100.

During packet reception, the MCU is allowed to access the RX packet buffer, in order to download the packet while it's being received, if so desired. In cases where both the MCU and the 802.15.4 Link Layer controller attempt to access RX packet buffer during reception, internal hardware arbitration is provided to delay the MCU access until 802.15.4 Link Layer completes its access.

During packet reception, the MCU is allowed to access the Source Address Table. Access to he Source Address Table is indirect, and is performed through the 802.15.4 Register Interface, specifically by programming SAM_TABLE register with the index of the table entry to be written or read, and the desired checksum in the case of write accesses. Because accesses to Source Address Table consist of discrete writes to 802.15.4 registers, and not long burst accesses, arbitration shall be able to accommodate Link Layer read accesses to the table while the Host access is underway, by delaying the Host access until the Link Layer completes.

During packet transmission MCU access to TX_RAM Buffer is also allowed. Arbitration shall be able to accommodate Link Layer read accesses to the TX RAM Buffer while the Host access is underway, by delaying the Host access until the Link Layer completes. This is very useful when sending enhanced ACK frames. But the 802.15.4 softwaremust not alter the Source Address Table once transmission has begun.

Arbitration

Arbitration hardware has been provided to allow the MCU to download data from the RX RAM Buffer while the packet is being received, in order to allow a headstart on software packet processing, if required by the application. Arbitration hardware has also been provided to allow the MCU to write data to the TX RAM Buffer while the packet is being sent, in order to allow software packet preparation, if required by the application. In the SoC, there is no provisions to wait the MCU on IPS or APB bus accesses to the radio. Therefore, in case of simultaneous access attempts by the MCU and the 802.15.4 Link Layer to the TX/RX RAM Buffer, arbitration hardware delays the MCU access to the TX/RX RAM Buffer until Link Layer completes its access. In the intended scenario, 802.15.4 software sets a RX watermark interrupt, and on this interrupt, proceeds to download the contents of the Packet RX buffer in RX RAM Buffer.

52.4.4.4.1.2.1.4 Event Timer

OVERVIEW

The 802.15.4 Link Layer Controller contains an internal Event Timer block that manages link layer timing.

The Event Timer consists of a prescaler and a 24-bit counter which increment whenever the 32MHz reference oscillator is operating (i.e., the controller is not in Deep Sleep Mode). Interrupts to the MCU may be generated when the current time of the counter matches several pre-determined values set in programmable registers. The current time is accessible at any time via a read operation, as well as, programmable via a write operation.

The Event Timer provides the following functions:

- Timer to generate current system time
- Interrupt generation at pre-determined system times
- Abort an RX sequence at pre-determined system time
- Latches timestamp value during packet reception
- Initiates timer-triggered sequences

Note: The Event Timer is actually a 28-bit value, with 24 integer bits and 4 fractional bits. For most operations involving the Event Timer, such as interrupt-generation and sequence-triggering, only the integer portion need be considered, and the fractional component can be ignored. Extended-precision (28-bit) Event Timer operations are required only to realize the increased accuracy required for entering and exiting Deep Sleep Mode. See Section Extended Precision Event Timer below.

EVENT TIMER TIME BASE

The Event Timer's base clock (tmr_clk) is derived from a prescaler which is clocked by the 32MHz crystal source. The prescaler provides a counter input frequency of 62.5KHz, which sets the granularity and resolution of the current time. The 24-bit counter automatically rolls over upon reaching its maximum value, yielding a maximum possible Event Timer duration of 268.436 seconds.

READING CURRENT TIME

"Current Time" is defined as the value of the Event Timer internal counter. This 24-bit value can be read as the upper 3 bytes of the EVENT_TMR register. The EVENT_TMR register resides at at address ZLL_BASE + 0x8, so the upper 3 bytes begin at ZLL_BASE + 0x9. The 24-bit value represents the integer component of the 28-bit Event Timer, which is all that is needed for most Event Timer operations. (For accessing the extended precision Event Timer, see Section Extended Precision Event Timer below.)

SETTING CURRENT TIME

"Current Time" is defined as the value of the Event Timer internal counter. This 24-bit value is available as the upper 3 bytes of the EVENT_TMR register. The EVENT_TMR register resides at at address ZLL_BASE + 0x8, so the upper 3 bytes begin at ZLL_BASE + 0x9. The current time is programmable, but does not have to be programmed. In the reset condition, the current time is set to zero. Current time advances from zero at the tmr_clk clock rate and rolls over to zero after reaching its maximum value.

The Event Timer can be updated in one of 2 ways:

EVENT_TMR_LD: Write the desired new EVENT_TMR value into the EVENT_TMR field of the EVENT_TMR register (upper 3 bytes), with the EVENT_TMR_LD bit set.

EVENT_TMR_ADD: Write the desired *increment* to the EVENT_TMR value into the EVENT_TMR field of the EVENT_TMR register (upper 3 bytes), with the EVENT_TMR_ADD bit set. The increment will be added to the current value of EVENT_TMR to become the new EVENT_TMR value. Since the Event Timer value is 24-bits, the addition is modulo 2^{24}.

Needless to say, EVENT_TMR_LD and EVENT_TMR_ADD are mutually exclusive, and no more than 1 of these bits should be set.

The 24-bit value represents the integer component of the 28-bit Event Timer, which is all that is needed for most Event Timer operations. (For accessing and updating the extended precision Event Timer, see Section Extended Precision Event Timer below.)

LATCHING THE TIMESTAMP

During packet reception, the 802.15.4 link layer controller has the ability generate a timestamp, or to latch a copy of the "current time" while continuing to increment its internal counter. This timestamp value latched within the Event Timer corresponds to the beginning of a receive packet where the actual packet data begins after the SFD (Start-of-Frame-Delimiter) has been received. The timestamp[23:0] can be accessed by reading the read-only register of the same name, TIMESTAMP, which resides at address ZLL_BASE + 0xC. Once the timestamp has been latched, it shall remain valid until the *next* SFD detection.

EVENT TIMER COMPARATORS

There are four 24-bit timer compare fields:

1. T1CMP[23:0] at address ZLL_BASE + 0x10
2. T2CMP[23:0] at address ZLL_BASE + 0x14
3. T3CMP[23:0] at address ZLL_BASE + 0x1C
4. T4CMP[23:0] at address ZLL_BASE + 0x20

And a special 16-bit timer compare field, for situations where the upper byte of EVENT_TMR is a don't-care.

- T2PRIMECMP[15:0] at address ZLL_BASE + 0x18

The TMR2IRQ status bit, can be set by a match to T2CMP or T2PRIMECMP. If register bit TC2PRIME_EN=1 (PHY_CTRL register, address ZLL_BASE + 0x04), then TMR2IRQ becomes set by a match to T2PRIMECMP (16-bit compare); if TC2PRIME_EN=0, then TMR2IRQ becomes set by a match to T2CMP (24-bit compare).

Each timer comparator has a enable bit that enables or disables the compare function. The enable bit is written to a 1 to enable the corresponding comparator, and the default condition is the timer compare disabled (reset to 0):

1. TMR1CMP_EN (for T1CMP)
2. TMP2CMP_EN (for T2CMP and T2PRIMECMP)
3. TMR3CMP_EN (for T3CMP)
4. TMR4CMP_EN (for T4CMP)

If a timer comparator is enabled using its associated bit, the corresponding interrupt status bit (TMRxIRQ) will be set by a timer compare match to its respective TxCMP register. If a timer comparator is disabled using its associated bit, the corresponding interrupt status bit (TMRxIRQ) will not be set by a timer compare match to its respective TxCMP register.

When enabled, all four fields can be continuously compared to the current value of the Event Timer counter. When a match occurs, the following corresponding internal status flags assert:

1. TMR1IRQ (T1CMP match)
2. TMR2IRQ (T2CMP or T2PRIMECMP match)
3. TMR3IRQ (T3CMP match)
4. TMR4IRQ (T4CMP match)

These 4 status bits all reside in the IRQSTS register at address ZLL_BASE + 0x0. The 4 interrupt status bits are write-1-to-clear. The status bit remains set until a 1 is written to the bit location in the IRQSTS register. Writing 0 to the bit, or reading the bit, will not change its state.

When a comparator match occurs and the internal status flag asserts, the following interrupt masks can enable an interrupt on the ipi_int_zigbee line to the MCU:

1. TMR1MSK, applies to TMRQ1IRQ
2. TMR2MSK, applies to TMRQ2IRQ
3. TMR3MSK, applies to TMRQ3IRQ
4. TMR4MSK, applies to TMRQ4IRQ

If the interrupt mask is set to 1 (masked), the respective interrupt status bit, TMRxIRQ, will not cause an interrupt on the ipi_int_zigbee line. If the interrupt mask is set to 0 (enabled), the respective interrupt status bit, TMRxIRQ, will cause an interrupt on ipi_int_zigbee. Timer mask bits, TMRxMSK, have no effect on the state of the TMRxIRQ interrupt status bits; they only allow (or prevent) the respective TMRxIRQ bit from generating an interrupt to the MCU on ipi_int_zigbee.

INTENDED EVENT TIMER USAGE

It is intended that the system utilize the current time value and the timer compare functions of the Event Timer to schedule system events, including:

1. Generating time-based interrupts
2. Aborting an RX operation
3. Triggering transceiver operations

GENERATING TIME-BASED INTERRUPTS

Generating time-based interrupts is accomplished by setting timer compare values relative to the current time, allowing the Event Timer counter to increment until a timer compare match is generated, and using this match to generate an interrupt to the host. The general procedure is as follows:

1. Disable the timer compare: set TMRxCMP_EN=0
2. Enable the timer compare interrupt mask: set TMRxMSK=1
3. Read the current time value from EVENT_TMR register
4. Determine an offset to this value to equal desired future time.

5. Write to EVENT_TMR register with the EVENT_TMR field set to this offset, and set EVENT_TMR_ADD=1
6. Re-enable the timer compare: set TMRxCMP_EN=1
7. Unmask the timer compare interrupt mask: set TMRxMSK=0
8. Wait for TMRxIRQ
9. After TMRxIRQ, program the appropriate TMRxCMP_EN bit to disable the compare function. If this is not done, the compare function will continue to run and generate another interrupt every time the counter rolls over and again matches the comparator.

USING T3CMP TO ABORT AN RX OPERATION

The Event Timer provides a timer-based mechanism to automatically abort an RX operation. The 802.15.4 link layer is put into an RX operation when XCVSEQ[2:0] (PHY_CTRL register, address ZLL_BASE + 0x4) is set to 0x01. An RX autosequence will commence, and will begin a search for preamble. Software can program in advance, a hardware timeout to occur, such that the RX autosequence can be automatically aborted by hardware after a certain amount of time elapses without a packet being detected. The general procedure is as follows:

1. Read the current time value from EVENT_TMR register
2. Add an offset to this value to equal desired future time to abort the RX operation.
3. Program register T3CMP[23:0] to value future time.
4. Program TC3TMOUT=1, (PHY_CTRL Register, address ZLL_BASE + 0x4) to 1, to enable hardware aborting of the RX operation.
5. Program XCVSEQ=1, to start the RX autosequence
6. When current time equals T3CMP[23:0], the 802.15.4 Sequence Manager aborts the RX autosequence, and the Sequence Manager returns to SEQ_IDLE state. The SEQIRQ interrupt status bit (IRQSTS Register, address ZLL_BASE + 0x0) will be set, and the TMR3IRQ interrupt status bit will also be set. The RXIRQ interrupt status bit will not be set, since no packet was received before the timeout. In the SEQ_CTRL_STATUS register (address ZLL_BASE + 0x78), the TC3_ABORTED status bit will also be asserted to indicate that the type of abort that occurred was a TMR3 timeout. This bit will self-clear at the start of the next autosequence.

As mentioned above, TMR3 with TC3TMOUT=1 can be used to abort an RX operation. Such an RX operation can be entered by launching a Sequence R (XCVSEQ=1), and can also be entered by launching a Sequence TR (XCVSEQ=4); after the TX operation of a Sequence TR completes, an RX operation begins, and can be aborted using this method. In addition, a Continuous CCA autosequence (XCVSEQ=5) can be aborted using this method. When a TMR3 timeout occurs with TC3TMOUT=1 during transceiver operations other than those listed above, TMR3 will not abort the autosequence, and TMR3 becomes merely a software timer, capable of setting TMR3IRQ and interrupting the MCU. The table below shows the effect of TMR3 timeouts on the 802.15.4 autosequences:

Table 547. TMR3 Hardware Abort Functions

SEQUENCE	TC3TMOUT=0	TC3TMOUT=1
I	S/W timer	S/W timer
R	S/W timer	Abort sequence
T	S/W timer	S/W timer
C	S/W timer	S/W timer
TR	S/W timer	Abort sequence, (during receive operation only)
CCCA	S/W timer	Abort sequence

USING T2CMP OR T2PRIMECMP TO TRIGGER TRANSCEIVER OPERATIONS

The Event Timer provides a timer-based mechanism to automatically launch a transceiver autosequence. Using this method, a sequence can be scheduled for time in the future, and the MCU can be put into a reduced power state, without the need to wake up at the appropriate time to start the autosequence. The general procedure is as follows.

1. Read the current time value from EVENT_TMR register.
2. Add an offset to this value to equal desired future time to launch the autosequence.
3. For a 24-bit compare, program register T2CMP[23:0] to value future time, and set TC2PRIME_EN=0. For a 16-bit compare, program register T2PRIMECMP[15:0] to value future time, and set TC2PRIME_EN=1. Set TMRTRIGEN=1 and program the desired autosequence into XCVSEQ[2:0]. The Sequence Manager will not launch the sequence immediately because it sees TMRTRIGEN=1.
4. When current time equals T2CMP[23:0] (for a 24-bit compare), or T2PRIMECMP[15:0] (for a 16-bit compare), the Sequence Manager will launch the scheduled autosequence in accordance with the XCVSEQ[2:0] field. The TMR2IRQ interrupt status bit will become set simultaneous with the autosequence launch.
5. The MCU can wake up at this point (if TMR2MSK=0), or can elect to continue in low-power state until the autosequence completes, at which time SEQIRQ will become set. If SEQMSK=0, then SEQIRQ will interrupt the MCU at the completion of the transceiver operation.

EXTENDED PRECISION EVENT TIMER

For most 802.15.4 transceiver operations referencing the Event Timer, the 24-bit precision and the 62.5KHz update rate (16µs period) are sufficient. However, the required precision for maintaining the 802.15.4 timebase is tighter: 1 microsecond, instead of 16. As long as the 32MHz reference oscillator is running there is no difficulty maintaining that precision. However, when the link layer has to enter low-power state, and the reference oscillator must be switched off, and alternate clock source must be temporarily employed to keep the timebase running. This low power state is known as Deep Sleep Mode, or DSM. The alternate clock source, a 32KHz crystal oscillator, is equally as precise as the reference oscillator, but with a much longer period. At the instant the reference oscillator is turned off and the switchover to the 32KHz is made, the EVENT_TMR becomes frozen at its current state. After a period of DSM, when the precisely-programmed wakeup point is reached, the reference oscillator, which has been previously restarted, is re-engaged by the link layer, and the EVENT_TMR resumes counting where it left off. The precise duration of time for which the EVENT_TMR was frozen, is known to software, based on DSM programming parameters. The EVENT_TMR must be corrected for this "time slept", by adding to it an amount equal to "time slept", in microseconds (hence the requirement for microsecond precision). After the precise correction is made, the EVENT_TMR is now up-to-date, as if the DSM entry/exit had never happened, and all previously scheduled events will occur on time, within 1µs precision.

To realize the required microsecond precision, the actual Event Timer has been expanded to 28 bits, with 24 integer bits and 4 fractional bits, as shown in the diagram below.

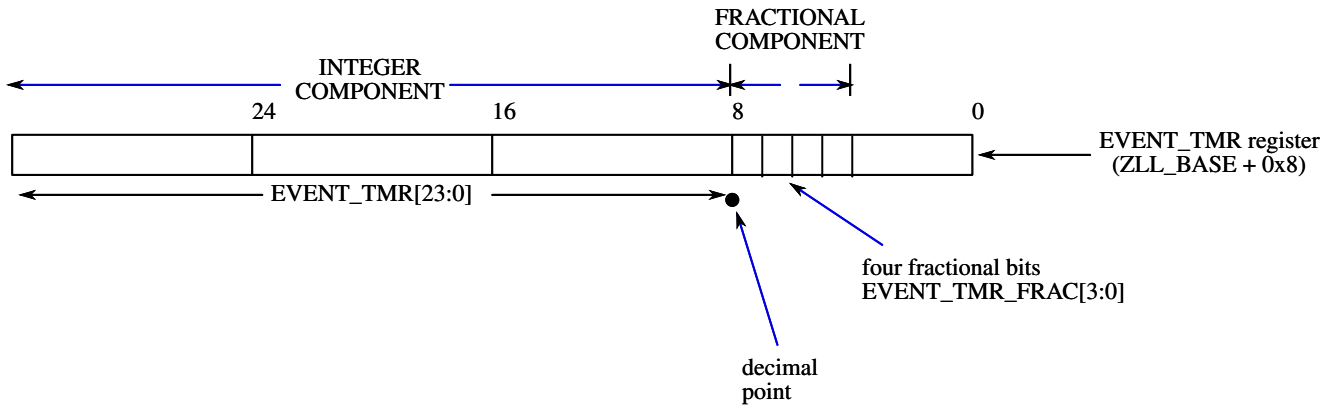


Figure 418. Event Timer Integer and Fractional Components

The 24-bit integer component is the EVENT_TMR value that has been referenced earlier in this section; most 802.15.4 operations require only the integer component, and the fractional component can be ignored. When the fractional bits are not required, writes to EVENT_TMR register (read-modify-write operations) with EVENT_TMR_LD=1 should leave the fractional bits unchanged.

Transceiver operations which reference the EVENT_TMR (i.e., automatic sequence launching, and RX sequence aborting), reference only the integer component, as shown below.

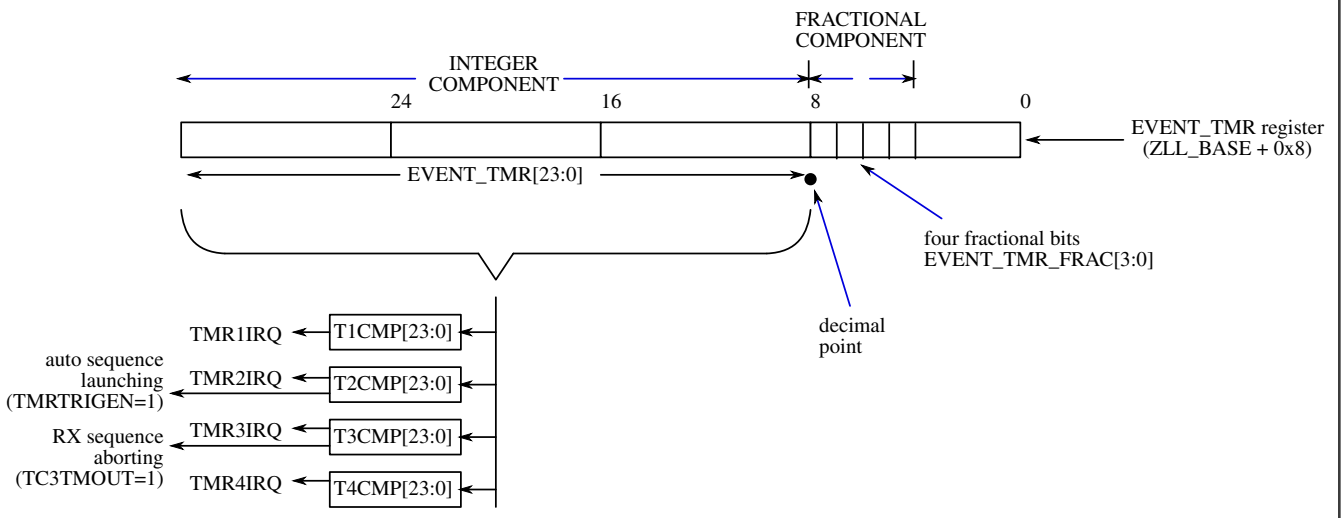


Figure 419. Event Timer Hardware Referencing

However, software EVENT_TMR updates to correct for "time slept" after a DSM cycle must make use of the full precision, including the fractional bits, in order to maintain microsecond accuracy. For example, say a DSM cycle was just completed in which the EVENT_TMR was frozen for exactly 163µs. The 163µs must be "added back" to the EVENT_TMR.

In this case the integer component is:

integer(163µs / 16µs) = **10**

And the fractional component is the remainder x 16:

(163µs / 16µs) - integer(163µs / 16µs) = 3/16 x 16 = **3**

So the value written to the EVENT_TMR with the EVENT_TMR_ADD bit set, accounting for the bit shifts to align to the integer and fractional components of the EVENT_TMR register, is:

(10 $lt;< 8) | (3 $lt;< 4), *or,*

EVENT_TMR = (10 $lt;< 8) | (3 $lt;< 4) | EVENT_TMR_ADD;

This operation adds 163µs to the EVENT_TMR current time, and after the update has occurred, the 802.15.4 timebase has been restored, as if no DSM cycle had occurred, within 1µs accuracy.

52.4.4.4.1.2.1.5 CCA/ED/LQI

52.4.4.4.1.2.1.5.1 Introduction

CCA/ED/LQI block resides inside 802.15.4 demodulator top. The purpose of this block is to perform the following operations: 1) Clear Channel Assessment: Modes 1, 2 and 3, 2) Energy Detection and 3) Link Quality Indicator.

This block takes RSSI value, as an input, for computations related to CCA modes 1 and 3, Energy Detection and LQI. For CCA2, this block takes output of 802.15.4 correlators for detecting an 802.15.4 signal in the channel of interest.

At the output, it provides a signal called (cca) to indicate if the channel of interest is busy (cca=1) or idle (cca=0), the final computed energy value (cca1_ed_fnl) and Link Quality Indicator (LQI) value. The cca signal is further used to generate cca interrupt, according to the set interrupt mask. The cca1_ed_fnl is a signed 8 bit value that can be read back as a register. LQI is an unsigned 8 bit value that is written at the end of each valid packet that is received and is available to be read in the packet buffer.

52.4.4.4.1.2.1.5.1.1 Block diagram

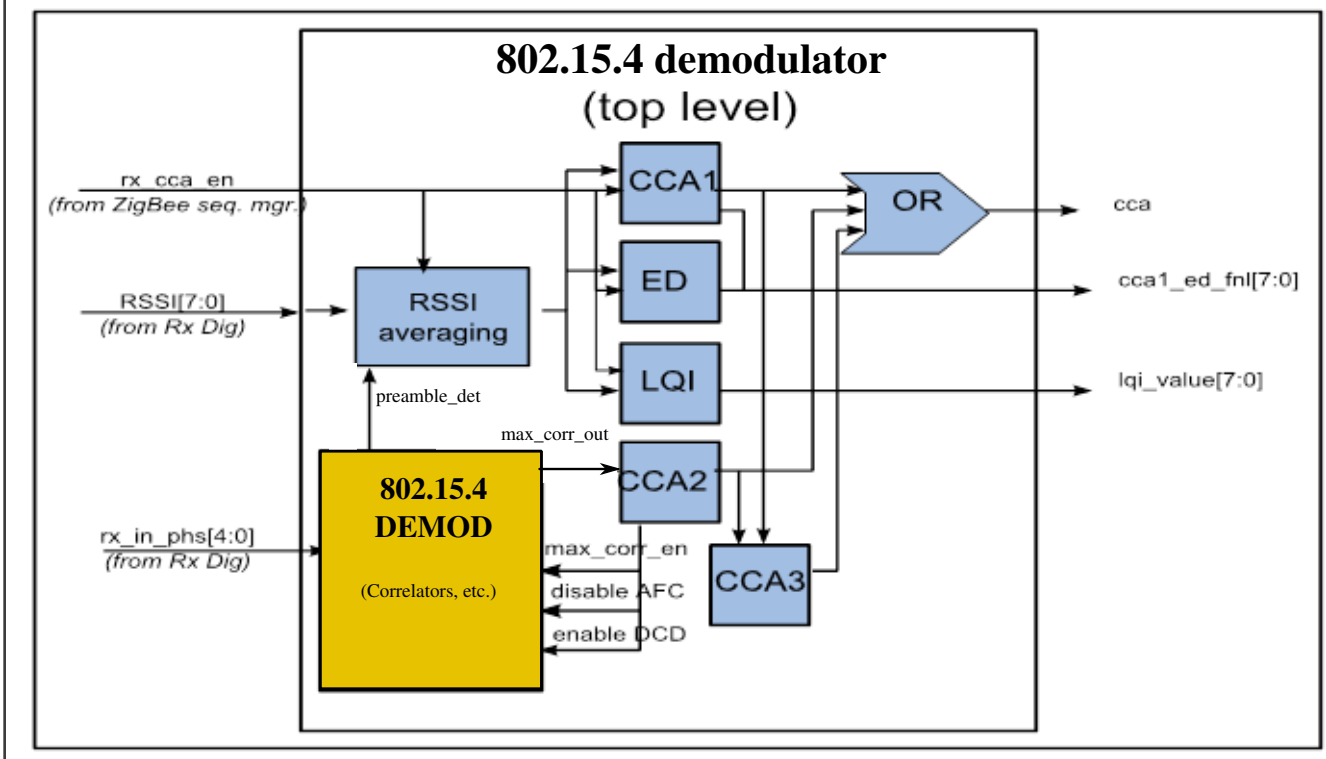


Figure 420. Block diagram

52.4.4.4.1.2.1.5.2 Memory Map and register definition

Field	R/W	Description
LQI_VALUE[7:0]	r	8-bit LQI value of each Rx packet
CCA1_ED_FNL[7:0]	r	8-bit signed value to indicate last energy detected
CCA1_THRESH[7:0]	rw	8-bit signed value to be compared against averaged signed RSSI value from Rx DIG block, to determine channel busy or idle
LQI_OFFSET_COMP[7:0]	rw	8-bit value to offset average of signed RSSI value coming from Rx DIG, in order to compute 8-bit LQI value.
CCA3_AND_NOT_OR	rw	This register bit controls how CCA1 and CCA2 are combined to assert CCA3 mode: 1 : CCA1 AND CCA2 0: CCA1 OR CCA2
CCA2_MIN_NUM_CORR_THRESH[2:0]	rw	3-bit value to compare against number of correlation peaks within CCA2 time.
CCA2_NUM_CORR_PEAKS[3:0]	r	4-bit value indicating number of correlation peaks detected in last CCA2 run
CCA2_CORR_THRESH[7:0]	rw	8-bit value to be compared against correlation peak value during CCA2 operation.

Table continues on the next page...

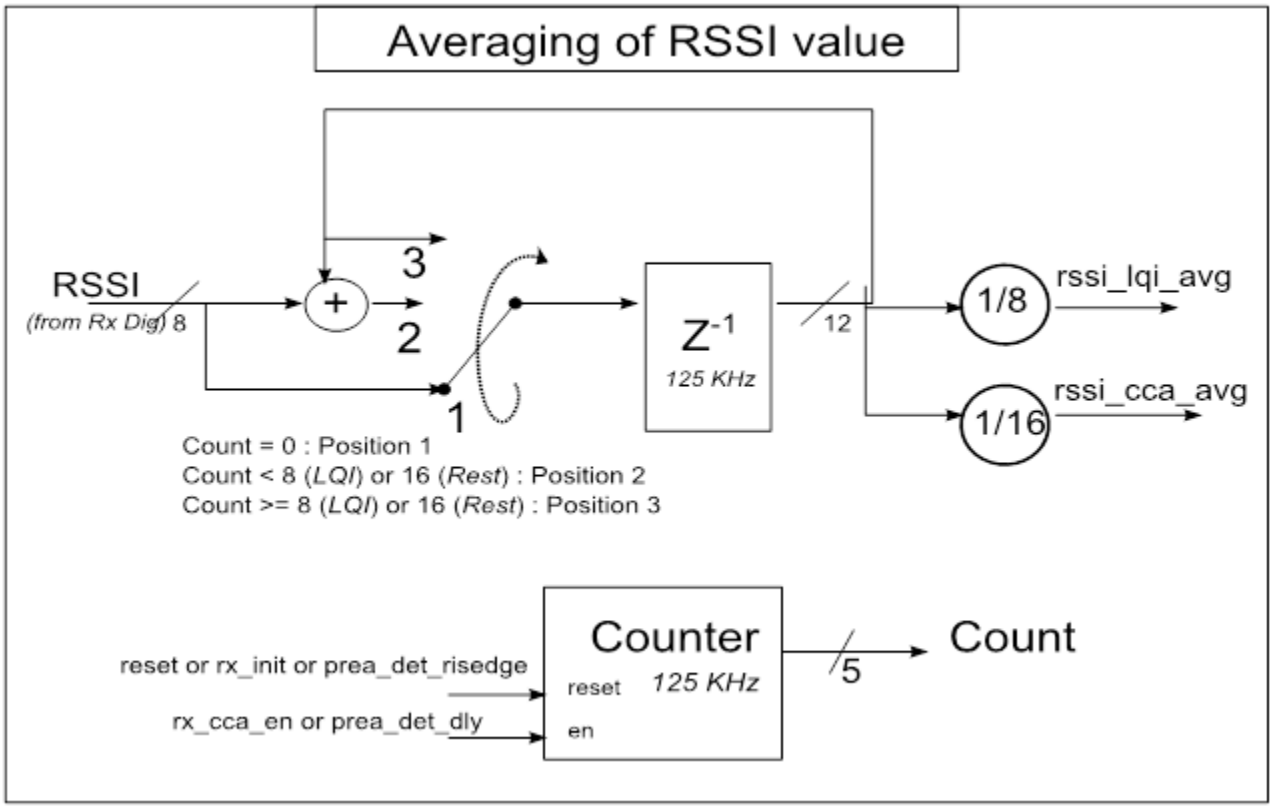
Table continued from the previous page...

Field	R/W	Description
LQI_START_AT_SFD	rw	Defines starting point for LQI computation during packet reception 1: Begin computing LQI at SFD detect (new for KW41) 0: Begin computing LQI at preamble detect (legacy)

52.4.4.4.1.2.1.5.3 Functional description

The following sections describe functional details of the module.

52.4.4.4.1.2.1.5.3.1 RSSI Averaging



The above picture shows how RSSI is averaged. 8-bit signed RSSI value from Rx Dig block is averaged for 128 us for CCA1/2/3/ED sequences. For LQI, it is averaged for 64 us. In both cases, the RSSI value is sampled at 125 KHz rate.

52.4.4.4.1.2.1.5.3.2 CCA1

When the 802.15.4 link layer is set up to perform CCA1 operation, rx_cca_en signal is asserted at the end of Rx warm up by the 802.15.4 Sequence Manager (ZSM). After rx_cca_en is asserted high, at the end of 128 us, i.e. count = 16, rssi_cca_avg is compared against 8-bit signed register cca1_thresh to assess CCA as follows:

If rssi_cca_avg >= cca1_thresh, CCA1 = 1, i.e. channel is busy.

Else CCA1 = 0, i.e. channel is idle.

52.4.4.4.1.2.1.5.3.3 CCA2

When the 802.15.4 link layer is set up to perform CCA2 operation, rx_cca_en signal is asserted at the end of Rx warm up by the 802.15.4 Sequence Manager (ZSM). During CCA2 operation, differential chip detection is enabled and automatic frequency correction is disabled, in order to receive correlation peaks related to all available 16 802.1.5.4 symbols. The signal max_corr_en is held high, in order to refresh maximum correlator value after each symbol period. 128 us after rx_cca_en is asserted high, i.e. count = 16, the number of maximum correlation peaks are counted which exceeded the value cca2_corr_thresh register. If the number of correlation peaks exceeds minimum desired number of correlation peaks (programmable register: cca2_num_corr_peaks), cca2 is asserted high to indicate the channel is busy and low otherwise, to indicate channel is idle.

52.4.4.4.1.2.1.5.3.4 CCA3

CCA mode 3 is a combination of CCA1 and CCA2. There are 2 combinations in which CCA mode 3 operates, based on the register setting of CCA3_AND_NOT_OR: 1) CCA1 OR CCA2 2) CCA1 AND CCA2. When the 802.15.4 link layer is set to perform CCA3, both CCA1 and CCA2 operations, as mentioned above and decides if the channel is busy or idle, according to the desired combination (i.e. AND/OR).

52.4.4.4.1.2.1.5.3.5 Energy Detection

During Energy Detection operation, the demodulator is expected to average RSSI value (from Rx_DIG) for 128 us, as mentioned above in the block diagram. At the end of 128 us, the register CCA1_ED_FNL is updated with this average energy value. Energy detection is similar to CCA1. Unlike CCA1, busy/idle signal is not generated.

52.4.4.4.1.2.1.5.3.6 Link Quality Indicator

LQI maps RSSI value (from Rx_DIG) to values between 0x00 and 0xFF, as shown in the following block diagram. Upon preamble detect, RSSI value is averaged for 64 us and mapped to LQI value. This latched LQI value is available in the register LQI_VALUE. Packet processor also appends this LQI value at the end of packet buffer.

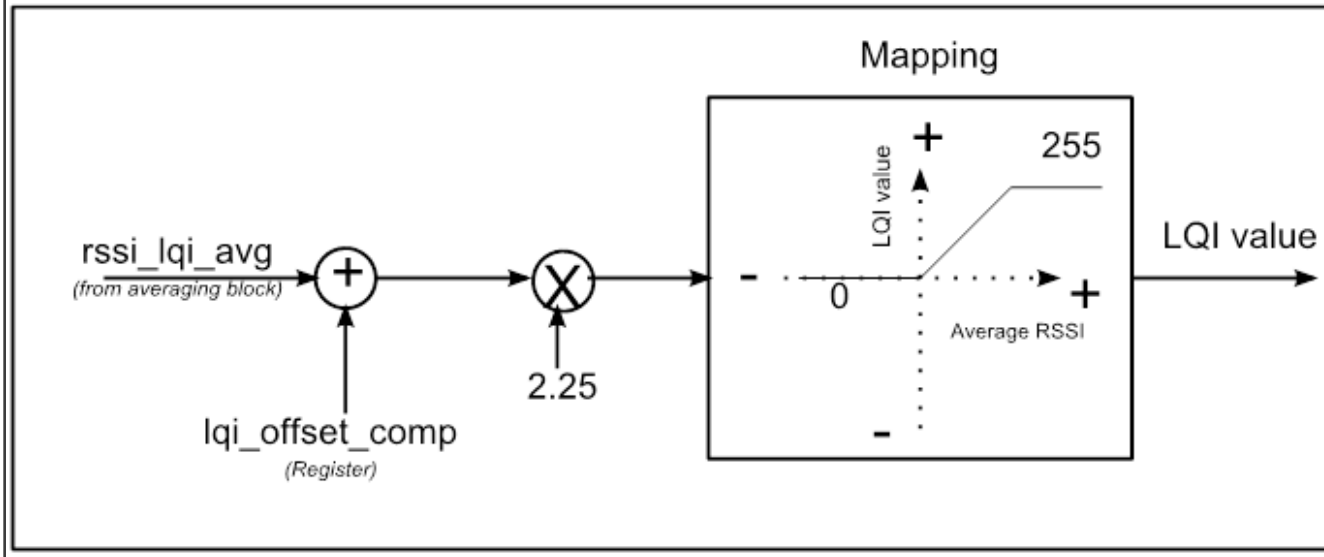


Figure 421. LQI Computation

The following picture shows an example of mapped LQI, when the register LQI_OFFSET_COMP is programmed to decimal value of 102.

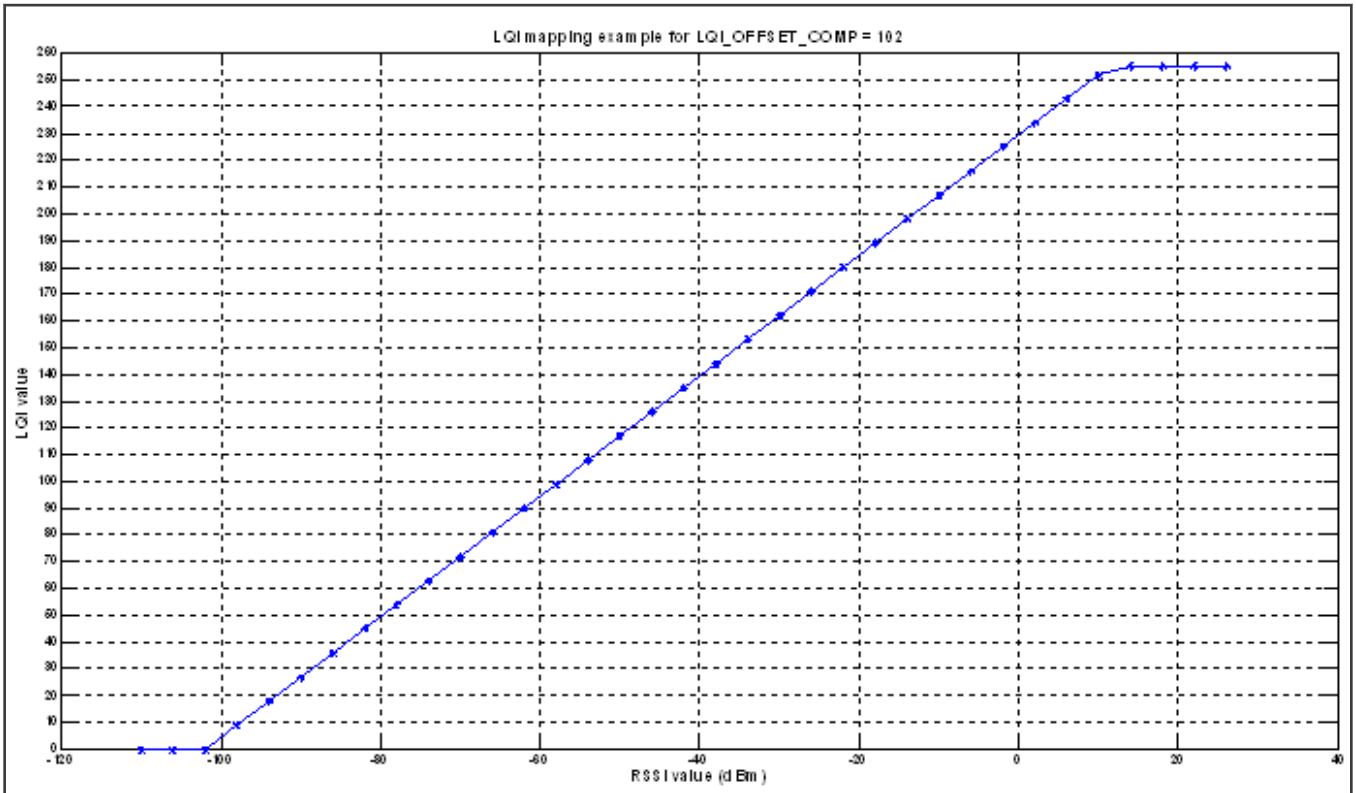


Figure 422. Plot of LQI vs. RSSI

52.4.4.4.1.2.1.5.3.7 Clocks

The CCA/ED/LQI module is a fully synchronous module. It has a single clock input **clk32m**. This clock input is driven by the RF Oscillator. The CCA/ED/LQI module has no asynchronous interfaces or clock domain crossings.

52.4.4.4.1.2.1.5.3.8 Reset

The CCA/ED/LQI module has a single, active-low, asynchronous reset input: **resetb** . At integration, this reset should be tied to the master reset for the entire transceiver. There are no special reset requirements.

52.4.4.4.1.2.1.5.3.9 Interrupts

The CCA/ED/LQI module does not generate any interrupts.

52.4.4.4.1.2.1.6 Interrupts

52.4.4.4.1.2.1.6.1 Introduction

This section describes the 802.15.4 Interrupt Architecture.

Revision	Date	Author	Changes
0.1	04-28-2014	D. Brown	Copy-over from Coconino
0.2	10-24-2015	D. Brown	Updated for KW41

The 802.15.4 Link Layer has a single, active high, interrupt line (ipi_int_zigbee) to the MCU. Internally, the Link Layer has 13 interrupt sources, as shown in the following table:

802.15.4 Interrupt Sources
SEQIRQ
TXIRQ
RXIRQ
CCAIRQ
RXWTRMRKIRQ
FILTERFAIL_IRQ
PLL_UNLOCK_IRQ
TMR1IRQ
TMR2IRQ
TMR3IRQ
TMR4IRQ
WAKE_IRQ
TSM_IRQ

Any or all of the interrupt sources, can be enabled to cause an assertion on ipi_int_zigbee. Each interrupt source has its own interrupt status bit in 802.15.4 register space. Each interrupt source is individually maskable (each has its own MASK bit), so that each interrupt source can be individual enabled to trigger an assertion on ipi_int_zigbee. There is also a global interrupt mask, TRCV_MSK, which can enable/disable all ipi_int_zigbee assertions by programming a single masking bit. All interrupt status bits (except TSM_IRQ) use a write-1-to-clear protocol. Interrupt status bits are not affected by reads. The ipi_int_zigbee pin is a level-sensitive interrupt indicator to the MCU; on an interrupt, ipi_int_zigbee will remain asserted until all active interrupt sources are cleared or masked.

52.4.4.4.1.2.1.6.1.1 Features

- 13 interrupt sources (interrupt status bits)
- each interrupt source individually maskable
- each interrupt source is individually write-1-to-clear.
- interrupts remain asserted until cleared.

52.4.4.4.1.2.1.6.2 Memory Map and register definition

Numerous register bits are provided to control 802.15.4 interrupt behaviour. The registers referred to below (IRQSTS1, IRQSTS2, IRQSTS3, PHY_CTRL2, PHY_CTRL3, and PHY_CTRL4) all reside in the 802.15.4 Address space.

Field	R/W	Description	Default
SEQIRQ	r/w1tc	1: A Sequencer Interrupt has occurred 0: A Sequencer Interrupt has not occurred	-
TXIRQ	r/w1tc	1: A TX Interrupt has occurred 0: A TX Interrupt has not occurred	-

Table continues on the next page...

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Field	R/W	Description	Default
RXIRQ	r/w1tc	1: A RX Interrupt has occurred 0: A RX Interrupt has not occurred	-
CCAIRQ	r/w1tc	1: A CCA Interrupt has occurred 0: A CCA Interrupt has not occurred	-
RXWTRMRKIRQ	r/w1tc	1: A RX Watermark Interrupt has occurred 0: A RX Watermark Interrupt has not occurred	-
FILTERFAIL_IRQ	r/w1tc	1: A Filter Fail Interrupt has occurred 0: A Filter Fail Interrupt has not occurred	-
PLL_UNLOCK_IRQ	r/w1tc	1: A PLL Unlock Interrupt has occurred 0: A PLL Unlock Interrupt has not occurred	-
TMR1IRQ	r/w1tc	1: A TMR1 Interrupt has occurred 0: A TMR1 Interrupt has not occurred	-
TMR2IRQ	r/w1tc	1: A TMR2 Interrupt has occurred 0: A TMR2 Interrupt has not occurred	-
TMR3IRQ	r/w1tc	1: A TMR3 Interrupt has occurred 0: A TMR3 Interrupt has not occurred	-
TMR4IRQ	r/w1tc	1: A TMR4 Interrupt has occurred 0: A TMR4 Interrupt has not occurred	-
WAKE_IRQ	r	1: A Wake Interrupt has occurred 0: A Wake Interrupt has not occurred	-
TSM_IRQ	r	1: A TSM Interrupt has occurred 0: A TSM Interrupt has not occurred	-
TMR1MSK	rw	1: Mask TMR1 Interrupt from asserting ipi_int_zigbee 0: Enable TMR1 Interrupt to assert ipi_int_zigbee	1
TMR2MSK	rw	1: Mask TMR2 Interrupt from asserting ipi_int_zigbee 0: Enable TMR2 Interrupt to assert ipi_int_zigbee	1
TMR3MSK	rw	1: Mask TMR3 Interrupt from asserting ipi_int_zigbee 0: Enable TMR3 Interrupt to assert ipi_int_zigbee	1
TMR4MSK	rw	1: Mask TMR4 Interrupt from asserting ipi_int_zigbee	1

Table continues on the next page...

Table continued from the previous page...

Field	R/W	Description	Default
		0: Enable TMR4 Interrupt to assert ipi_int_zigbee	
SEQMSK	rw	1: Mask Sequencer Interrupt from asserting ipi_int_zigbee 0: Enable Sequencer Interrupt to assert ipi_int_zigbee	1
TXMSK	rw	1: Mask TX Interrupt from asserting ipi_int_zigbee 0: Enable TX Interrupt to assert ipi_int_zigbee	1
RXMSK	rw	1: Mask RX Interrupt from asserting ipi_int_zigbee 0: Enable RX Interrupt to assert ipi_int_zigbee	1
CCAMSK	rw	1: Mask CCA Interrupt from asserting ipi_int_zigbee 0: Enable CCA Interrupt to assert ipi_int_zigbee	1
RX_WMRK_MSK	rw	1: Mask RX Watermark Interrupt from asserting ipi_int_zigbee 0: Enable RX Watermark Interrupt to assert ipi_int_zigbee	1
FILTERFAIL_MSK	rw	1: Mask Filter Fail Interrupt from asserting ipi_int_zigbee 0: Enable Filter Fail Interrupt to assert ipi_int_zigbee	1
PLL_UNLOCK_MSK	rw	1: Mask PLL Unlock Interrupt from asserting ipi_int_zigbee 0: Enable PLL Unlock Interrupt to assert ipi_int_zigbee	1
WAKE_MSK	rw	1: Mask Wake Interrupt from asserting ipi_int_zigbee 0: Enable Wake Interrupt to assert ipi_int_zigbee	1
TSM_MSK	rw	1: Mask TSM Interrupt from asserting ipi_int_zigbee 0: Enable TSM Interrupt to assert ipi_int_zigbee	1
TRCV_MSK	rw	1: Mask all Interrupts from asserting ipi_int_zigbee 0: Enable any Interrupt to assert ipi_int_zigbee	0
T1CMP[23:0]	rw	TMR1 compare value. If TMR1CMP_EN=1 and the Event Timer matches this value, TMR1IRQ is set.	0xFFF
T2CMP[23:0]	rw	TMR2 compare value. If TMR2CMP_EN=1 and the Event Timer matches this value, TMR2IRQ is set.	0xFFF
T2PRIMECMP[15:0]	rw	TMR2-prime compare value. If TMR2CMP_EN=1 and TC2PRIME_EN=1 and the lower 16 bits of Event Timer matches this value, TMR2IRQ is set.	0xFF
T3CMP[23:0]	rw	TMR3 compare value. If TMR3CMP_EN=1 and the Event Timer matches this value, TMR3IRQ is set.	0xFFF
T4CMP[23:0]	rw	TMR4 compare value. If TMR4CMP_EN=1 and the Event Timer matches this value, TMR4IRQ is set.	0xFFF

Table continues on the next page...

Table continued from the previous page...

Field	R/W	Description	Default
TMR1CMP_EN	rw	1: Allow an Event Timer Match to T1CMP to set TMR1IRQ 0: Don’t allow an Event Timer Match to T1CMP to set TMR1IRQ	0
TMR2CMP_EN	rw	1: Allow an Event Timer Match to T2CMP or T2PRIMECMP to set TMR2IRQ 0: Don’t allow an Event Timer Match to T2CMP or T2PRIMECMP to set TMR2IRQ	0
TMR3CMP_EN	rw	1: Allow an Event Timer Match to T3CMP to set TMR3IRQ 0: Don’t allow an Event Timer Match to T3CMP to set TMR3IRQ	0
TMR4CMP_EN	rw	1: Allow an Event Timer Match to T4CMP to set TMR4IRQ 0: Don’t allow an Event Timer Match to T4CMP to set TMR4IRQ	0
TC2PRIME_EN	rw	1: Allow a match of the lower 16 bits of Event Timer to T2PRIMECMP to set TMR2IRQ 0: Don’t allow a match of the lower 16 bits of Event Timer to T2PRIMECMP to set TMR2IRQ	0
RX_WTR_MARK[7:0]	rw	Receive byte count (octets) needed to trigger a RXWTRMRKIRQ interrupt . A setting of 0 generates an interrupt at end of the Frame Length field (first byte after SFD). A setting of 1 generates an interrupt after the first byte of Frame Control Field, etc.	0xFF

NOTE

For the standalone Block Guide shell project the DIL reference is commented out so that register tables will not show up in the project until they are explicitly included (see the .ditamap file).

52.4.4.4.1.2.1.6.3 Functional description

52.4.4.4.1.2.1.6.3.1 Interrupt Status Bit Structure

The 802.15.4 Link Layer has 13 interrupt sources, each represented in the register map by an interrupt status bit. All interrupt status bits share a common, generic structure. If a particular interrupt source is enabled, a “TRIGGERING EVENT” for that interrupt source, will always set the status bit. A write-1-to-clear input from the IPS bus, will clear the status bit, but only if there is not a simultaneous triggering event. The triggering event prevails over a software clear attempt, if both events coincide. The clock gate guarantees that the status bit only sees a clock when either a triggering event occurs, or a write-1-to-clear pulse arrives from the IPS bus. This reduces interrupt status bit power consumption to an absolute minimum. The common interrupt status bit structure is shown in the following diagram.

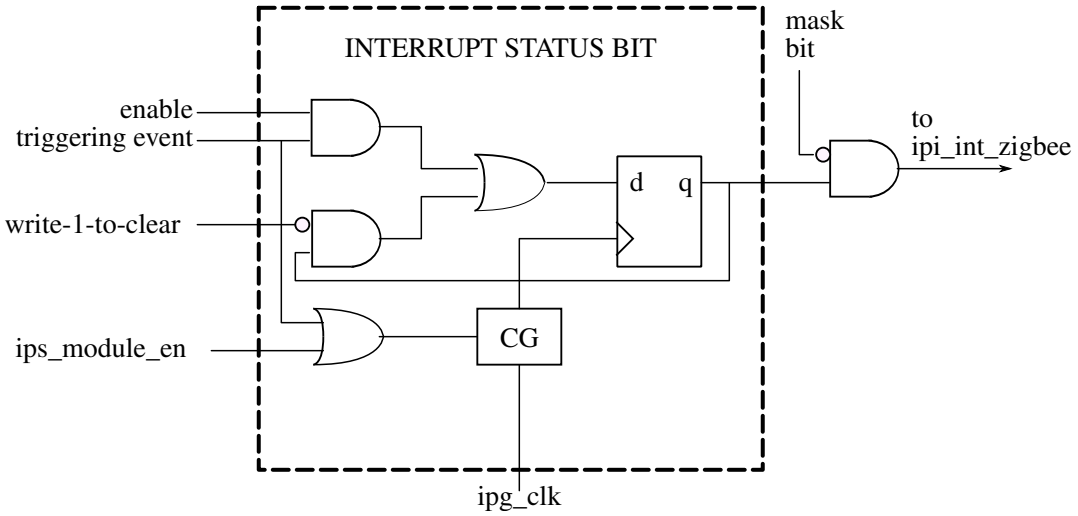

Figure 423. Interrupt Status Bit

Note that for any 802.15.4 interrupt source, if the triggering event occurs, the Interrupt Status Bit will be set regardless of the state of the corresponding MASK bit. If any of the 13 interrupts is to be ignored, software should set the corresponding MASK bit, and apply the appropriate bit mask when reading the IRQSTS1, IRQSTS2, or IRQSTS3 register, to mask out the unwanted status bit.

52.4.4.4.1.2.1.6.3.2 802.15.4 Interrupt Architecture

The 13 802.15.4 interrupt sources (status bits) are combined with their individual MASK bits, and then logically OR'ed together, in sum-of-products fashion, to generate single line to the MCU: ipi_int_zigbee. A global mask bit, TRCV_MSK, can enable or disable ipi_int_zigbee altogether. There is no prioritization of interrupt sources, they all have equal weight. The ipi_int_zigbee output is a level-sensitive indicator and will remain asserted until all interrupt status bits are cleared (or the corresponding mask bits set). The following diagram depicts the 802.15.4 Interrupt Architecture.

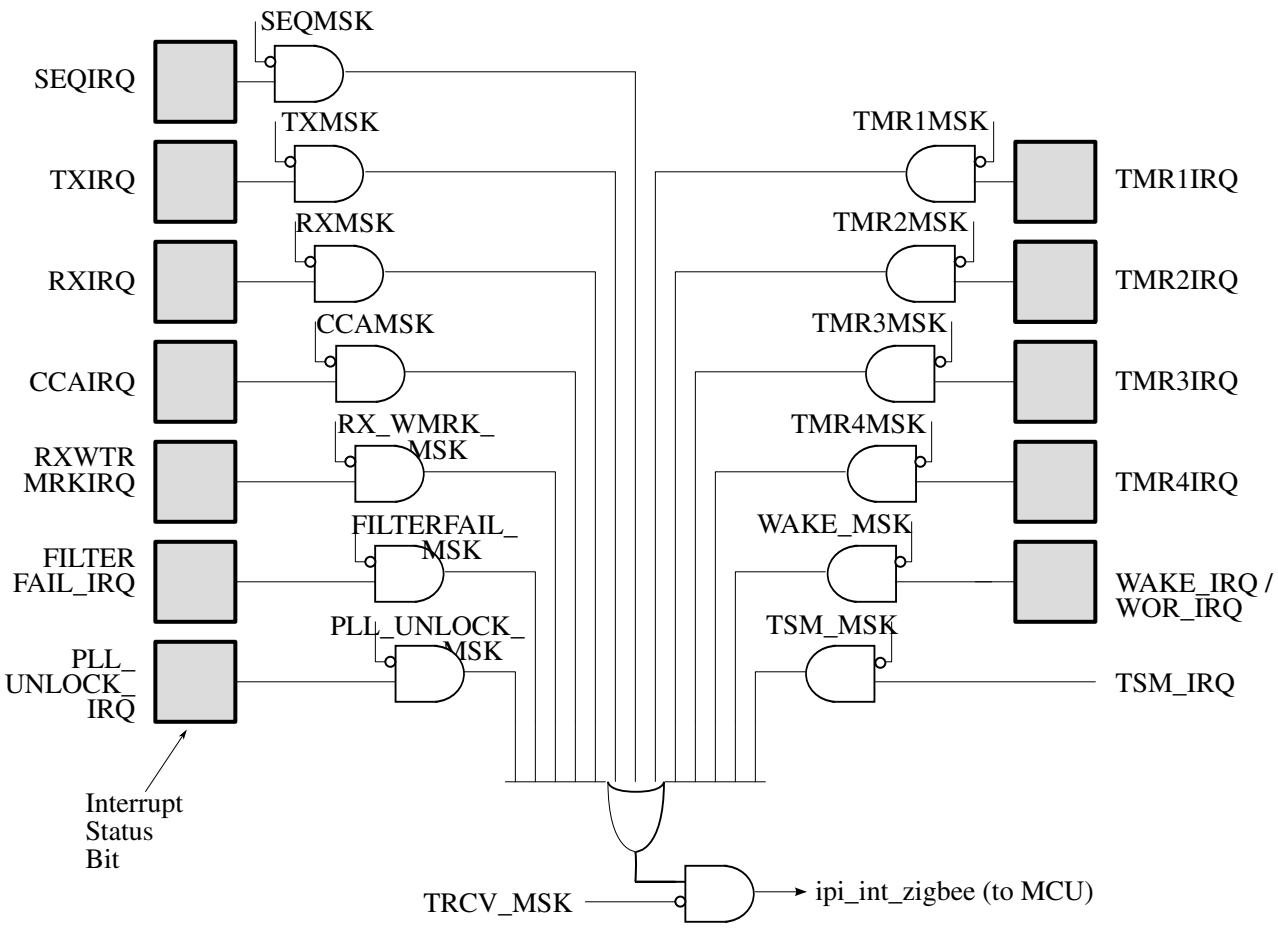

Figure 424. 802.15.4 Interrupt Architecture

52.4.4.4.1.2.1.6.3.3 Clearing Interrupts

All interrupt status bit use a write-1-to-clear protocol. Writing a '1' to the interrupt status bit, in the IRQSTS1, IRQSTS2, or IRQSTS3 register, clears the offending interrupt. Writing a '0' to an interrupt status bit has no effect on the bit. Interrupt status bits are not affected by reads.

Note: The TSM interrupt is an exception from the interrupt-clearing rules stated above. See Section TSM Interrupt below.

52.4.4.4.1.2.1.6.3.4 Timer Interrupts

The 802.15.4 Link Layer features a 24-bit Event Timer (see Section Event Timer). The Link Layer has 4 Timer interrupts (TMR1IRQ, TMR2IRQ, TMR3IRQ, and TMR4IRQ), each with its own 24-bit compare register (T1CMP, T2CMP, T3CMP, and T4CMP), and each with its own compare enable (TMR1CMP_EN, TMR2CMP_EN, TMR3CMP_EN, and TMR4CMP_EN). For each timer compare enable, if the bit is set, a match on the respective 24-bit compare value to the Event Timer will cause the corresponding interrupt status bit to become set. If the compare enable is low, Event Timer matches won't cause the corresponding interrupt status bit to become set.

In addition, a 16-bit T2PRIMECMP compare value is provided, along with a compare-enable bit: TC2PRIME_EN. When TC2PRIME_EN is set (and TMR2CMP_EN is also set), a match on T2PRIMECMP with the *lower 16 bits of Event Timer*, will cause TMR2IRQ to become set, rather than a full 24-bit compare.

52.4.4.4.1.2.1.6.3.5 PLL Unlock Interrupt

When an PLL unlock event occurs during a 802.15.4 autosequence, the PLL_UNLOCK_IRQ status bit will become set. The ZSM Sequence Manager will begin monitoring for PLL unlock only after a complete transceiver warmup has occurred; unlocks which occur during warmup will not cause a PLL_UNLOCK_IRQ. A PLL unlock which occurs after the warmup period, can be enabled to cause a sequence abort. (See Section Sequence Aborting for more details).

52.4.4.4.1.2.1.6.3.6 Filterfail Interrupt

Filterfail interrupt will occur during packet reception, when a packet fails filtering rules. On a Filterfail interrupt, the FILTERFAIL_CODE register can be read to ascertain more information about the nature of the filter failure. Filterfail interrupt is not expected to be widely used in mission modes; it has been provided primarily for debug purposes.

52.4.4.4.1.2.1.6.3.7 RX Watermark Interrupt

RX Watermark interrupt will occur during packet reception, when the number of received bytes matches the contents of the RX_WTR_MARK register, minus 1. For the purpose of defining RX_WTR_MARK, the first byte received is the Frame Length field (PHR). The second byte received is the least-significant byte of Frame Control Field, etc. For example, to cause an RX Watermark Interrupt to occur after the 10th received byte, set RX_WTR_MARK=11.

52.4.4.4.1.2.1.6.3.8 CCA Interrupt

CCA interrupts occur at the end of CCA and ED measurement intervals. The presence, and timing, of CCA interrupts varies based on which autosequence is engaged. See Chapter ZSM Sequence Manager, Section Supported Sequences for more details on when to expect a CCAIRQ for each of the relevant autosequences (Sequences C, T, TR, and CCCA).

52.4.4.4.1.2.1.6.3.9 RX Interrupt

RX interrupts occur at the end of an RX operation. An RX operation can be a standalone Sequence R, or the “R” portion of a Sequence TR. An RXIRQ, in combination with a SEQIRQ, is considered a “Data Indication”. RX interrupts are not generated on packets which fail FCS (CRC check), or fail packet filtering. Either of these two conditions results in an RX recycle back to the preamble-search state. To prevent RX recycling on packets which fail filtering or FCS, set the NO_RX_RECYCLE bit of the SEQ_MGR_CTRL register to 1. To receive a Data Indication (including RXIRQ) on packets which fail CRC, clear the CRC_MSK bit of the PHY_CTR2 register to 0. To inhibit packet filtering and enable Data Indication on packets which would otherwise fail packet filtering rules, set the PROMISCUOUS bit of the PHY_CTRL4 register to 1.

52.4.4.4.1.2.1.6.3.10 TX Interrupt

TX interrupts occur at the end of a TX operation. An TX operation can be a standalone Sequence T, the “T” portion of a Sequence TR, or the auto-TXACK portion of a Sequence R with AUTOACK=1.

52.4.4.4.1.2.1.6.3.11 Sequencer Interrupt

The Sequencer Interrupt (SEQIRQ), indicates that an autosequence has completed, and the 802.15.4 Sequence Manager has returned to its idle state. A SEQIRQ will *always* occur at the end of an autosequence, even if the autosequence terminated abnormally (such as a Software Abort, a TC3 Timeout, or a PLL Unlock Abort). **Note:** the ABORT_STS register can be read to determine which of these abnormal terminations occurred, if any. The SEQIRQ always occurs whenever the Sequence Manager transitions from non-idle to idle state. When SEQIRQ occurs, software can be sure that the Sequence Manager is in its idle state, and a new sequence can be programmed immediately.

52.4.4.4.1.2.1.6.3.12 TSM Interrupt

TSM_IRQ is a debug feature, enabling the Transceiver Sequence Manager (TSM) to generate an interrupt at any point in a TX or RX Warmup. TSM is a multipurpose hardware resource shared by all of the protocol engines in the SoC. Thus, TSM does not have its own interrupts; its interrupts are assigned to whichever link layer controller is currently executing an RF operation. The 802.15.4 interrupt TSM_IRQ is asserted when the TSM interrupt is enabled in the transceiver's TSM_CTRL register, and the TSM interrupt asserts during an 802.15.4 TX or RX Warmup. The TSM Interrupt status bit in the IRQSTS register of 802.15.4 space is read-only. It is a logical OR of the 2 TSM_IRQ interrupt status bits of the XCVR_STATUS register in XCVR address space. and the asserted status bit(s) should be cleared there. There is no intended mission-mode use for TSM_IRQ. See the TSM Chapter for more details.

52.4.4.4.1.2.1.6.3.13 Wake Interrupt

For Manual DSM: This is WAKE_IRQ. A WAKE_IRQ will be triggered when the 802.15.4 Link Layer Controller has awoken from a Manual DSM (Deep Sleep Mode) cycle. WAKE_IRQ indicates that the RF Oscillator has been restarted, and the 802.15.4 EVENT_TMR has resumed counting.

For Wake-On-Radio:: This is WOR_IRQ. This interrupt will become set when 802.15.4 has been assigned to Wake-On-Radio, and one or more of the following Wake-On-Radio conditions occurs:

1. A Wake-On-Radio slot of type "NO_RF" has completed, and MCU wakeup is requested in the descriptor
2. A Wake-On-Radio maximum slot count has been reached
3. A Wake-On-Radio Early Exit condition has been encountered

See Chapter *Wake-On-Radio* for more details

52.4.4.4.1.2.2 Operation sections

52.4.4.4.1.2.2.1 Simultaneous CCA/RX

The 802.15.4 Link Layer controller features an autosequence that precedes a packet transmission with a CCA (Clear Channel Assessment), to ensure the channel is idle before transmitting. If the CCA indicates a busy channel, the autosequence ends after the CCA, without transmitting. In slotted mode, 2 CCA measurements take place, with the start points for the measurements 320us apart. Both must indicate an idle channel for transmission to proceed.

During intervals of severe network congestion, high node density, and packets which are heavily fragmented, the situation can arise where Device A is preparing to transmit a packet, or fragment, and performing pre-transmit CCA, and during the CCA, Device B attempts to transmit another packet or fragment to Device A. Previous NXP 802.15.4 transceivers were unable to receive a packet during CCA, so Device B's packet will be missed by Device A. For the Gen3 2.4GHz radio, the capability to receive-during-CCA has been added to 802.15.4. This capability is referred to as "Simultaneous CCA/RX".

To enable this capability, 3 enhancements have been made to the digital receiver and the 802.15.4 sequence manager:

1. CCA Mode 2 Algorithm Separated from 802.15.4 Demodulator
2. New 802.15.4 State Machine Transitions
3. New TSM Fast RX-to-TX Capability

1. Separated CCA Mode 2 Algorithm

One reason for the lack of prior support, is that the CCA Mode 2 algorithm has been tightly integrated with the 15.4 demodulator, so that both functions cannot simultaneously co-exist. The Gen3 digital receiver separates these functions, removing the CCA Mode 2 impediment to Simultaneous CCA/RX. See Chapter *Receiver Digital Module*, Section *IEEE 802.15.4 CCA mode 2*. (CCA Mode 1 does not utilize the demodulator, so such impediment exists.)

The legacy CCA Mode 2 hardware has been retained as a back-up. The control bit USE_DEMOD_CCA2 selects between legacy (1) and new CCA Mode 2 (0). This bit must be set to 0 to utilize Simultaneous CCA/RX. The following table summarizes the programmability associated with CCA Mode 2. The third column references table *IEEE 802.15.4 CCA mode 2 parameters* in Chapter *Receiver Digital Module*, Section *IEEE 802.15.4 CCA mode 2*

REGISTER NAME	ADDRESS SPACE	ASSOCIATED CCA MODE 2 PARAMETER	DESCRIPTION
USE_DEMOD_CCA2	XCVR	n/a	CCA Mode 2 hardware selector. • 0: use new CCA Mode 2

Table continues on the next page...

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REGISTER NAME	ADDRESS SPACE	ASSOCIATED CCA MODE 2 PARAMETER	DESCRIPTION
			• 1: use demodulator-based (legacy) CCA Mode 2
CCA2_CORR_THRESH[7:0]	802.15.4	zb_cca2_thresh_corr[7:0]	Threshold used to compare correlation products. **Note:** this register is shared between the new and legacy CCA Mode 2 hardware
CCA2_CNT_THRESH[9:0]	XCVR	zb_cca2_thresh_cnt[9:0]	Threshold to compare count of correlation products exceeding CCA2_CORR_THRESH[7:0]
CCA2_SYM_THRESH[9:0]	XCVR	zb_cca2_thresh_sym[9:0]	Threshold used to detect repetition sequence addresses corresponding to correlation products that exceed CCA2_CORR_THRESH[7:0]
CCA2_REF_SEQ[7:0]	XCVR	zb_cca2_ref_seq[7:0]	Selection of the sequence addresses to be used.
CCA2_INTERVAL[1:0]	XCVR	zb_cca2_duration[1:0]	Specifies the CCA2 measurement window duration: • 0x00 - 64 µs • 0x01 - 128 µs • 0x02 - 256 µs • 0x03 - 512 µs

Note: Set CCA2_DURATION=0x01 (128us) for 802.15.4 operation.

2. New 802.15.4 State Machine Transitions

Using Simultaneous CCA/RX, the 802.15.4 Link Layer controller needs to be able to anticipate preamble, and even SFD detection, during the states in which it is taking CCA measurement. Those states are RX_CCA1, for non-slotted, and RX_CCA2, for slotted operation. If preamble and/or SFD is detected in those states, the 802.15.4 sequence manager needs to transition to a packet reception state, and then receive the packet in its entirety as if the called sequence was Sequence R. To address this, these new state transitions have been added to the 802.15.4 Sequence Manager (ZSM) state machine:

- RX_CCA1 -> RX_PRE (preamble detected during 1st CCA but no SFD)
- RX_CCA1 -> RX_PKT (preamble + SFD detected during 1st CCA)
- RX_CCA2 -> RX_PRE (preamble detected during 2nd CCA but no SFD)
- RX_CCA2 -> RX_PKT (preamble + SFD detected during 1st CCA)

The following diagram highlights the new ZSM state transitions, in red:

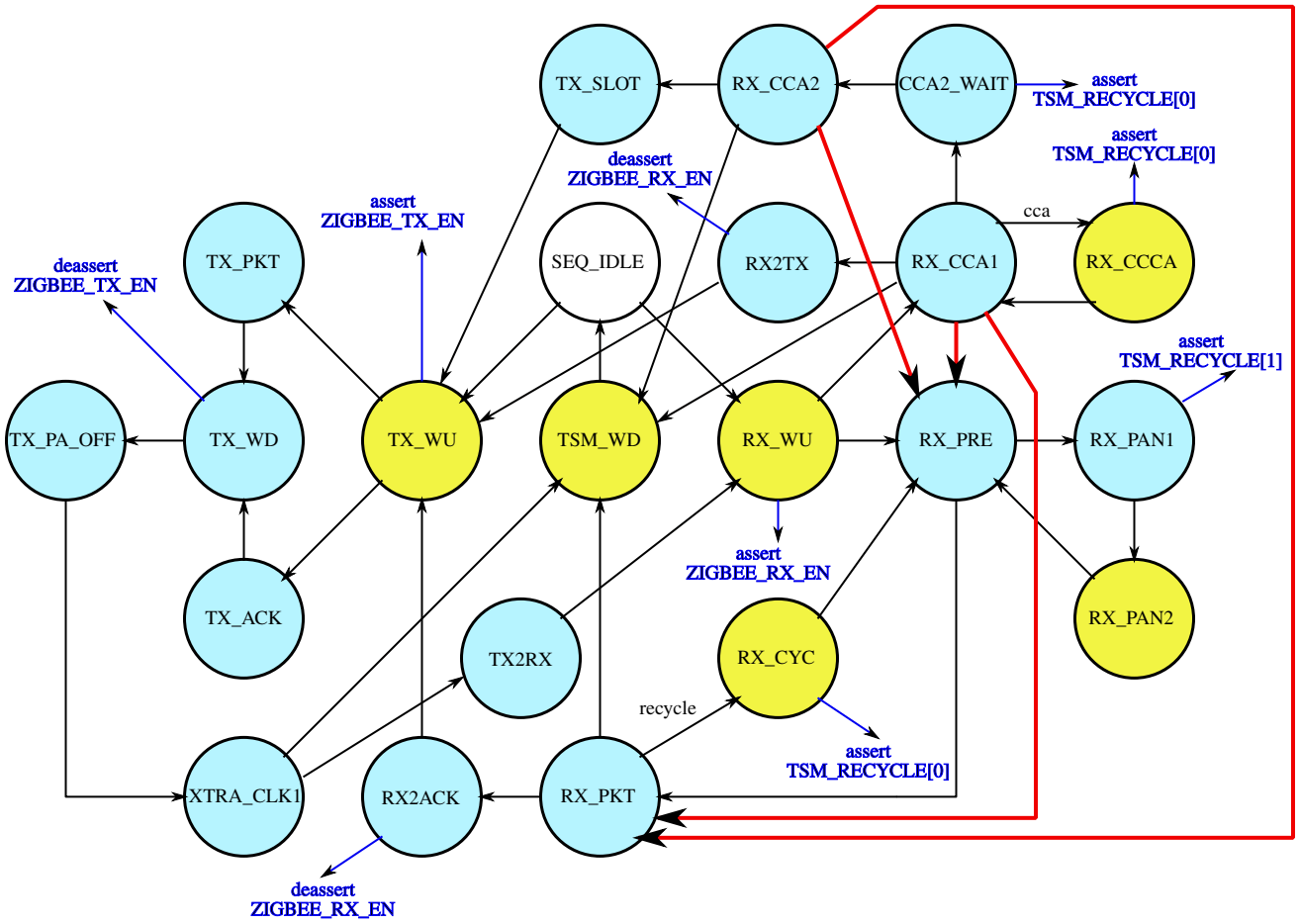

Figure 425. NEW ZSM STATE TRANSITIONS FOR SIMUL CCA/RX

False preambles may occur during the CCA states as well. False preambles occur when the 802.15.4 demodulator detects a sufficient number of consecutive 0 symbols to meet the preamble threshold, but the symbol which follows is neither a '0' nor a '7'. False preambles result in the 802.15.4 demodulator signal sfd_rst asserting either during, or after, the CCA state. If a false preamble is declared *within* the 128µs CCA window, then the fact that there was a false preamble has no bearing on the channel status, the CCA measurement determines channel status, as usual. If the false preamble is declared *after* the CCA window, the channel is assessed to be busy and the autosequence terminates without transmission, because the scheduled transmission time has been missed.

In defining the Simultaneous CCA/RX operation, 9 "scenarios", or cases, were developed to help ensure correct hardware response to various permutations of preamble and SFD arrival times, preamble falsing, channel status, and RX packet goodness. These scenarios were used to guide the hardware design, for each of the 3 CCA modes, and for mode 3, both boolean combinations. The 9 scenarios are listed in the table below, with the correct hardware response indicated. The hardware response consists of a sequence of state transitions, as well as assertion (or non-assertion) of the various 802.15.4 interrupts. The final combination of asserted interrupts assists software in determining what transpired during the autosequence, and therefore what must be done next.

SCENARIO	#1	#2	#3	#4	#5	#6	#7	#8	#9
CHANNEL IDLE @ 128us	1	0	0	0	0	0	0	0	0
CHANNEL BUSY @ 128us	0	1	0	0	0	0	0	0	0
PREAMBLE ASSERTED DURING CCA SFD_RST OCCURS DURING CCA CHANNEL OTHERWISE IDLE @ 128us	0	0	1	0	0	0	0	0	0
PREAMBLE ASSERTED DURING CCA SFD_RST OCCURS DURING CCA CHANNEL OTHERWISE BUSY @ 128us	0	0	0	1	0	0	0	0	0
PREAMBLE ASSERTED @ 128us SFD NOT ASSERTED @ 128us SFD_RST ASSERTS LATER (FALSE PRE)	0	0	0	0	1	0	0	0	0
PREAMBLE ASSERTED @ 128us SFD NOT ASSERTED @ 128us SFD ASSERTS LATER (BAD PKT)	0	0	0	0	0	1	0	0	0
PREAMBLE ASSERTED @ 128us SFD ASSERTED @ 128us (BAD PKT)	0	0	0	0	0	0	1	0	0
PREAMBLE ASSERTED @ 128us SFD NOT ASSERTED @ 128us SFD ASSERTS LATER (GOOD PKT)	0	0	0	0	0	0	0	1	0
PREAMBLE ASSERTED @ 128us SFD ASSERTED @ 128us (GOOD PKT)	0	0	0	0	0	0	0	0	1
OUTCOME:									
AUTOSEQUENCE ENDS AFTER:	TX	CCA	TX	CCA	SFD_RST	RX	RX	RX	RX
MODE SWITCH TO SFD SEARCH OCCURS AT:	--	--	--	--	128us	128us	--	128us	--
MODE SWITCH TO PKT RECEPTION OCCURS AT:	--	--	--	--	--	--	SFD DET	--	SFD DET
CCAIRQ?	yes (CCA=0)	yes (CCA=1)	yes (CCA=0)	yes (CCA=1)	yes (CCA=1)	yes (CCA=1)	yes (CCA=1)	yes (CCA=1)	yes (CCA=1)
RXIRQ?	no	no	no	no	no	no	no	yes	yes
TXIRQ?	yes	no	yes	no	no	no	no	no	no

Figure 426. SIMUL CCA/RX SCENARIOS

A single register bit enables Simultaneous CCA/RX mode: SIMUL_CCA_RX. This bit resides in the CCA_CTRL register in 802.15.4 address space. By default SIMUL_CCA_RX=0, meaning that the new ZSM transitions are inhibited. Set this bit to 1, to enable the new transitions. Simultaneous CCA/RX works with any CCA Mode (1, 2, or 3), and works for both non-slotted (single CCA before TX) and slotted (2 CCA before TX) modes.

Note that to use the Simultaneous CCA/RX feature, software (not just hardware) needs to anticipate packet reception during a Sequence T (not just a Sequeunce TR). This may not exist today, since prior to Gen3, the 802.15.4 controller did not have this capability.

3. New TSM Fast RX-to-TX Capability

The 802.15.4 Sequence Manager (ZSM), makes use of the radio's all-protocol Transceiver Sequence Manager (TSM) to execute TX and RX warmup and warmdown sequences; TSM handles low-level commanding, with precise, programmable timing, of the analog and digital blocks in the transmit and receive chains, absolving the higher-level sequence managers from this responsibility. TSM sequences have, in the past, been discrete TX or RX operations, with a required software command to initiate the sequence, and a return-to-idle after the sequence is complete, before a new sequence-start command can be issued. For 802.15.4 Simultaneous CCA/RX mode, it is highly desirable to be able to jump directly from the end of a CCA measurement, which is essentially an RX operation, to a packet transmit operation, without returning the TSM to IDLE in between, if CCA deems the channel to be free. A new TSM transition called Fast RX2TX accomplishes this. The 802.15.4 ZSM will signal to TSM when to perform such a transition, and TSM will respond by jumping from the RX ON phase, to a programmable point within the TX

warmup. See Chapter *Transceiver Sequence Manager*, Section *FAST TSM Warmup and FAST RX2TX Transition* for more details on this TSM feature, and a description of the ZSM -> TSM signaling required to execute such a transition.

A single register bit enables TSM Fast RX-to-TX: FAST_RX2TX_EN. This bit resides in the TSM_FAST_CTRL1 register in XCVR address space. By default FAST_RX2TX_EN=0, meaning that this TSM capability is inhibited, and RX-to-TX transitions remain discrete RX and TX sequences (legacy).

Once enabled with FAST_RX2TX_EN=1, the ZSM will request a TSM Fast RX-to-TX warmup, by asserting fast_rx2tx_wu, when all of the following conditions are met:

- 802.15.4 autosequence is T or TR
- Pre-TX CCA is enabled with CCABFRTX=1
- ZSM state is RX_CCA1 (non-slotted or slotted) or RX_CCA2 (slotted mode only)
- 128µs measurement timeout expires
- Neither preamble-detect nor SFD-detect are *currently* asserted
- Channel is deemed idle (CCA=0)

The TSM will respond to fast_rx2tx_wu by jumping from the "ON" phase of the RX operation to the "WARMUP" phase of the TX operation at the programmed point. Simultaneously, ZSM must jump to its TX_WU state to wait for the TX warmup to complete. This requires 2 new state transitions, to enable the Simultaneous CCA/RX feature, shown in red in the diagram below:

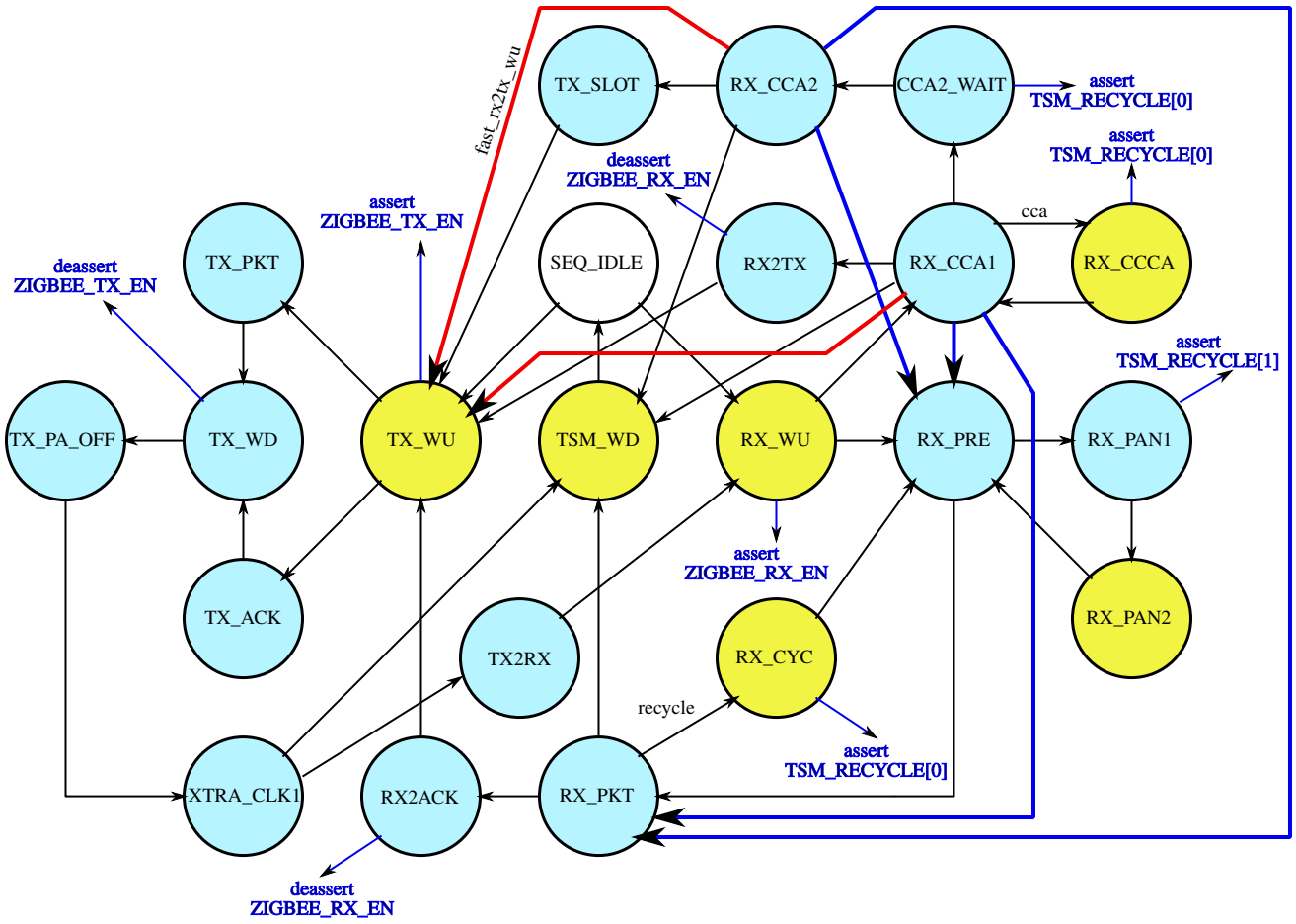

Figure 427. ZSM STATE TRANSITIONS FOR FAST RX2TX

Once the TX warmup completes, the 802.15.4 controller will transmit the packet as per the Sequence T command.

52.4.4.4.1.2.2.2 Memory Mapping

In the SoC memory map, space has been allocated to 802.15.4. Within the SoC, peripherals are allocated memory space in 4KB blocks, called IPS slots. 802.15.4 occupies one such slot. 802.15.4 address space consists of the 802.15.4 registers, as well as the Packet Buffer (RAM), which is memory-mapped into 802.15.4 memory space. The partitioning of address space for 802.15.4 is shown in the diagram below.

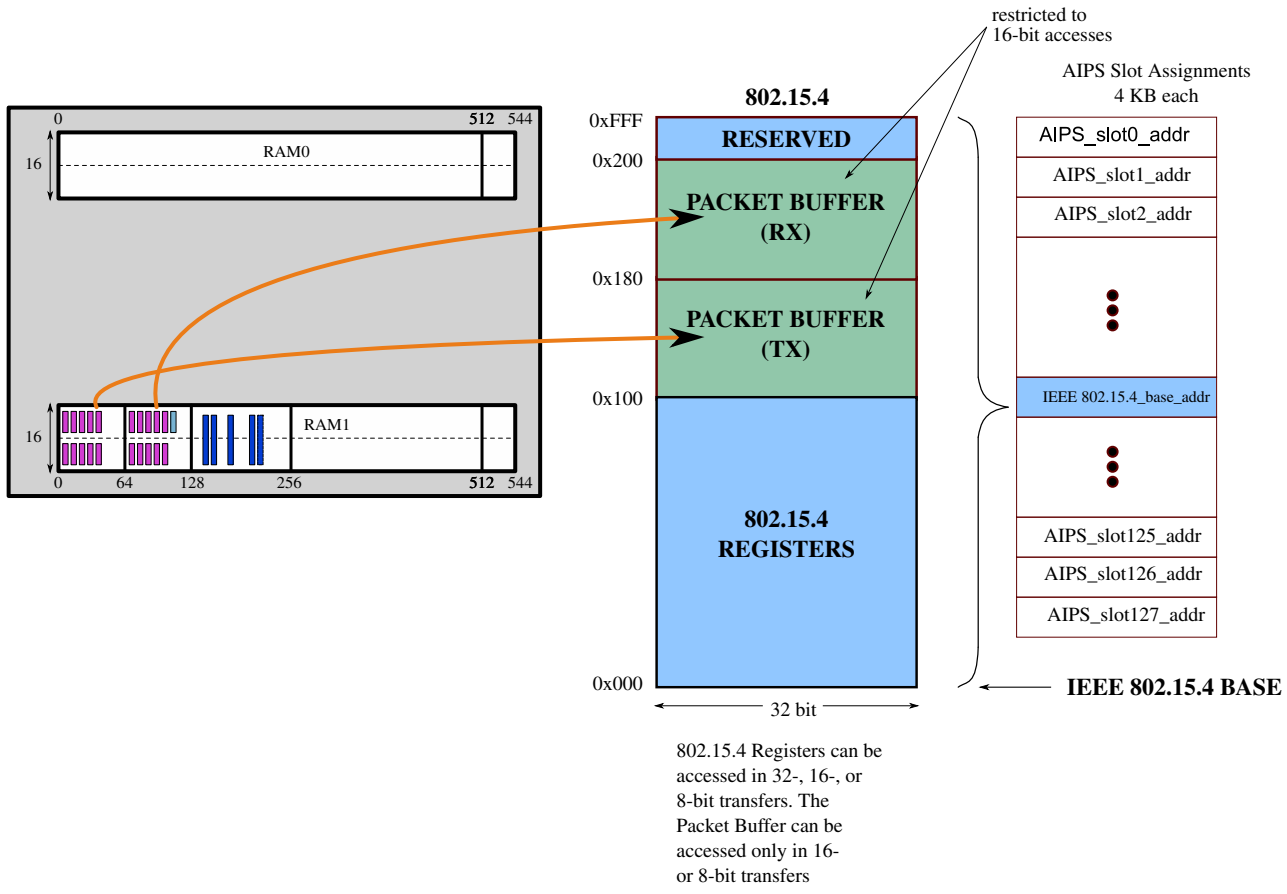

Figure 428. 802.15.4 MEMORY MAPPING

NOTE

See AIPS Memory Map for specific memory assignments details.

The Packet Buffer (RAM), is accessible by the MCU in 16-, or 8-bit accesses. The 802.15.4 Registers are accessible in 32-, 16-, or 8-bit accesses. The Source Address Table partition in RAM, is not accessible directly by the MCU, but via a prescribed protocol using the 802.15.4 SAM_TABLE register (see Section Source Address Management). Therefore, the table is not memory-mapped directly into 802.15.4 address space.

52.4.4.4.1.2.2.3 Manual DSM

When the 802.15.4 Link Layer anticipates long periods of inactivity, the Link Layer controller can be put into a Deep Sleep Mode (DSM), where all of its clocks are turned off. In addition, the 802.15.4 Link Layer can be configured to optionally turn off the RF Oscillator, if it is not otherwise needed by the SoC. Deep Sleep Mode results in dramatic power savings. The procedure described below, is called Manual DSM.

To make Manual DSM possible, the transceiver incorporates a low-frequency, high-precision Deep Sleep Timer, TIMER. This timer is clocked by a crystal-referenced 32.768KHz oscillator. The timer is 24-bit wide, yielding a 8.5 minute rollover (the maximum length of a deep sleep period).

The hardware to implement DSM within the SoC, is partitioned across several modules, and several power domains. This is to allow the maximum achievable power savings, by retaining full voltage for only those modules which need to be active in DSM, and placing the remaining modules in “state retention” mode. The diagram below depicts the partitioning of DSM hardware across the various modules, including the 802.15.4 Link Layer Controller.

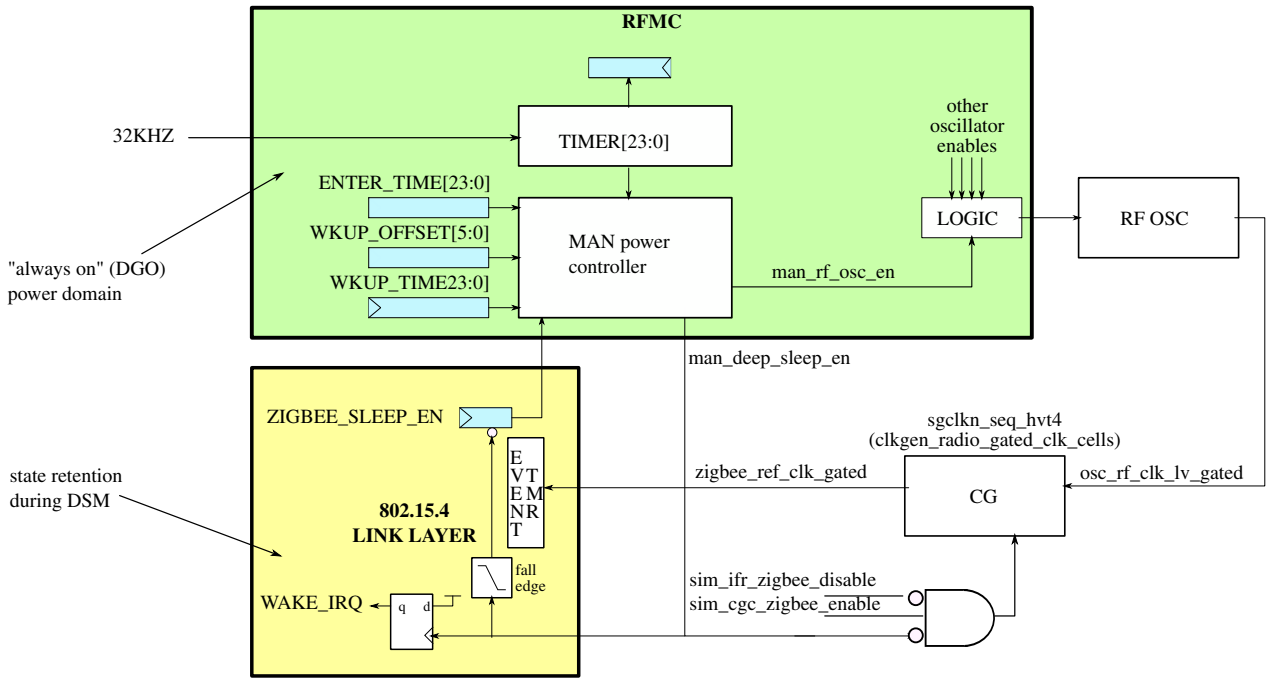

Figure 429. MANUAL DSM BLOCK DIAGRAM

The concept behind Manual DSM, as it is implemented for 802.15.4, is to allow the 802.15.4 timebase to be maintained for a period of time, while the RF Oscillator is turned off and much of the SoC is placed in state-retention. During DSM, the timebase management is temporarily transferred from the 802.15.4 EVENT_TMR to the low-power TIMER, and after DSM exit, timebase management is transferred back to the EVENT_TMR, under software control. During DSM, the EVENT_TMR is frozen. The total time spent in DSM is known to software, so that upon exiting DSM, the EVENT_TMR can be updated to correct for the precise amount of time it was frozen.

DSM entry and exit, and RF Oscillator re-start during Manual DSM, are governed by 5 registers, as described in the table below.

Field	R/W	Description
ENTER_TIME[23:0]	rw	If ZIG_SLEEP_REQUEST=1, enter DSM & freeze EVENT_TMR when ENTER_TIME matches TIMER. **NOTE** This register resides in WOR Address Space
WKUP_OFFSET[5:0]	rw	Determines the power and RF oscillator re-start times relative to WKUP_TIME **NOTE** This register resides in RFMC Address Space

Table continues on the next page...

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Field	R/W	Description
WKUP_TIME[23:0]	rw	Exit Deep Sleep Mode, and resume EVENT_TMR, when WKUP_TIME matches TIMER **NOTE** This register resides in WOR Address Space
ZIG_SLEEP_REQUEST	w	Enable a match on ENTER_TIME[23:0] to TIMER[23:0], to enter Deep Sleep Mode, by writing a 1 to this bit. Cancel a pending sleep request by writing a 0 to it, if already set, at least 2 32.768KHz clock cycles prior to ENTER_TIME[23:0]
TIMER[23:0]	r	Current State of the 32KHz Sleep Timer **NOTE** This register resides in RFMC Address Space

Procedure

The procedure to schedule a Manual DSM cycle (entry/exit) as well as to program the desired RF Oscillator re-start time, and the calculation to restore the 802.15.4 EVENT_TMR after a DSM cycle, is described below.

1. Software determines the future time at which it would like to enter DSM, by reading the TIMER, computing the number of 32KHz clock cycles remaining until the desired DSM start-time, and writing this value into ENTER_TIME register. The value programmed into ENTER_TIME should be no fewer than 4 clocks greater (in the future) than the current time as read from TIMER.
2. Software determines the future time at which it would like to exit DSM, by computing the number of 32KHz clock cycles remaining until the desired DSM exit-time, and writing this value into WKUP_TIME register.
3. Software writes a 1 to DSM_CTRL[ZIG_SLEEP_REQUEST]. This bit resides in 802.15.4 address space. This bit is write-only and always reads back 0. Writing this bit to 1 enables a DSM cycle to commence using the values programmed into ENTER_TIME and WKUP_TIME.
4. MCU can go into a low power state.
5. When TIMER = ENTER_TIME, the EVENT_TMR will be clock-gated so that it will remain frozen at its current count. The RF Oscillator will be turned off (unless overridden due to a non-802.15.4-related SoC requirement)
6. All hardware in the low-voltage domain will be placed into state-retention, or other low-power state.
7. When TIMER = WKUP_TIME, clocking of the 802.15.4 Link Layer Controller will resume and the EVENT_TMR will be ungated (allowed to resume counting).
8. Software computes the time that the SoC was in DSM (and hence the time the EVENT_TMR was frozen), in microseconds, with the equation:

   (WKUP_TIME – ENTER_TIME) / 32768 * 1000000

9. Software increments the 802.15.4 EVENT_TMR by this amount, by writing this value to the EVENT_TMR register with EVENT_TMR_ADD=1. **Note:** The 802.15.4 EVENT_TMR has an integer component (24 bits) and a fractional component (4 bits). The fractional component provides the microsecond precision to the Event Timer, so both components need to be accounted for when compensating for the DSM "time slept".
10. On the next 1MHz clock edge, the EVENT_TMR has been restored to where it would have been, had no DSM occurred, with 1.0-microsecond accuracy.

Note that the 1.0-microsecond accuracy quoted above, assumes an ideal 32.768KHz source. Any ppm error in the 32.768KHz source will degrade the microsecond accuracy proportionally to the magnitude of the error.

Once ZIG_SLEEP_REQUEST has been set to 1 to request Manual DSM, the request can be cancelled by writing a 0 to the bit. The cancellation must be performed at least 2 32.768KHz before the ENTER_TIME[23:0] match to TIMER[23:0] to avoid a race condition to enter DSM.

The following timing diagram depicts an 802.15.4-driven DSM entry/exit cycle.

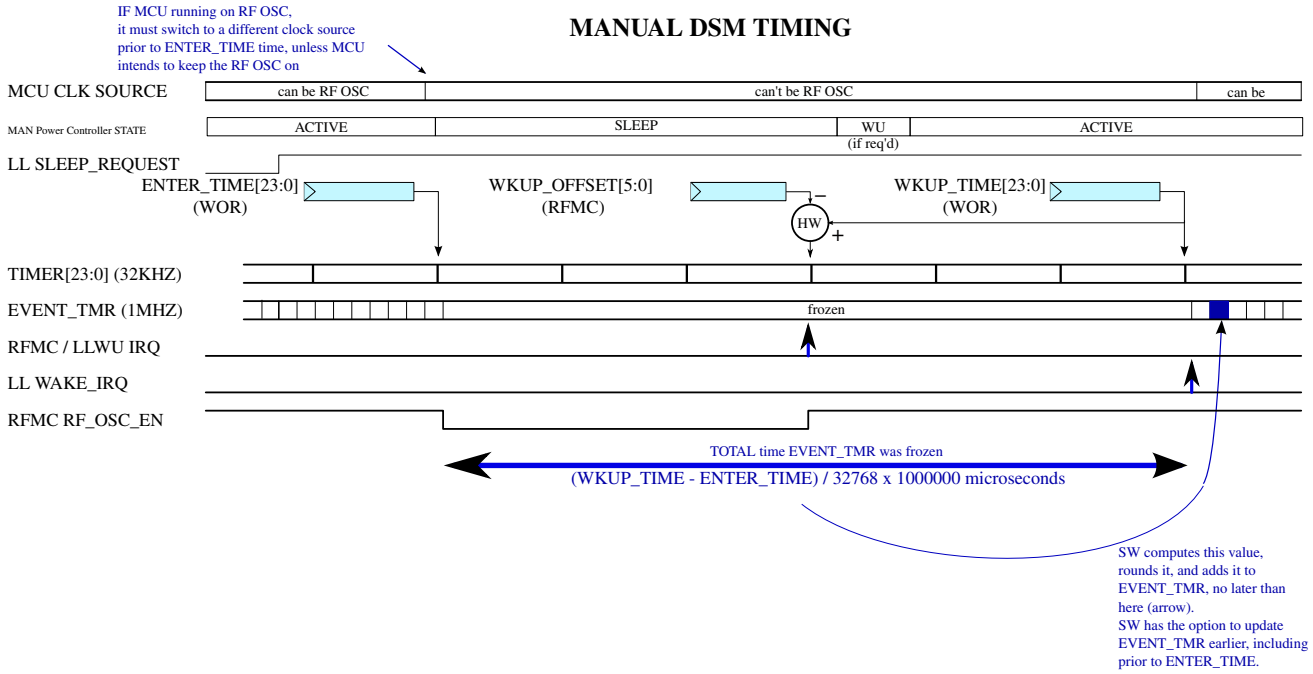

Figure 430. 802.15.4 DEEP SLEEP TIMING

DSM Early Exit

Circumstances may arise where the Manual DSM cycle may occasionally need to be cut short, due to circumstances beyond the control of the radio. When this happens, the SoC, starting with the MCU, is awakened out of its low power state, long before the RFMC TIMER reaches WKUP_TIME. Therefore, software handling the event which triggered the wakeup, will determine if the radio needs to be awakened as well. If this is the case, software will advance the WKUP_TIME setting to a point in the near future, but no fewer than 4 32KHz clock cycles beyond the current time ascertained by reading TIMER. So, to execute a Manual DSM Early Exit, software shall read TIMER, add +4 to the value, and write the sum to the WOR WKUP_TIME register. Software shall then wait for the 802.15.4 WAKE_IRQ interrupt, which will assert once the full radio wakeup from the low power state has completed. Software should then take whatever steps are necessary to configure the radio to respond to the conditions which triggered the early exit. Servicing of a DSM early exit interrupt is beyond the scope of this document.

52.4.4.4.1.2.2.4 Wake-On-Radio

The 802.15.4 Link Layer can take advantage of the automated sequence- and DSM-scheduling provided by Wake-On-Radio. Wake-On-Radio is one of two DSM control schemes that can be selected for 802.15.4, as an alternative to Manual DSM. See Chapter *Wake-On-Radio*.

Several changes to the 802.15.4 Link Layer Controller have been made to support Wake-On-Radio.

Interrupt WAKE_IRQ has been made dual-purpose. If Wake-On-Radio is disabled, i.e., WOR_CTRL[WOR_EN]=0, or Wake-On-Radio not assigned to 802.15.4, WAKE_IRQ performs its legacy function for Manual DSM. (See Section Manual DSM). If Wake-On-Radio is enabled, i.e., WOR_EN=1, and assigned to 802.15.4, this interrupt becomes WOR_IRQ, and has new functionality specific to Wake-On-Radio. See Chapter *Wake-On-Radio*, Section *Interrupt Management*, for more details on the meaning, and handling of WOR_IRQ.

In addition to WOR_IRQ, numerous interface changes have been made to support Wake-On-Radio. The changes allow, for example, WOR to manage 802.15.4's RF interrupts, inhibit timestamp updates, etc. The added port signals are listed in the table below, along with a description or each:

WAKE-ON-RADIO INTERFACE SIGNAL	DIRECTION	DESCRIPTION
wor_event_tmr_add[27:0]	WOR -> 802.15.4	The Event Timer "Addback" value computed by WOR to compensate for the amount of time Event Timer was frozen during DSM
wor_addback	WOR -> 802.15.4	A 1µs-long pulse commanding the 802.15.4 Event Timer to auto-increment by the the amount appearing on wor_event_tmr_add[27:0]
wor_force_wake_irq	WOR -> 802.15.4	Force WOR_IRQ to assert, due to an occurrence of one of the 3 WOR_IRQ interrupt triggers
wor_block_wake_irq	WOR -> 802.15.4	Inhibit the legacy WAKE_IRQ assertion when WOR_EN=1 (this interrupt becomes WOR_IRQ)
tx_start_ext	WOR -> 802.15.4	A 1µs-long pulse to the 802.15.4 command decoder to initiate a WOR-driven TX sequence
rx_start_ext	WOR -> 802.15.4	A 1µs-long pulse to the 802.15.4 command decoder to initiate a WOR-driven RX sequence
seq_stop_ext	WOR -> 802.15.4	A 1µs-long pulse to the 802.15.4 command decoder to stop (abort) a WOR-driven RX sequence
wor_allow_irq	WOR -> 802.15.4	Inhibits RF interrupts, so that interrupt assertions can be managed based on WOR descriptor settings. Controlled dynamically by the WOR state machine.
timestamp_inhibit	WOR -> 802.15.4	In Wake-On-Radio, the legacy 802.15.4 TIMESTAMP register becomes WOR TIMESTAMP0 (timestamp for SLOT0).

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WAKE-ON-RADIO INTERFACE SIGNAL	DIRECTION	DESCRIPTION
		This signal blocks this register from updating on SLOTS 1-3
wake_irq_trig	WOR <- 802.15.4	WOR uses this signal to cancel ZIG_SLEEP_REQUEST and transition from IN_DSM -> COMP_ADDBACK state
event_tmr[27:0]	WOR <- 802.15.4	802.15.4 Event Timer, used by WOR for timestamp capture
event_tmr_plus_1[27:0]	WOR <- 802.15.4	802.15.4 Event Timer + 1, used by WOR to schedule RF operation starts and stops
tx_irq_trig	WOR <- 802.15.4	TXIRQ trigger, indicates the completion of a packet transmission, used by WOR to transition out of WAKE_SEQ_END state
rx_irq_trig	WOR <- 802.15.4	RXIRQ trigger, indicates the completion of a good packet reception, used by WOR to transition out of WAKE_SEQ_END state
rx_status_for_wor[2:0]	WOR <- 802.15.4	Internal RX status signals used by WOR to formulate TIMESTAMPx_STS[2:0]
timestamp_clk_en	WOR <- CGM <- 802.15.4	Timestamp clock gate enable, the resultant clock is used by WOR to update the TIMESTAMP1,2, and 3 registers

52.4.4.4.1.2.2.5 Fast Antenna Diversity (FAD)

FAD ALGORITHM

The Fast Antenna Diversity (FAD) mode, when enabled, will allow the choice between two antennae to be selected during the preamble search. By continually monitoring the received signal the FAD block will select the first antenna on which the received signal has a correlation factor above a predefined, programmable, threshold. This threshold is register programmable. The FAD accomplishes the antenna selection by sequentially switching between the two antenna testing for the presence of a suitably strong s0 symbol, the first antenna to reach this condition is then selected for the reception of the packet.

The first antenna is monitored for a period equal to 1 symbol, T_s = 16µs, then the antenna monitoring is switched to the second antenna, T_a = 8µs. T_a is required to allow for the external pin diodes to turn on/off to select the antenna. $T_s + T_a$ = 24µs which allows enough time to be able to test both antenna within the first 4 preamble symbols, $T_{fad} = 3 \times T_a + 2 \times T_s$ = 56µs, thus T_{fad} $lt; 4 x T_s $lt; 64µs.

The FAD will continually switch between the two antenna until one is found which a sufficiently strong s0 detection. By virtue of the fact that the FAD operation covers less than four s0 symbols before the antenna is selected still allows the symbol demodulator to then detect at least four s0 symbols before declaring "Preamble Detect".

The symbol correlator runs during the T_a period to calculate the max correlation factor for the antenna Cx. However since T_c is not guaranteed to coincide with 1 unique symbol T_s the correlation must be able to work across symbols. To accomplish

this the correlator will rotate the s0 PN chip code through its 32 combinations in order to find the s0 symbol split across two adjacent symbols.

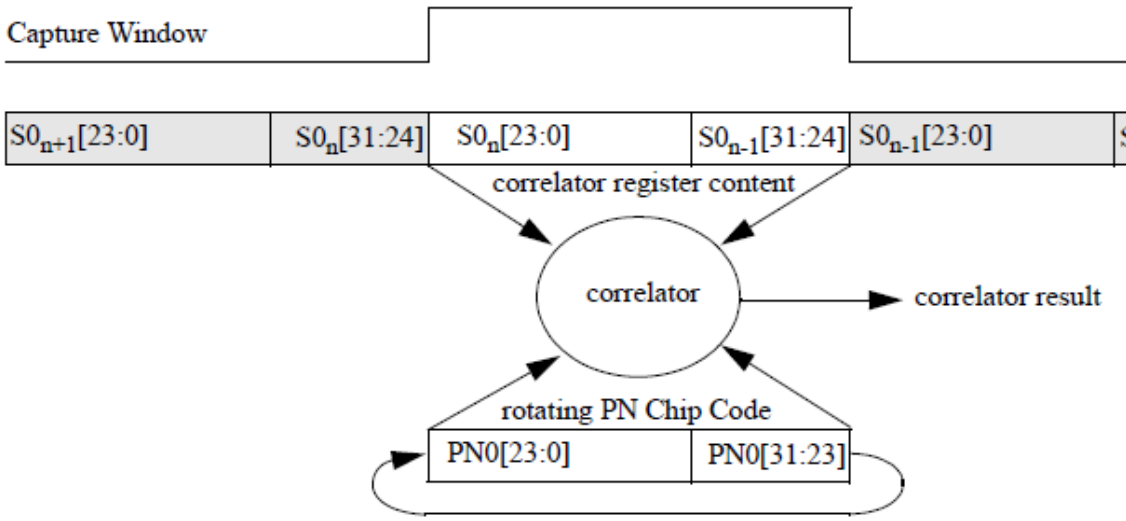


Figure 431. S0 Symbol Search

When the S0 PN Chip code becomes aligned to the Symbol data within the correlator register a correlation peak is produced that is used to determine the Antenna has a sufficiently strong signal to be selected.

It is not possible to choose between Antenna with the highest correlation factor, since indeed 1 antenna could receive no signal and thus is not distinguishable from a clear channel. This being the case, the first antenna that meets the requirements, correlation factor above the defined threshold, is selected.

When a correlator peak is detected, a second check is done ½ symbol later. A new peak should be detected with the rotation equal to ½ symbols ±2 chips. If it is the case the channel is validated and the classical *CORR_NVAL* consecutive S0 is used to certify a correct preamble, where *CORR_NVAL* is the programmable number of consecutive S0 symbols required to declare preamble detected.

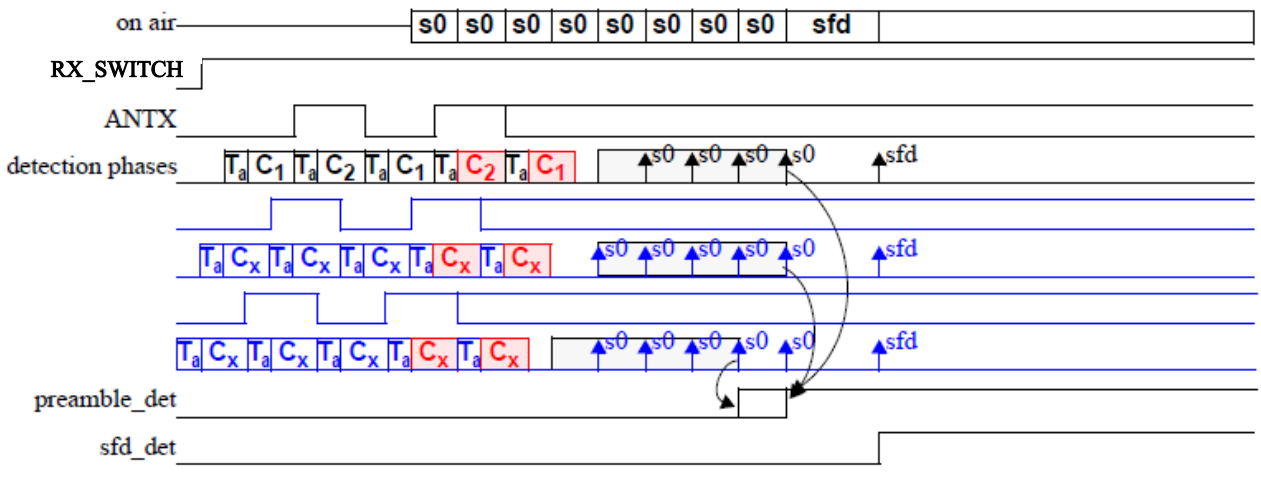


Figure 432. FAD Switching

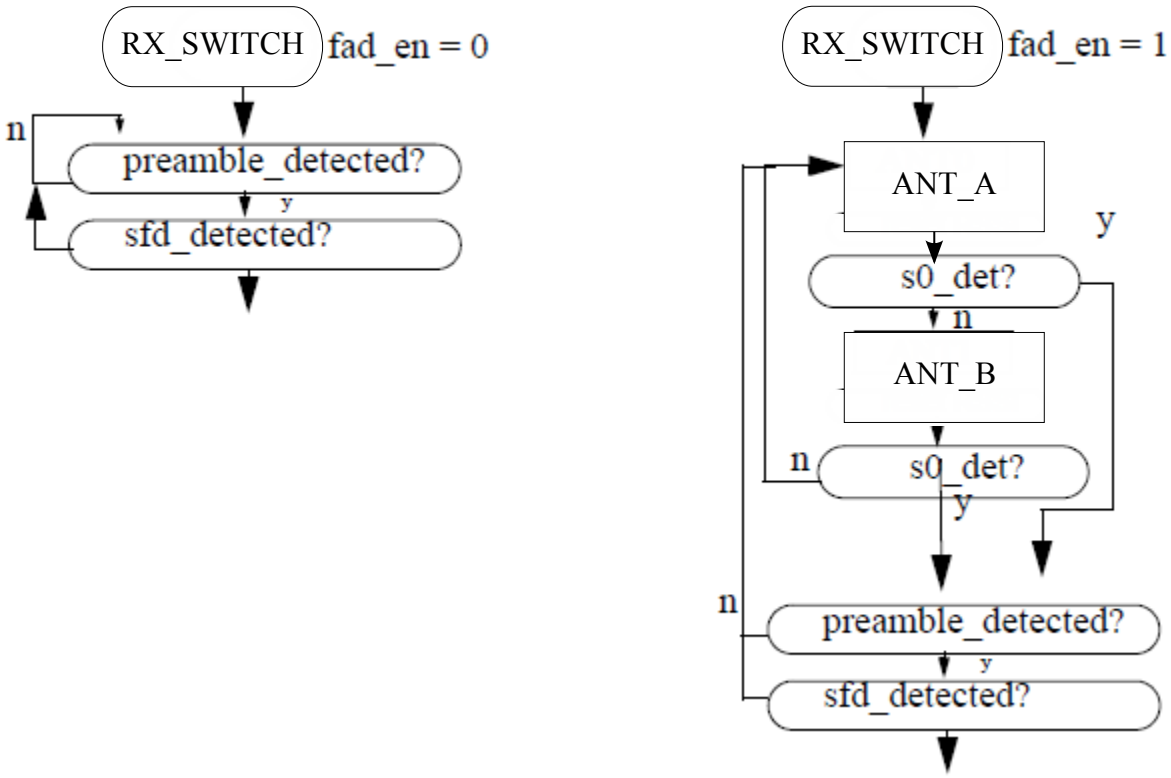


Figure 433. FAD Decision Flow Diagram

The choice of the antenna is also used for the transmit. Since the antx_out value (the last antenna selected by the FAD algorithm) is kept after the end of the receive, the following TX will use the last best antenna found during the last receive. This is true also for any ensuing CCA or ED RX frame; the antenna selected will be the one selected by the FAD algorithm during the last successful preamble search. So a CCA will search for an empty channel on the best antenna chosen at the last RX. When FAD is enabled (FAD_CTRL[FAD_EN]=1), the state of the antenna can be ascertained at any time by reading the FAD_CTRL[ANTX] bit: 0 = ANT_A, 1 = ANT_B. When FAD_CTRL[FAD_EN]=0, antenna selection is placed under direct software control, and the value written to the FAD_CTRL[ANTX] bit becomes the selected antenna: 0 = ANT_A, 1 = ANT_B. The FAD_CTRL register resides in XCVR space.

FAD PIN INTERFACE

This content has been moved to: Chapter *Transceiver Sequence Manager*, Section *Fast Antenna Diversity (FAD)*

52.4.4.4.1.2.2.6 Wifi Coexistence

Provisions have been made to allow for the 2.4GHz transceiver to coexist in the same space as a WiFi transceiver IC, which shares the same frequency band. The coexistence scheme designates the WiFi transceiver as the master, and the 2.4GHz transceiver as the slave. The objective of the coexistence strategy is to prevent both the WiFi and 2.4GHz transceivers transmitting simultaneously; a configuration option exists to also prevent the 2.4GHz transceiver from receiving when the WiFi transceiver owns the RF channel.

A very basic mechanism is used in cases where 2.4GHz radio does not generate requests, but instead defers to the WiFi transceiver to grant permission to use the medium. The WiFi IC generates a signal, RF_NOT_ALLOWED. If this signal is asserted, then 2.4GHz radio does not perform any communication. When this signal is de-asserted, then 2.4GHz radio is free to perform communications. In case the signal RF_NOT_ALLOWED is de-asserted when 2.4GHz radio has already initiated the transmission/reception of a packet then the 2.4GHz radio must stop its activity immediately .

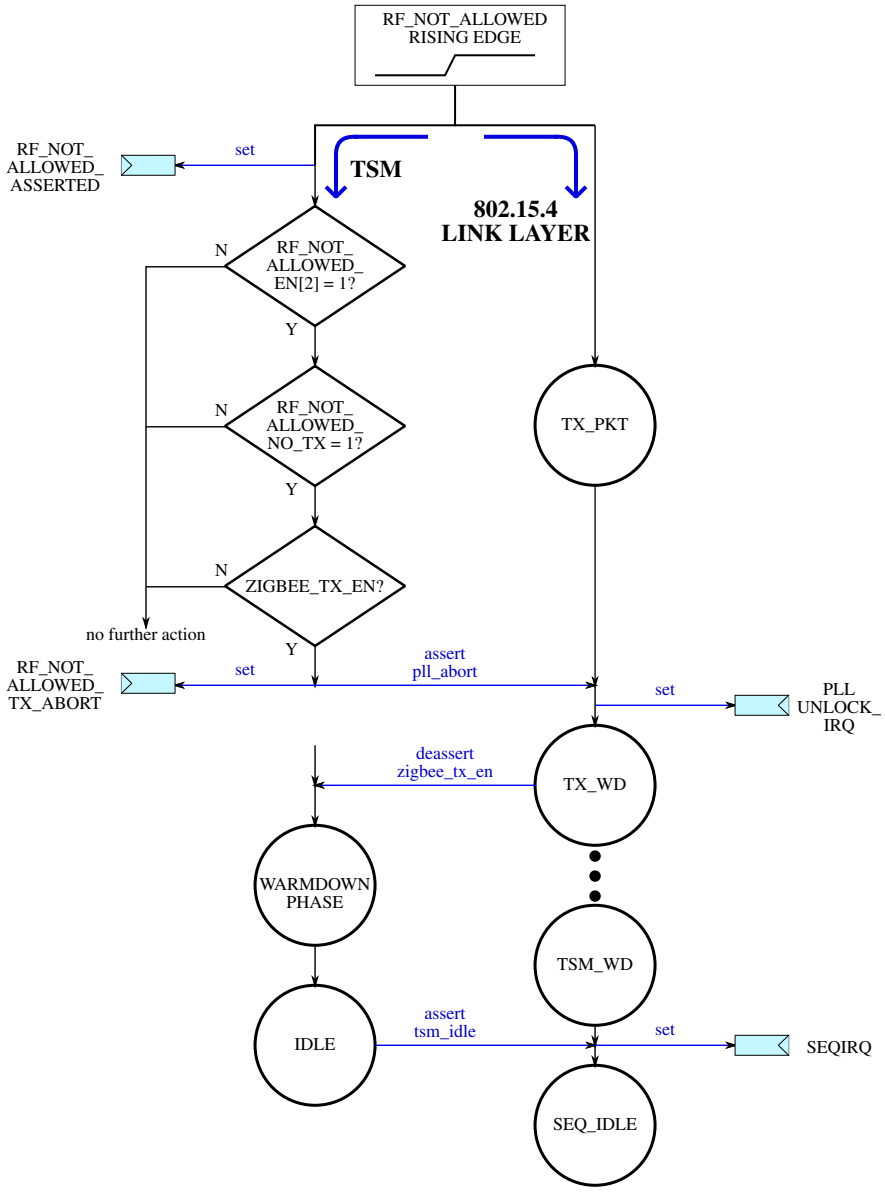
When RF_NOT_ALLOWED aborting is enabled, the 802.15.4 Link Layer hardware must respond to RF_NOT_ALLOWED assertions, by aborting any autosequence which is currently underway, and Link Layer software must not initiate any new autosequences until RF_NOT_ALLOWED has been deasserted. The hardware response must be handled autonomously by the Link Layer, with no MCU intervention required, because the RF_NOT_ALLOWED assertions can occur during a Wake-On-Radio timeslot which has been designated as "no-MCU-wakeup" in the slot's descriptor. In this scenario, the aborting of the autosequence occurs without any assistance from, or notification of, the MCU.

In the multi-protocol 2.4GHz radio, RF_NOT_ALLOWED aborting can be individually enabled/disabled for each protocol engine. For 802.15.4, RF_NOT_ALLOWED_EN[2] is the associated enable control bit. This bit resides in the COEX_CTRL register in XCVR address space. When this bit is 0, transitions on RF_NOT_ALLOWED are ignored by the 802.15.4 Link Layer hardware; when this bit is 1, the 802.15.4 Link Layer hardware will monitor RF_NOT_ALLOWED at all times, and abort any active autosequence which is underway when an assertion on the pin occurs. The complete hardware response to RF_NOT_ALLOWED assertions is described below.

Additional control over RF_NOT_ALLOWED aborting is provided by the RF_NOT_ALLOWED_NO_TX and RF_NOT_ALLOWED_NO_RX control bits. If RF_NOT_ALLOWED_NO_TX=1, then an RF_NOT_ALLOWED abort will occur only if an 802.15.4 autosequence is active, and currently executing a TX operation (zigbee_tx_en=1); 802.15.4 autosequence TX operations will not be aborted if RF_NOT_ALLOWED_NO_TX=0. If RF_NOT_ALLOWED_NO_RX=1, then an RF_NOT_ALLOWED abort will occur only if an 802.15.4 autosequence is active, and currently executing an RX operation (zigbee_rx_en=1); 802.15.4 autosequence RX operations will not be aborted if RF_NOT_ALLOWED_NO_RX=0. The RF_NOT_ALLOWED_NO_TX and RF_NOT_ALLOWED_NO_RX control bits reside in the COEX_CTRL register.

For the purposes of triggering a hardware abort, the *pll_abort* input to the 802.15.4 Sequence Manager (ZSM) is used. This is because the hardware response to the RF_NOT_ALLOWED assertion is identical to that of a PLL unlock event. This also means that, when RF_NOT_ALLOWED aborting is enabled for 802.15.4, the PLL_UNLOCK_IRQ interrupt status bit, will be dual purpose: it will not only indicate a PLL unlock condition, but also a RF_NOT_ALLOWED abort. PLL aborting and RF_NOT_ALLOWED aborting are enabled separately, with the COEX_CTRL register maintaining the control bits required for the latter. The status bits for RF_NOT_ALLOWED aborting are also available in COEX_CTRL, so that software will be able to distinguish the source of the PLL_UNLOCK_IRQ, in case both PLL and RF_NOT_ALLOWED aborting are enabled.

The sequence of events which results in a hardware abort of an 802.15.4 TX operation triggered by an assertion on RF_NOT_ALLOWED, is a collaboration between the TSM (Transceiver Sequence Manager) and the 802.15.4 Sequence Manager (ZSM), as shown in the following diagram.



Upon assertion on RF_NOT_ALLOWED, the TSM sets the RF_NOT_ALLOWED_ASSERTED status bit in COEX_CTRL, then checks that the conditions for a hardware abort are all met:

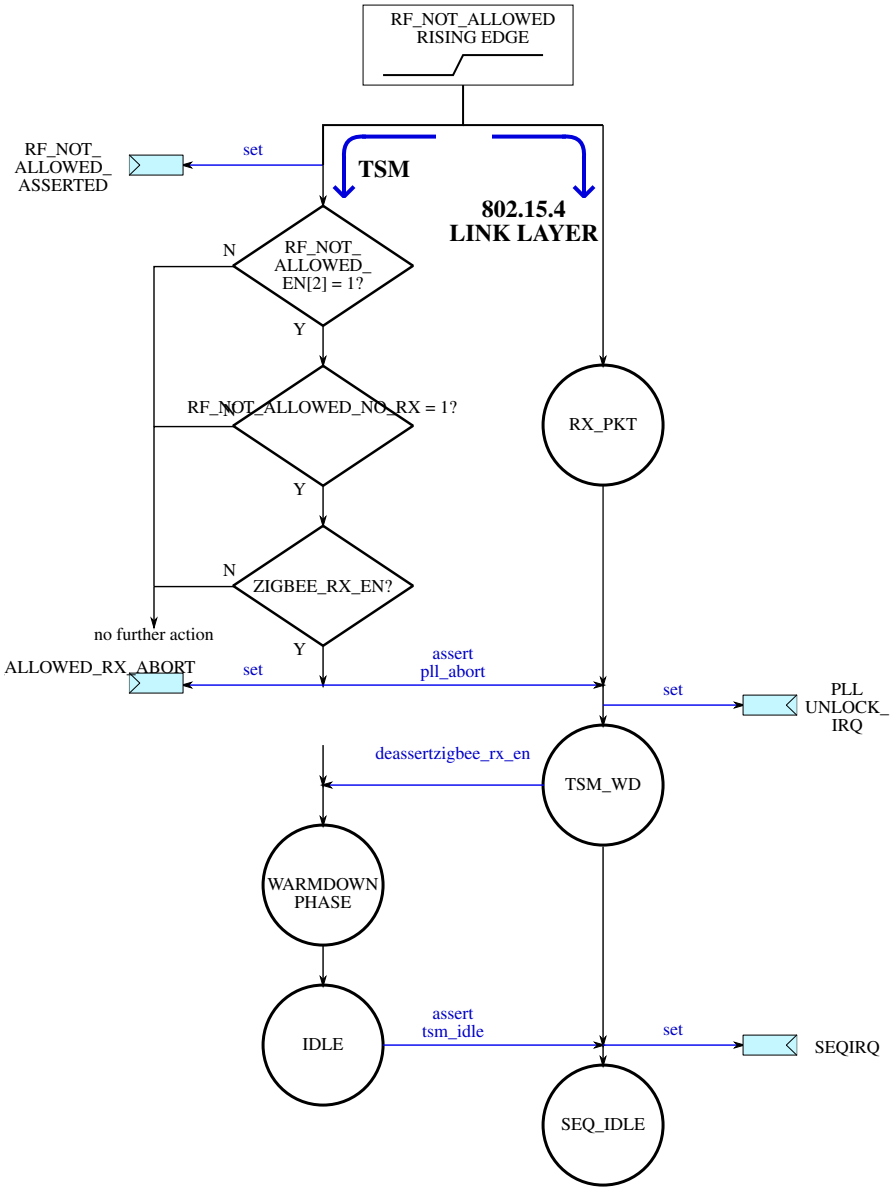
- RF_NOT_ALLOWED_EN[2] = 1, which enables 802.15.4 to respond to RF_NOT_ALLOWED events
- RF_NOT_ALLOWED_NO_TX = 1, which enables TX operations to be aborted
- zigbee_tx_en = 1, TX request to TSM from 802.15.4 ZSM, indicating TX operation in progress

If all conditions are not met, no further action is taken. Otherwise, the TSM sets COEX_CTRL[RF_NOT_ALLOWED_TX_ABORT], and also asserts *pll_unlock* to the 802.15.4 ZSM Sequence Manager. The ZSM responds by asserting IRQSTS1[PLL_UNLOCK_IRQ] in 802.15.4 space. ZSM enters TX_WD state, which deasserts zigbee_tx_en to the TSM. This initiates the TSM TX warmdown, while the ZSM simultaneously steps through its TX warmdown sequence of states. ZSM enters TSM_WD to wait for TSM to return to idle. Once this occurs, ZSM asserts IRQSTS1[SEQIRQ] and returns to its SEQ_IDLE state. Three status bits are now set to indicate to software that the source of the abort was an RF_NOT_ALLOWED assertion:

- IRQSTS1[PLL_UNLOCK_IRQ]
- COEX_CTRL[RF_NOT_ALLOWED_ASSERTED]

- COEX_CTRL[RF_NOT_ALLOWED_TX_ABORT]

The sequence of events which results in a hardware abort of an 802.15.4 RX operation triggered by an assertion on RF_NOT_ALLOWED, is shown in the following diagram.



Upon assertion on RF_NOT_ALLOWED, the TSM sets the RF_NOT_ALLOWED_ASSERTED status bit in COEX_CTRL, then checks that the conditions for a hardware abort are all met:

- RF_NOT_ALLOWED_EN[2] = 1, which enables 802.15.4 to respond to RF_NOT_ALLOWED events
- RF_NOT_ALLOWED_NO_RX = 1, which enables RX operations to be aborted
- zigbee_rx_en = 1, RX request to TSM from 802.15.4 ZSM, indicating RX operation in progress

If all conditions are not met, no further action is taken. Otherwise, the TSM sets COEX_CTRL[RF_NOT_ALLOWED_RX_ABORT], and also asserts *pll_unlock* to the 802.15.4 ZSM Sequence Manager. The ZSM responds by asserting IRQSTS1[PLL_UNLOCK_IRQ] in 802.15.4 space. ZSM enters TSM_WD state, which deasserts zigbee_rx_en to the TSM. This initiates the TSM RX warmdown. ZSM waits in the TSM_WD to wait for TSM to return to idle. Once this occurs, ZSM asserts IRQSTS1[SEQIRQ] and returns to its SEQ_IDLE state. Three status bits are now set to indicate to software that the source of the abort was an RF_NOT_ALLOWED assertion:

- IRQSTS1[PLL_UNLOCK_IRQ]
- COEX_CTRL[RF_NOT_ALLOWED_ASSERTED]
- COEX_CTRL[RF_NOT_ALLOWED_RX_ABORT]

Please refer to RADIO_MISC.COEX_CTRL register to get all description details for each field.

52.4.4.4.1.2.2.7 Enhanced Acknowledgment (Enh-Ack) Support

This device supports to send Enh-Ack frame, acknowledging to a frame version 2 of DATA or MAC Data Request Command packet. By the combination of Destination Address Mode, Source Address Mode and PAN ID Compression, the 802.15.4-2015 protocol specifies 14 possible packet structures in its Table 7-2. According to specific application scenarios, this device defines case 5 and 7 ~ 14 are legal, as shown in the Figure 434. Reception and acknowledgement to cases 7 and 8 can be selectively enabled by setting ENABLE_HW_MODE7_8 to 0x1. Other cases will be filtered out by default unless LENIENCY[40] is set. HW can be forced to send autoack for all frame version 2 packets by setting FORCE_ACK_ENABLE_FOR_ FV2 to 0x1.

CASE #	Destination Address Mode	Source Address Mode	Destination Address	Source Address	Destination PAN ID	Source PAN ID	PAN ID Compression	SAM (checksum)	ACK
#1	0	0	Not Present	Not Present	Not Present	Not Present	0	NO	NO
#2	0	0	Not Present	Not Present	Present	Not Present	1	NO	NO
#3A	2	0	Short	Not Present	Present	Not Present	0	NO	NO
#3B	3	0	Extended	Not Present	Present	Not Present	0	NO	NO
#4A	2	0	Short	Not Present	Not Present	Not Present	1	NO	NO
#4B	3	0	Extended	Not Present	Not Present	Not Present	1	NO	NO
#5A	0	2	Not Present	Short	Not Present	Present	0	SAM(SP+SA)	YES
#5B	0	3	Not Present	Extended	Not Present	Present	0	SAM(SP+SA)	YES
#6A	0	2	Not Present	Short	Not Present	Not Present	1	NO	NO
#6B	0	3	Not Present	Extended	Not Present	Not Present	1	NO	NO
#7	3	3	Extended	Extended	Present	Not Present	0	NO	NO
#8	3	3	Extended	Extended	Not Present	Not Present	1	NO	NO
#9	2	2	Short	Short	Present	Present	0	SAM(SP+SA)	YES
#10	2	3	Short	Extended	Present	Present	0	SAM(SP+SA)	YES
#11	3	2	Extended	Short	Present	Present	0	SAM(SP+SA)	YES
#12	2	3	Short	Extended	Present	Not Present	1	SAM(DP+SA)	YES
#13	3	2	Extended	Short	Present	Not Present	1	SAM(DP+SA)	YES
#14	2	2	Short	Short	Present	Not Present	1	SAM(DP+SA)	YES

Figure 434. Supported Address Modes of Beacon, MAC Command and DATA Frame

In response to these supported packets, the format of the ACK packet may be in case #7~14, as shown in the table. This rule is used in the TR sequence with RXACKRQD is set.

CASE #	Destination Address Mode	Source Address Mode	Destination Address	Source Address	Destination PAN ID	Source PAN ID	PAN ID Compression
#1	0	0	Not Present	Not Present	Not Present	Not Present	0
#2	0	0	Not Present	Not Present	Present	Not Present	1
#3A	2	0	Short	Not Present	Present	Not Present	0
#3B	3	0	Extended	Not Present	Present	Not Present	0
#4A	2	0	Short	Not Present	Not Present	Not Present	1
#4B	3	0	Extended	Not Present	Not Present	Not Present	1
#5A	0	2	Not Present	Short	Not Present	Present	0
#5B	0	3	Not Present	Extended	Not Present	Present	0
#6A	0	2	Not Present	Short	Not Present	Not Present	1
#6B	0	3	Not Present	Extended	Not Present	Not Present	1
#7	3	3	Extended	Extended	Present	Not Present	0
#8	3	3	Extended	Extended	Not Present	Not Present	1
#9	2	2	Short	Short	Present	Present	0
#10	2	3	Short	Extended	Present	Present	0
#11	3	2	Extended	Short	Present	Present	0
#12	2	3	Short	Extended	Present	Not Present	1
#13	3	2	Extended	Short	Present	Not Present	1
#14	2	2	Short	Short	Present	Not Present	1

Figure 435. Supported Address Modes of ACK Frame

The Enh-Ack frame is formatted as illustrated in Figure 436, also can be found in Figure 7-16 in IEEE Std 802.15.4-2015.

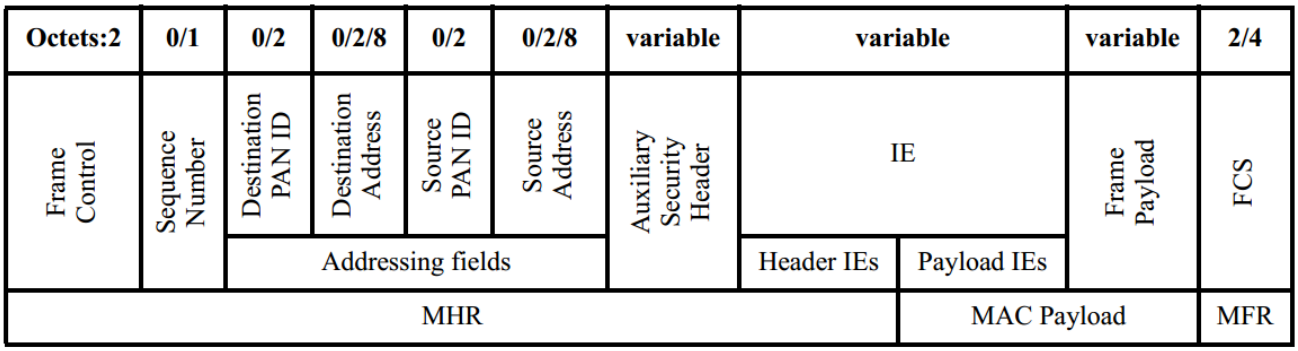


Figure 436. Enh-Ack frame format

The Frame Control field of the Enh-Ack frame is formatted as illustrated in Figure 437, also can be found in Figure 7-2 in IEEE Std 802.15.4-2015.

Bits: 0–2	3	4	5	6	7	8	9	10–11	12–13	14–15
Frame Type	Security Enabled	Frame Pending	AR	PAN ID Compression	Reserved	Sequence Number Suppression	IE Present	Destination Addressing Mode	Frame Version	Source Addressing Mode

Figure 437. Frame Control Field of Enh-Ack

Enh-Ack is much more complicated than Imm-Ack because it may contain IEs and Frame Payload Field, and it also introduces data decryption and encryption. This makes it very difficult to achieve a turnaround time of 192us in pure software or pure hardware. So the entire Enh-Ack process is completed through software and hardware cooperation.

The main idea is that the software is responsible for decrypting, analyzing received packets and forming the Enh-Ack packet(Full-Enh-Ack). At the turnaround time, the hardware automatically sends the Full-Enh-Ack. If the software cannot prepare the Full-Enh-Ack in time, the hardware will send an Empty-Enh-Ack frame. After the hardware sends Empty-Enh-Ack, the software will send a complete Enh-Ack packet, which is Full-Enh-Ack.

According to the requirements of 802.15.4 -2015 spec for Enh-Ack frame format, the fields in Full-Enh-Ack and Empty-Enh-Ack frame are as follows:

In the Full-Enh-Ack:

- The Frame Control field:
  - The Frame Type is b010, Acknowledgment type
  - The Frame Version is b10.
  - Security Enabled field shall be set if security feature is enabled.
  - If the Enh-Ack frame is being sent in response to a received either a Data frame or Data Request command the Frame Pending field is calculated by the Source Address Management process; If the Enh-Ack frame is being sent in response to another type of MAC command, the Frame Pending field is zero.
  - The AR field is zero.
  - The PAN ID compression field and Sequence Number Compression field shall be set to be the same value as the corresponding fields in the Frame Control field of the frame that is being acknowledged.
  - The IEs present field shall be set to one if IEs are included in the Enh-Ack frame.
  - The Destination Addressing Mode field shall contain the value of the Source Addressing Mode field in the Frame Control field of the frame that is being acknowledged.
  - The Source Addressing mode field shall be set as appropriate for the address of the device transmitting the Enh-Ack frame.
- The Sequence Number field, when present shall contain the value of the sequence number received in the frame for which the acknowledgment is to be sent.
- The Source Address field, when present, is from MACSHORTADDRS0(if CURRENT_NETWORK is 0) or MACSHORTADDRS1(if CURRENT_NETWORK is 1) when EMPTY_SRC_ADDR_MODE is 2; or is from MACLONGADDRS0(if CURRENT_NETWORK is 0) or MACLONGADDRS1(if CURRENT_NETWORK is 1) when EMPTY_SRC_ADDR_MODE is 3.
- The Source PAN ID field, when present, is from MACPANID0 (if CURRENT_NETWORK is 0) or MACPANID1(if CURRENT_NETWORK is 1).

- The Destination Address field, when present, shall contain the value of the Source Address field from the frame that is being acknowledged. The Destination PAN ID, when present, contains the value from the Source PAN ID field from the frame that is being acknowledged.
- The Auxiliary Security Header, IE and Frame Payload may be included.

Because Empty-Enh-Ack is a simplified format, compared with Full-Enh-Ack, there are some *differences*.

- The Frame Control field:
  - The Frame Type is b010, Acknowledgment type.
  - The Frame Version is b10.
  - *Security Enabled field is 0, indicating the Enh-Ack frame is not protected. (when EMPTY_SECURITY_ENABLED_OVRD_EN is 1, this field tracks the EMPTY_SECURITY_ENABLED_OVRD bit)*
  - *The Frame Pending field is 1, indicating that there will be a Full-Enh-Ack frame after the Empty-Enh-Ack frame. (when ACK_FRM_PND_CTRL is 1, this field tracks the ACK_FRM_PND bit)*
  - The AR field is zero
  - The PAN ID compression field and Sequence Number Compression field shall be set to be the same value as the corresponding fields in the Frame Control field of the frame that is being acknowledged.
  - *The IEs present field is 0, indicating there is no IEs field in the Empty-Enh-Ack*
  - The Destination Addressing Mode field shall contain the value of the Source Addressing Mode field in the Frame Control field of the frame that is being acknowledged
  - *The Source Addressing mode field is from register EMPTY_SRC_ADDR_MODE, which should be 2 or 3 only.*
- The Sequence Number field, when present shall contain the value of the sequence number received in the frame for which the acknowledgment is to be sent.
- The Source Address field, when present, is from MACSHORTADDRS0(if CURRENT_NETWORK is 0) or MACSHORTADDRS1(if CURRENT_NETWORK is 1) when EMPTY_SRC_ADDR_MODE is 2; or is from MACLONGADDRS0(if CURRENT_NETWORK is 0) or MACLONGADDRS1(if CURRENT_NETWORK is 1) when EMPTY_SRC_ADDR_MODE is 3.
- The Source PAN ID field, when present, is from MACPANID0 (if CURRENT_NETWORK is 0) or MACPANID1(if CURRENT_NETWORK is 1).
- The Destination Address field, when present, shall contain the value of the Source Address field from the frame that is being acknowledged. The Destination PAN ID, when present, contains the value from the Source PAN ID field from the frame that is being acknowledged.
- *The Auxiliary Security Header, IE and Frame Payload are not exist.*

The key steps/points of the Enhanced Acknowledgment flow are as follows.

- The hardware provides a mechanism to ensure that the software can read and write RAM during the process of receiving and sending packets.
- The hardware provides RXWTRMRKIRQ, which can provide an interrupt indication when receiving any number bytes of packets, by software configuration.
- During the receiving process, by dynamically configuring the RX_WTR_MARK register, software no longer waits until the entire packet is received, but after a part of the packet is written into RAM by the hardware. The purpose of this is to enable the software to start decrypting and parsing the package in advance.
- After received the unencrypted MHR and parsed the Frame Version 2, the hardware checks whether the packet is sent to this device and whether it complies with the 802.15.4 -2015 spec. The detailed parsing flow is show in Figure 438. For stage "Address Mode Checking(Valid case in Table 7-2)", it checks if the frame type is Beacon, MAC Command or DATA, check if it is a valid case in Figure 434; if the frame type is ACK, check if it is a valid case in Figure 435. Other rule-checking for each

stage is described in Packet Filtering Detail. If the packet does not pass the parsing flow, the hardware may abort process and set FILTERFAIL_IRQ. Software should also abort its process when received FILTERFAIL_IRQ.

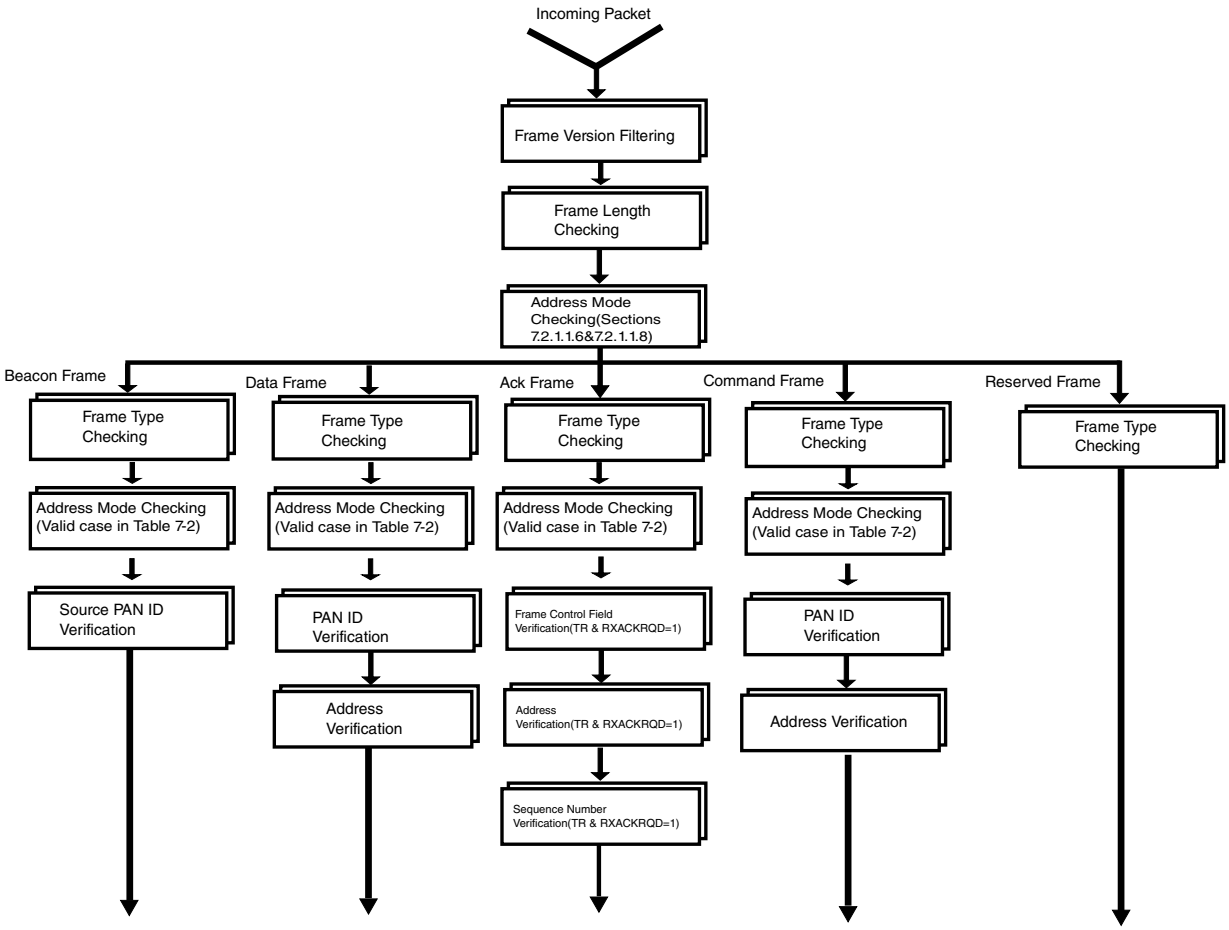


Figure 438. Packet Filtering Flow Diagram of Frame Version 2

- If received DATA or MAC Command packet, the hardware will automatically perform the Source Address Management process if it is enabled, and calculate Frame Pending field, put it in register HW_FRAME_PENDING. This bit will be placed in the Frame Pending field of Enh-Ack, if the software further parses the packet is a MAC Data Request Command or DATA type packet. Otherwise, Enh-Ack's Frame Pending field is 0 and HW_FRAME_PENDING is not used.
- Software may also do some additional rule checks and can abort the process on fail.
- If data authenticity is enabled, software also checkes the data authenticity by message integrity code(MIC). If fail, the software can abort the process.
- At the end of packet, the CRC check is performed by hardware. If CRC fails, the auto acknowledge process is aborted. There are two cases if CRC fails. For each case, the software will be notified to be aborted: Case 1. if NO_RX_RECY CLE is 0 (by default), hardware automaticly recycles and RECYC_IRQ is asserted; Case 2. if NO_RX_RECY CLE is 1, RXIRQ and SEQIRQ are asserted. Software aborts if register CRCVALID is 0.
- If the received packet meets the following conditions, the software starts to prepare the Enh-Ack packet and hardware starts to schedule the acknowledge time.
  - the Frame Version is 2
  - the AR field is 1
  - the Frame Type is DATA or MAC Command

  - filtering flow check pass
  - MIC check pass
  - CRC check pass
- At the 192us turnaround time, if no software abort, hardware starts sending Preamble(4 bytes) and SFD(1 byte), which lasts for 160us. So from the receipt of the last CRC bit, there is a total of 352us for the software to prepare the Enh-Ack packet.
- The software needs to prepare the Length Field first, because this is the first field to be sent after Preamble and SFD. After writing Length Field to RAM, the software needs to set register SW_LEN_RDY to 1.
- After the SFD is sent, the SW_LEN_RDY is used by the hardware to check whether the software Enh-Ack package has been assembled. If SW_LEN_RDY is 1, the hardware continues to read the Full-Enh-Ack from RAM and send it to the air; else, hardware will send an unencrypted Empty-Enh-Ack packet with the correct MHR, but no IEs and Frame Payload. At the same time, the hardware will generate an EMPTY_ACK_IRQ if enabled.
- While the hardware is sending Full-Enh-Ack's Length Field, the software can continue to calculate and write the rest of the packet into RAM.
- Due to possible software and hardware race conditions, before sending the Header IE field(HIE), the hardware has a checkpoint. If the HIE exists in the Enh-Ack packet, after writing the HIE into the RAM, the software needs to set the register SW_HIE_RDY to 1. This SW_HIE_RDY is used by the hardware to check whether the software is capable of completing the HIE and other reset Fields.
- The register SW_MHR_LENGTH is used by the software to tell the hardware the specific location of the HIE in the packet.
- If SW_HIE_RDY is checked as 1, the hardware continues to read bytes from RAM and send them to air; Otherwise, hardware aborts the sequence and generates an interrupt ACK_ABORT_IRQ if enabled.
- When the last byte of the Full-Enh-Ack or Empty-Enh-Ack is sent according to the length specified by the Length field, the sequence completes with the TXIRQ set.

Just like the usage of RXACKRQD bit in Imm-Ack, it can also be used in Enh-Ack. If RXACKRQD=1, then Sequence TR is executed as a Sequence T followed by a Receive-Acknowledge-Only frame. This type of receive operation is special, and not the same as a standalone Sequence R. The Ack-only receive operation filters all incoming frames, looking only for an Enh-Ack frame if the frame version is 2. And the Enh-Ack frame should pass the following checks which is also shown in Figure 438.

- Frame Control field check (can be overridden by leniency[41])
  - The received PAN ID Compression matches the transmitted PAN ID Compression
  - The received Sequence Number Suppression matches the transmitted Sequence Number Suppression
  - The received Destination Address Mode matches the transmitted Source Address Mode
- Address Field check (can be overridden by leniency[42])
  - The Destination Address field, when present, shall contain the value of the Source Address field from the frame that is being acknowledged.
  - The Destination PAN ID, when present, contains the value from the Source PAN ID field from the frame that is being acknowledged
- Sequence Number Check(same as Imm-Ack, can be overridden by leniency[9])

All non-matching frames are discarded, and after each non-matching frame, the sequence manager will return the receiver to preamble-detect mode. This receive operation will continue until the matching Enh-Ack frame is received. Unlike Imm-Ack, the hardware will put the entire Enh-Ack frame in RAM. Because Enh-Ack may contain other information required by the software.

52.4.4.4.1.2.3 Mode sections

The zigbee has two operation modes. In TX mode the IP sends data to be transmitted. In RX mode the data is received.

52.4.4.4.1.2.3.1 TX mode

The MCU writes the data packet and it?s header on packet buffer. On ZLL register IRQSTS information like if the transmission was complete is available.

52.4.4.4.1.2.3.2 RX mode

The receiving packets are filtered, if they are addressed to this device they are stored on packet buffer and the data is available for MCU. On ZLL register IRQSTS information like received packet length and if the reception was complete are available.

52.4.4.4.1.2.4 Clocking

This system is turned by external crystal oscillator (26 MHz or 32 MHz).

52.4.4.4.1.2.5 Interrupts

The interrupts are described in the section of submodules interrupt 802.15.4 Interrupt Architecture.

52.4.4.4.1.3 External signals

52.4.4.4.1.3.1 External signals

This section must be detailed.

52.4.4.4.1.4 Initialization

52.4.4.4.1.4.1 Initialization

In order to perform the initialization correctly the following modules should be configured.

52.4.4.4.1.4.1.1 RADIO XCVR_TX_DIG

In the TXDIG_CTRL register Modulator sel is FSK PFC_en (Phase to Frequency Conversion) must be enabled for zigbee, symbol_to_chip also need to be enabled.

Modulator sel is FSK PFC_en (Phase to Frequency Conversion) must be enabled for zigbee, symbol_to_chip also need to be enabled.

52.4.4.4.1.4.1.2 RADIO XCVR_PLL_DIG

PLL Channel Mapping (CHAN_MAP) field band select 100b - IEEE 802.15.4 O-QPSK PHY in ISM band

52.4.4.4.1.4.1.3 RADIO XCVR_MISC

PLL Channel Mapping (CHAN_MAP) field band select 100b - IEEE 802.15.4 O-QPSK PHY in ISM band

52.4.4.4.1.4.1.4 RADIO XCVR_RX_DIG

RXDIG Control 0 DRS (CTRL0_DRS) CIC decimation Rate must be set to 8. RXDIG Control 1 (CTRL1) WB-NORM must be enabled

Acquisition Filter Coeffs 0~3 DRS (ACQ_FILT_0_3_DRS) must be adjusted according to the clock.

52.4.4.4.1.5 Application information

52.4.4.4.1.5.1 Application

After the correct initialization the IP is ready for receive and transmit in the good zigbee channel. Here we have a simple example.

52.4.4.4.1.5.1.1 Packet transmission

In the first step MCU must write a valid zigbee frame on packet buffer.

Next the field ZLL PHY control register PHY_CTRL[XCVSEQ] must be written to value 010 -T(TRANSMIT).

Once the transmission is complete on ZLL register IRQSTS the field TX_IRQ is set to 1.

52.4.4.4.1.5.1.2 Packet Reception

In the first step is configure ZLL register DUAL_PAN_CTRL[DUAL_PAN_DWELL] according to the size needed for RX Buffer.

Next the field ZLL PHY control register PHY_CTRL[XCVSEQ] must be written to value 001 -R(RECEIVE).

Once the reception is complete on ZLL register IRQSTS the field RX_IRQ is set to 1. Other fields of this register should also be checked. The field CRCVALID indicates if the CRC for the last received packet is correct. The number of received bytes is counted, field RXWTRMRKIR indicates if the number of received bytes is bigger than the watermark the flag is set.

ZLL register IRQSTS contains the field FILTERFAIL_IR, if the most recent received packet has been rejected due to elements within the packet and this flag is set to 1.

52.4.4.4.1.6 Memory Map and Registers

52.4.4.4.1.6.1 ZLL register descriptions

52.4.4.4.1.6.1.1 ZLL memory map

RADIO.ZLL base address: 48A0_1000h

Offset	Register	Width (In bits)	Access	Reset value
0h	INTERRUPT REQUEST STATUS (IRQSTS)	32	RW	See section
4h	PHY CONTROL (PHY_CTRL)	32	RW	0807_FF00h
8h	EVENT TIMER (EVENT_TMR)	32	RW	See section
Ch	TIMESTAMP (TIMESTAMP)	32	R	See section
10h	T1 COMPARE (T1CMP)	32	RW	00FF_FFFFh
14h	T2 COMPARE (T2CMP)	32	RW	00FF_FFFFh
18h	T2 PRIME COMPARE (T2PRIMECMP)	32	RW	0000_FFFFh
1Ch	T3 COMPARE (T3CMP)	32	RW	00FF_FFFFh
20h	T4 COMPARE (T4CMP)	32	RW	00FF_FFFFh
24h	PA POWER (PA_PWR)	32	RW	0000_0000h
28h	CHANNEL NUMBER 0 (CHANNEL_NUM0)	32	RW	0000_0012h
2Ch	LQI AND RSSI (LQI_AND_RSSI)	32	R	See section
30h	MAC SHORT ADDRESS 0 (MACSHORTADDRS0)	32	RW	FFFF_FFFFh
34h	MAC LONG ADDRESS 0 LSB (MACLONGADDRS0_LSB)	32	RW	FFFF_FFFFh
38h	MAC LONG ADDRESS 0 MSB (MACLONGADDRS0_MSB)	32	RW	FFFF_FFFFh
3Ch	RECEIVE FRAME FILTER (RX_FRAME_FILTER)	32	RW	See section
40h	CCA AND LQI CONTROL (CCA_LQI_CTRL)	32	RW	0866_004Bh
44h	CCA2 CONTROL (CCA2_CTRL)	32	RW	See section
4Ch	DSM CONTROL (DSM_CTRL)	32	RW	0000_0000h
54h	MAC SHORT ADDRESS FOR PAN1 (MACSHORTADDRS1)	32	RW	FFFF_FFFFh
58h	MAC LONG ADDRESS 1 LSB (MACLONGADDRS1_LSB)	32	RW	FFFF_FFFFh

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
5Ch	MAC LONG ADDRESS 1 MSB (MACLONGADDRS1_MSB)	32	RW	FFFF_FFFFh
60h	DUAL PAN CONTROL (DUAL_PAN_CTRL)	32	RW	See section
64h	CHANNEL NUMBER 1 (CHANNEL_NUM1)	32	RW	0000_007Fh
68h	SAM CONTROL (SAM_CTRL)	32	RW	8080_4000h
6Ch	SOURCE ADDRESS MANAGEMENT TABLE (SAM_TABLE)	32	RW	See section
70h	SOURCE ADDRESS MANAGEMENT MATCH (SAM_MATCH)	32	R	See section
74h	SAM FREE INDEX (SAM_FREE_IDX)	32	R	See section
78h	SEQUENCE CONTROL AND STATUS (SEQ_CTRL_STS)	32	RW	See section
7Ch	ACK DELAY (ACKDELAY)	32	RW	002D_0002h
80h	FILTER FAIL CODE (FILTERFAIL_CODE)	32	RW	See section
84h	RECEIVE WATER MARK (RX_WTR_MARK)	32	RW	0000_00FFh
8Ch	SLOT PRELOAD (SLOT_PRELOAD)	32	RW	0000_0074h
90h	802.15.4 SEQUENCE STATE (SEQ_STATE)	32	R	See section
94h	TIMER PRESCALER (TMR_PRESCALE)	32	RW	0000_0005h
98h	LENIENCY LSB (LENIENCY_LSB)	32	RW	0000_0000h
9Ch	LENIENCY MSB (LENIENCY_MSB)	32	RW	0000_0000h
A0h	PART ID (PART_ID)	32	R	0000_0004h
A4h	COEXISTENCE CONTROL (COEX_CTRL)	32	RW	0000_0304h
A8h	COEXISTENCE PRIORITY (COEX_PRIORITY)	32	RW	0000_0000h
ACh	ENHACK_CTRL 0 (ENHACK_CTRL0)	32	RW	0000_FF00h

52.4.4.4.1.6.1.2 INTERRUPT REQUEST STATUS (IRQSTS)

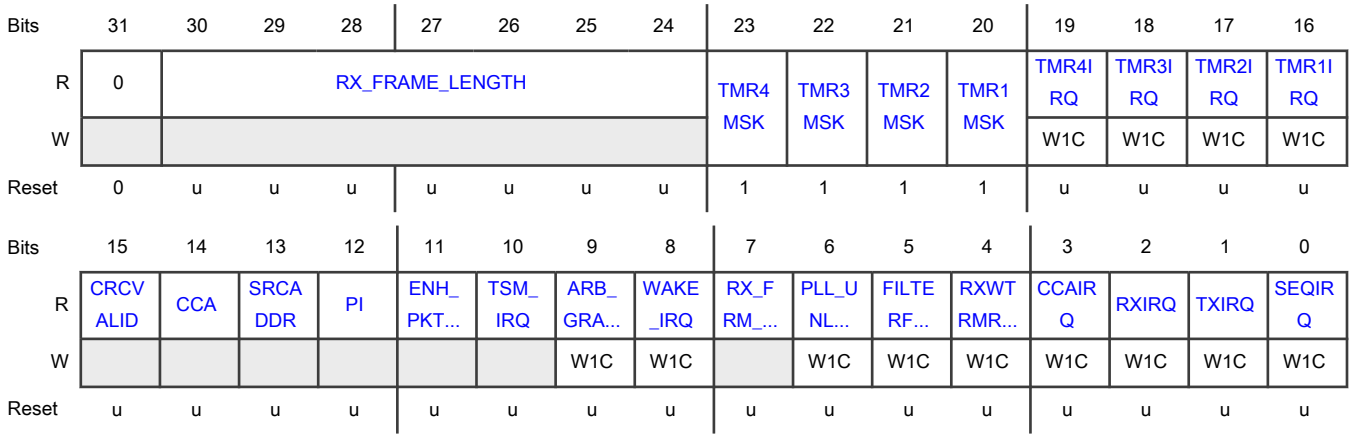
Offset

Register	Offset
IRQSTS	0h

Function

The IRQSTS register indicates the status of interrupt requests in the 802.15.4 module.

Diagram



Fields

Field	Function
31 —	Reserved
30-24 RX_FRAME_LENGTH	Receive Frame Length Contents of the PHR (PHY header), or FrameLength field, of the most recently received packet. Read-only.
23 TMR4MSK	Timer Comparator 4 Interrupt Mask bit 0b - allows interrupt when comparator matches event timer count 1b - Interrupt generation is disabled, but a TMR4IRQ flag can be set
22 TMR3MSK	Timer Comparator 3 Interrupt Mask bit 0b - allows interrupt when comparator matches event timer count 1b - Interrupt generation is disabled, but a TMR3IRQ flag can be set
21 TMR2MSK	Timer Comparator 2 Interrupt Mask bit 0b - allows interrupt when comparator matches event timer count 1b - Interrupt generation is disabled, but a TMR2IRQ flag can be set
20 TMR1MSK	Timer Comparator 1 Interrupt Mask bit 0b - allows interrupt when comparator matches event timer count 1b - Interrupt generation is disabled, but a TMR1IRQ flag can be set
19 TMR4IRQ	Timer 4 IRQ Timer Comparator 4 Interrupt Status bit: Indicates T4CMP comparator value matched event timer counter. This is write '1' to clear bit
18	Timer 3 IRQ

Table continues on the next page...

Table continued from the previous page...

Field	Function
TMR3IRQ	Timer Comparator 3 Interrupt Status bit: Indicates T3CMP comparator value matched event timer counter. This is write '1' to clear bit
17 TMR2IRQ	Timer 2 IRQ Timer Comparator 2 Interrupt Status bit: Indicates comparator value matched event timer counter. This flag is shared between the T2CMP (24-bit) and T2PRIMECMP (16-bit) compare registers. This is write '1' to clear bit
16 TMR1IRQ	Timer 1 IRQ Timer Comparator 1 Interrupt Status bit: Indicates T1CMP comparator value matched event timer counter. This is write '1' to clear bit
15 CRCVALID	CRC Valid Status Code Redundancy Check Valid: This flag indicates the compare result between the FCS field, in the most-recently received frame, and the internally calculated CRC value. This flag is cleared at next receiver warm up. 0b - Rx FCS != calculated CRC (incorrect) 1b - Rx FCS = calculated CRC (correct)
14 CCA	CCA Status Channel IDLE/BUSY indicator. This indicator is valid at CCAIRQ and also at SEQIRQ. This flag is cleared at next receiver warm up. 0b - IDLE 1b - BUSY
13 SRCADDR	Source Address Match Status If Source Address Management is engaged, meaning at least one of the following bits is set: SAP0_EN SAA0_EN SAP1_EN SAA1_EN Then SRCADDR will be set to 1 if the packet just received is a poll request (PI=1), *and* at least one of the following conditions is met: SAP0_EN and SAP0_ADDR_PRESENT SAA0_EN and SAA0_ADDR_ABSENT SAP1_EN and SAP1_ADDR_PRESENT SAA1_EN and SAA1_ADDR_ABSENT If SRCADDR=1, this indicates to SW that the Packet Processor has determined that an auto-TxACK frame must be transmitted with the FramePending subfield of the FrameControlField set to 1. HW will assemble and transmit this Ack packet. If the above conditions are not met, SRCADDR will be cleared to 0.

Table continues on the next page...

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Field	Function
12 PI	Poll Indication 0b - the received packet was not a data request 1b - the received packet was a data request, regardless of whether a Source Address table match occurred, or whether Source Address Management is enabled or not
11 ENH_PKT_STATUS	Enhanced Packet Status 0b - The last packet received was neither 4e- nor 2015-compliant 1b - The last packet received was 4e- or 2015-compliant (RX_FRAME_FILTER register should be queried for additional status bits)
10 TSM_IRQ	TSM IRQ TSM Interrupt Request 0b - A TSM Interrupt has not occurred 1b - A TSM Interrupt has occurred
9 ARB_GRANT_DEASSERTION_IRQ	arb_grant Deassertion IRQ arb_grant(!RF_NOT_ALLOWED) Deassertion Interrupt Status bit. A '1' indicates an arb_grant deassertion event has occurred. This is write a '1' to clear bit. 0b - An arb_grant Deassertion Interrupt has not occurred 1b - An arb_grant Deassertion Interrupt has occurred
8 WAKE_IRQ	WAKE Interrupt Request Wake Interrupt. The RFMC TIMER has matched the WOR WKUP_TIME register, and DSM has exited. The 802.15.4 EVENT_TMR has resumed counting. 0b - A Wake Interrupt has not occurred 1b - A Wake Interrupt has occurred
7 RX_FRM_PEND	RX Frame Pending Status of the frame pending bit of the frame control field for the most-recently received packet. Read-only.
6 PLL_UNLOCK_IRQ	PLL Unlock IRQ PLL Un-lock Interrupt Status bit. A '1' indicates an unlock event has occurred in the PLL. This is write a '1' to clear bit. 0b - A PLL Unlock Interrupt has not occurred 1b - A PLL Unlock Interrupt has occurred
5 FILTERFAIL_IRQ	Filter Fail IRQ Receiver Packet Filter Fail Interrupt Status bit. A '1' indicates that the most-recently received packet has been rejected due to elements within the packet. This is write a '1' to clear bit. In Dual PAN mode, FILTERFAIL_IRQ applies to either or both networks, as follows:

Table continues on the next page...

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Field	Function
	A: If PAN0 and PAN1 occupy different channels and CURRENT_NETWORK=0, FILTERFAIL_IRQ applies to PAN0. **B:** If PAN0 and PAN1 occupy different channels and CURRENT_NETWORK=1, FILTERFAIL_IRQ applies to PAN1. **C:** If PAN0 and PAN1 occupy the same channel, FILTERFAIL_IRQ is the logical 'AND' of the individual PANs' Filter Fail status. 0b - A Filter Fail Interrupt has not occurred 1b - A Filter Fail Interrupt has occurred
4 RXWTRMRKIRQ	Receive Watermark IRQ Receiver Byte Count Water Mark Interrupt Status bit. A '1' indicates that the number of bytes specified in the RX_WTR_MARK register has been reached. This is write a '1' to clear bit. 0b - A Receive Watermark Interrupt has not occurred 1b - A Receive Watermark Interrupt has occurred
3 CCAIRQ	CCA IRQ Clear Channel Assessment Interrupt Status bit. A '1' indicates completion of CCA operation. This is write '1' to clear bit. 0b - A CCA Interrupt has not occurred 1b - A CCA Interrupt has occurred
2 RXIRQ	RX IRQ Receiver Interrupt Status bit. A '1' indicates the completion of a receive operation. This is write a '1' to clear bit. 0b - A RX Interrupt has not occurred 1b - A RX Interrupt has occurred
1 TXIRQ	TX IRQ Transmitter Interrupt Status bit. A '1' indicates the completion of a transmit operation. This is write a '1' to clear bit. 0b - A TX Interrupt has not occurred 1b - A TX Interrupt has occurred
0 SEQIRQ	Sequencer IRQ Sequence-end Interrupt Status bit. A '1' indicates the completion of an autosequence. This interrupt will assert whenever the Sequence Manager transitions from non-idle to idle state, for any reason. This is write a '1' to clear bit. 0b - A Sequencer Interrupt has not occurred 1b - A Sequencer Interrupt has occurred

52.4.4.4.1.6.1.3 PHY CONTROL (PHY_CTRL)

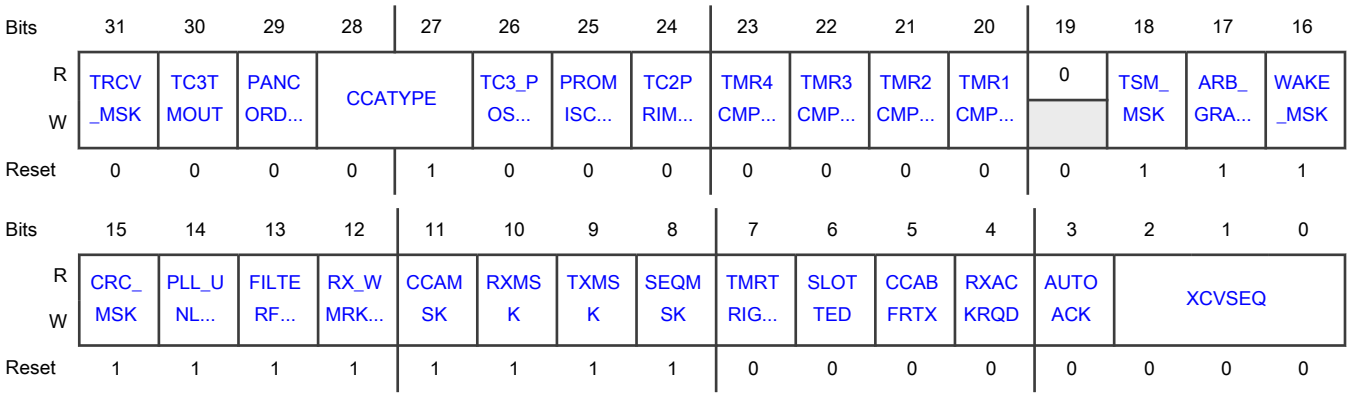
Offset

Register	Offset
PHY_CTRL	4h

Function

PHY Control Register

Diagram



Fields

Field	Function
31 TRCV_MSK	Transceiver Global Interrupt Mask Transceiver Global Interrupt Mask 0b - Enable any unmasked interrupt source to assert zigbee interrupt 1b - Mask all interrupt sources from asserting zigbee interrupt
30 TC3TMOUT	TMR3 Timeout Enable TMR3 Timeout Enable 0b - TMR3 is a software timer only 1b - Enable TMR3 to abort Rx or CCCA operations.
29 PANCORDNTR0	Device is a PAN Coordinator on PAN0 Device is a PAN Coordinator on PAN0. Allows device to receive packets with no destination address, if Source PAN ID matches.
28-27 CCATYPE	Clear Channel Assessment Type Clear Channel Assessment Type. Selects one of four possible functions for CCA or Energy Detect, per below. 00b - ENERGY DETECT 01b - CCA MODE 1

Table continues on the next page...

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Field	Function
	10b - CCA MODE 2 11b - CCA MODE 3
26 TC3_POSTPONE_ON_SFD	Postpone TC3 Timeout On SFD Enable If this bit is set, if a TMR3 timeout occurs while a packet is being received (*rx_sfd_detect* = 1), the timeout-related abort will be deferred until the packet reception is completed. If the packet is good, HW will signal Data Indication; otherwise the 802.15.4 ZSM (Sequence Manager) will return to SEQ_IDLE and await further commanding. 0b - TC3 Abort will occur on TMR3 timeout, regardless of rx_sfd_detect 1b - TC3 Abort will be deferred on TMR3 timeout if rx_sfd_detect is asserted; otherwise the TC3 Abort will occur immediately
25 PROMISCUOUS	Promiscuous Mode Enable Bypasses most packet filtering. 0b - normal mode 1b - all packet filtering except frame length checking (FrameLength>=5 and FrameLength<=127) is bypassed.
24 TC2PRIME_EN	Timer 2 Prime Compare Enable 0b - Don't allow a match of the lower 16 bits of Event Timer to T2PRIMECMP to set TMR2IRQ 1b - Allow a match of the lower 16 bits of Event Timer to T2PRIMECMP to set TMR2IRQ
23 TMR4CMP_EN	Timer 4 Compare Enable 0b - Don't allow an Event Timer Match to T4CMP to set TMR4IRQ 1b - Allow an Event Timer Match to T4CMP to set TMR4IRQ
22 TMR3CMP_EN	Timer 3 Compare Enable 0b - Don't allow an Event Timer Match to T3CMP to set TMR3IRQ 1b - Allow an Event Timer Match to T3CMP to set TMR3IRQ
21 TMR2CMP_EN	Timer 2 Compare Enable 0b - Don't allow an Event Timer Match to T2CMP or T2PRIMECMP to set TMR2IRQ 1b - Allow an Event Timer Match to T2CMP or T2PRIMECMP to set TMR2IRQ
20 TMR1CMP_EN	Timer 1 Compare Enable 0b - Don't allow an Event Timer Match to T1CMP to set TMR1IRQ 1b - Allow an Event Timer Match to T1CMP to set TMR1IRQ
19 —	Reserved
18	Mask generating interrupt from TSM

Table continues on the next page...

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Field	Function
TSM_MSK	0b - allows assertion of a TSM interrupt to generate a zigbee interrupt 1b - Assertion of a TSM interrupt will set the TSM_IRQ status bit, but a zigbee interrupt is not generated
17 ARB_GRANT_DEASSERTION_MSK	arb_grant Deassertion Interrupt Mask 0b - allows arb_grant deassertion event to generate a zigbee interrupt 1b - An arb_grant deassertion event will set the ARB_GRANT_DEASSERTION_IRQ status bit, but a zigbee interrupt is not generated
16 WAKE_MSK	Mask wakeup from DSM 0b - Allows a wakeup from DSM to generate a zigbee interrupt 1b - Wakeup from DSM will set the WAKE_IRQ status bit, but a zigbee interrupt is not generated
15 CRC_MSK	CRC Mask CRC Mask 0b - sequence manager ignores CRCVALID and considers the receive operation complete after the last octet of the frame has been received. 1b - sequence manager requires CRCVALID=1 at the end of the received frame in order for the receive operation to complete successfully; if CRCVALID=0, sequence manager will return to preamble-detect mode after the last octet of the frame has been received.
14 PLL_UNLOCK_MSK	PLL Unlock Interrupt Mask 0b - allows PLL unlock event to generate a zigbee interrupt 1b - A PLL unlock event will set the PLL_UNLOCK_IRQ status bit, but a zigbee interrupt is not generated
13 FILTERFAIL_MSK	FilterFail Interrupt Mask FilterFail Interrupt Mask 0b - allows Packet Processor Filtering Failure to generate a zigbee interrupt 1b - A Packet Processor Filtering Failure will set the FILTERFAIL_IRQ status bit, but a zigbee interrupt is not generated
12 RX_WMRK_MSK	RX Watermark Interrupt Mask RX Watermark Interrupt Mask 0b - allows a Received Byte Count match to the RX_WTR_MARK threshold register to generate a zigbee interrupt 1b - A Received Byte Count match to the RX_WTR_MARK threshold register will set the RXWTRMRKIRQ status bit, but a zigbee interrupt is not generated
11 CCAMSK	CCA Interrupt Mask CCA Interrupt Mask

Table continues on the next page...

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Field	Function
	0b - allows completion of a CCA operation to generate a zigbee interrupt 1b - Completion of a CCA operation will set the CCA status bit, but a zigbee interrupt is not generated
10 RXMSK	RX Interrupt Mask 0b - allows completion of a RX operation to generate a zigbee interrupt 1b - Completion of a RX operation will set the RXIRQ status bit, but a zigbee interrupt is not generated
9 TXMSK	TX Interrupt Mask 0b - allows completion of a TX operation to generate a zigbee interrupt 1b - Completion of a TX operation will set the TXIRQ status bit, but a zigbee interrupt is not generated
8 SEQMSK	Sequencer Interrupt Mask 0b - allows completion of an autosequence to generate a zigbee interrupt 1b - Completion of an autosequence will set the SEQIRQ status bit, but a zigbee interrupt is not generated
7 TMRTRIGEN	Timer2 Trigger Enable 0b - programmed sequence initiates immediately upon write to XCVSEQ. 1b - allow timer TC2 (or TC2') to initiate a preprogrammed sequence (see XCVSEQ register).
6 SLOTTED	Slotted Mode Slotted Mode, for beacon-enabled networks. Applies only to Sequences T, TR, and R, ignored during all other sequences. Used, in concert with CCABFRTX, to determine how many CCA measurements are required prior to a transmit operation. Also used during R sequence to determine whether the ensuing transmit acknowledge frame (if any) needs to be synchronized to a backoff slot boundary.
5 CCABFRTX	CCA Before TX Applies only to Sequences T and TR, ignored during all other sequences. 0b - no CCA required, transmit operation begins immediately. 1b - at least one CCA measurement is required prior to the transmit operation (see also SLOTTED).
4 RXACKRQD	Receive Acknowledge Frame required Applies only to Sequence TR, ignored during all other sequences. 0b - An ordinary receive frame (any type of frame) follows the transmit frame. 1b - A receive Ack frame is expected to follow the transmit frame (non-Ack frames are rejected).
3 AUTOACK	Auto Acknowledge Enable Applies only to Sequence R and Sequence TR, ignored during other sequences

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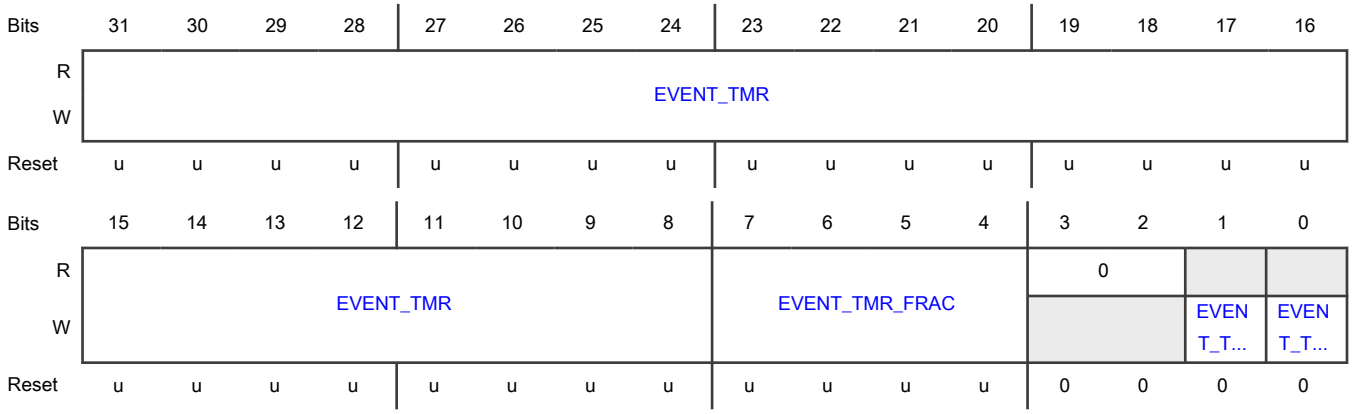
Field	Function
	0b - sequence manager will not follow a receive frame with a Tx Ack frame, under any conditions; the autosequence will terminate after the receive frame. 1b - sequence manager will follow a receive frame with an automatic hardware-generated Tx Ack frame, assuming other necessary conditions are met.
2-0 XCVSEQ	802.15.4 Transceiver Sequence Selector The Transceiver Sequence Selector register selects an autosequence for the sequence manager to execute. Sequence initiation can be immediate, or scheduled (see TMRTRIGEN). A write of XCVSEQ=IDLE will abort any ongoing sequence. A write of XCVSEQ=IDLE must always be performed after a sequence is complete, and before a new sequence is programmed. Any write to XCVSEQ other than XCVSEQ=IDLE during an ongoing sequence, shall be ignored. The mapping of XCVSEQ to sequence types is as follows: 000b - I (IDLE) 001b - R (RECEIVE) 010b - T (TRANSMIT) 011b - C (CCA) 100b - TR (TRANSMIT/RECEIVE) 101b - CCCA (CONTINUOUS CCA) 110b - Reserved 111b - Reserved

52.4.4.4.1.6.1.4 EVENT TIMER (EVENT_TMR)

Offset

Register	Offset
EVENT_TMR	8h

Diagram



Fields

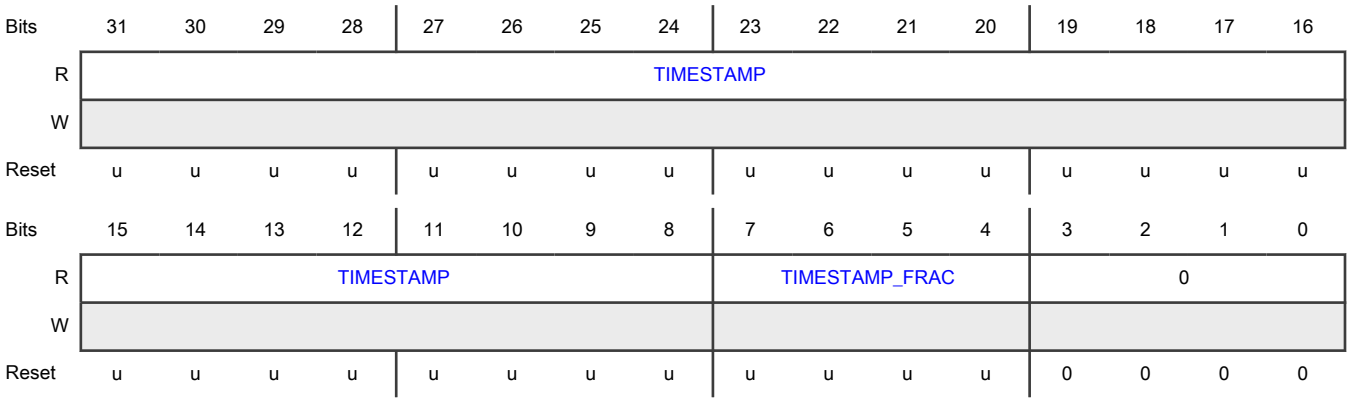
Field	Function
31-8 EVENT_TMR	Event Timer Integer Component The EVENT_TMR represents a 28-bit number with 24 Integer bits and 4 Fractional bits. This field is the integer component, which appears to the left of the decimal point. Most 802.15.4 operations which relate to the Event Timer require only the integer component.
7-4 EVENT_TMR_FRAC	Event Timer Fractional Component The EVENT_TMR represents a 28-bit number with 24 Integer bits and 4 Fractional bits. This field is the fractional component, which appears to the right of the decimal point. The fractional component can be ignored for most 802.15.4 operations which relate to the Event Timer; it has been provided only to allow for microsecond accuracy when software updates the Event Timer after a long period of DSM (sleep) mode
3-2 —	Reserved
1 EVENT_TMR_ADD	Event Timer Add Enable Increments the Event Timer by the values written to the EVENT_TMR[23:0] and EVENT_TMR_FRAC[3:0] fields of this register.
0 EVENT_TMR_LD	Event Timer Load Enable Loads the Event Timer with the values written to the EVENT_TMR[23:0] and EVENT_TMR_FRAC[3:0] fields of this register.

52.4.4.4.1.6.1.5 TIMESTAMP (TIMESTAMP)

Offset

Register	Offset
TIMESTAMP	Ch

Diagram



Fields

Field	Function
31-8 TIMESTAMP	Timestamp Holds the latched value of the integer portion of the Event Timer current time corresponding to the beginning of the most recently received packet, at the point of SFD detection
7-4 TIMESTAMP_FRAC	Timestamp Fractional Holds the latched value of the fractional portion of the Event Timer current time corresponding to the beginning of the most recently received packet, at the point of SFD detection
3-0 —	Reserved

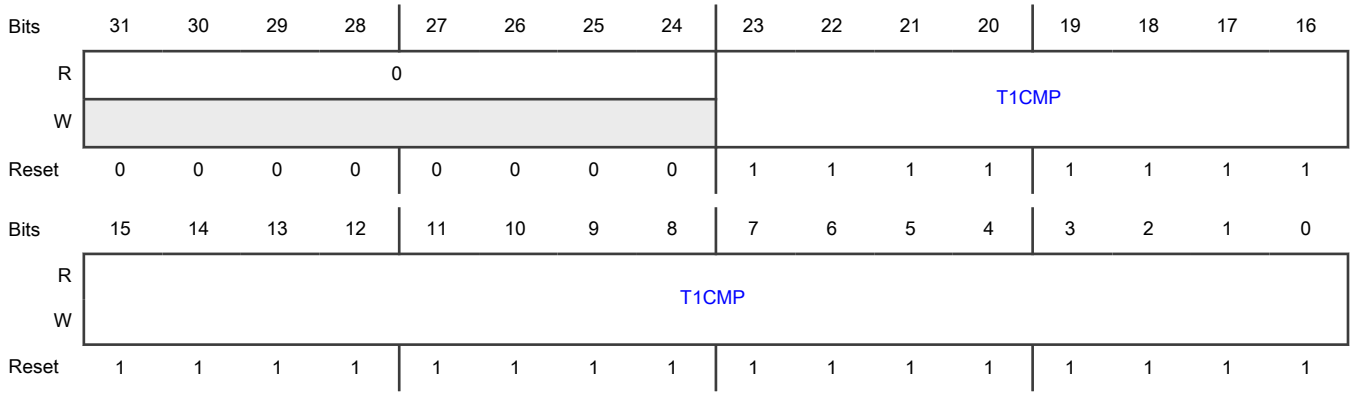
52.4.4.4.1.6.1.6 T1 COMPARE (T1CMP)

Offset

Register	Offset
T1CMP	10h

Function
TMR1 Compare Value

Diagram



Fields

Field	Function
31-24 —	Reserved
23-0 T1CMP	TMR1 Compare Value TMR1 compare value. If TMR1CMP_EN=1 and the Event Timer matches this value, TMR1IRQ is set.

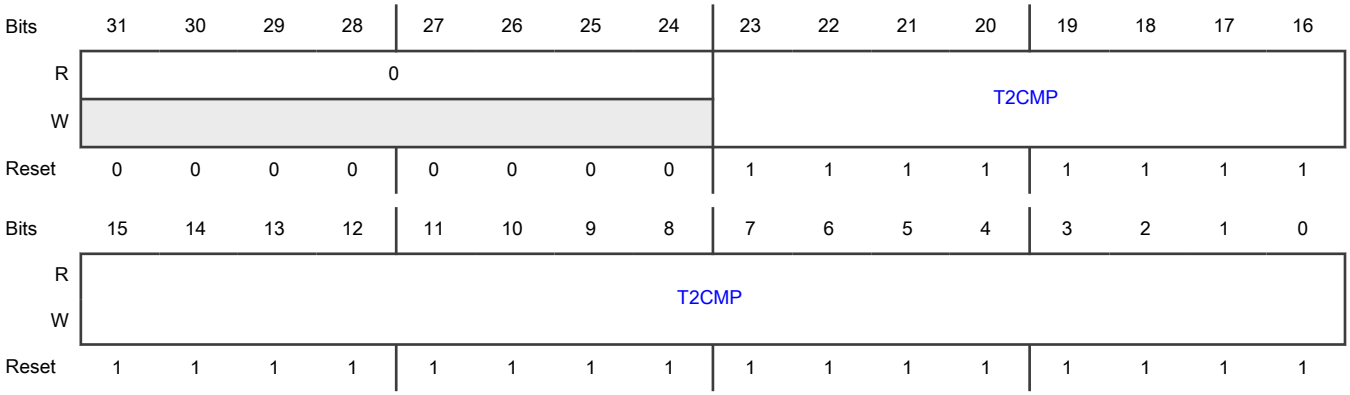
52.4.4.4.1.6.1.7 T2 COMPARE (T2CMP)

Offset

Register	Offset
T2CMP	14h

Function
TMR2 Compare Value

Diagram



Fields

Field	Function
31-24 —	Reserved
23-0 T2CMP	TMR2 Compare Value TMR2 compare value. If TMR2CMP_EN=1 and TC2PRIME_EN=0 and the Event Timer matches this value, TMR2IRQ is set.

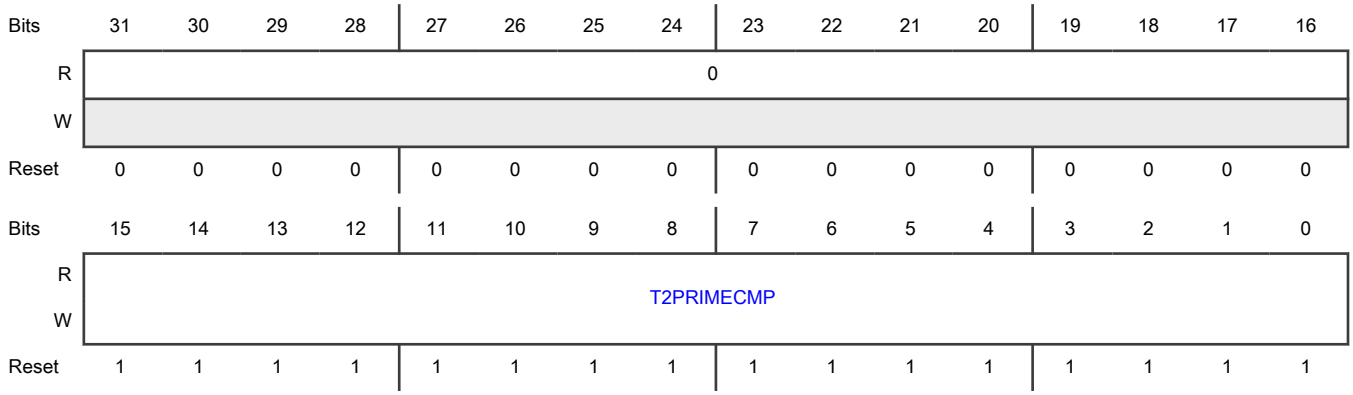
52.4.4.4.1.6.1.8 T2 PRIME COMPARE (T2PRIMECMP)

Offset

Register	Offset
T2PRIMECMP	18h

Function
TMR2 Prime Compare Value

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 T2PRIMECMP	TMR2 Prime Compare Value TMR2 compare value. If TMR2CMP_EN=1 and TC2PRIME_EN=1 and the Event Timer matches this value, TMR2IRQ is set.

52.4.4.4.1.6.1.9 T3 COMPARE (T3CMP)

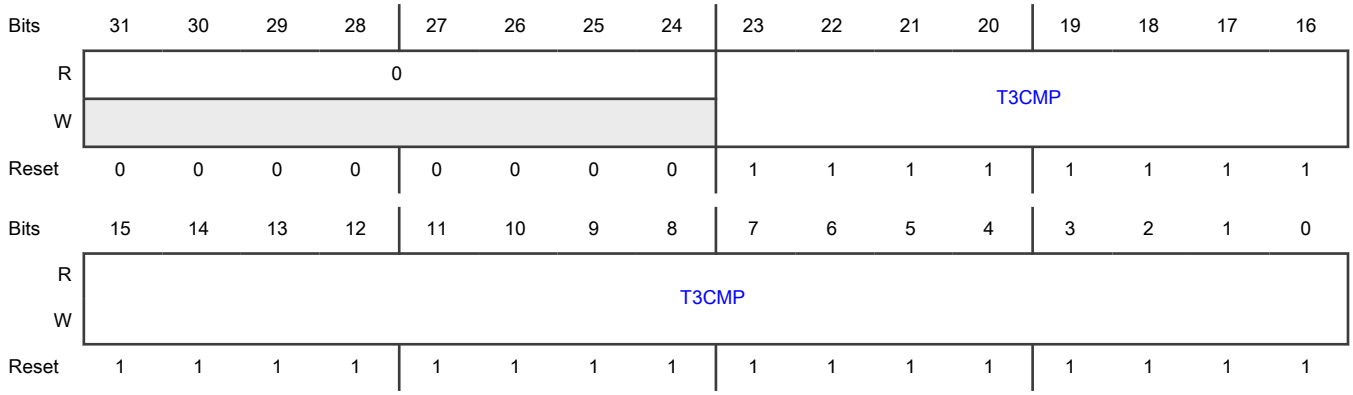
Offset

Register	Offset
T3CMP	1Ch

Function

TMR3 Compare Value

Diagram



Fields

Field	Function
31-24 —	Reserved
23-0 T3CMP	TMR3 Compare Value TMR3 compare value. If TMR3CMP_EN=1 and the Event Timer matches this value, TMR3IRQ is set.

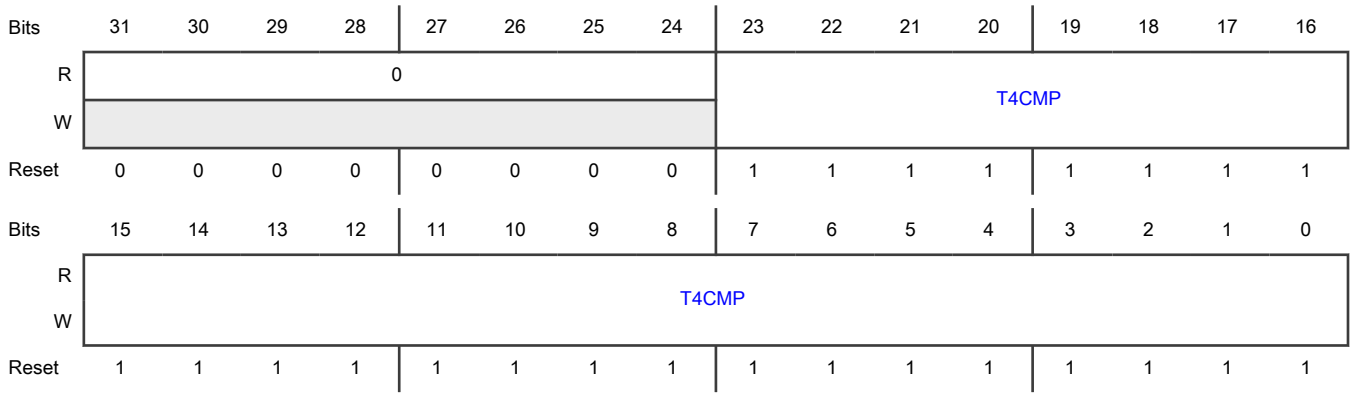
52.4.4.4.1.6.1.10 T4 COMPARE (T4CMP)

Offset

Register	Offset
T4CMP	20h

Function
TMR4 Compare Value

Diagram



Fields

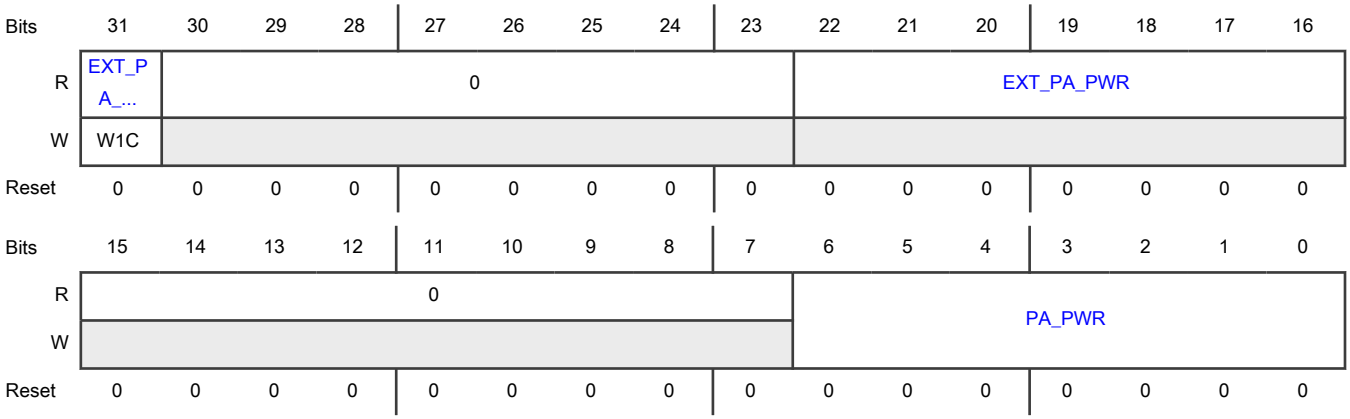
Field	Function
31-24 —	Reserved
23-0 T4CMP	TMR4 Compare Value TMR4 compare value. If TMR4CMP_EN=1 and the Event Timer matches this value, TMR4IRQ is set.

52.4.4.4.1.6.1.11 PA POWER (PA_PWR)

Offset

Register	Offset
PA_PWR	24h

Diagram



Fields

Field	Function
31 EXT_PA_PWR_CHG	External PA Power Change Flag This flag is asserted when zfdbk_txpower_ind asserts during transmitting and grant has been asserted. This is write a '1' to clear bit.
30-23 —	Reserved
22-16 EXT_PA_PWR	External PA Power When transmitting and grant has been asserted, if zfdbk_txpower_ind asserts, then zfdbk_tx_power[5:0] is assigned to PA_PWR[6:1] and the status bit EXT_PA_PWR_CHG is set for software to check later. The value recorded in EXT_PA_PWR[6:0] is {zfdbk_tx_power[5:0],PA_PWR[0]} for debug purposes.
15-7 —	Reserved
6-0 PA_PWR	PA Power Only the 6 LSB are actually connected to the PA Power controller

52.4.4.4.1.6.1.12 CHANNEL NUMBER 0 (CHANNEL_NUM0)

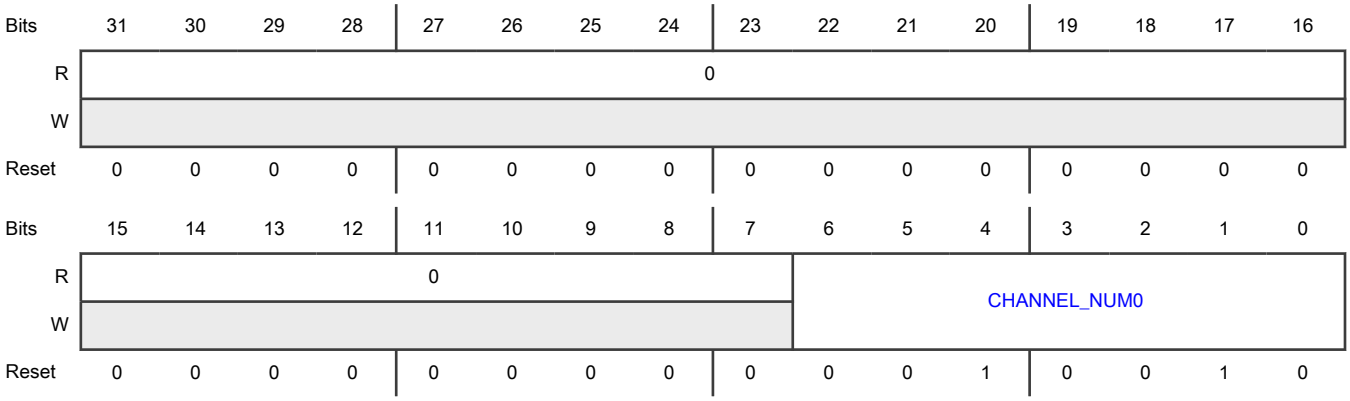
Offset

Register	Offset
CHANNEL_NUM0	28h

Function

Channel Number for PAN0

Diagram



Fields

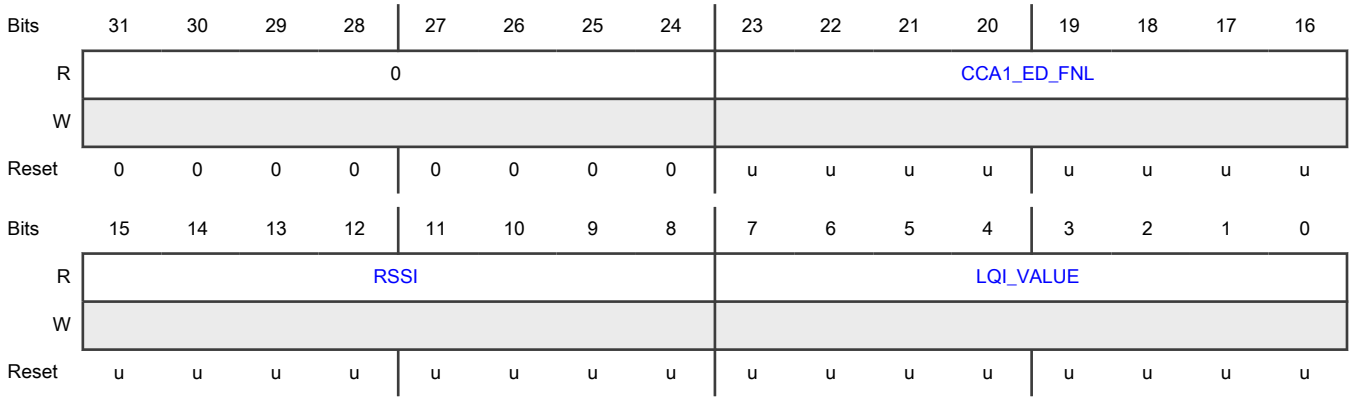
Field	Function
31-7 —	Reserved
6-0 CHANNEL_NUM0	Channel Number for PAN0 This is the mapped channel number used to transmit and receive Zigbee packets. If Dual PAN is engaged, this register applies to PAN0. CHANNEL_NUM0 should be in the range: 11 <= CHANNEL_NUM0 <= 26

52.4.4.4.1.6.1.13 LQI AND RSSI (LQI_AND_RSSI)

Offset

Register	Offset
LQI_AND_RSSI	2Ch

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 CCA1_ED_FNL	Final Result for CCA Mode 1 and Energy Detect Output register to show final averaged RSSI value or compensated value of the same at the end of a CCA Mode1 or Energy Detect computation.
15-8 RSSI	RSSI Value Received Signal Strength Indicator, in dBm
7-0 LQI_VALUE	LQI Value Link Quality Indicator for the most recently received packet. (LQI is also available in the Packet Buffer, at the end of the received packet data)

52.4.4.4.1.6.1.14 MAC SHORT ADDRESS 0 (MACSHORTADDRS0)

Offset

Register	Offset
MACSHORTADDRS0	30h

Function

MAC SHORT ADDRESS for PAN0

Diagram

Fields

Field	Function
31-16 MACSHORTADDRS0	MAC SHORT ADDRESS FOR PAN0 MAC Short Address for PAN0, for 16-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.
15-0 MACPANID0	MAC PAN ID for PAN0 MAC PAN ID for PAN0. The packet processor compares the incoming packet's Destination PAN ID against the contents of this register to determine if the packet is addressed to this device; or if the incoming packet is a Beacon frame, the packet processor compares the incoming packet Source PAN ID against this register. Also, if PANCORDNTR0=1, and the incoming packet has no Destination Address field, and if the incoming packet is a Data or MAC Command frame, the packet processor compares the incoming packet Source PAN ID against this register.

52.4.4.4.1.6.1.15 MAC LONG ADDRESS 0 LSB (MACLONGADDRS0_LSB)

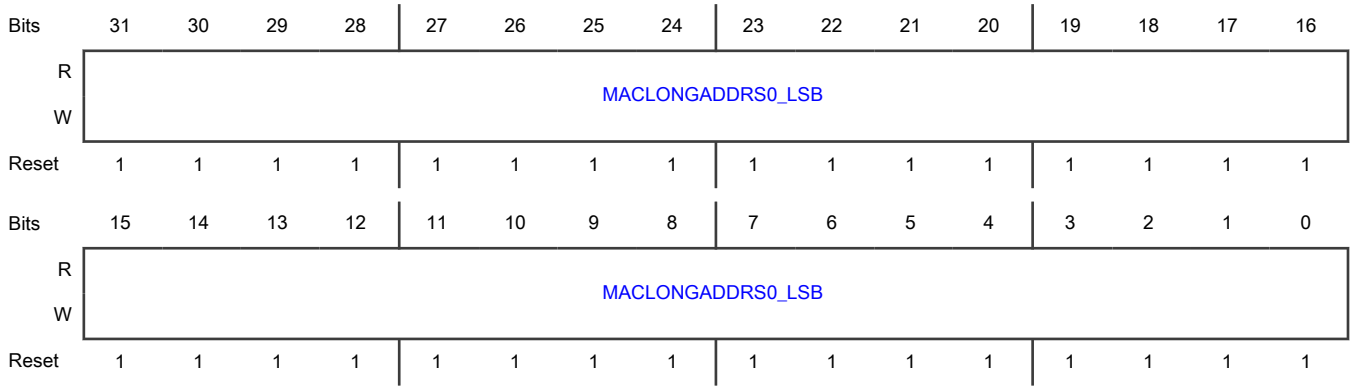
Offset

Register	Offset
MACLONGADDRS0_LSB	34h

Function

MAC LONG ADDRESS for PAN0 LSB

Diagram



Fields

Field	Function
31-0 MACLONGADDRS0_LSB	MAC LONG ADDRESS for PAN0 LSB MAC Long Address for PAN0, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.

52.4.4.4.1.6.1.16 MAC LONG ADDRESS 0 MSB (MACLONGADDRS0_MSB)

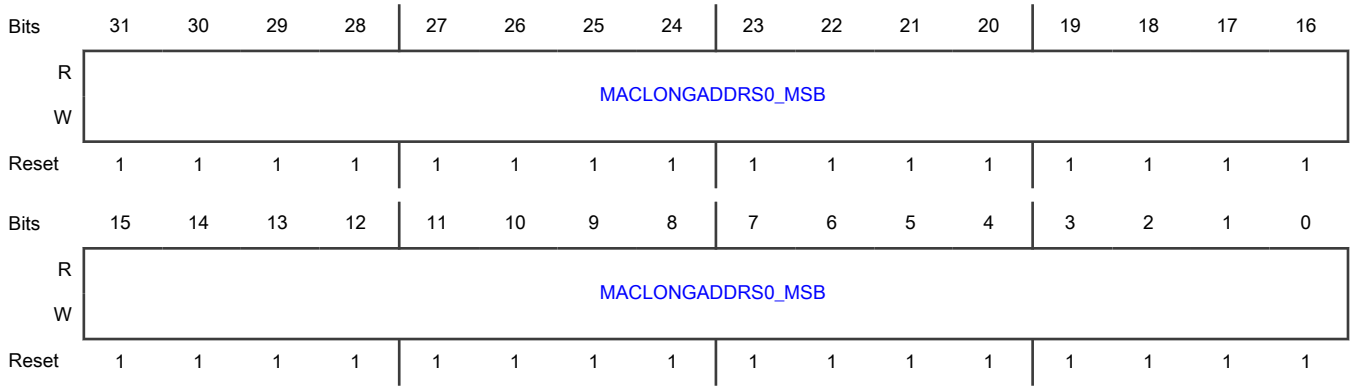
Offset

Register	Offset
MACLONGADDRS0_MSB	38h

Function

MAC LONG ADDRESS for PAN0 MSB

Diagram



Fields

Field	Function
31-0 MACLONGADDRS0_MSB	MAC LONG ADDRESS for PAN0 MSB MAC Long Address for PAN0, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.

52.4.4.4.1.6.1.17 RECEIVE FRAME FILTER (RX_FRAME_FILTER)

Offset

Register	Offset
RX_FRAME_FILTER	3Ch

Function
RECEIVE FRAME FILTER

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0								EXTENDE...	0	MULTIPU...	LLDN_RE...	FV2_CMD...	FV2_ACK...	FV2_DAT...	FV2_BEA...
W																
Reset	0	0	0	0	0	0	0	0	u	0	u	u	u	u	u	u

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	EXTENDE...	ACTIVE_...	0		FRM_VER_FILTER				EXTENDE...	NS_FT	MULTIPU...	LLDN_FT	CMD_FT	ACK_FT	DATA_FT	BEACON_...
W																
Reset	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1

Fields

Field	Function
31-24 —	Reserved
23 EXTENDED_RECD	Extended Packet Received 0b - The last packet received was not Frame Type EXTENDED 1b - The last packet received was Frame Type EXTENDED, and EXTENDED_FT=1 to allow such packets.
22	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
21 MULTIPURPOSE_RECD	Multipurpose Packet Received 0b - last packet received was not Frame Type MULTIPURPOSE 1b - The last packet received was Frame Type MULTIPURPOSE, and MULTIPURPOSE_FT=1 to allow such packets.
20 LLDN_RECD	LLDN Packet Received 0b - The last packet received was not Frame Type LLDN 1b - The last packet received was Frame Type LLDN, and LLDN_FT=1 to allow such packets.
19 FV2_CMD_RECD	Frame Version 2 MAC Command Packet Received 0b - The last packet received was not Frame Type MAC Command with Frame Version 2 1b - The last packet received was Frame Type MAC Command with Frame Version 2, and FRM_VER_FILTER[2]=1 to allow such packets
18 FV2_ACK_RECD	Frame Version 2 Acknowledge Packet Received 0b - The last packet received was not Frame Type Ack with Frame Version 2 1b - The last packet received was Frame Type Ack with Frame Version 2, and FRM_VER_FILTER[2]=1 to allow such packets
17 FV2_DATA_RECD	Frame Version 2 Data Packet Received 0b - The last packet received was not Frame Type Data with Frame Version 2 1b - The last packet received was Frame Type Data with Frame Version 2, and FRM_VER_FILTER[2]=1 to allow such packets
16 FV2_BEACON_RECD	Frame Version 2 Beacon Packet Received 0b - The last packet received was not Frame Type Beacon with Frame Version 2 1b - The last packet received was Frame Type Beacon with Frame Version 2, and FRM_VER_FILTER[2]=1 to allow such packets
15 EXTENDED_FCS_CHK	Verify FCS on Frame Type Extended 0b - Packet Processor will not check FCS for Frame Type EXTENDED (default) 1b - Packet Processor will check FCS at end-of-packet based on packet length derived from PHR, for Frame Type EXTENDED
14 ACTIVE_PROMISCUOUS	Active Promiscuous 0b - normal operation 1b - Provide Data Indication on all received packets under the same rules which apply in PROMISCUOUS mode, however acknowledge those packets under rules which apply in non-PROMISCUOUS mode
13-12	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
11-8 FRM_VER_FILTER	Frame Version selector. The incoming packet's Frame Control Field is parsed to obtain the FrameVersion subfield, and that value is compared against this register, in accordance with the following: xxx1: Accept received packets with FrameVersion=00 xx1x: Accept received packets with FrameVersion=01 x1xx: Accept received packets with FrameVersion=10 1xxx: Accept received packets with FrameVersion=11 These filtering rules apply to Beacon, Acknowledge, Data, and MAC Command Frame Types, since these frame types require a 2-octet Frame Control Field which embeds a 2-bit FrameVersion subfield. Later frame types introduced in the 802.15.4e addendum (LLDN, Multipurpose) don't guarantee a FrameVersion subfield with the original meaning, so these filtering rules do not apply to these frame types. See registers LLDN_FT and MULTIPURPOSE_FT. For Acknowledge frames, FrameVersion bits are ignored by the Packet Processor, irrespective of FRM_VER_FILTER.
7 EXTENDED_FT	Extended Frame Type Enable 0b - reject all Extended frames 1b - Extended frame type enabled (Frame Type 7).
6 NS_FT	"Not Specified" Frame Type Enable This bit enables reception of all Frame Types not covered by the other _FT bits in this register. 0b - reject all "Not Specified" frames 1b - Not-specified (reserved) frame type enabled. Applies to Frame Type 6. No packet filtering is performed, except for frame length checking (FrameLength>=5 and FrameLength<=127). No AUTOACK is transmitted for this Frame Type
5 MULTIPURPOSE_FT	Multipurpose Frame Type Enable 0b - reject all Multipurpose frames 1b - Multipurpose frame type enabled (Frame Type 5).
4 LLDN_FT	LLDN Frame Type Enable 0b - reject all LLDN frames 1b - LLDN frame type enabled (Frame Type 4).
3 CMD_FT	MAC Command Frame Type Enable 0b - reject all MAC Command frames 1b - MAC Command frame type enabled.
2	Ack Frame Type Enable

Table continues on the next page...

Table continued from the previous page...

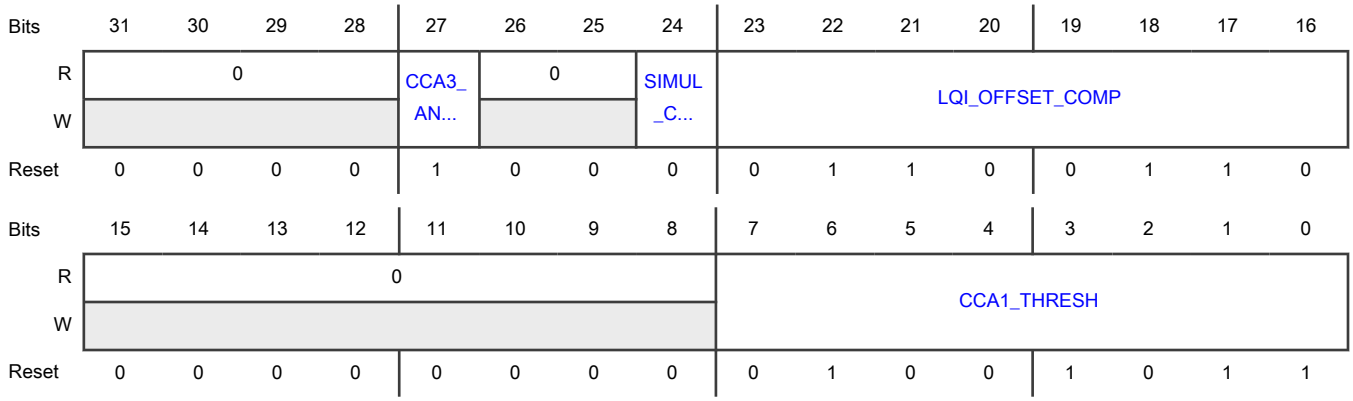
Field	Function
ACK_FT	0b - reject all Acknowledge frames 1b - Acknowledge frame type enabled.
1 DATA_FT	Data Frame Type Enable 0b - reject all Beacon frames 1b - Data frame type enabled.
0 BEACON_FT	Beacon Frame Type Enable 0b - reject all Beacon frames 1b - Beacon frame type enabled.

52.4.4.4.1.6.1.18 CCA AND LQI CONTROL (CCA_LQI_CTRL)

Offset

Register	Offset
CCA_LQI_CTRL	40h

Diagram



Fields

Field	Function
31-28 —	Reserved
27 CCA3_AND_NOT_OR	CCA Mode 3 AND not OR Determines the way CCA3 is required to be detected

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - CCA1 or CCA2 1b - CCA1 and CCA2
26-25 —	Reserved
24 SIMUL_CCA_RX	Simultaneous CCA and Receive Enable During autosequences of type Sequence T or Sequence TR with CCA before TX, this bit allows a packet to be received if preamble and SFD are detected during the CCA measurement window. 0b - Packets can't be received during CCA measurement 1b - Packet reception is enabled during CCA measurement if preamble and SFD are detected
23-16 LQI_OFFSET_COMP	LQI Offset Compensation Programmable amount to offset RSSI based LQI value
15-8 —	Reserved
7-0 CCA1_THRESH	CCA Mode 1 Threshold Programmable energy threshold register for CCA mode 1.

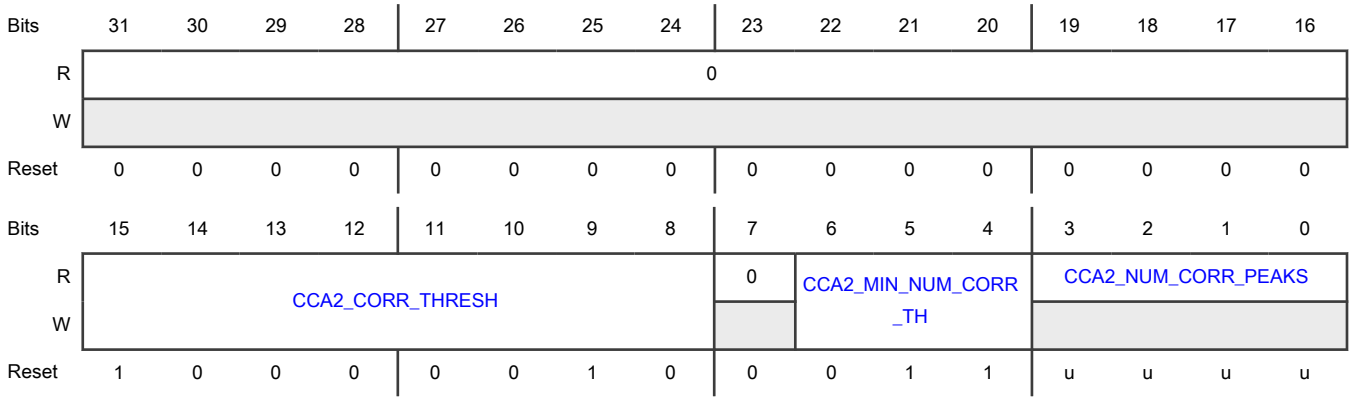
52.4.4.4.1.6.1.19 CCA2 CONTROL (CCA2_CTRL)

Offset

Register	Offset
CCA2_CTRL	44h

Function
CCA Mode 2 Control

Diagram



Fields

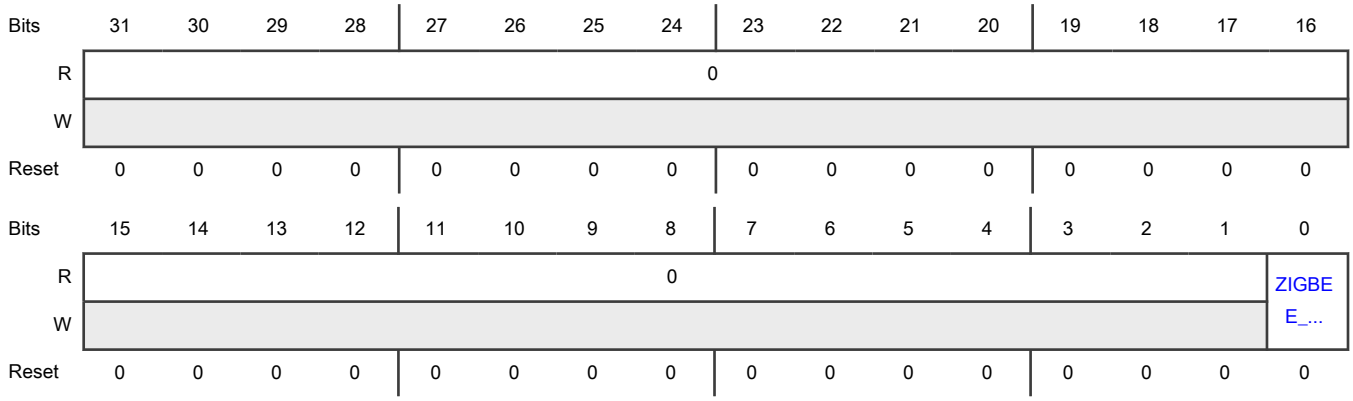
Field	Function
31-16 —	Reserved
15-8 CCA2_CORR_THRESH	CCA Mode 2 Correlation Threshold Correlator threshold used to qualify correlator peaks counted by CCA2_NUM_CORR_PEAKS. Correlator peaks exceeding this value increment CCA2_NUM_CORR_PEAKS.
7 —	Reserved
6-4 CCA2_MIN_NUM_CORR_TH	CCA Mode 2 Threshold Number of Correlation Peaks Programmable threshold to be compared against number of correlation peaks that exceeded CCA2_CORR_THRESH for detecting CCA mode 2. Number of peaks detected = CCA2_MIN_NUM_CORR_TH + 1; Example: If it is programmed to 3, CCA2 logic looks for at least 4 correlation peaks that crossed the threshold, to indicate channel is idle or busy.
3-0 CCA2_NUM_CORR_PEAKS	CCA Mode 2 Number of Correlation Peaks Detected Counts of number of peaks that crossed CCA2_CORR_THRESH in CCA Mode 2 operation

52.4.4.4.1.6.1.20 DSM CONTROL (DSM_CTRL)

Offset

Register	Offset
DSM_CTRL	4Ch

Diagram



Fields

Field	Function
31-1 —	Reserved
0 ZIGBEE_SLEEP_REQUEST	802.15.4 Deep Sleep Mode Request for Manual DSM If 802.15.4 is assigned to Manual DSM (XCVR_CTRL[MAN_DSM_SEL] = 1), setting ZIGBEE_SLEEP_REQUEST to 1 enables Deep Sleep Mode (DSM) to be entered when the RFMC TIMER matches the WOR ENTER_TIME register.

52.4.4.4.1.6.1.21 MAC SHORT ADDRESS FOR PAN1 (MACSHORTADDRS1)

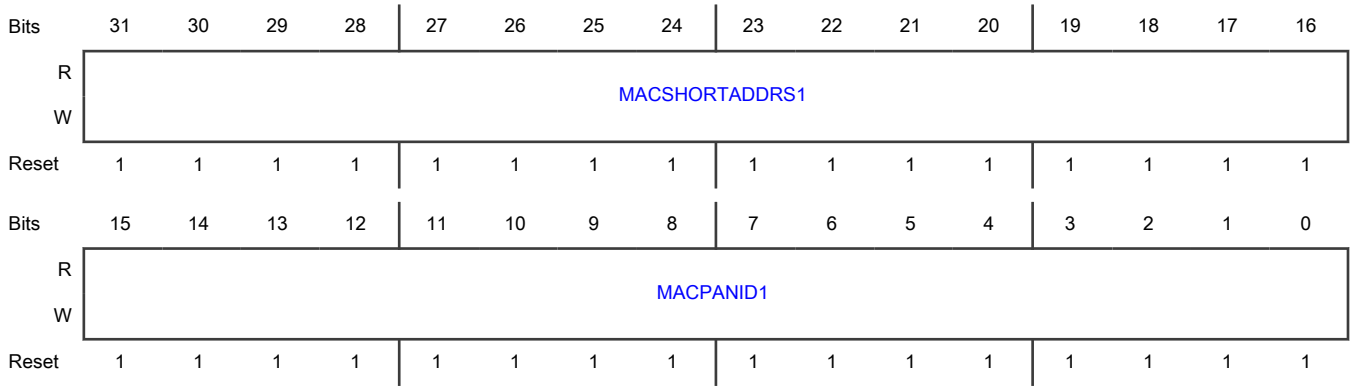
Offset

Register	Offset
MACSHORTADDRS1	54h

Function

The MACSHORTADDRS1 register .

Diagram



Fields

Field	Function
31-16 MACSHORTADDRS1	MAC SHORT ADDRESS for PAN1 MAC Short Address for PAN1, for 16-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.
15-0 MACPANID1	MAC PAN ID for PAN1 MAC PAN ID for PAN1. The packet processor compares the incoming packet's Destination PAN ID against the contents of this register to determine if the packet is addressed to this device; or if the incoming packet is a Beacon frame, the packet processor compares the incoming packet Source PAN ID against this register. Also, if PANCORDNTR1=1, and the incoming packet has no Destination Address field, and if the incoming packet is a Data or MAC Command frame, the packet processor compares the incoming packet Source PAN ID against this register.

52.4.4.4.1.6.1.22 MAC LONG ADDRESS 1 LSB (MACLONGADDRS1_LSB)

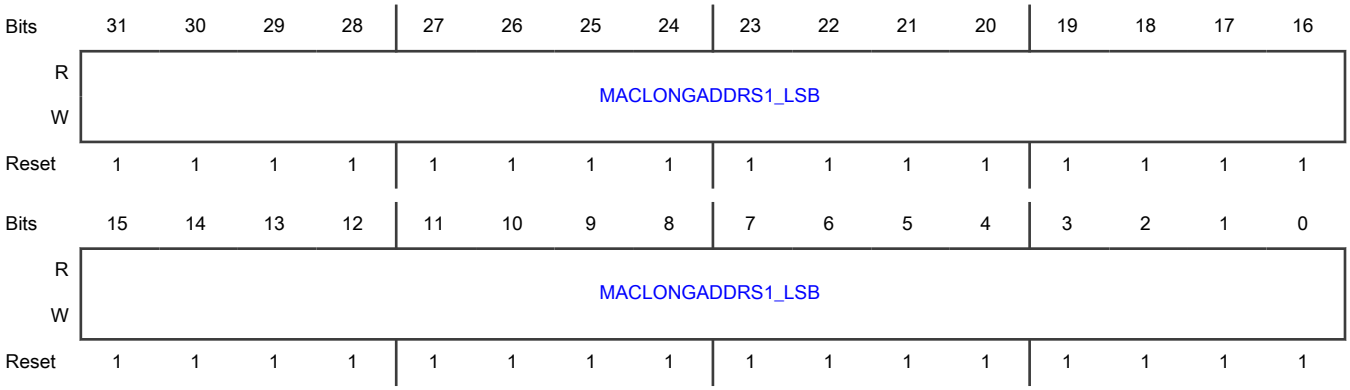
Offset

Register	Offset
MACLONGADDRS1_LSB	58h

Function

MAC Long Address for PAN1, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.

Diagram



Fields

Field	Function
31-0	MAC LONG ADDRESS for PAN1 LSB

Table continues on the next page...

Field	Function
MACLONGADDRS1_LSB	MAC Long Address for PAN1, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.

52.4.4.4.1.6.1.23 MAC LONG ADDRESS 1 MSB (MACLONGADDRS1_MSB)

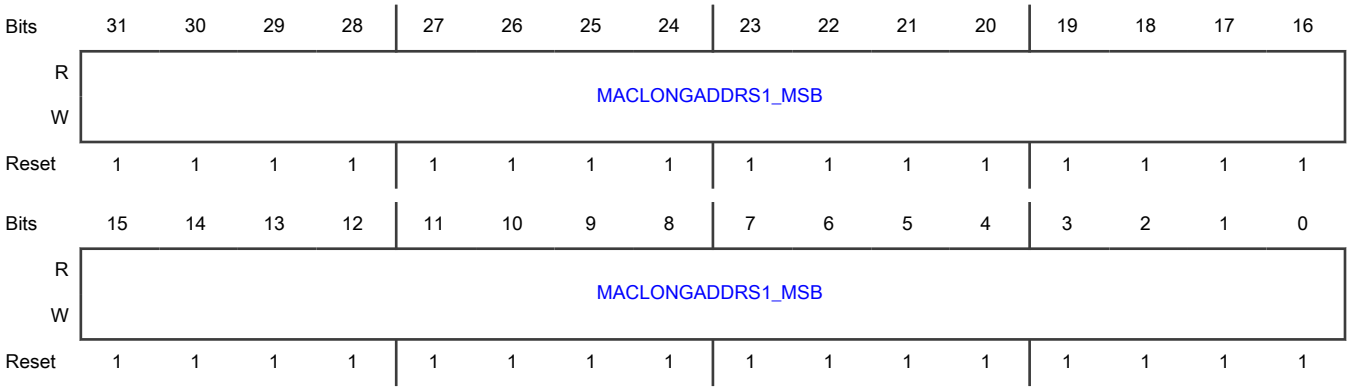
Offset

Register	Offset
MACLONGADDRS1_MSB	5Ch

Function

MAC Long Address for PAN1, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.

Diagram



Fields

Field	Function
31-0 MACLONGADDRS1_MSB	MAC LONG ADDRESS for PAN1 MSB MAC Long Address for PAN1, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.

52.4.4.4.1.6.1.24 DUAL PAN CONTROL (DUAL_PAN_CTRL)

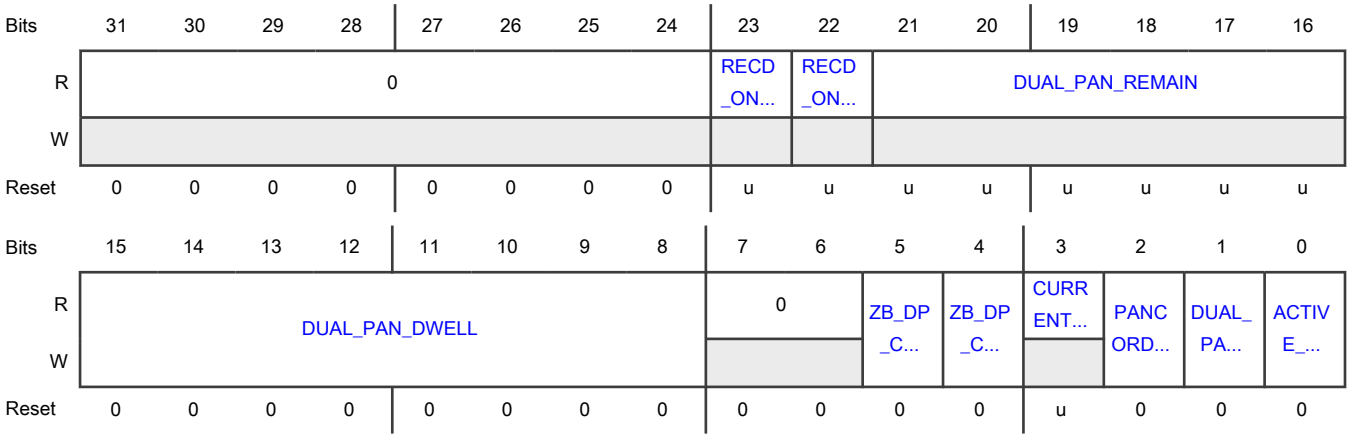
Offset

Register	Offset
DUAL_PAN_CTRL	60h

Function

Dual PAN Control Register

Diagram



Fields

Field	Function
31-24 —	Reserved
23 RECD_ON_PAN1	Last Packet was Received on PAN1 Indicates the packet which was just received, was received on PAN1. In Dual PAN mode operating on 2 different channels, RECD_ON_PAN1 will be set if CURRENT_NETWORK=1 when the packet was received, regardless of FILTERFAIL status. In DUAL PAN mode operating with same channel on both networks, CURRENT_NETWORK will be ignored and RECD_ON_PAN1 will be set only if a valid packet was received on PAN1 (PAN1's FILTERFAIL_FLAG is deasserted). RECD_ON_PAN1 remains valid until the start of the next autoseqeuence.
22 RECD_ON_PAN0	Last Packet was Received on PAN0 Indicates the packet which was just received, was received on PAN0. In Dual PAN mode operating on 2 different channels, RECD_ON_PAN0 will be set if CURRENT_NETWORK=0 when the packet was received, regardless of FILTERFAIL status. In DUAL PAN mode operating with same channel on both networks, CURRENT_NETWORK will be ignored and RECD_ON_PAN0 will be set only if a valid packet was received on PAN0 (PAN0's FILTERFAIL_FLAG is deasserted). RECD_ON_PAN0 remains valid until the start of the next autoseqeuence.
21-16 DUAL_PAN_REMAIN	Time Remaining before next PAN switch in auto Dual PAN mode This read-only register indicates time remaining before next PAN switch in auto Dual PAN mode. The units for this register, depend on the PRESCALER setting (bits [1:0]) in the DUAL_PAN_DWELL register. Tthe units are the same as the TIMEBASE determined by the prescaler, as per the following table: DUAL_PAN_DWELL[1:0]=0b00 (TIMEBASE=0.5ms) DUAL_PAN_REMAIN UNITS=0.5ms DUAL_PAN_DWELL[1:0]=0b01 (TIMEBASE=2.5ms) DUAL_PAN_REMAIN UNITS=2.5ms

Table continues on the next page...

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Field	Function
	DUAL_PAN_DWELL[1:0]=0b10 (TIMEBASE=10ms) DUAL_PAN_REMAIN UNITS=10ms DUAL_PAN_DWELL[1:0]=0b11 (TIMEBASE=50ms) DUAL_PAN_REMAIN UNITS=50ms The readback value indicates that between N-1 and N timebase units remain until the next PAN switch. For example, a DUAL_PAN_REMAIN readback value of 3, with a DUAL_PAN_DWELL PRESCALER setting of 2 (10ms), indicates that between 20ms (2*10ms) and 30ms (3*10ms), remain until the next automatic PAN switch.
15-8 DUAL_PAN_DWELL	Dual PAN Channel Frequency Dwell Time Channel Frequency Dwell Time. In Auto Dual PAN mode, hardware will toggle the PAN, after dwelling on the current PAN for the interval described below (assuming Preamble/SFD not detected). A write to DUAL_PAN_DWELL, always re-initializes the DWELL TIMER to the programmed value. If a write to DUAL_PAN_DWELL occurs during an autosequence, the DWELL TIMER will begin counting down immediately. If a write to DUAL_PAN_DWELL occurs when there is no autosequence underway, the DWELL TIMER will not begin counting until the next autosequence begins; it will begin counting at the start of the sequence warmup. DUAL_PAN_DWELL[1:0] select the timebase for the dwell time. There are 4 options: DUAL_PAN_DWELL[1:0]=0b00 --> TIMEBASE=0.5ms DUAL_PAN_DWELL[1:0]=0b01 --> TIMEBASE=2.5ms DUAL_PAN_DWELL[1:0]=0b10 --> TIMEBASE=10ms DUAL_PAN_DWELL[1:0]=0b11 --> TIMEBASE=50ms DUAL_PAN_DWELL[7:2] select how many multiples of the time base to use, from 1 (DUAL_PAN_DWELL[7:2]=0) to 64 (DUAL_PAN_DWELL[7:2]=63). Given those definitions, the table below specifies the minimum and maximum dwell times for each TIMEBASE option: DUAL_PAN_DWELL[1:0]=0b00 --> MIN_DWELL=0.5ms MAX_DWELL=32ms DUAL_PAN_DWELL[1:0]=0b01 --> MIN_DWELL=2.5ms MAX_DWELL=160ms DUAL_PAN_DWELL[1:0]=0b10 --> MIN_DWELL=10ms MAX_DWELL=640ms DUAL_PAN_DWELL[1:0]=0b11 --> MIN_DWELL=50ms MAX_DWELL=3.2seconds A write to DUAL_PAN_DWELL also causes the value of ACTIVE_NETWORK to get latched into the hardware. This latched value will be the starting point for the automatic dual-pan mode (i.e., start on PAN0 or on PAN1). The starting value takes effect immediately (if sequence is underway and DUAL_PAN_AUTO=1), or is otherwise delayed until sequence starts and DUAL_PAN_AUTO=1.
7-6 —	Reserved
5 ZB_DP_CHAN_OVRD_SEL	Dual PAN Channel Override Selector This bit works with **ZB_DP_CHAN_OVRD_EN** to allow one of the two Dual PAN channels to use Direct Frequency programming. See description for **ZB_DP_CHAN_OVRD_EN** .
4	Dual PAN Channel Override Enable

Table continues on the next page...

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Field	Function
ZB_DP_CHAN_OVRD_EN	In Dual PAN mode, in case there is a need to generate a frequency which may be offset from the 16 prescribed 5MHz-spaced channels, to, for example, avoid interference on one of the Dual PAN channels, a method has been provided to accomplish that, by designating one of the two PAN channels to use the transceiver's set of direct frequency-programming registers, instead of CHANNEL_NUMx. Programming the direct frequency-programming registers -- integer, numerator, and denominator, allows an RF frequency to be selected with much more precision than the 5MHz granularity of the Zigbee mapped-channel registers, CHANNEL_NUM0 and CHANNEL_NUM1. Two bits have been provided in 802.15.4 space to realize this feature: ZB_DP_CHAN_OVRD_SEL and ZB_DP_CHAN_OVRD_EN. When ZB_DP_CHAN_OVRD_EN=1, this enables one of the Dual PAN channels to use the direct frequency programming. The ZB_DP_CHAN_OVRD_SEL bit determines which channel uses the direct programming, according to the following: If ZB_DP_CHAN_OVRD_EN=0, then PAN0 frequency is determined by register CHANNEL_NUM0[6:0] and PAN1 frequency is determined by register CHANNEL_NUM1[6:0]. If ZB_DP_CHAN_OVRD_EN=1 and ZB_DP_CHAN_OVRD_SEL=0, then PAN0 frequency is determined by DIRECT FREQUENCY PROGRAMMING and PAN1 frequency is determined by register CHANNEL_NUM1[6:0]. If ZB_DP_CHAN_OVRD_EN=1 and ZB_DP_CHAN_OVRD_SEL=1, then PAN0 frequency is determined by register CHANNEL_NUM0[6:0] and PAN1 frequency is determined by DIRECT FREQUENCY PROGRAMMING. **NOTE** Direct Frequency Programming is accomplished by setting the PLL's Integer, Numerator, and Denominator registers to the appropriate values for the desired RF frequency.
3 CURRENT_NETWORK	Indicates which PAN is currently selected by hardware This read-only bit indicates which PAN is currently selected by hardware in automatic Dual PAN mode 0b - PAN0 is selected 1b - PAN1 is selected
2 PANCORDNTR1	Device is a PAN Coordinator on PAN1 Device is a PAN Coordinator on PAN1. Allows device to receive packets with no destination address, if Source PAN ID matches.
1 DUAL_PAN_AUTO	Activates automatic Dual PAN operating mode Activates automatic Dual PAN operating mode. In this mode, PAN-switching is controlled by hardware at a pre-programmed rate, determined by DUAL_PAN_DWELL. 0: Manual Dual PAN mode (or Single PAN mode). 1: Auto Dual PAN Mode Whenever DUAL_PAN_AUTO=0, CURRENT_NETWORK=ACTIVE_NETWORK at all times. In other words, software directly controls which PAN is selected. Whenever DUAL_PAN_AUTO=1, CURRENT_NETWORK is controlled by hardware.
0	Active Network Selector

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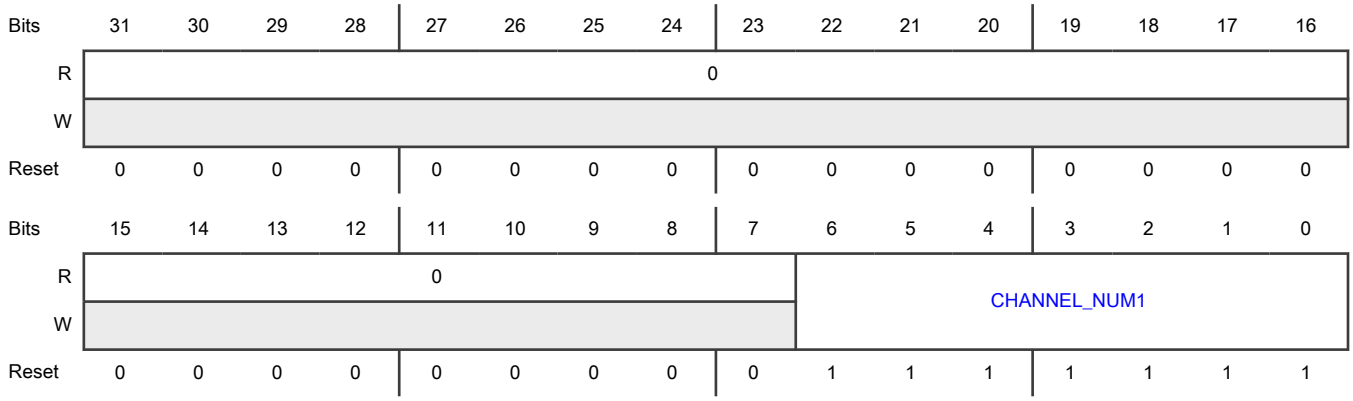
Field	Function
ACTIVE_NETWORK	Selects the PAN on which to transceive, by activating a PAN parameter set (PAN0 or PAN1). In Manual Dual PAN mode (or Single PAN mode), this bit selects the active PAN parameter set (channel and addressing parameters) which governs all autosequences. In Auto Dual PAN mode, this bit selects the PAN on which to begin transceiving, latched at the point at which DUAL_PAN_DWELL register is written. 0b - Select PAN0 1b - Select PAN1

52.4.4.4.1.6.1.25 CHANNEL NUMBER 1 (CHANNEL_NUM1)

Offset

Register	Offset
CHANNEL_NUM1	64h

Diagram



Fields

Field	Function
31-7 —	Reserved
6-0 CHANNEL_NUM1	Channel Number for PAN1 This is the mapped channel number used to transmit and receive Zigbee packets. This register applies to PAN1 only. CHANNEL_NUM1 should be in the range: 11 <= CHANNEL_NUM1 <= 26 **Note** : This register should not be programmed, and left in its default state, if Dual PAN mode is not in use.

52.4.4.4.1.6.1.26 SAM CONTROL (SAM_CTRL)

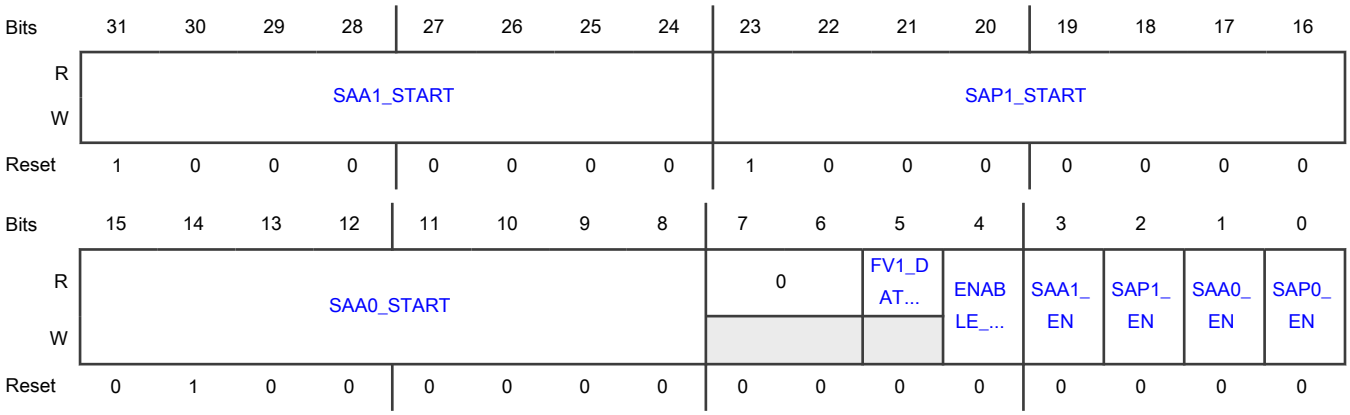
Offset

Register	Offset
SAM_CTRL	68h

Function

Source Address Management Control Register

Diagram



Fields

Field	Function
31-24 SAA1_START	First Index of SAA1 partition
23-16 SAP1_START	First Index of SAP1 partition
15-8 SAA0_START	First Index of SAA0 partition
7-6 —	Reserved
5 FV1_DATA_PKT_IND	Data Packet Indication for Frame Version 1 packet (valid only when ENABLE_FV1_DATA_PKT_IND is set) 0b - Data Packet Indication not received 1b - Data Packet Indication received
4	Enables HW Frame Pending calculation for Frame Version 1 Data Packets 0b - Disables HW Frame Pending calculation for Frame Version 1 Data Packet 1b - Enables HW Frame Pending calculation for Frame Version 1 Data Packet

Table continues on the next page...

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Field	Function
ENABLE_FV1_DATA_PKT_IND	
3 SAA1_EN	Enables SAA1 Partition of the SAM Table 0b - Disables SAA1 Partition 1b - Enables SAA1 Partition
2 SAP1_EN	Enables SAP1 Partition of the SAM Table 0b - Disables SAP1 Partition 1b - Enables SAP1 Partition
1 SAA0_EN	Enables SAA0 Partition of the SAM Table 0b - Disables SAA0 Partition 1b - Enables SAA0 Partition
0 SAP0_EN	Enables SAP0 Partition of the SAM Table 0b - Disables SAP0 Partition 1b - Enables SAP0 Partition

52.4.4.4.1.6.1.27 SOURCE ADDRESS MANAGEMENT TABLE (SAM_TABLE)

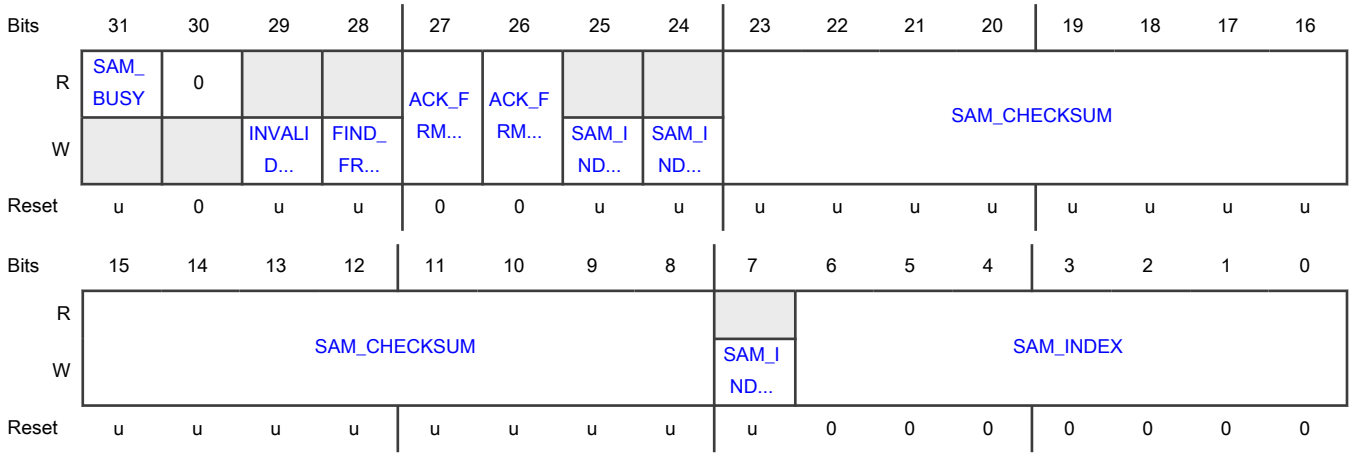
Offset

Register	Offset
SAM_TABLE	6Ch

Function

Source Address Management Table

Diagram



Fields

Field	Function
31 SAM_BUSY	SAM Table Update Status Bit Hardware is in the process of updating the Source Address table, either in response to a poll indication from the packet processor, or due to software setting FIND_FREE_IDX=1. In the latter case, software should poll SAM_BUSY until low before accessing the "First Free Index" registers. Read-only bit.
30 —	Reserved
29 INVALIDATE_ALL	Invalidate Entire SAM Table Writing a 1 to this bit clears all 128 Valid bits. Invalidates the entire table. Write-only bit. Writing 0 to this bit has no effect. Readback value is indeterminate.
28 FIND_FREE_IDX	Find First Free Index After modifying Valid bits (enabling or invalidating), write this bit to 1 to force hardware to update the "First Free Index" registers to account for the changed Valid bits. This hardware update process takes 4us. Software can poll SAM_BUSY to determine when the table update is complete. Write-only bit. Writing 0 to this bit has no effect. Readback value is indeterminate.
27 ACK_FRM_PND_CTRL	Manual Control for AutoTxAck FramePending field 0b - the FramePending field of the Frame Control Field of the next automatic TX acknowledge packet is determined by hardware 1b - the FramePending field of the Frame Control Field of the next automatic TX acknowledge packet tracks ACK_FRM_PEND
26 ACK_FRM_PND	State of AutoTxAck FramePending field when SAM Acceleration is Disabled Software can take manual control of the FramePending field of the Frame Control Field of the next automatic TX acknowledge packet, by setting ACK_FRM_PND_CTRL=1; in that case FramePending will track the state of this bit. The FramePending field also tracks this bit if Source Address Management is completely disabled, i.e.,

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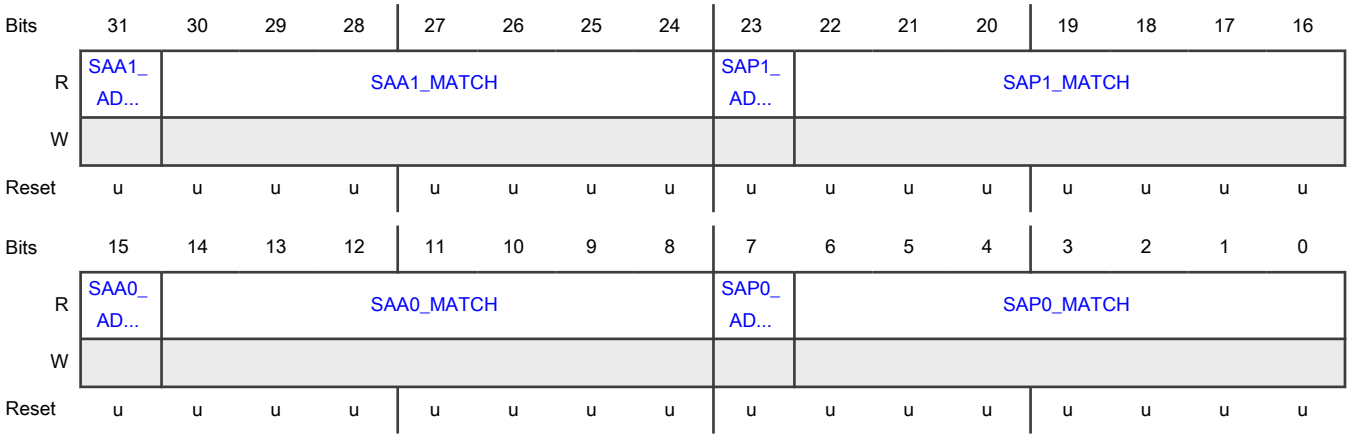
Field	Function
	SAP0_EN=SAA0_EN=SAP1_EN=SAA1_EN=0 Otherwise, the FramePending field is determined by Source Address Management (SAM) hardware.
25 SAM_INDEX_EN	Enable the SAM table index selected by SAM_INDEX
24 SAM_INDEX_INV	Invalidate the SAM table index selected by SAM_INDEX
23-8 SAM_CHECKSUM	Software-computed source address checksum, to be installed into a table index Software-computed source address checksum, to be installed into a table index. The value on SAM_CHECKSUM[15:0] can be installed into the table with a single, atomic 32-bit write; in that case, the write data would contain the desired SAM_INDEX[6:0] and SAM_CHECKSUM[15:0], and SAM_INDEX_WR=1. If SAM_INDEX_WR=0, then the SAM_INDEX[6:0] register is written, but the checksum is *not* written to the table. The readback value of SAM_CHECKSUM[15:0] is the contents of the SAM Table at the location pointed to by SAM_INDEX[6:0]. To readback from a specific table index, software should first write the desired index to SAM_INDEX[6:0], and then read back the checksum from the table on SAM_CHECKSUM[15:0].
7 SAM_INDEX_WR	Enables SAM Table Contents to be updated For 32-bit writes, SAM_INDEX_WR must be set to indicate that the table entry specified by SAM_INDEX[6:0] is to be written; if SAM_INDEX_WR=0, the table entry is not written, but the SAM_INDEX[6:0] register is updated. For 8-bit writes, this bit is ignored.
6-0 SAM_INDEX	Contains the SAM table index to be enabled or invalidated Contains the table index to be enabled or invalidated. Software must ensure that the index is within the range of the desired partition.

52.4.4.4.1.6.1.28 SOURCE ADDRESS MANAGEMENT MATCH (SAM_MATCH)

Offset

Register	Offset
SAM_MATCH	70h

Diagram



Fields

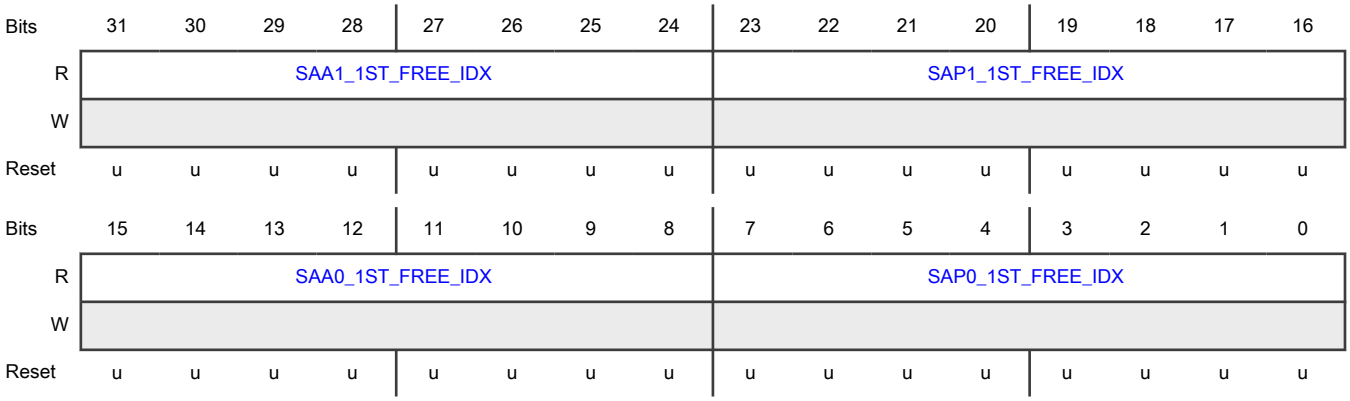
Field	Function
31 SAA1_ADDR_ABSENT	A Checksum Match is Absent in the SAP1 Partition of the SAM Table
30-24 SAA1_MATCH	Index in the SAA1 Partition of the SAM Table corresponding to the first checksum match
23 SAP1_ADDR_PRESENT	A Checksum Match is Present in the SAP1 Partition of the SAM Table
22-16 SAP1_MATCH	Index in the SAP1 Partition of the SAM Table corresponding to the first checksum match
15 SAA0_ADDR_ABSENT	A Checksum Match is Absent in the SAA0 Partition of the SAM Table
14-8 SAA0_MATCH	Index in the SAA0 Partition of the SAM Table corresponding to the first checksum match
7 SAP0_ADDR_PRESENT	A Checksum Match is Present in the SAP0 Partition of the SAM Table
6-0 SAP0_MATCH	Index in the SAP0 Partition of the SAM Table corresponding to the first checksum match

52.4.4.4.1.6.1.29 SAM FREE INDEX (SAM_FREE_IDX)

Offset

Register	Offset
SAM_FREE_IDX	74h

Diagram



Fields

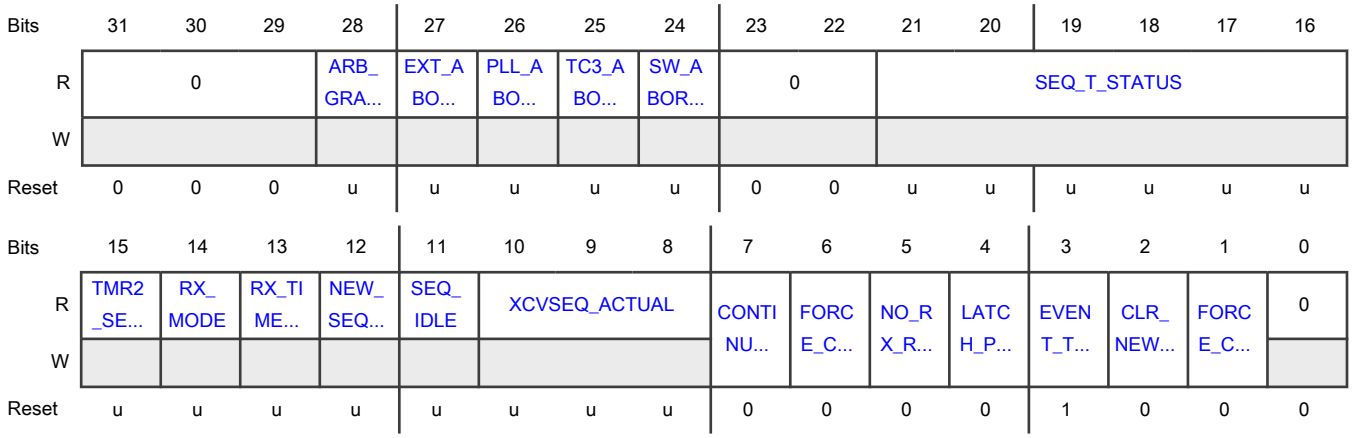
Field	Function
31-24 SAA1_1ST_FREE_IDX	First non-enabled (invalid) index in the SAA1 partition
23-16 SAP1_1ST_FREE_IDX	First non-enabled (invalid) index in the SAP1 partition
15-8 SAA0_1ST_FREE_IDX	First non-enabled (invalid) index in the SAA0 partition
7-0 SAP0_1ST_FREE_IDX	First non-enabled (invalid) index in the SAP0 partition

52.4.4.4.1.6.1.30 SEQUENCE CONTROL AND STATUS (SEQ_CTRL_STS)

Offset

Register	Offset
SEQ_CTRL_STS	78h

Diagram



Fields

Field	Function
31-29 —	Reserved
28 ARB_GRANT_DEASSERTION_ABORTED	Autosequence has terminated due to an arb_grant deassertion event when asserted, indicates that the autosequence has terminated due to an arb_grant deassertion event. This bit is valid at the SEQIRQ interrupt. Hardware will maintain this bit asserted until the next autosequence commences. Read-only bit.
27 EXT_ABORTED	Autosequence has terminated due to a Wake-On-Radio command when asserted, indicates that the autosequence has terminated due to an external event, such as a Wake-On-Radio stop command. This bit is valid at the SEQIRQ interrupt. Hardware will maintain this bit asserted until the next autosequence commences. Read-only bit.
26 PLL_ABORTED	Autosequence has terminated due to an PLL unlock event when asserted, indicates that the autosequence has terminated due to an PLL unlock event. This bit is valid at the SEQIRQ interrupt. Hardware will maintain this bit asserted until the next autosequence commences. Read-only bit.
25 TC3_ABORTED	autosequence has terminated due to an TMR3 timeout when asserted, indicates that the autosequence has terminated due to an TC3 (TMR3) timeout during a receive operation. This bit is valid at the SEQIRQ interrupt. Hardware will maintain this bit asserted until the next autosequence commences. Read-only bit.
24 SW_ABORTED	Autosequence has terminated due to a Software abort. when asserted, indicates that the autosequence has terminated due to an Software abort. Software can abort any programmed autosequence by writing Sequence I to XCVSEQ. This bit is valid at the SEQIRQ interrupt. Hardware will maintain this bit asserted until the next autosequence commences. Read-only bit.
23-22	Reserved

Table continues on the next page...

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Field	Function
—	
21-16 SEQ_T_STATUS	Status of the just-completed or ongoing Sequence T or Sequence TR Status of the just-completed (or ongoing) Sequence T or Sequence TR autosequence. This register is valid at all times during, and after, the Sequence T or Sequence TR. Not valid for other types of autosequences. This is a read-only register. The bits of this register map to status, according to the following table: [0] 1st CCA complete (CCABFRTX=1) [1] 2nd CCA complete (SLOTTED=1) [2] Tx operation complete [3] Rx Recycle occurred (Sequence TR only) [4] Rx operation complete (Sequence TR only) [5] TxAck operation complete(Sequence TR only)
15 TMR2_SEQ_TRIG_ARMED	indicates that TMR2 has been programmed and is armed to trigger a new autosequence when asserted, indicates that TMR2 has been programmed and is "armed" to trigger a new autosequence, when Zigbee Sequence Manager timer-triggering mode is selected (i.e., TMRTRIGEN=1). When timer-triggering mode is selected, TMR2 must be re-programmed (using either T2CMP or T2PRIMECMP), in advance of each new sequence. Once TMR2 is programmed, this bit will be asserted, and will remain asserted until the new sequence commences (at TMR2 match). Hardware will deassert this bit when the new sequence starts. When TMRTRIGEN=0, this bit should be ignored. Read-only bit.
14 RX_MODE	RX Operation in Progress when asserted, this Sequence Manager Output indicates that an RX operation is in progress. An RX operation can be part of a complex transmit autosequence such as a Sequence TR. CCA and ED operations are considered RX operations, during which rx_mode is asserted. Read-only bit.
13 RX_TIMEOUT_PENDING	Indicates a TMR3 RX Timeout is Pending when asserted, indicates that a TMR3 timeout (RX timeout) flag has been set by Hardware, but the Sequence Manager has not yet aborted because an RX operation is not currently underway. This would be the case, for example, during a Sequence TR, if a TMR3 timeout were to occur during the transmit operation of this sequence; the sequence would not be aborted by Hardware until the receive operation begins. This bit will always be 0 if TC3TMOUT=0. Read-only bit.
12 NEW_SEQ_INHIBIT	New Sequence Inhibit When asserted, indicates that a new programmed autosequence has commenced (TMR2 match has occurred if TMRTRIGEN=1). Once this bit is asserted, software is blocked from commanding any "new" autosequences (other than Sequence I to abort the current sequence), until the current sequence completes. Hardware will ignore a sequence-change command from software while this bit is asserted. Hardware will automatically deassert this bit once the sequence completes. Read-only bit.
11 SEQ_IDLE	ZSM Sequence Idle Indicator

Table continues on the next page...

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Field	Function
10-8 XCVSEQ_ACTUAL	Indicates the programmed sequence that has been recognized by the ZSM Sequence Manager Reflects the programmed sequence that has been recognized by the Zigbee Sequence Manager. Takes into account the fact that sequence-change commands from software are ignored while a sequence is underway (see NEW_SEQ_INHIBIT). Read-only bits.
7 CONTINUOUS_EN	Enable Continuous TX or RX Mode Continuous Mode Enable (Continuous TX or RX). **Note:** Dual PAN mode should not be engaged in Continuous TX or RX modes. 0b - normal operation 1b - Continuous TX or RX mode is enabled (depending on XCVSEQ setting).
6 FORCE_CRC_ERROR	Induce a CRC Error in Transmitted Packets 0b - normal operation 1b - Force the next transmitted packet to have a CRC error
5 NO_RX_RECYCLE	Disable Automatic RX Sequence Recycling when asserted, prevents the Zigbee Sequence Manager (ZSM) from automatically re-starting (recycling) the receiver when a packet is received which results in a FilterFail or CRC failure. Normally, on a RX recycle, the ZSM returns to the RX_WU (warmup) state, and then resumes from there with a new, foreshortened, Rx warmup, in search of a new preamble. When this bit is set, the Sequence Manager will instead return to idle state, and issue a SEQIRQ, after a FilterFail or CRC failure.
4 LATCH_PREAMBLE	Stickiness Control for Preamble Detection 0b - Don't make PREAMBLE_DET and SFD_DET bits of PHY_STS (SEQ_STATE) Register "sticky", i.e. , these status bits reflect the realtime, dynamic state of preamble_detect and sfd_detect 1b - Make PREAMBLE_DET and SFD_DET bits of PHY_STS (SEQ_STATE) Register "sticky", i.e., occurrences of preamble and SFD detection are latched and held until the start of the next autosequence
3 EVENT_TMR_DO_NOT_LATCH	Overrides the automatic hardware latching of the Event Timer when asserted, overrides the automatic hardware latching of the Event Timer that prevents the timer from updating while software reads the 3 Event Timer bytes. This allows the Event Timer LS byte to continue to update without reading the upper 2 bytes. Overriding the automatic latching of the Event Timer should be used with caution, as it can allow the Event Timer lower bytes to get out-of-sync with the upper bytes. However, it can be useful when polling the Event Timer LS byte for a value that is just a few counts in the future.
2 CLR_NEW_SEQ_INHIBIT	Overrides the automatic hardware locking of the programmed XCVSEQ while an autosequence is underway when asserted, overrides the automatic hardware locking of the programmed XCVSEQ while an autosequence is underway. Asserting this feature will allow software to change the programmed autosequence "on-the-fly", without aborting and returning to idle between sequences. Overriding the hardware lockout of XCVSEQ should be used with caution, since the Sequence Manager is not designed (or verified) for manual state transitions between one type of autosequence and other (i.e., Sequence T -> Sequence R).

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Field	Function
1 FORCE_CLK_ON	Force On 802.15.4 phy_gck Force On 802.15.4 phy_gck 0b - Allow TSM to control 802.15.4 phy_gck, for minimum power consumption (default) 1b - Force on 802.15.4 phy_gclk at all times, for debug purposes only
0 —	Reserved

52.4.4.4.1.6.1.31 ACK DELAY (ACKDELAY)

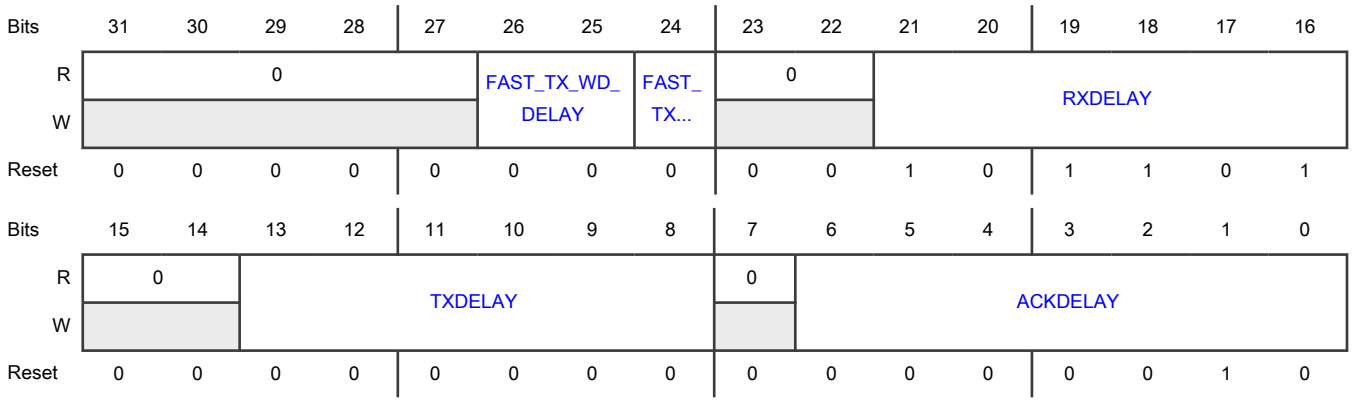
Offset

Register	Offset
ACKDELAY	7Ch

Function

Provides a fine-tune adjustment of the time delay between Rx warmdown and the beginning of Tx warmup for an autoTxAck packet.

Diagram



Fields

Field	Function
31-27 —	Reserved
26-25	FAST_TX_WD_DELAY

Table continues on the next page...

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Field	Function
FAST_TX_WD_DELAY	Provides a fine-tune adjustment of the time delay from the beginning of Tx warmdown to the end of Tx warmdown when FAST_TX_WD_EN is set to 1.
24 FAST_TX_WD_EN	Fast TX_WD enable/disable When this bit is enabled, the Zigbee squence manager executes the fast TX warmdown sequence by bypassing TX_PA_OFF and XTAL_CLK1 and jumping from TX_WD to TSM_WD directly. 0b - Disable fast Tx warmdown sequence. 1b - Enable fast Tx warmdown sequence.
23-22 —	Reserved
21-16 RXDELAY	RX Delay Provides a fine-tune adjustment of the time delay between Tx warmdown and the beginning of Rx warmup for TR sequence. RXDELAY register will apply to both SLOTTED and UNSLOTTED TR sequence. This is an unsigned value. Resolution = 2us. Range = 3 - 127us. Max RXDELAY = 0x3F. Min RXDELAY = 0x01.
15-14 —	Reserved
13-8 TXDELAY	TX Delay Provides a fine-tune adjustment of the time delay between post-CCA Rx warm-down and the beginning of Tx warm-up for an Tx (non-Ack) packet. TXDELAY register will apply in both SLOTTED and UNSLOTTED modes, but only to T sequences (e.g., T, TR, and T(R)), not TxAck operations. This is a two's complement value. The minimum permissible value is -19 (0x2D). Values less than -19 will lead to unexpected results. Resolution = 2us. Range = +/- 62us. Max TXDELAY = 0x1F. Min TXDELAY = 0x2D.
7 —	Reserved
6-0 ACKDELAY	ACK Delay

Table continues on the next page...

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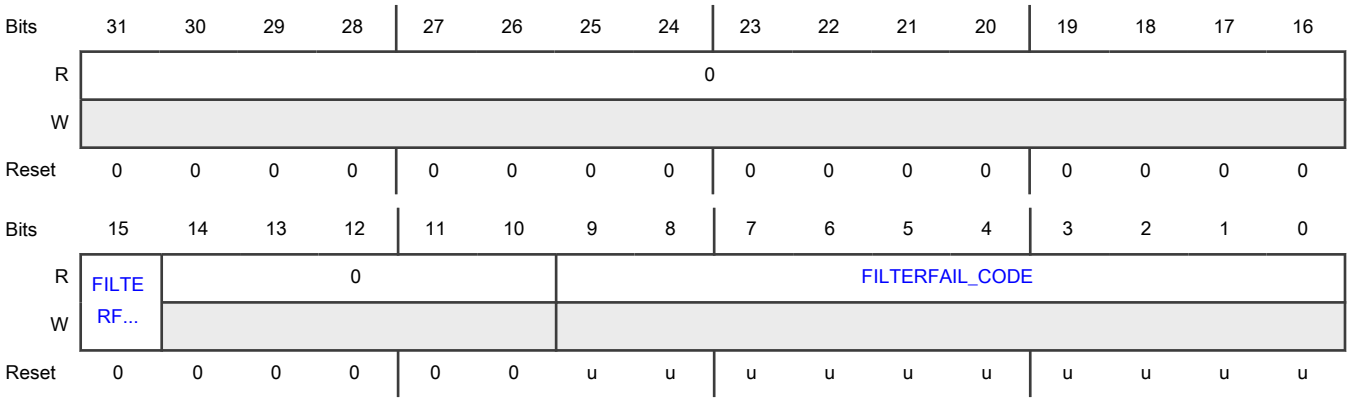
Field	Function
	Provides a fine-tune adjustment of the time delay between Rx warmdown and the beginning of Tx warmup for an Tx Acknowledge packet. ACKDELAY register will apply to both SLOTTED and UNSLOTTED TxAck, but only to TxAck (not T sequences). This is a two's complement value. Resolution = 2us. Range = -128 - 126us. Max ACKDELAY = 0x3F. Min ACKDELAY = 0x40.

52.4.4.4.1.6.1.32 FILTER FAIL CODE (FILTERFAIL_CODE)

Offset

Register	Offset
FILTERFAIL_CODE	80h

Diagram



Fields

Field	Function
31-16 —	Reserved
15 FILTERFAIL_PAN_SEL	PAN Selector for Filter Fail Code 0b - FILTERFAIL_CODE[9:0] will report the FILTERFAIL status of PAN0 1b - FILTERFAIL_CODE[9:0] will report the FILTERFAIL status of PAN1
14-10	Reserved

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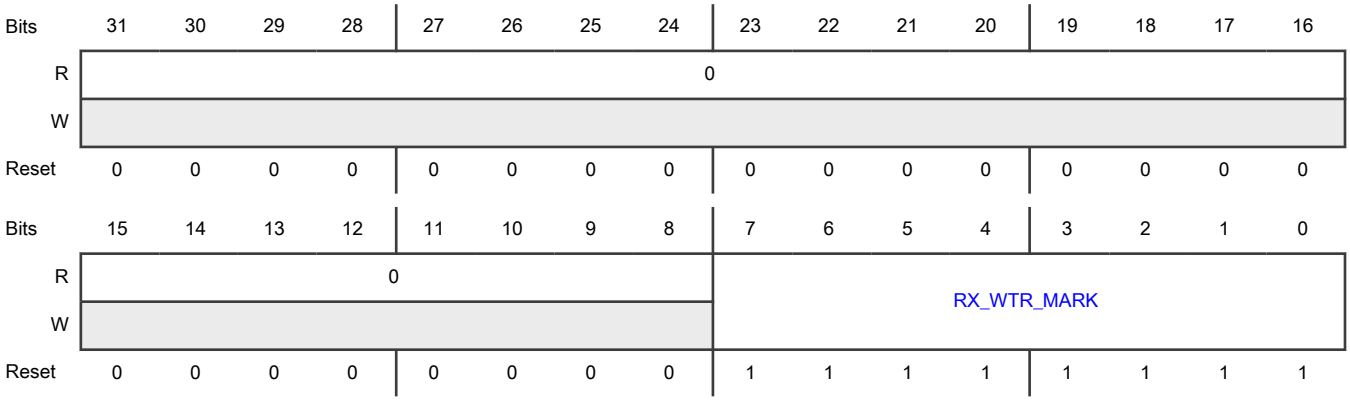
Field	Function
—	
9-0 FILTERFAIL_CODE	Filter Fail Code Code indicating what condition, or conditions, caused the Packet Processor to reject the just-received packet. The bits of FILTERFAIL_CODE indicate the reason for packet rejection. For a description of the individual FILTERFAIL_CODE bits, see the 802.15.4 Link Layer Controller chapter.

52.4.4.4.1.6.1.33 RECEIVE WATER MARK (RX_WTR_MARK)

Offset

Register	Offset
RX_WTR_MARK	84h

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 RX_WTR_MARK	RECEIVE WATER MARK Receive byte count (octets) needed to trigger a RXWTRMRKIRQ interrupt . A setting of 0 generates an interrupt at end of the Frame Length field (first byte after SFD). A setting of 1 generates an interrupt after the first byte of Frame Control Field, etc.

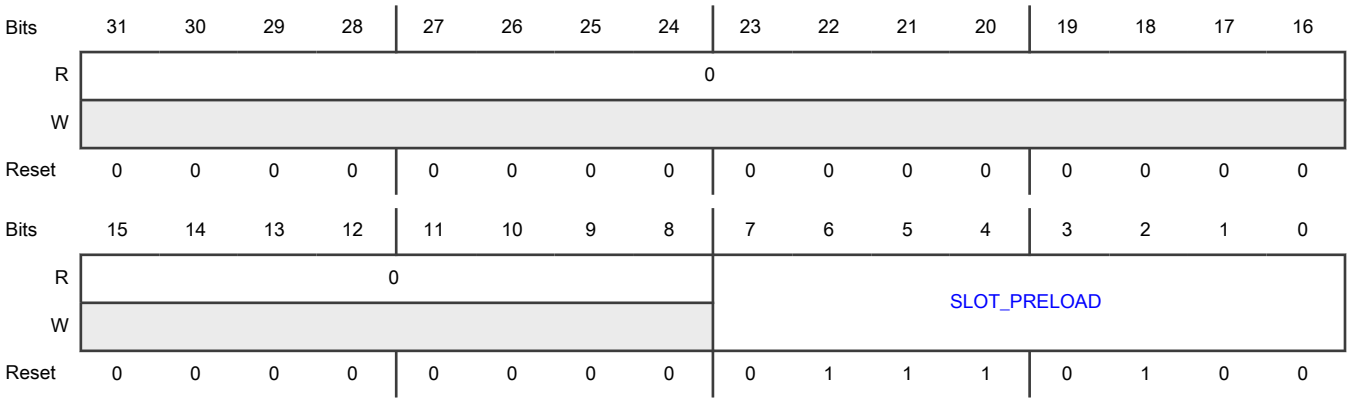
52.4.4.4.1.6.1.34 SLOT PRELOAD (SLOT_PRELOAD)

Offset

Register	Offset
SLOT_PRELOAD	8Ch

Function
Slotted Mode Preload

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 SLOT_PRELOAD	Slotted Mode Preload This register represents the number that gets loaded into the slot_timer at SFD detect, which ultimately determines when the next slot boundary will occur. Due to processing delays within the analog front-end and digital modem, the point at which SFD is detected by the modem, is delayed relative to over-the-air timing. This register setting compensates for that delay. This timing parameter is critical for the Sequence R autosequence in slotted mode, when an automatic TxAck is required.

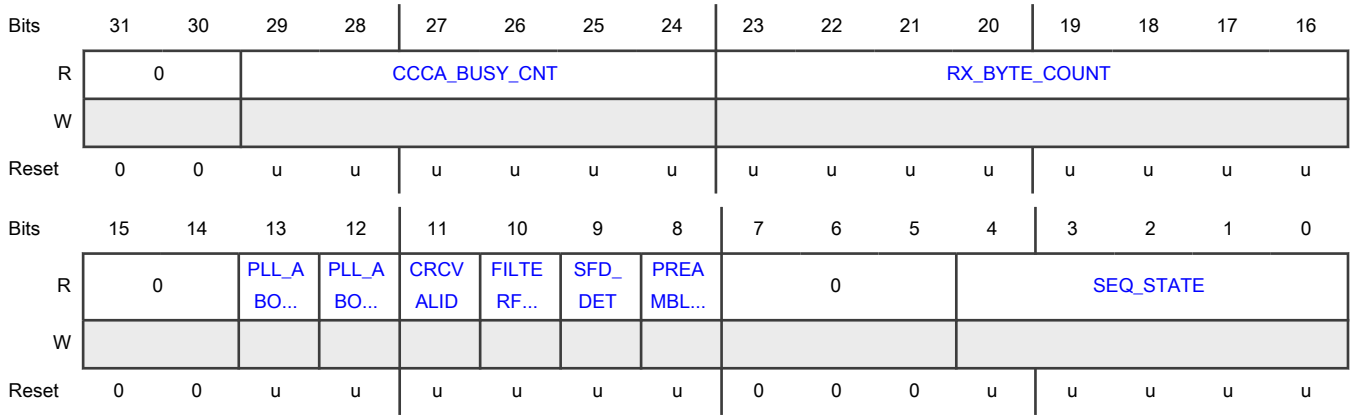
52.4.4.4.1.6.1.35 802.15.4 SEQUENCE STATE (SEQ_STATE)

Offset

Register	Offset
SEQ_STATE	90h

Function
802.15.4 Sequence State Register

Diagram



Fields

Field	Function
31-30 —	Reserved
29-24 CCCA_BUSY_CNT	Number of CCA Measurements resulting in Busy Channel For Sequence CCCA mode only, this register indicates the number of "busy" CCA attempts which occurred during the autosequence, before the channel was detected to be idle. This register can also be read in real-time (during the autosequence) to determine how many busy CCA attempts have occurred to that point. The register saturates at 63 (i.e, if there are more than 63 busy attempts, the register will continue to read 63). This register is automatically cleared to zero by hardware when the next autosequence commences. Read-only register.
23-16 RX_BYTE_COUNT	Realtime Received Byte Count During packet reception, this read-only register is a real-time indicator of the number of bytes that have been received. This register will read 0 until SFD and PHR have been received. It will read 1 after the first byte of Frame Control Field has been received, etc.
15-14 —	Reserved
13 PLL_ABORTED	Autosequence has terminated due to an PLL unlock event when asserted, indicates that the autosequence has terminated due to an PLL unlock event. This bit is valid at the SEQIRQ interrupt. Hardware will maintain this bit asserted until the next autosequence commences. This bit is a read-only mirror of the register bit of the same name in the ABORT_STS (SEQ_CTRL_STS) register.
12 PLL_ABORT	Raw PLL Abort Signal This bit reflects the instantaneous, consolidated status of the PLL unlock detection circuits; if asserted high, indicates that at least one of the three PLL unlock detect mechanisms is currently reporting an unlocked condition.
11	CRC Valid Indicator

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Field	Function
CRCVALID	Cyclic Redundancy Check Valid: This flag indicates the compare result between the FCS field, in the most-recently received frame, and the internally calculated CRC value. This flag is cleared at next receiver warm up. 0b - Rx FCS != calculated CRC (incorrect) 1b - Rx FCS = calculated CRC (correct)
10 FILTERFAIL_FLAG_SEL	Consolidated Filter Fail Flag 0: The incoming, or just-received packet, passed packet filtering rules. 1: The incoming, or just-received packet, failed packet filtering rules When FILTERFAIL_FLAG_SEL=1, a non-zero FILTERFAIL_CODE is present (see FILTERFAIL_CODE registers). In Dual PAN mode, FILTERFAIL_FLAG_SEL applies to either or both networks, as follows: **A:** If PAN0 and PAN1 occupy different channels and CURRENT_NETWORK=0, FILTERFAIL_FLAG_SEL applies to PAN0. **B:** If PAN0 and PAN1 occupy different channels and CURRENT_NETWORK=1, FILTERFAIL_FLAG_SEL applies to PAN1. **C:** If PAN0 and PAN1 occupy the same channel, FILTERFAIL_FLAG_SEL is the logical 'AND' of the individual PANs' FILTERFAIL_FLAG bits.
9 SFD_DET	SFD Detected 0: an 802.15.4 preamble-and-SFD have not been detected. 1: An 802.15.4 preamble-and-SFD have been detected. The function of this read-only bit depends on the setting of the LATCH_PREAMBLE bit of the SEQ_MGR_CTRL register. If LATCH_PREAMBLE=1, any preamble-and-SFD detection during a Sequence R (even false detections), will set this bit, and it will remain set (sticky) until the start of the next autosequence. If LATCH_PREAMBLE=0, this bit is not sticky, and reflects the instantaneous state of the SFD-detection circuit; for false SFD, the bit will clear when the false nature of the SFD is recognized (i.e., an RX recycle). When LATCH_PREAMBLE=0, SFD_DET should be considered valid only while an autosequence is underway.
8 PREAMBLE_DET	Preamble Detected 0: an 802.15.4 preamble has not been detected. 1: An 802.15.4 preamble has been detected. The function of this read-only bit depends on the setting of the LATCH_PREAMBLE bit of the SEQ_MGR_CTRL register. If LATCH_PREAMBLE=1, any preamble detection during a Sequence R (even false detections), will set this bit, and it will remain set (sticky) until the start of the next autosequence. If LATCH_PREAMBLE=0, this bit is not sticky, and reflects the instantaneous state of the preamble-detection circuit; for false preambles, the bit will clear when the false nature of the preamble is recognized. When LATCH_PREAMBLE=0, PREAMBLE_DET should be considered valid only while an autosequence is underway.
7-5	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
4-0 SEQ_STATE	ZSM Sequence State This read-only register reflects the instantaneous state of the 802.15.4 Sequence Manager

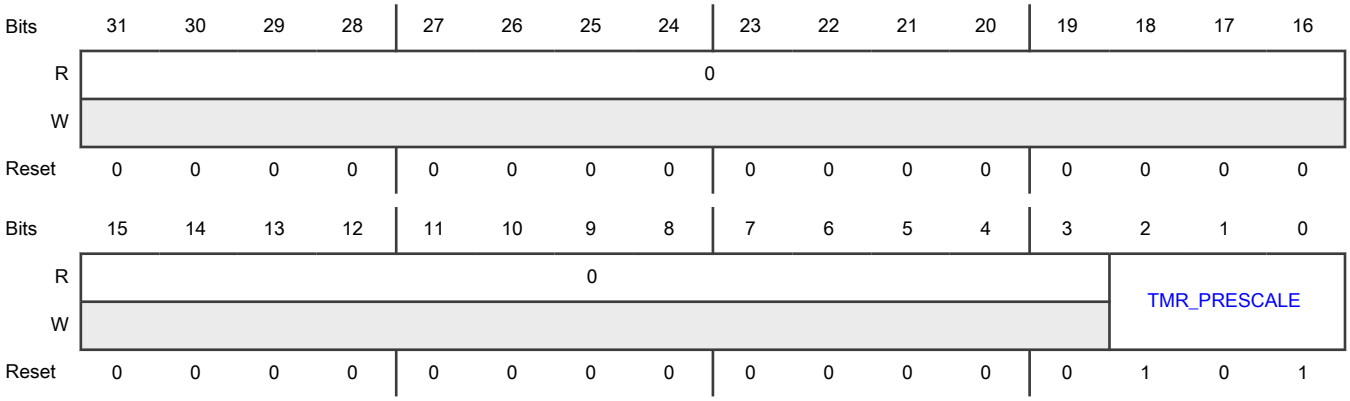
52.4.4.4.1.6.1.36 TIMER PRESCALER (TMR_PRESCALE)

Offset

Register	Offset
TMR_PRESCALE	94h

Function
Timer Prescaler Control Register

Diagram



Fields

Field	Function
31-3 —	Reserved
2-0 TMR_PRESCALE	Timer Prescaler Timer Prescaler. Establishes the Event Timer clock rate (and also maximum timer duration) **Note:** To take advantage of the EVENT_TMR Fractional bits for 802.15.4 DSM mode, only the default setting ("5", or 62.5KHz) is allowed. 000b - Reserved

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Field	Function
	001b - Reserved 010b - 500kHz (33.55 S) 011b - 250kHz (67.11 S) 100b - 125kHz (134.22 S) 101b - 62.5kHz (268.44 S) -- default 110b - 31.25kHz (536.87 S) 111b - 15.625kHz (1073.74 S)

52.4.4.4.1.6.1.37 LENIENCY LSB (LENIENCY_LSB)

Offset

Register	Offset
LENIENCY_LSB	98h

Function

Packet Processor Leniency Bits (LSB)

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	LENIENCY_LSB															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	LENIENCY_LSB															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 LENIENCY_LSB	Leniency LSB Register The Packet Processor performs filtering on all received packets, in order to determine whether the packet is intended for the device. The packet filtering is based on rules. In case any of the packet filtering rules need to be overridden, a 43-bit "leniency register" has been provided. When the leniency register is programmed to its default value (0), all hardware packet filtering rules are in effect, and if an incoming

Table continues on the next page...

Field	Function
	packet violates any rule, a "Filter Fail" will occur (packet will be rejected). When a given leniency register bit is asserted, the packet filtering rule assigned to that bit will not be in effect, and if any incoming packet violates that rule (but no other rules), then a "Filter Fail" will not occur, the packet will not be rejected, the packet will be treated as "intended for the device", and software will be notified of the incoming packet. For a description of the function of the individual leniency bits, see the 802.15.4 Link Layer Controller chapter.

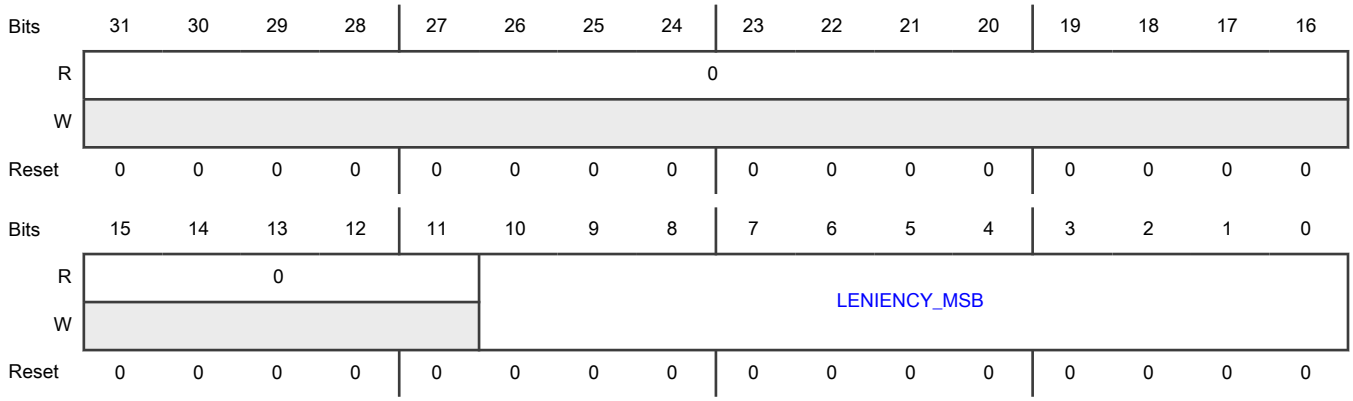
52.4.4.4.1.6.1.38 LENIENCY MSB (LENIENCY_MSB)

Offset

Register	Offset
LENIENCY_MSB	9Ch

Function
Packet Processor Leniency Bits (MSB)

Diagram



Fields

Field	Function
31-11 —	Reserved
10-0 LENIENCY_MSB	Leniency MSB Register The Packet Processor performs filtering on all received packets, in order to determine whether the packet is intended for the device. The packet filtering is based on rules. In case any of the packet filtering rules need to be overridden, a 43-bit "leniency register" has been provided. When the leniency register is programmed to its default value (0), all hardware packet filtering rules are in effect, and if an incoming packet violates any rule, a "Filter Fail" will occur (packet will be rejected). When a given leniency register bit is asserted, the packet filtering rule assigned to that bit will not be in effect, and if any incoming packet

Table continues on the next page...

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Field	Function
	violates that rule (but no other rules), then a "Filter Fail" will not occur, the packet will not be rejected, the packet will be treated as "intended for the device", and software will be notified of the incoming packet. For a description of the function of the individual leniency bits, see the 802.15.4 Link Layer Controller chapter.

52.4.4.4.1.6.1.39 PART ID (PART_ID)

Offset

Register	Offset
PART_ID	A0h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								PART_ID							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Fields

Field	Function
31-8 —	Reserved
7-0 PART_ID	802.15.4 Part ID

52.4.4.4.1.6.1.40 COEXISTENCE CONTROL (COEX_CTRL)

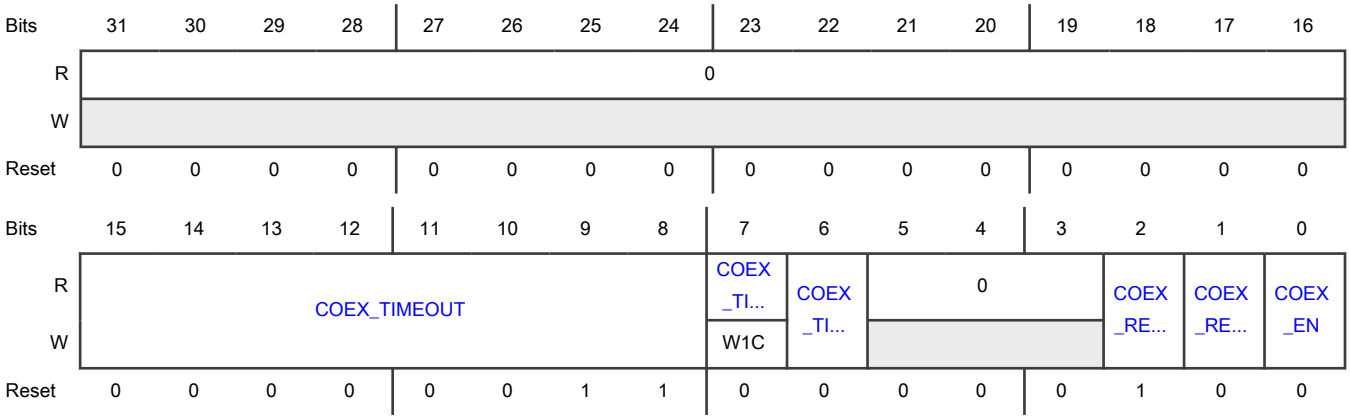
Offset

Register	Offset
COEX_CTRL	A4h

Function

Coexistence Control Registers.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-8 COEX_TIMEOUT	Coexistence timeout value After arb_request asserts, arb_grant should assert before the timeout value. Otherwise the sequence is abort and COEX_TIMEOUT_IRQ bit is set. The step of the timeout value is 32us.
7 COEX_TIMEOUT_IRQ	Coexistence Timeout Interrupt Indicates coexistence timeout occurs. This is write '1' to clear bit.
6 COEX_TIMEOUT_MSK	Coexistence Timeout Interrupt Mask bit 0b - allows interrupt when coexistence timeout 1b - Interrupt generation is disabled, but a COEX_TIMEOUT_IRQ flag can be set
5-3 —	Reserved
2 COEX_REQ_ON_PD	Coexistence Request on Preamble detected 0b - arb_request is delayed until SFD is detected during R sequence. 1b - arb_request is delayed until preamble is detected during R sequence.
1 COEX_REQ_DELAY_EN	Coexistence Request Delay Enable 0b - arb_request is not delayed during R sequence. 1b - arb_request is delayed until preamble is detected during R sequence.

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Table continued from the previous page...

Field	Function
0 COEX_EN	Coexistence Enable 0b - Coexistence function is disabled. 1b - Coexistence function is enabled.

52.4.4.4.1.6.1.41 COEXISTENCE PRIORITY (COEX_PRIORITY)

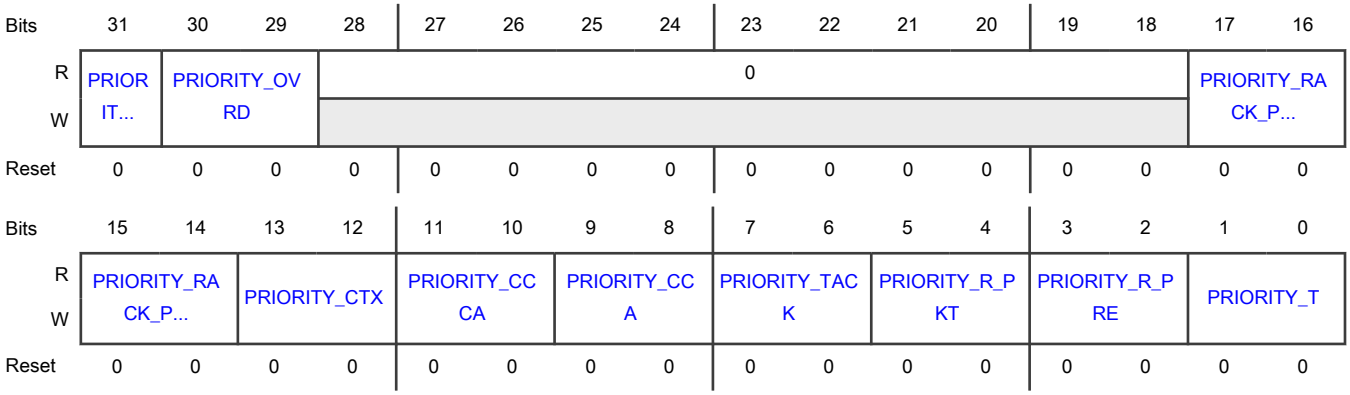
Offset

Register	Offset
COEX_PRIORITY	A8h

Function

Programmable 2-bit priority for each RX or TX state in each ZSM.

Diagram



Fields

Field	Function
31 PRIORITY_OVRD_EN	PRIORITY_OVRD_EN Enable/Disable overriding PRIORITY value. 0b - Disable overriding PRIORITY value. 1b - Enable overriding PRIORITY value.
30-29 PRIORITY_OVRD	PRIORITY_OVRD When PRIORITY_OVRD_EN is set to 1, PRIORITY_OVRD is used to override PRIORITY value.
28-18	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
17-16 PRIORITY_RACK_PKT	PRIORITY_RACK_PKT PRIORITY value during receiving ACK packet.
15-14 PRIORITY_RACK_PRE	PRIORITY_RACK_PRE PRIORITY value during searching preamble of ACK packet.
13-12 PRIORITY_CTX	PRIORITY_CT PRIORITY value for CCA before TX Packet.
11-10 PRIORITY_CCCA	PRIORITY_CCCA PRIORITY value for Continuous CCA.
9-8 PRIORITY_CCA	PRIORITY_CCA PRIORITY value for CCA.
7-6 PRIORITY_TACK	PRIORITY_TACK PRIORITY value for TX ACK Packet.
5-4 PRIORITY_R_PKT	PRIORITY_R_PKT PRIORITY value for RX Packet.
3-2 PRIORITY_R_PRE	PRIORITY_R_PRE PRIORITY value of searching Preamble for RX Packet.
1-0 PRIORITY_T	PRIORITY_T PRIORITY value for TX Packet.

52.4.4.4.1.6.1.42 ENHACK_CTRL 0 (ENHACK_CTRL0)

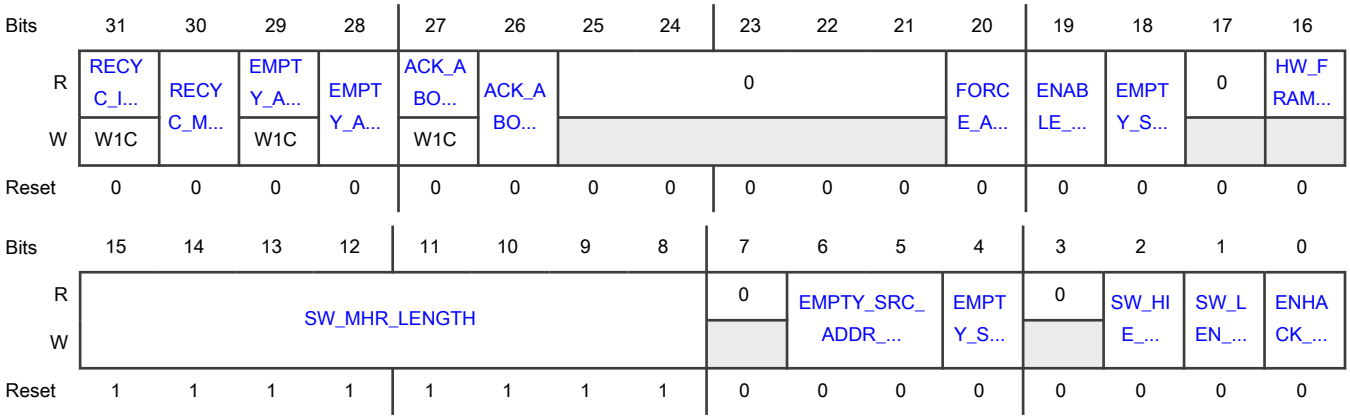
Offset

Register	Offset
ENHACK_CTRL0	ACh

Function

Control Register 0 for Enhanced Acknowledgment Feature

Diagram



Fields

Field	Function
31 RECYC_IRQ	Recycle IRQ This interrupt status bit indicates the hardware recycle on filter fail or CRC invalid.
30 RECYC_MSK	Recycle IRQ Mask bit 0b - allows interrupt when recycle 1b - Interrupt generation is disabled, but a RECYC_IRQ flag can be set
29 EMPTY_ACK_IRQ	Empty Enhanced Acknowledgment IRQ This interrupt status bit indicates the Empty Enhanced Acknowledgment is to be sent.
28 EMPTY_ACK_MSK	Empty Enhanced Acknowledgment IRQ Mask bit 0b - allows interrupt when Empty Enhanced Acknowledgment 1b - Interrupt generation is disabled, but a EMPTY_ACK_IRQ flag can be set
27 ACK_ABORT_IRQ	Enhanced Acknowledgment Abort IRQ This interrupt status bit indicates the HIE field is not ready by software.
26 ACK_ABORT_MSK	Enhanced Acknowledgment Abort IRQ Mask bit 0b - allows interrupt when HIE field is not ready by software. 1b - Interrupt generation is disabled, but a ACK_ABORT_IRQ flag can be set
25-21 —	Reserved

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Field	Function
20 FORCE_ACK_ENABLE_FOR_FV2	Force autoack for all frame version 2 packets 0b - Normal operation 1b - Force autoack for all frame version2 packets
19 ENABLE_HW_MODE7_8	Enable autoack for frame version 2 extended addressing modes 0b - Disable autoack for frame version 2 extended addressing modes 1b - Enable autoack for frame version 2extended addressing modes
18 EMPTY_SECURITY_ENABLED_OVRD_EN	Override enable of Security Enabled field in Empty Enhanced Acknowledgment 0b - Security Enabled field in Empty Enhanced Acknowledgment frame is 0. 1b - Security Enabled field in Empty Enhanced Acknowledgment frame is from EMPTY_SECURITY_ENABLED_OVRD.
17 —	Reserved
16 HW_FRAME_PENDING	Hardware calculated Frame Pending field When received a DATA or Command Frame, hardware calculates the Frame Pending field by Source Address Management. This bit can be used by software to build the Enhanced Acknowledgment frame.
15-8 SW_MHR_LENGTH	Software calculated MHR(excludes the HIE field) Length in bytes.
7 —	Reserved
6-5 EMPTY_SRC_ADDR_MODE	Source Address Mode field in Empty Enhanced Acknowledgment
4 EMPTY_SECURITY_ENABLED_OVRD	Override value of Security Enabled field in Empty Enhanced Acknowledgment
3 —	Reserved
2 SW_HIE_RDY	Software enhanced acknowledgment frame HIE field ready 0b - Software enhanced acknowledgment frame HIE field is not ready. 1b - Software enhanced acknowledgment frame HIE field is ready in RAM

Table continues on the next page...

Table continued from the previous page...

Field	Function
1 SW_LEN_RDY	Software enhanced acknowledgment frame Length field ready 0b - Software enhanced acknowledgment frame Length field is not ready. 1b - Software enhanced acknowledgment frame Length field is ready in RAM
0 ENHACK_EN	Enhanced Acknowledgment Enable 0b - Enhanced acknowledgment is disabled. 1b - Enhanced acknowledgment is enabled.

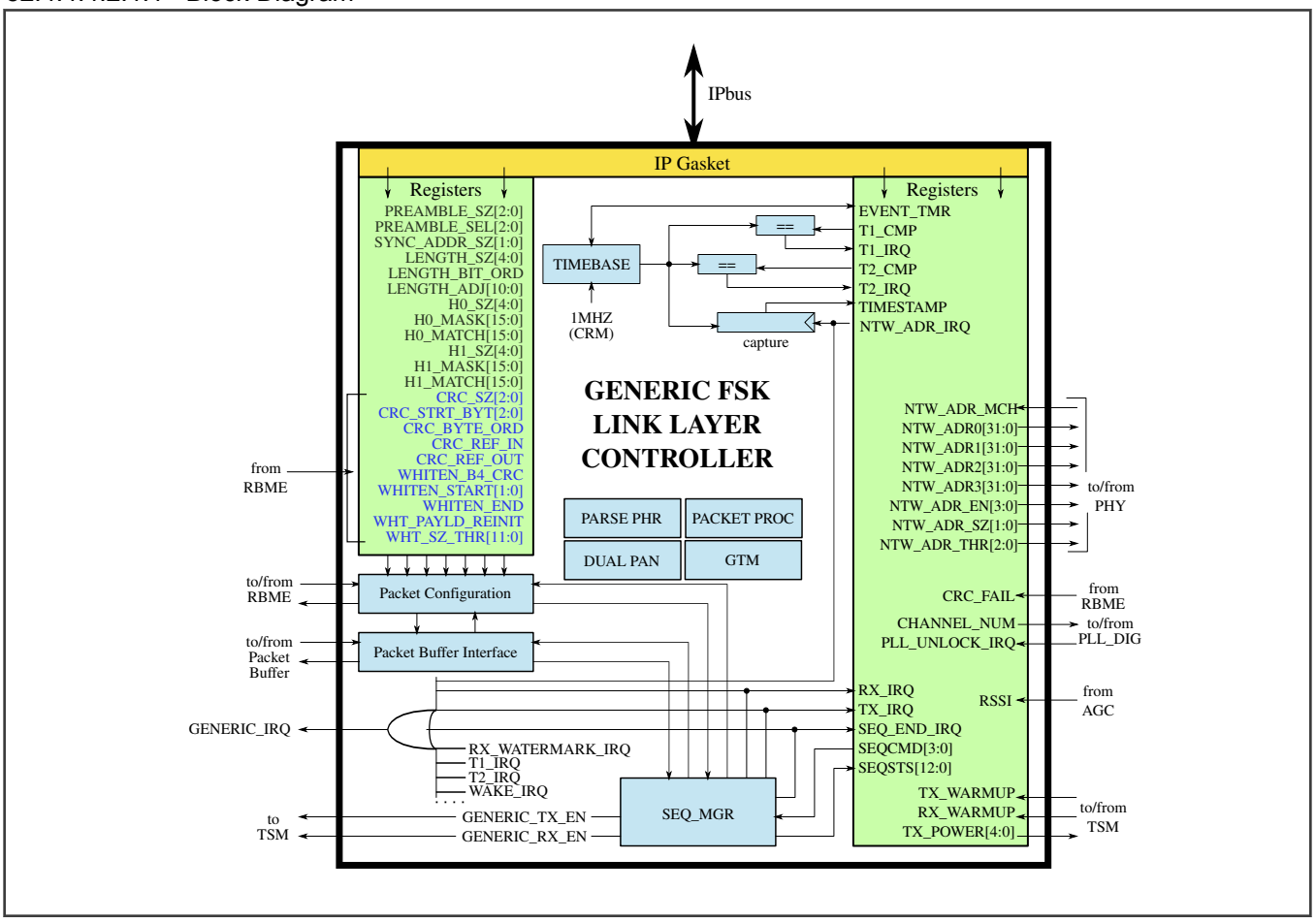
52.4.4.4.2 Generic FSK Link Layer

52.4.4.4.2.1 Overview

The Generic FSK protocol enables radio operation using a custom GFSK/GMSK or MSK modulation format achieved by programming a set of PHY variables such as BT product, modulation index and modulation filter co-efficients (such that max frequency deviation <= 500kHz). Generic FSK mode also offers a highly configurable packet structure, variable bit rate transmission and reception, some limited packet processing, and interface to a RAM-based Packet Buffer.

The Generic FSK Link Layer Controller provides the interface between Generic FSK software, and the transceiver hardware. The interface consists of an IP bus-based set of registers, which provide command, control, and status to Generic FSK software. The Link Layer controller features programmability that allows for a highly configurable packet structure, defining the lengths, bit ordering, and contents of individual packet fields, defining the start and end points for whitening, CRC, and providing for some primitive parsing of the packet header. The Link Layer Controller implements a Sequence Command Set consisting of 20 commands; a command decoder to interpret the commands in realtime as they are received from Generic FSK software, and to provide the necessary control signals to the radio's Transceiver Sequence Manager (TSM); a high-precision timebase based on an external crystal-based oscillator; an Interrupt Control Unit; finite state machines to control the transmission and reception of Generic FSK packets; controls for CRC generation (TX) and verification (RX); controls for data whitening; interface to RAM-based Packet Buffer for packet storage; and provisions for entering and exiting low-power Deep Sleep Mode.

52.4.4.4.2.1.1 Block Diagram



52.4.4.4.2.1.2 Features

- Highly configurable packet structure
- Optimized Sequence Command Set
- High-precision timebase to maintain network timing
- Two timer-compare mechanisms for Interrupt Generation and Sequence Launching
- Hardware automation for packet transmit and receive, CRC and Whitening
- Up to 4 Network Addresses to synchronize to, can be 8-bit, 16-bit or 32-bit
- Packet Lengths up to 2047 Bytes
- Support complex auto-sequence, like CCA before TX, Auto-ACK, TR.
- Many operating modes can support the sending and receiving of multiple protocol packets, such as 802.15.4, Bluetooth LE, etc.
- Generic test mode(GTM)
- Deep Sleep Mode support

52.4.4.4.2.2 Functional Description

52.4.4.4.2.2.1 Packet Configuration

The Generic FSK Link Layer Controller provides the capability to configure the over-the-air packet structure by way of a set of programmable registers. The Generic FSK packet has a consistent structure, which consists of various elements which are transmitted and received in fixed order. Most of the packet elements have associated configurability, which allows software to pre-configure, for example, the size of the element (in number of bits, or octets), or bit ordering of the element. In addition, the generic structure defines a variable-length header, for which some (optional) primitive parsing is provided, allowing hardware to differentiate packets based on header-bit settings, into compliant and non-compliant packets. Data Indication is provided on compliant packets only. Non-complaint packets are discarded. By default, all packet elements are transmitted and received LSB-first.

The Generic FSK Link Layer Controller supports a packet structure based on the following template:

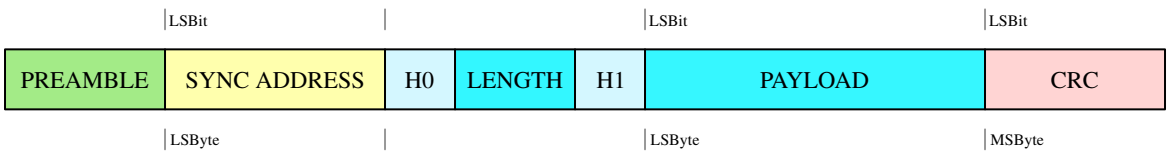


Figure 439. GENERIC_FSK Packet Structure

The Generic_FSK Link Layer controller transmits and receives packets which conform to the format shown above. The elements of the packet are transmitted in received in the order shown, although some of the packet elements may be optionally skipped, depending on the configuration options chosen.

The following diagram depicts the register configurability associated with the Preamble, Sync Address, H0, Length, and H1 elements of the packet structure.

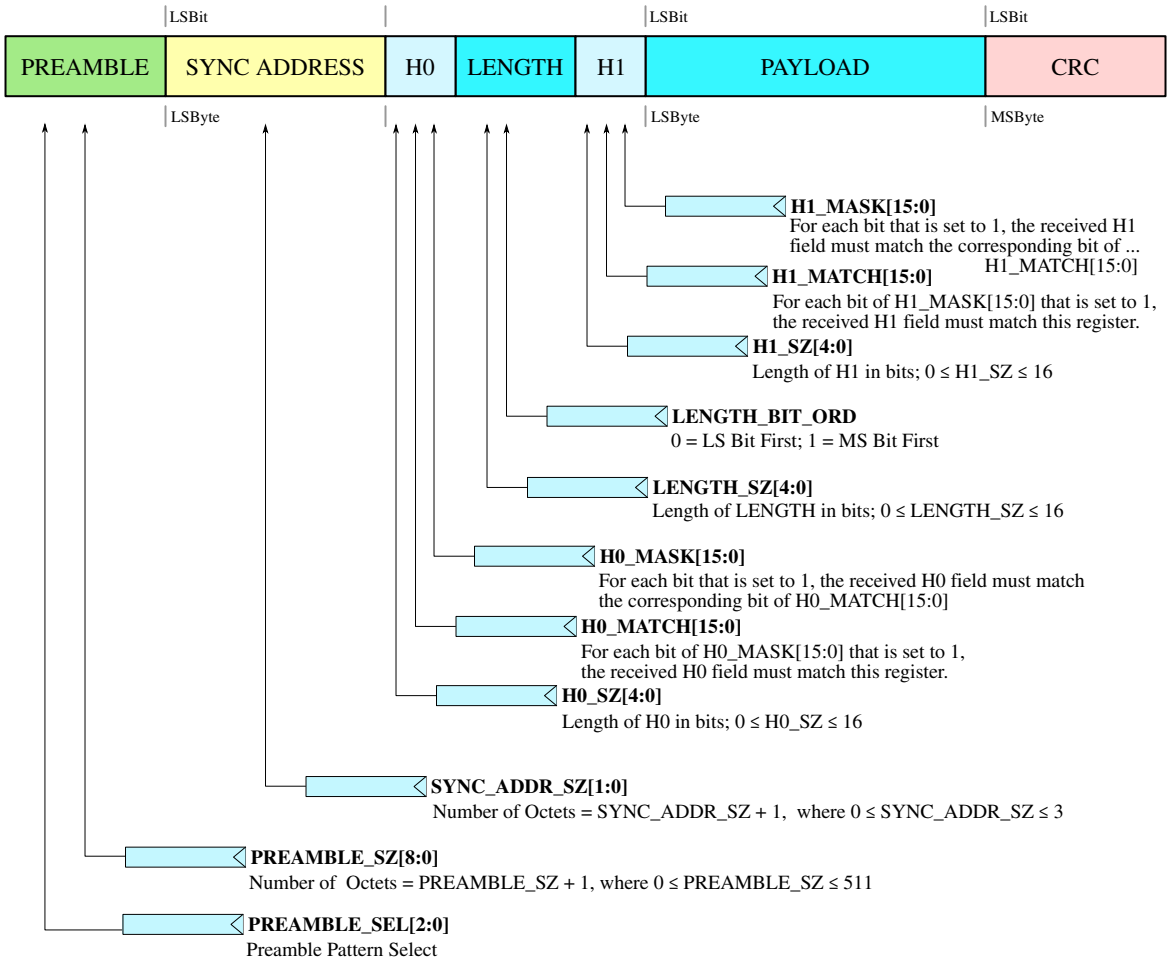


Figure 440. Packet Structure Definitions (Part 1)

The following diagram depicts the register configurability associated with the Payload and CRC elements of the packet structure.

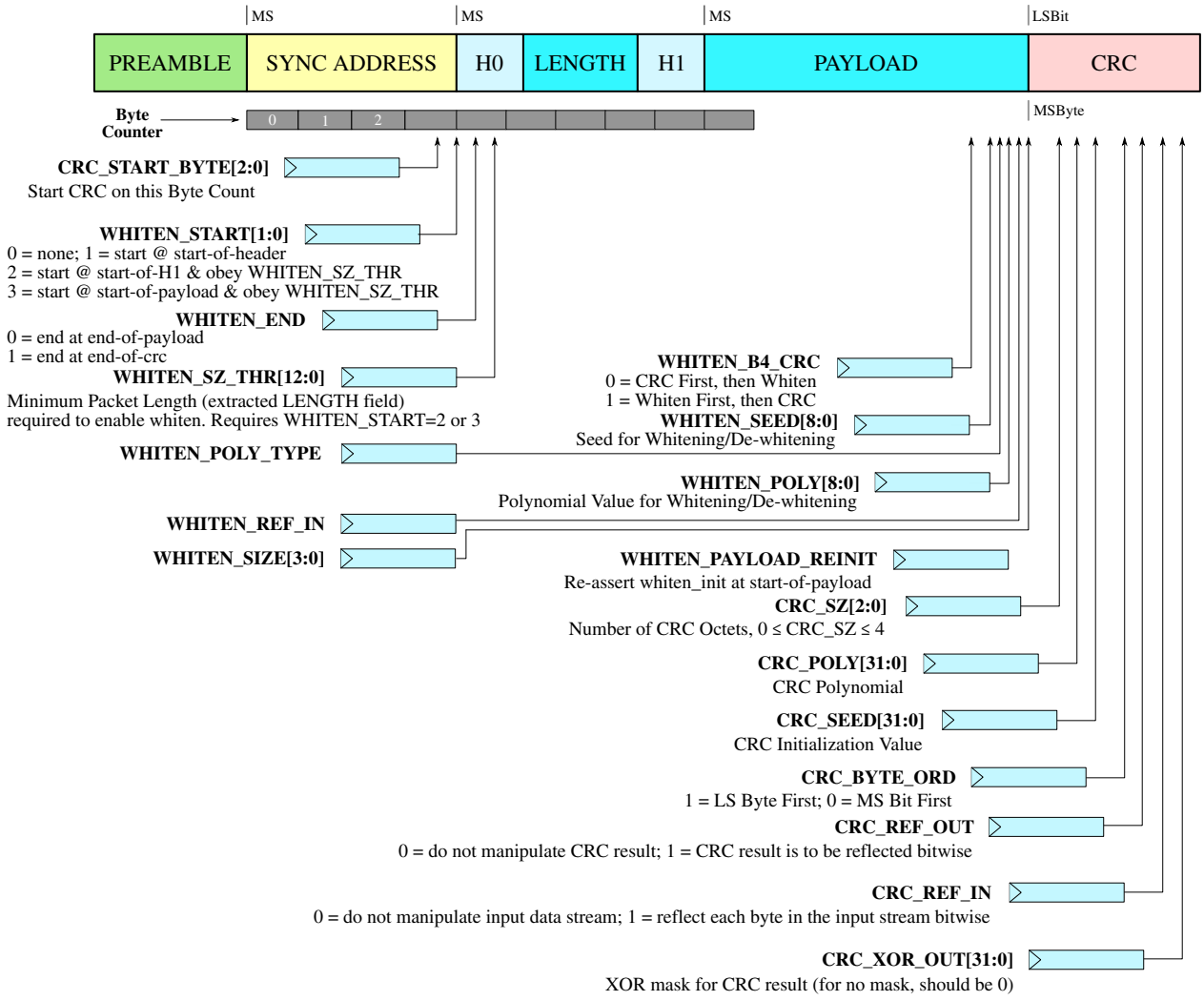


Figure 441. Packet Structure Definitions (Part 2)

The following subsections describe each of the packet elements, and the configurability associated with each.

PREAMBLE

When PREAMBLE_SEL=0x0, the preamble pattern is 0x55 or 0xAA. Like all packet elements, preamble is transmitted LSB first. The Sync Address, which immediately follows the preamble, determines which of the 2 preamble options is selected by hardware: the controller hardware selects the preamble pattern based on the first transmitted bit of Network Address, such that the last bit of preamble is the opposite polarity from the first bit of Network Address, forcing a bit transition at this boundary. The number of octets of preamble is programmable, via the PREAMBLE_SZ[2:0] register, with a range from 1 to 8 octets. A setting of PREAMBLE_SZ=0 yields a single preamble octet, whereas a setting of PREAMBLE_SZ=7 yields 8 octets. For transmission, the Generic FSK BYTE_COUNTER will be negative during preamble transmission. If PREAMBLE_SZ=0 (1 preamble octet), BYTE_COUNTER will be -1 while the single preamble octet is being transmitted. If PREAMBLE_SZ=7 (8 octets), BYTE_COUNTER will be -8 during the first preamble octet, -7 during the next, and so on and so forth, until the eighth and final octet, during which the BYTE_COUNTER will be -1. Unlike most packet elements, the preamble is generated and shifted out by hardware (only preamble and CRC are hardware-generated); there is no software setup required, and preamble does not appear in the Packet Buffer TX buffer. During reception, the Link Layer controller does not receive preamble, since preamble detection is performed by the PHY; preamble does not appear in the Packet Buffer RX buffer.

When PREAMBLE_SEL=0x1, the preamble pattern is fixed to register GEN_PREAMBLE[7:0], regardless of the Sync Address.

When PREAMBLE_SEL=0x2 or 0x3, the preamble pattern is fixed to 0b01 or 0b10, regardless of the Sync Address. At this case, PREAMBLE_SZ is the two-bits number not the byte number. If PREAMBLE_SZ=7 (8 two-bits), BYTE_COUNTER will be -8 during the first preamble two-bits, -7 during the next, and so on and so forth, until the eighth and final two-bits, during which the BYTE_COUNTER will be -1.

SYNC (NETWORK) ADDRESS

Sync Address, known synonymously as Network Address or Access Address depending on the protocol in use, is the second packet element transmitted by the Link Layer controller, and the first element received. In a network of associated devices, all devices generally share a common Network Address. The first bit of Network Address determines the preamble selection for transmission, as noted above. For TX, Network Address is the first packet element programmed into the Packet Buffer TX buffer, in LSB-first format. For RX, Network Address is also the first element stored into the Packet Buffer RX buffer, in LSB-first format. The register NTW_ADR_SZ[1:0] determines the length, in octets, of the Network Address field in the packet structure. A setting of NTW_ADR_SZ=0 yields a single-octet Network Address, whereas a setting of NTW_ADR_SZ=3 yields 4 octets. For reception, up to four unique Network Addresses are supported. Any combination of the 4 can be simultaneously searched for. Network Address correlation is performed in the PHY. Multiple Network Address capability allows GENERIC_FSK devices to be associated to more than one network simultaneously, if the network topology supports it; this feature also enables multi-protocol operation. Each of the 4 Network Address options has its own enable bit, NTW_ADR_EN[x]; when the enable bit for a Network Address is set to 1, the PHY is instructed to search for that Network Address pattern in the demodulated data, and when the enable bit is set to 0, the PHY will disregard that pattern. Each of the 4 Network Address options shares one NTW_ADR_SZ register, to program its octet size during reception. Additionally, each of the 4 Network Address options shares one register NTW_ADR_THR[2:0], which determine the number of bit errors that can be tolerated by the PHY during Network Address correlation to the respective Network Address option. Finally, when the PHY detects a match to one of the 4 Network Address options, with a number of bit errors less than or equal to the threshold programmed into NTW_ADR_THR, a read only status bit, NTW_ADR_MCH[x] becomes set, indicating which of the 4 patterns matched. After a match has been detected, the PHY shall hold NTW_ADR_MCH[x] valid (sticky), until the next receiver warmup, or the next RX recycle. (Specifically, the TSM output rx_init clears the NTW_ADR_MCH[x] bits; TSM will assert this signal during either an RX warmup or a recycle). A table listing the registers which apply to Network Address Management, for each of the 4 Network Address options, is shown below.

NTW_ADR PATTERN REGISTER	NTW_ADR ENABLE BIT	NTW_ADR SIZE REGISTER	NTW_ADR THRESHOLD REGISTER	NTW_ADR PATTERN-MATCH STATUS BIT
NTW_ADR_0[31:0]	NTW_ADR_EN[0]	NTW_ADR_SZ[1:0]	NTW_ADR_THR[2:0]	NTW_ADR_MCH[0]
NTW_ADR_1[31:0]	NTW_ADR_EN[1]	NTW_ADR_SZ[1:0]	NTW_ADR_THR[2:0]	NTW_ADR_MCH[1]
NTW_ADR_2[31:0]	NTW_ADR_EN[2]	NTW_ADR_SZ[1:0]	NTW_ADR_THR[2:0]	NTW_ADR_MCH[2]
NTW_ADR_3[31:0]	NTW_ADR_EN[3]	NTW_ADR_SZ[1:0]	NTW_ADR_THR[2:0]	NTW_ADR_MCH[3]

For Network Addresses of size less than 4 octets, the PHY expects the desired pattern to occupy the least-significant byte positions of the NTW_ADR_x register. Unused byte positions may be filled with any value.

NOTE

When programming the NTW_ADR_x, NTW_ADR_EN[x], NTW_ADR_SZ, and NTW_ADR_THR for any RX operation, the following software restrictions apply:

1. All NTW_ADR_x patterns which are enabled by their respective NTW_ADR_EN[x]=1 must be unique (disabled NTW_ADR_x registers need not follow this restriction).
2. Given restriction #1 above, not only must the patterns be unique, but the bit patterns of NTW_ADR_x and NTW_ADR_y must differ by an amount greater than the bit-error threshold, i.e., NTW_ADR_THR.

These restrictions are designed to preclude multiple, simultaneous pattern matches during a pattern search. Results are indeterminate if the restrictions are violated.

When the PHY detects a pattern match on any enabled NTW_ADR_x during reception, and asserts NTW_ADR_MCH[x], the GENERIC_FSK Link Layer Controller shall assert NTW_ADR_IRQ. The NTW_ADR_IRQ is the Link Layer's first indication that

a packet is being received. After any NTW_ADR_IRQ assertion, a packet will be received and stored into the Packet Buffer RX buffer.

HEADER

The packet header is comprised of H0, LENGTH, and H1, in that order. Each of the 3 fields of the header has programmable length, from 0 to 16 bits. A size of zero for any of the header components infers that the component is skipped in the packet structure. Although the size of the individual H0, LENGTH, and H1 components need not be aligned to a byte boundary, the overall header must be byte-aligned. That is, the sum of the sizes (in bits) of H0, LENGTH, and H1, must be a integer multiple of 8 bits. This is a software restriction, a violation of which may result in indeterminate behavior.

For GENERIC_FSK protocol, the purpose of the header is twofold:

1. To frame the LENGTH field, so that LENGTH can be extracted and interpreted by the GENERIC_FSK packet processor, so as to determine how and when perform the required bit-stream processing on the data. In most wireless protocols with regular structures, the LENGTH field is embedded within the packet header, but its positioning, number of LENGTH bits, bit ordering, and interpretation can differ. The GENERIC_FSK configurability thus provides support for a wide range of header formats, yielding a high likelihood that most current and future packet formats and LENGTH fields will be parsable by the GENERIC_FSK Link Layer controller.
2. To provide rudimentary packet filtering on the non-LENGTH header bits, namely H0 and H1. Screening of packets based on H0 and/or H1 bit comparisons can reduce power consumption, by avoiding notification to the host processor on received packets that do not comply with pre-configured H0 and/or H1 bitmasks, enabling longer MCU sleep durations.

The header components, and their configurability options, are further described below.

H0

H0 is an optional header packet element. Its length in bits is determined by register H0_SZ[4:0]. Legal values for H0_SZ are:

0 <= H0_SZ <= 16

If H0 is present (non-zero size), it can be filtered-on by the GENERIC_FSK packet processor; each bit of H0 can be forced to match a programmable bitmask, or ignored. Every bit of H0 that is forced to match the bitmask, must match; otherwise, the packet is rejected. The registers H0_MATCH[15:0] and H0_MASK[15:0] control H0 filtering. For every bit of H0_MASK that is set to one, the received bit in the H0 portion of the header must match the corresponding bit of H0_MATCH. Bits of H0_MASK which are cleared, do not require a match of received data bits to H0_MATCH bits. If any bit of received data which is qualified with H0_MASK[x]=1 fails to match its corresponding H0_MATCH[x] bit, the H0_FAIL register status bit will be set, an RX recycle will occur, and the host processor will not be notified. (The recycle operation will self-clear the H0_FAIL bit). For debug purposes, the control bit REC_BAD_PKT has been provided. If REC_BAD_PKT=1 and a H0-mismatch occurs, the RX recycle is prevented, the full packet is received, the MCU is notified, and the H0_FAIL flag stays asserted. In this case, the H0-fail flag will stay asserted until the next RX warmup (specifically, rx_init clears the bit).

The equation for H0_FAIL is thus:

H0_FAIL = [$H0_{received}$^H0_MATCH[15:0]) & H0_MASK > 0

LENGTH

LENGTH is an optional header packet element. Its length in bits is determined by the register LENGTH_SZ[4:0]. Legal values for LENGTH_SZ are:

0 <= LENGTH_SZ <= 16

If LENGTH is present (non-zero size), its value determines the number of octets remaining in the packet after the header is complete, that is, PAYLOAD octets plus CRC octets, as depicted below.

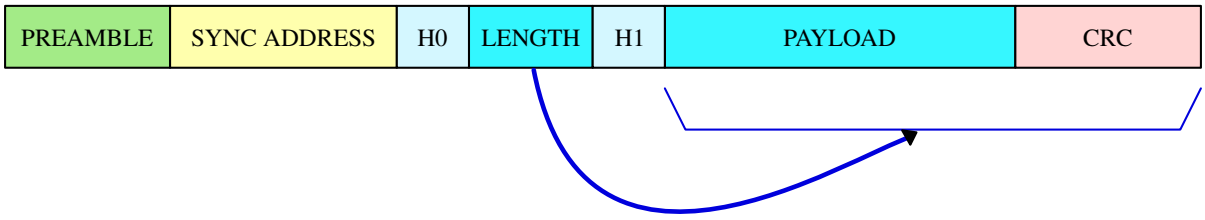


Figure 442. LENGTH Field Interpretation with No LENGTH_ADJ

For example, if the payload consists of 16 octets, and CRC is 4 octets, the LENGTH field of the header should be set to 20. The packet processor will extract the packet length from the LENGTH field of the header, and use this information to determine the timing of the CRC, Whitening control signals, as well as end-of-packet interrupt triggering.

In case a protocol exists for which the LENGTH field is to be interpreted differently, a configurability option has been provided to compensate for this. Hypothetically, this could happen, for example, in a proprietary packet structure, in which LENGTH is to be defined to represent PAYLOAD only, excluding CRC. The register LENGTH_ADJ, allows a fixed offset to be applied to the extracted LENGTH field, such that the sum of LENGTH + LENGTH_ADJ represents the number of PAYLOAD + CRC octets, as depicted below:

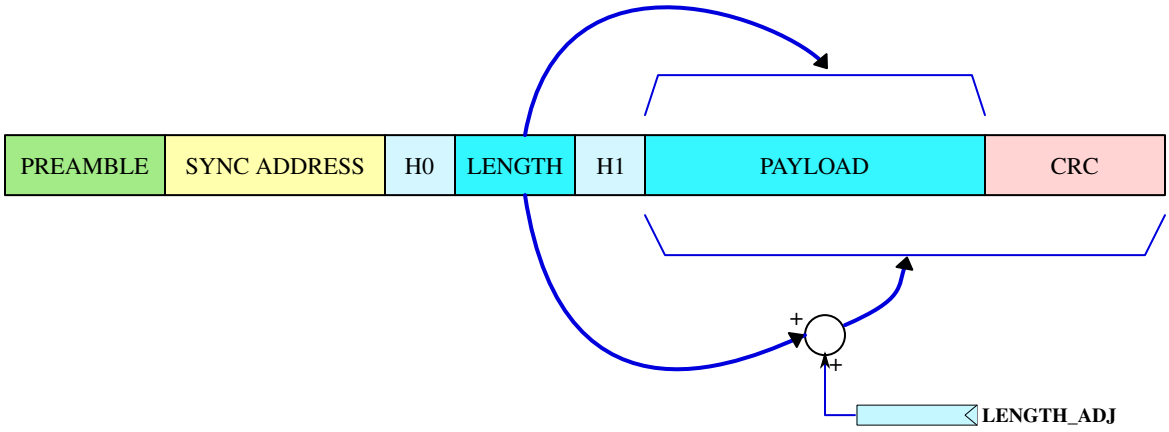


Figure 443. LENGTH Field Interpretation with LENGTH_ADJ

Applying the previous example, if, using a proprietary format, LENGTH were to be defined as payload-length only, LENGTH would be set to 16. In order for the packet processor to correctly time the CRC and Whitening control signals, etc., the LENGTH_ADJ register should be programmed to 4 in this case, so that the packet processor would operate on a 20-octet "PAYLOAD + CRC" PDU. The LENGTH_ADJ register represents a signed value, so that negative offsets can be applied. The legal range for LENGTH_ADJ is:

-1024 <= LENGTH_ADJ <= 1023

The LENGTH field could be ordered MSB first or LSB first. The packet processor must be able to accommodate either case, in order to extract the LENGTH field properly from the header, so a configurability option has been provided. The register bit LENGTH_BIT_ORD specifies the bit order. If LENGTH_BIT_ORD=0, ordering is LSB-first, as shown below.

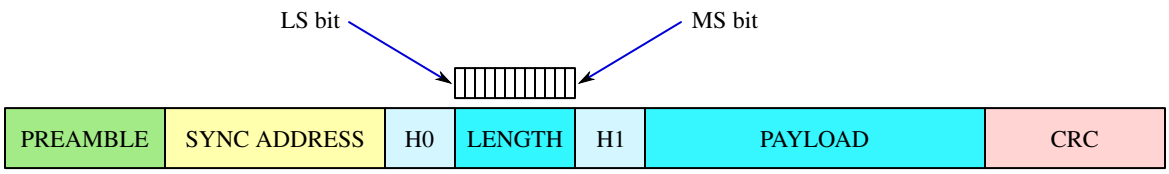


Figure 444. LENGTH Bit Ordering (LSB First)

If LENGTH_BIT_ORD=1, ordering is MSB-first, as shown below.

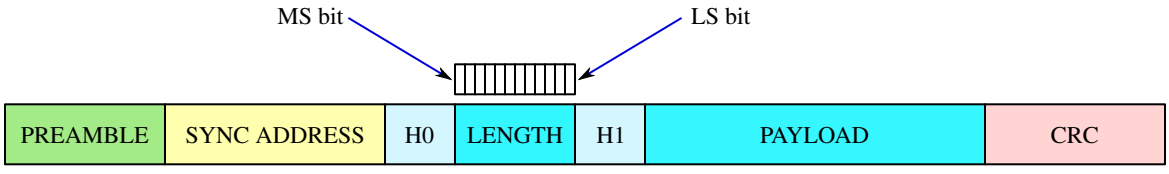


Figure 445. LENGTH Bit Ordering (MSB First)

If LENGTH_SZ=0, then LENGTH is not present in the header. The packet processor interprets this as LENGTH=0. If, in this case, LENGTH_ADJ=0 also, the packet processor interprets this to mean that the packet ends with the last bit of H1, and there are no PAYLOAD or CRC octets (CRC_SZ should be programmed to 0 in this case). There is no CRC verification in this scenario. If, in this case, LENGTH_SZ=0, meaning an empty payload field, but a CRC check is desired, CRC_SZ should be programmed to the desired number of CRC octets, and LENGTH_ADJ should be programmed to the same value: LENGTH_ADJ = CRC_SZ.

For GENERIC_FSK, valid payload lengths are from 0 to 2047 octets, i.e.,

0 <= LENGTH <= 2047

If LENGTH_ADJ is non-zero, then the maximum limit of 2047 applies to the sum of LENGTH and LENGTH_ADJ, i.e.,

0 <= (LENGTH + LENGTH_ADJ) <= 2047

A restriction on LENGTH_ADJ follows:

If the packet ends immediately after the LENGTH field of the header, i.e., H1_SZ=0 and there is neither payload nor CRC, then LENGTH_ADJ must be set to 0.

Although the LENGTH field has a maximum size of 16 bits, since the maximum receivable packet size is 2047 bytes, any received LENGTH bits above bit [10] are ignored by the packet processor, which effectively clamps LENGTH at 2047 bytes. There may be cases where it is desirable to limit the maximum received packet length to values less than 2047, so that received packets whose extracted LENGTH field indicates to be larger than a pre-set limit, are rejected by the packet processor. A configurability option has been provided for this, the register LENGTH_MAX[6:0]. The LENGTH_MAX setting configures a pre-set limit on the extracted LENGTH field, in multiples of 16 octets. A special case exists for LENGTH_MAX=0 (the register default), which implies no hardware-limiting; this setting should be used to allow reception of full-length 2047-octet packets. If LENGTH_MAX=1, packets with LENGTH >= 16 octets are rejected. If LENGTH_MAX=2, packets with LENGTH >= 32 octets are rejected. If LENGTH_MAX=127 (the maximum setting) packets with LENGTH >= 2032 octets are rejected. To determine compliance with LENGTH_MAX, the packet processor compares the LENGTH_MAX register with the extracted LENGTH field directly, not the adjusted length (LENGTH + LENGTH_ADJ). If a packet is received during which the extracted LENGTH field exceeds the LENGTH_MAX setting, the LENGTH_FAIL register status bit will be set, an RX recycle will occur, and the host processor will not be notified. (The recycle will self-clear the LENGTH_FAIL bit). For debug purposes, the control bit REC_BAD_PKT has been provided. If REC_BAD_PKT=1 and a LENGTH_MAX violation occurs, the RX recycle is prevented, the full packet is received, the MCU is notified, and the LENGTH_FAIL flag stays asserted. In this case, the LENGTH_FAIL flag will stay asserted until the next RX warmup (specifically, rx_init clears the bit).

H1

H1 is an optional header packet element. Its length in bits is determined by register H1_SZ[4:0]. Legal values for H1_SZ are 0 ≤ H1_SZ ≤ 16. If H1 is present (non-zero size), it can be filtered-on by the GENERIC_FSK packet processor; each bit of H1 can be forced to match a programmable bitmask, or ignored. Every bit of H1 that is forced to match the bitmask, must match; otherwise, the packet is rejected. The registers H1_MATCH[15:0] and H1_MASK[15:0] control H1 filtering. For every bit of H1_MASK that is set to one, the received bit in the H1 portion of the header must match the corresponding bit of H1_MATCH. Bits of H1_MASK which are cleared, do not require a match of received data bits to H1_MATCH bits. If any bit of received data which is qualified with H1_MASK[x]=1 fails to match its corresponding H1_MATCH[x] bit, the H1_FAIL register status bit will be set, an RX recycle will occur, and the host processor will not be notified. (The recycle will self-clear the H1_FAIL bit). For debug purposes, the control bit REC_BAD_PKT has been provided. If REC_BAD_PKT=1 and a H1-mismatch occurs, the RX recycle is prevented, the full packet is received, the MCU is notified, and the H1_FAIL flag stays asserted. In this case, the H1-fail flag will stay asserted until the next RX warmup (specifically, rx_init clears the bit).

The equation for H1_FAIL is thus:

$H1_FAIL = [H1_{received} \text{^} H1_MATCH[15:0]) \& H1_MASK > 0$

PAYLOAD

In the GENERIC_FSK packet structure, the payload directly followed the header. For transmission, payload bytes are serialized, and transmitted, LSB first, in order, as they are received from the Packet Buffer interface. During reception, payload bytes are received LSB first, undergo serial-to-parallel conversion to octets, 4 octets are packed into a 32-bit word, and the word is transferred to memory via Packet Buffer. For both TX and RX, since the packet processor interprets the extracted LENGTH to represent the number of Payload + CRC octets, the actual number of payload octets is computed from the following equation:

$Number_of_Payload_Octets = (LENGTH_{extracted} + LENGTH_ADJ – CRC_SZ)$

For TX, payload bytes are subjected to whitening . They are also shifted through CRC to compute a CRC checksum value. Whitening and CRC computing are all optional. For RX, payload bytes are subjected to de-whitening and CRC verification. De-whitening and CRC verification are all optional. For both TX and RX, (de-)whitening can precede CRC, or follow it. For more details on CRC, whitening, see Section Bitstream Processing.

CRC

In the GENERIC_FSK packet structure, the CRC field directly followed the payload. The size of the CRC field, in octets, is set by the CRC_SZ register. The valid range for CRC_SZ is:

0 <= CRC_SZ <= 4

For both TX and RX, the portion of the packet which are subjected to CRC is programmable, via the register CRC_START_BYTE[3:0]. The register CRC_START_BYTE programs the absolute byte count of the first byte for which CRC shifting is desired. The CRC_START_BYTE value is referenced to the GENERIC_FSK Byte Counter. The Byte Counter starts at 0 for the first octet of Sync Address, and increments octet-for-octet henceforth, until the last octet of CRC is transmitted or received. An example of CRC_START_BYTE programming is shown below.

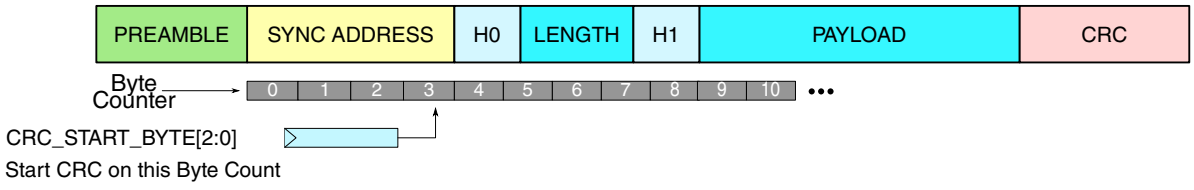


Figure 446. CRC Start Byte

In this example

SYNC_ADDR_SZ = 4

Header Size = 4 i.e. (H0_SZ + LENGTH_SZ +H1_SZ)/8 = 4

To initiate CRC shifting at the start of Sync Address, program CRC_START_BYTE = 0

To initiate CRC shifting at the start of Header, program CRC_START_BYTE = 4

To initiate CRC shifting at the start of Payload, program CRC_START_BYTE = 9

The CRC_START_BYTE should not be programmed so large as to exceed the length of the PDU; that is, larger than extracted LENGTH – CRC_SZ. If CRC_SZ=0, program CRC_START_BYTE=0.

For more details on how the GENERIC_FSK packet processor controls the CRC generation and verification processes, see Section Bitstream Processing.

EXAMPLE

A real-world example follows, describing how the GENERIC_FSK Link Layer packet configuration can be applied to transmit and receive packets which conforms to, e.g., IEEE 802.15.4-2015 SUN FSK PHY packet format.

IEEE 802.15.4-2015 SUN FSK PHY header(PHR) is as follows.

Table 548. Format of the PHR(without mode switching) for MR-FSK

Bit string index	0	1-2	3	4	5-15
Bit mapping	MS	R_1-R_0	FCS	DW	L_{10}-L_0
Field Name	Mode Switch	Reserved	FCS Type	Data Whitening	Frame Length

The GENERIC_FSK Link Layer controller supports such a header format, and can be programmed to transmit and receive packets which conform to it. To correctly size and order the GENERIC_FSK header elements so as to conform with this header format:

1. The LENGTH field ends the header, so there is no H1 (H1_SZ=H1_MASK=0)
2. The 5 bits which precede LENGTH in the header, are grouped into H0 (H0_SZ=5)
3. The size of the LENGTH field is 11 bits (LENGTH_SZ=11)
4. The LENGTH is specified as MSB-first (LENGTH_BIT_ORD=1)

For this example, we would like to leverage the H0-filtering capability built into the GENERIC_FSK Link Layer to screen the 802.15.4-2015 SUN FSK header, to require that the bit fields in the received packet comply with the following conditions:

1. MS (Mode Switch, bit [0] of header) = 0
2. DW (Data Whitening, bit [4]) = 1
3. FCS (FCS Type, bit [3]) = 1 (Four-octet FCS)
4. Bits [1] and [2] are marked as Reserved, to be ignored on reception

Given these parameters, the following diagram shows how we would program the GENERIC_FSK Link Layer controller to accept this packet configuration, and then screen H0 accordingly:

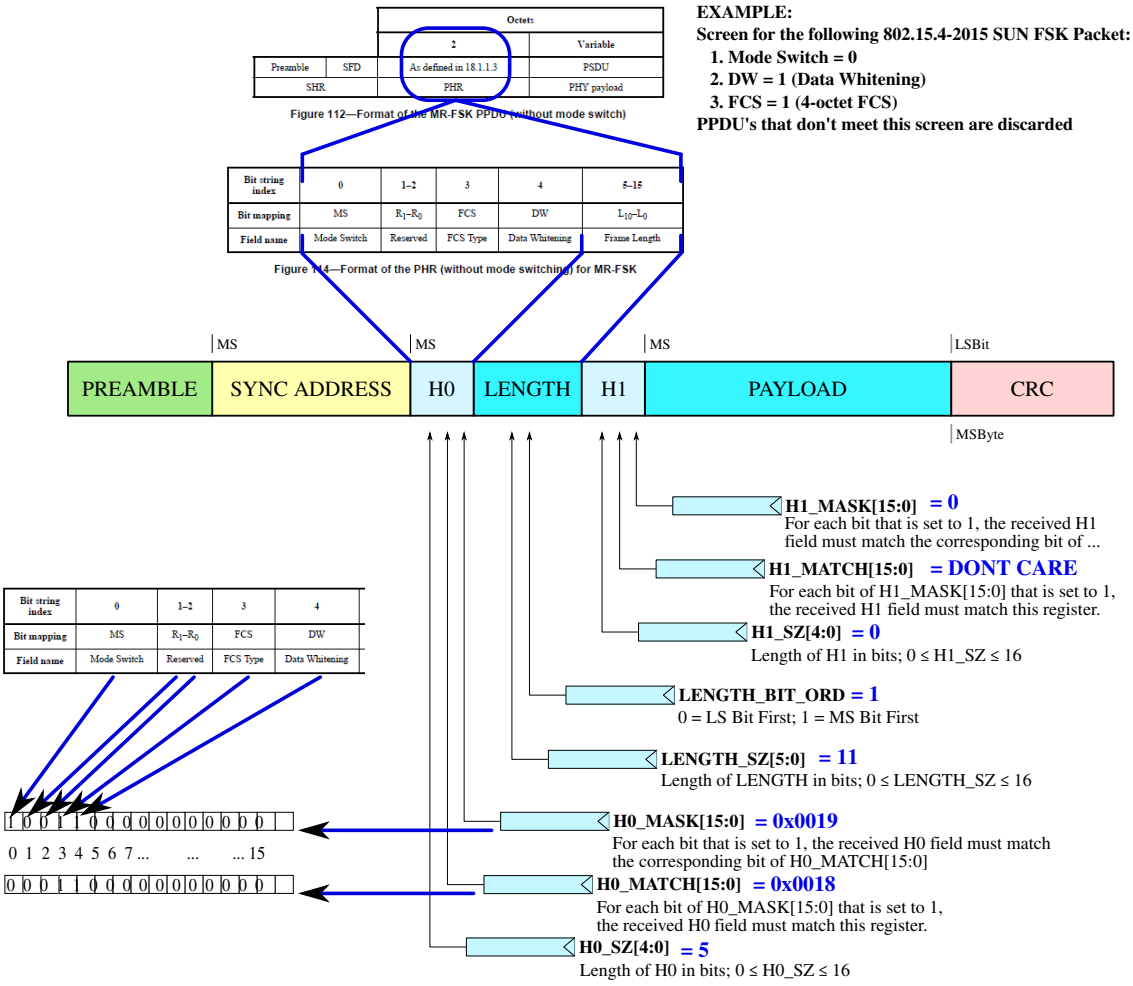


Figure 447. GENERIC FSK PACKET STRUCTURE AS APPLIED TO 802.15.4-2015 SUN FSK PHR

Received packets which meet the H0 filtering screen are fully received, and Data Indication is provided to the host processor. Packets which fail the screen result in an RX recycle, and no notification to the host.

52.4.4.4.2.2.2 Bitstream Processing

The CRC/Whitener block is inside RBME.

The GENERIC_FSK Link Layer controller provides control for CRC verification and Data De-whitening as the packet is being received.

The RBME provides control for CRC generation and Data Whitening as the packet is being transmitted.

The following diagram provides another perspective of bitstream processing.

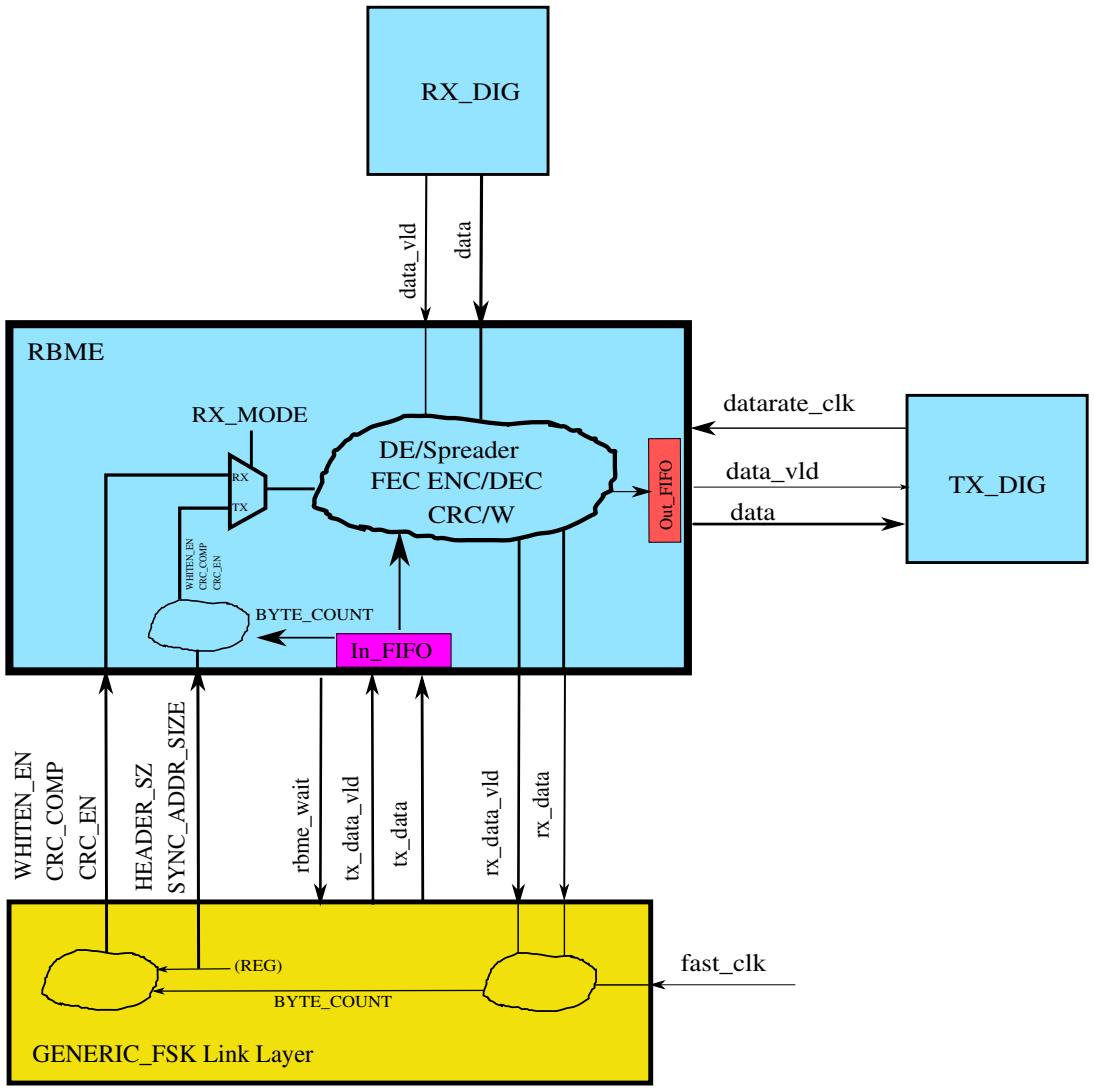


Figure 448. Basic Bitstream Between RBME and Link Layer

The following sections provide more detail on how CRC and whitening, are controlled, and describes the configuration options associated with each.

CRC & WHITENING

The GENERIC_FSK Link Layer controller dynamically manages CRC verification process (for RX), RBME manages the CRC generation process (for TX), by way of 3 timing signals that it asserts to the CRC/Whitener module.

The CRC engine in the CRC/Whitener block shall only shift incoming bits (data_in) through its LFSR when all the following conditions are met:

1. crcw_init=0
2. crc_en=1
3. tx_data_in_vld=1 (signal is data_in_vld at the CRC/Whitener)

The CRC/Whitener shall only shift bits out of its CRC LFSR, to the TX digital block, when all the following conditions are met:

1. crcw_init=0
2. crc_comp=1

3. tx_data_in_vld=1 (signal is data_in_vld at the CRC/Whitener)

The GENERIC_FSK Link Layer and RBME use the extracted LENGTH field of the packet, as well as the registers which control the size of the individual packet elements, in order to determine when to assert the CRC-related control signals, **crc_en** and **crc_comp**. This is true for both transmission and reception.

The calculations used by the GENERIC_FSK Link Layer to determine when to assert the CRC-related control signals are summarized in the Figure 449.

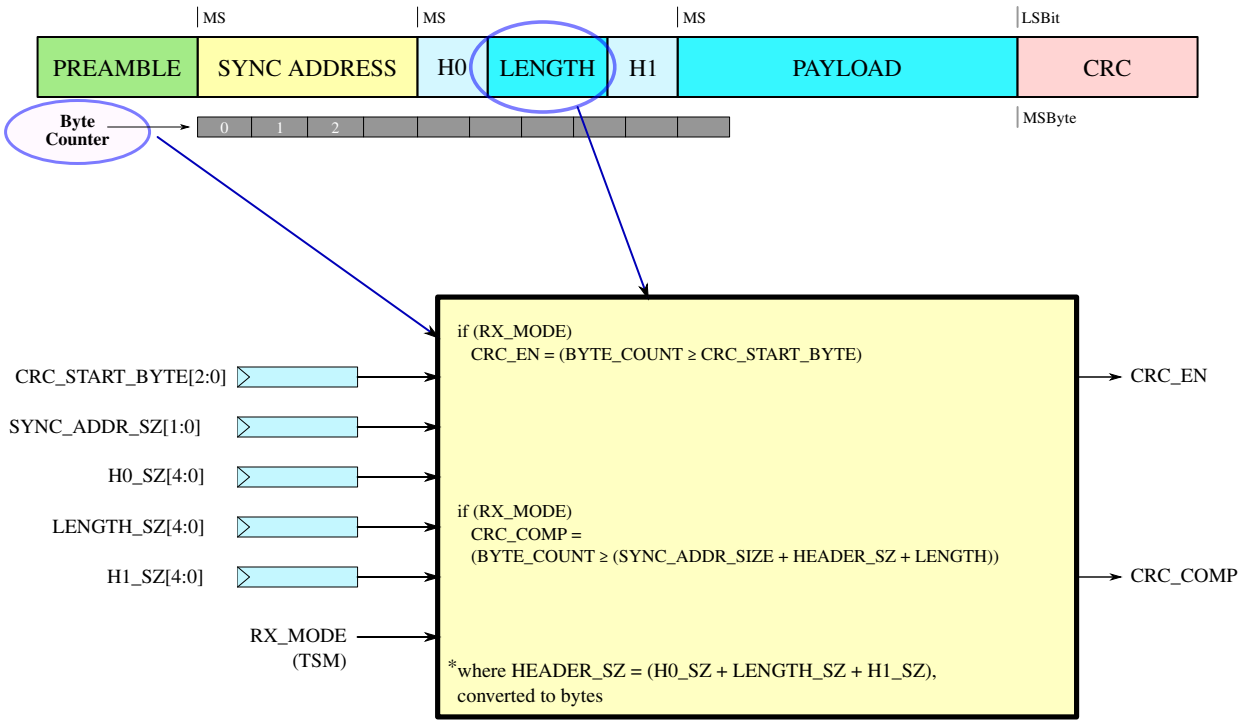


Figure 449. CONTROL OF CRC IN LINK LAYER (RX)

The calculations used by the RBME to determine when to assert the CRC related control signals are summarized in the Figure 450.

Note, the RBME and Link Layer has their own BYTE_COUNT, for TX and RX respectively.

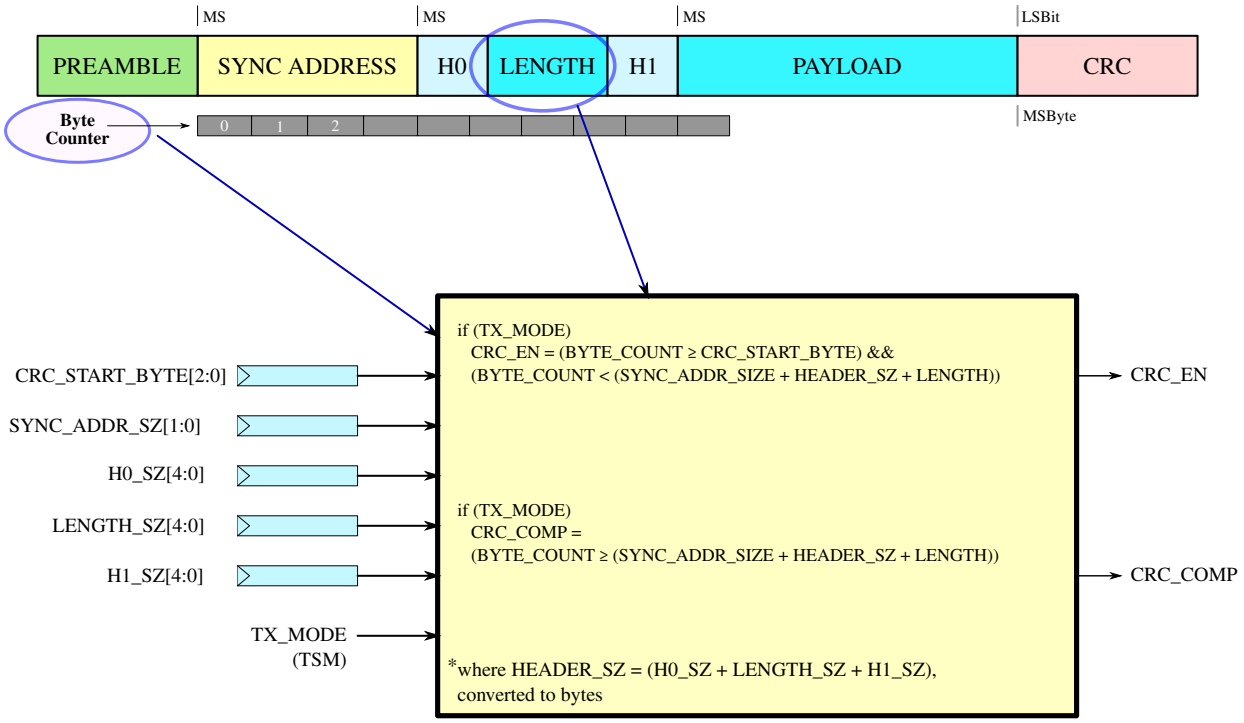


Figure 450. CONTROL OF CRC IN RBME (TX)

Likewise, the Link Layer controller and RBME optionally enables whitening and de-whitening of the packet bitstream, and controls the portions of the packet which are subjected to whitening. For both TX and RX, the portion of the packet which are subjected to whitening/de-whitening is programmable; the following table describes the 3 registers which determine which elements of the packet bitstream are whitened/de-whitened.

REGISTER NAME	FUNCTIONAL DESCRIPTION
WHITEN_START[1:0]	**0**: No whitening/de-whitening **1**: Begin whitening/de-whitening at the start of the header (H0) field, regardless of packet length. **2**: Begin whitening/de-whitening at the start of the header H1 field, but only if the extracted length field meets or exceeds WHITEN_SZ_THR, i.e., ($LENGTH_{extracted}$ >= WHITEN_SZ); otherwise, there is no whitening/de-whitening of the bitstream **3**: Begin whitening/de-whitening at the start of the PAYLOAD, but only if the extracted length field meets or exceeds WHITEN_SZ_THR, i.e., ($LENGTH_{extracted}$ >= WHITEN_SZ); otherwise, there is no whitening/de-whitening of the bitstream
WHITEN_END	**0**: Whitening/de-whitening ends with the last bit of the last PAYLOAD byte

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REGISTER NAME	FUNCTIONAL DESCRIPTION
	1: Whitening/de-whitening ends with the last bit of the last CRC byte
WHITEN_SZ_THR[12:0]	If WHITEN_START=2 or WHITEN_START=3, apply whitening/de-whitening at the point determined by WHITEN_START, but only if the extracted LENGTH field of the packet meets or exceeds this WHITEN_SZ_THR threshold; if LENGTHextracted < WHITEN_SZ_THR, there is no whitening/de-whitening of the bitstream. If WHITEN_START < 2, this register has no effect.

The GENERIC_FSK Link Layer controller dynamically manages the data whitening process (for TX), and de-whitening (for RX), via 2 timing signals that it asserts to the CRC/Whitener module.

The Whitening/de-whitening engine in the CRC/Whitener block shall only shift incoming bits (data_in) through its LFSR when all the following conditions are met:

1. crcw_init=0
2. whiten_en=1
3. tx_data_in_vld=1 (signal is data_in_vld at the CRC/Whitener)

The GENERIC_FSK Link Layer and RBME use the extracted LENGTH field of the packet, as well as the registers which control the size of the individual packet elements, in order to determine when to assert the whitening-related control signal, whiten_en. This is true for both transmission and reception.

The calculations used to determine when to assert whiten_en control signals are summarized in the following diagram.

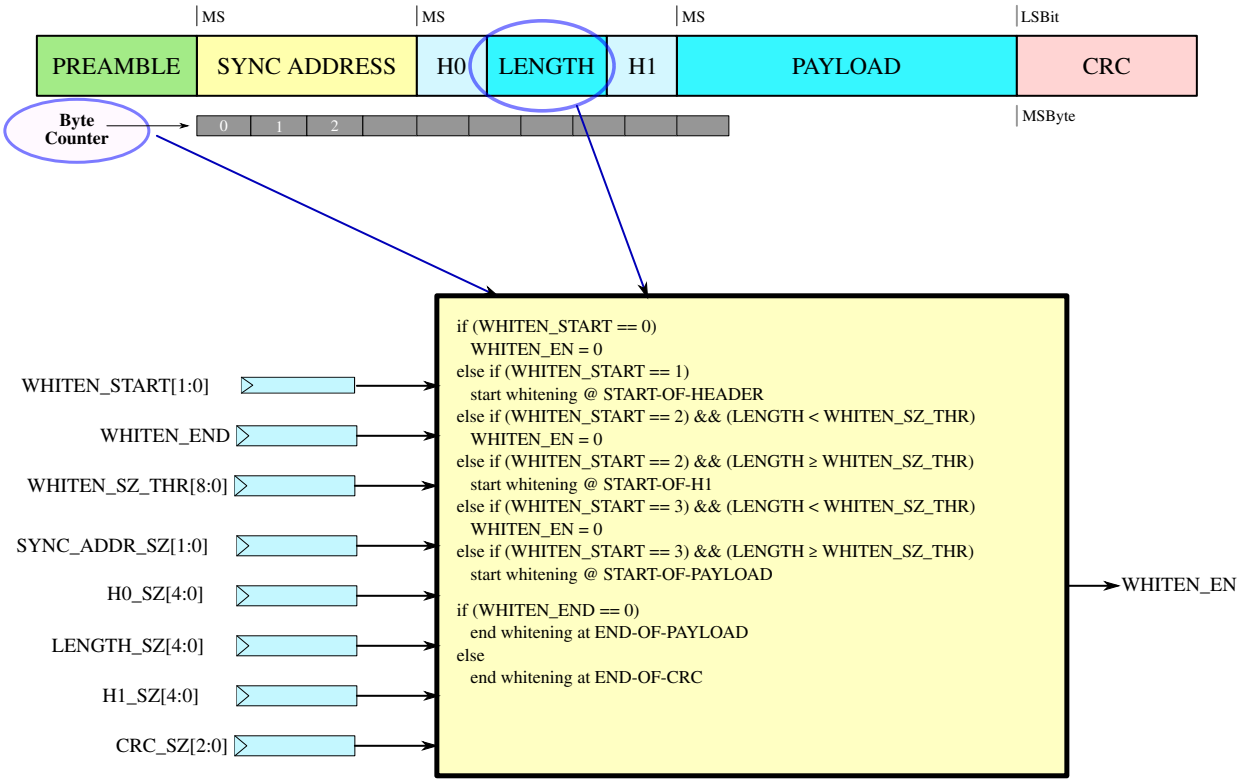

Figure 451. CONTROL OF WHITENING (TX and RX)

The order in which CRC and whitening are performed, is configurable, via the static register bit WHITEN_B4_CRC. This bit is programmed in the RBME, and sent to the CRC/Whitening engine to control the ordering. The following table describes how the bitstream is processed for both settings of WHITEN_B4_CRC, for both TX and RX.

	TX	RX
WHITEN_B4_CRC=1	In the CRC/Whitener, the CRC engine shifts in data bits which have been whitened first through the whitener LSFR. The entire post-whitened bitstream is then transmitted to the TX Digital.	Since the entire bitstream, including CRC, has been pre-whitened, the incoming bitstream from the PHY is shifted directly through the CRC LFSR to verify the checksum. The entire bitstream is simultaneously de-whitened by the whitener LFSR and shifted out to the Link Layer.
WHITEN_B4_CRC=0	In the CRC/Whitener, the CRC engine shifts in data bits which have not been whitened. Whitening is performed on the CRC LFSR output. The entire post-whitened bitstream is then transmitted to the TX Digital.	The entire bitstream is de-whitened first by the whitener LFSR, and then shifted through the CRC LFSR to verify the checksum. The entire de-whitened bitstream is simultaneously shifted out to the Link Layer.

A diagram depicting an example of bitstream processing flow during packet transmission, with WHITEN_B4_CRC=1 (the register default), is shown below.

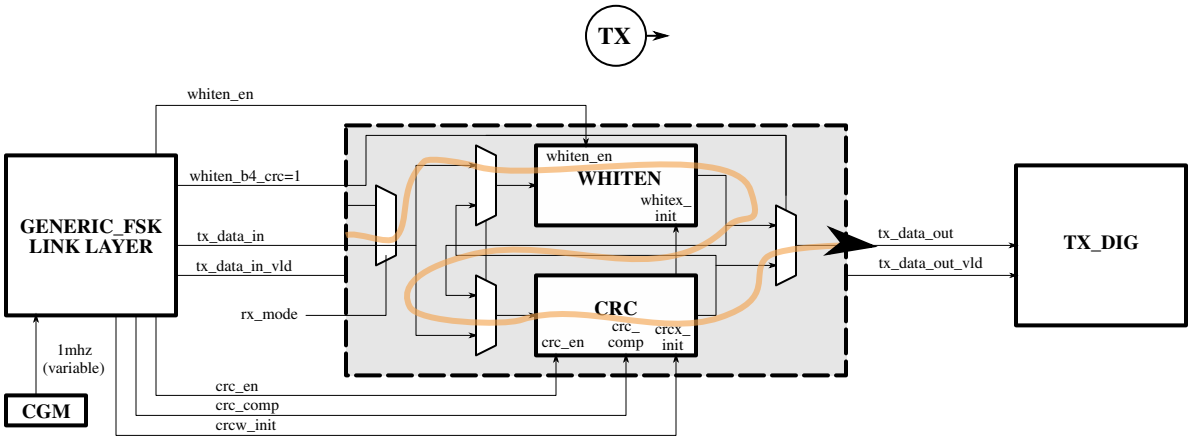

Figure 452. Whitening Before CRC (TX)

A diagram depicting an example of bitstream processing flow during packet reception, with WHITEN_B4_CRC=1, is shown below.

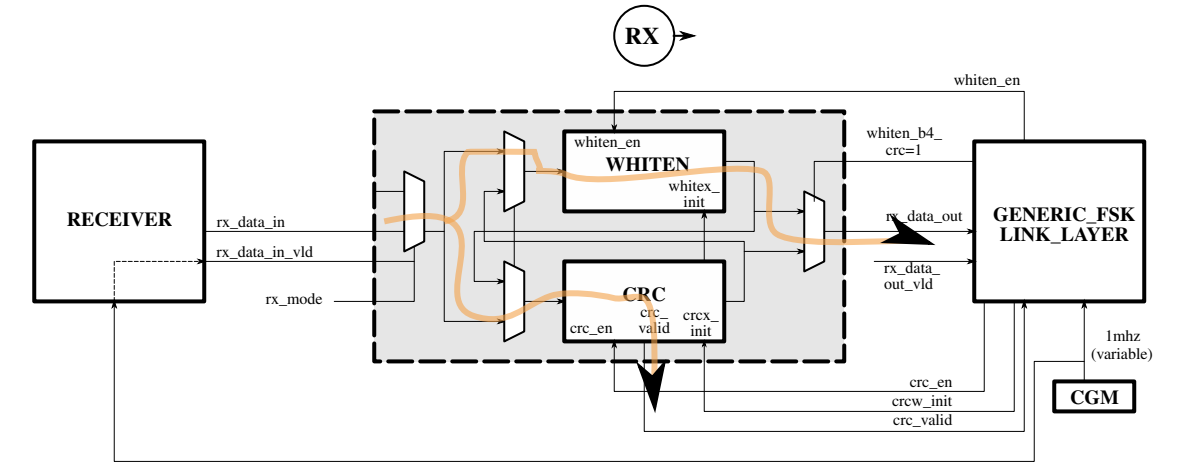

Figure 453. Whitening Before CRC (RX)

A timing diagram depicting a real-world example of TX bitstream processing timing is shown below. In this example, the desired start point for CRC shifting is the start of Network Address, so CRC_START_BYTE=0. The desired start point for whitening is the start of the header (H0), so WHITEN_START=1. It is also desired to stop whitening after the last bit of the last PAYLOAD byte, so WHITEN_END=0.

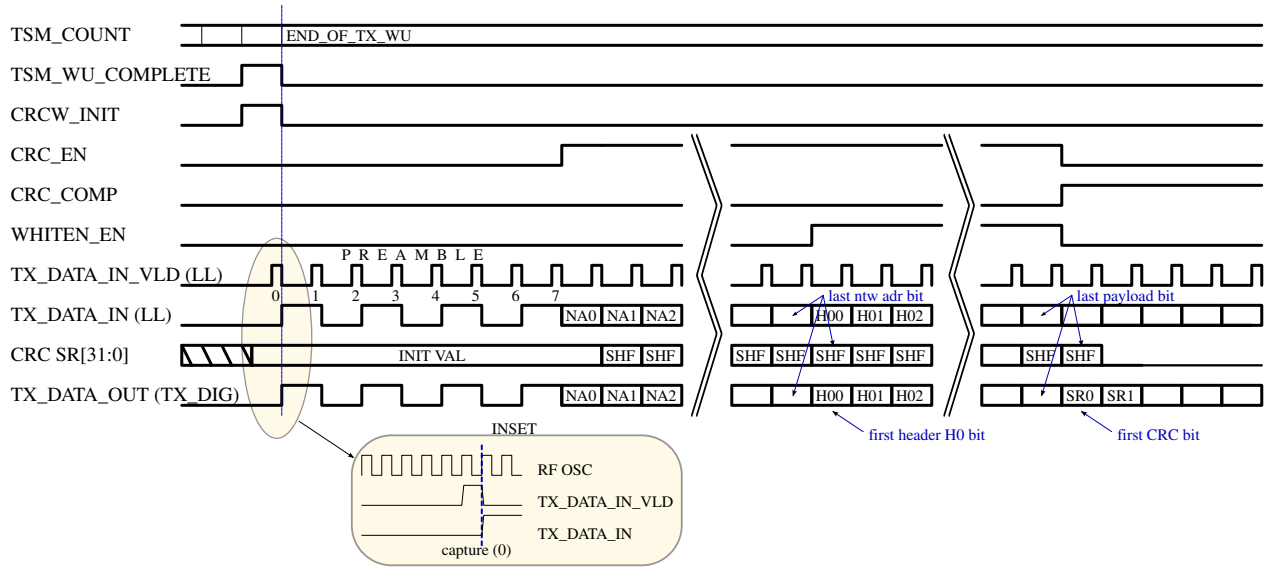

Figure 454. BIT STREAM PROCESSING CRC AND WHITENING TX TIMING

The bitstream depicted in the previous timing diagram, with CRC and whitening applied, is shifted out to the TX digital block, and transmitted over the air. A receiving device, will receive and process this same bitstream, by applying de-whitening, and verifying CRC on the de-whitened bitstream. The CRC and whitening parameters (registers) would be programmed to the receiving device, identically to how they are programmed for the transmitting device, specifically:

CRC_START_BYTE=0

WHITEN_START=1

WHITEN_END=0

A similar timing diagram depicting this RX bitstream processing timing, is shown below.

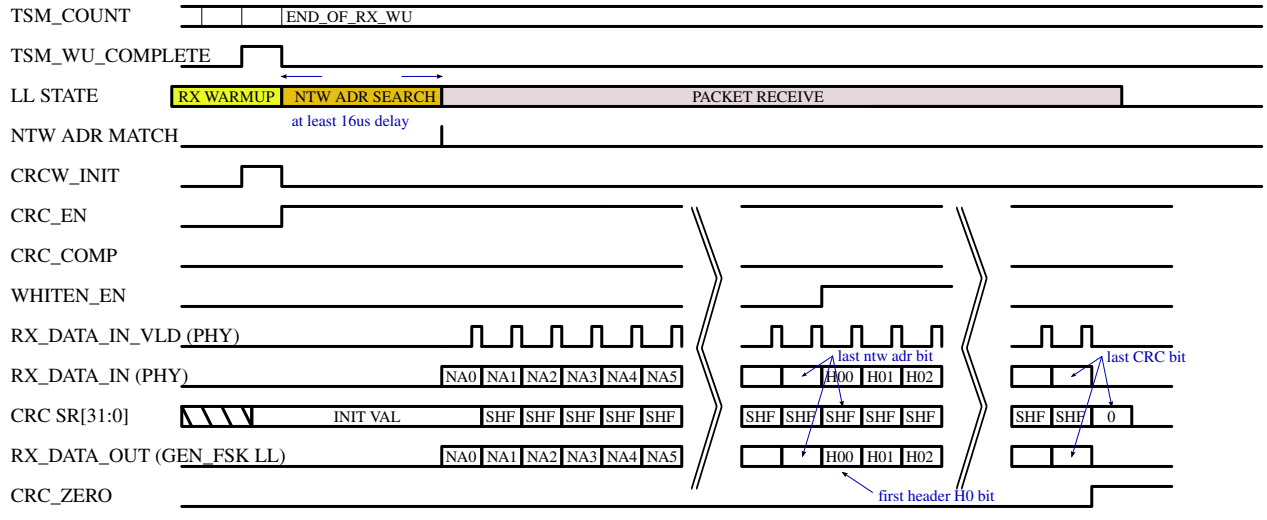

Figure 455. BIT STREAM PROCESSING CRC AND WHITENING RX TIMING

The GENERIC_FSK Link Layer controller provides a special whitening option, that causes the whitening LFSR to be re-initialized at the start of the PAYLOAD. The register bit WHITEN_PAYLOAD_REINIT, when 1, will result in the LFSR being re-initialized to its programmed initial state, determined by WHITEN_SEED[8:0], coincident with the first bit of the first byte of PAYLOAD. This applies to both TX and RX. When WHITEN_PAYLOAD_REINIT=0, there is no such re-initialization. This feature is only relevant when whitening/de-whitening is programmed to start before the PAYLOAD, i.e., WHITEN_START=1 or WHITEN_START=2.

The RBME provides a number of other configurability options, which affect the internal operation of the CRC engine, and not the Link Layer controller. A listing of these registers which affect CRC internal operation, appears in the table below. For more details on how these registers affect CRC operation, see the CRC/Whitener Chapter.

CRC-related Register	Brief Description
CRC_POLY[31:0]	CRC Polynomial 1: XOR exists in the bit's feedback path 0: no XOR in the bit's feedback path
CRC_SEED[31:0]	CRC Initialization Value
CRC_BYTE_ORD	0: LS Byte First 1: MS Byte First
CRC_REF_IN	0: do not manipulate input data stream 1: reflect each byte in the input stream bitwise
CRC_REF_OUT	0: do not manipulate CRC result 1: CRC result is to be reflected bitwise (operated on entire word)
CRC_XOR_OUT[31:0]	XOR mask for CRC result (for no mask, should be 0)

Similarly, there are a number of configurable whitening options provided by the RBME, which affect the internal operation of the whitening engine, and not the Link Layer controller. A listing of these registers which affect whitener internal operation, appears in the table below. For more details on how these registers affect whitener operation, see the CRC/Whitener Chapter.

Whitener-related Register	Brief Description
WHITEN_ POLY[8:0]	Polynomial Value for Whitening/De-whitening
WHITEN_POLY_TYPE	Whiten polynomial type. A Fibonacci type LFSR is used with the whiten polynomial if this bit is asserted. Otherwise, a Galois type LFSR is used.
WHITEN_SEED[31:0]	Initialization Value for Whitening/De-whitening
WHITEN_SIZE[3:0]	Whitener Length
WHITEN_REF_IN	The input data stream is reflected, bit-wise, per byte, if this bit is asserted. Bit 7 becomes bit 0, bit 6 becomes bit 1, etc. This bit will only cause the reflection of the payload data bits as they are used in the whiten calculation and will not cause any change in the output bit order.

52.4.4.4.2.2.3 Fixed Packet Length

The GENERIC_FSK Link Layer controller expects a stream of consecutive bits specifying the length of the packet, to be transmitted and received over-the-air, as part of the packet bitstream, with the length specification typically encoded into the packet header, as shown below.

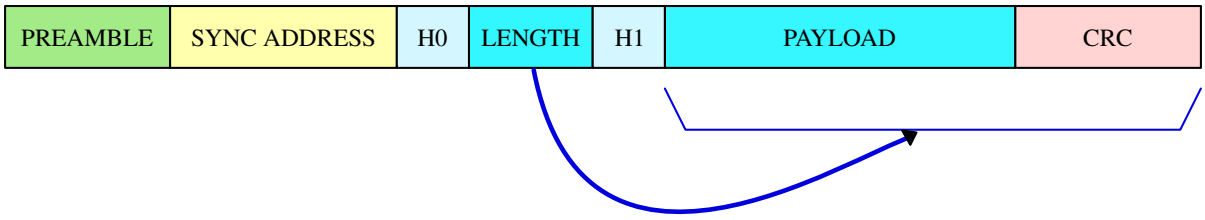

Figure 456. PACKET STRUCTURE WITH LENGTH FIELD IN HEADER

Some protocols don't include any length instructions in the packet header, as shown below.

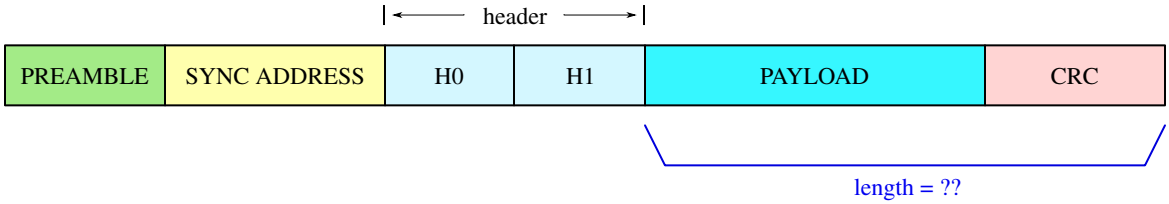

Figure 457. PACKET STRUCTURE WITH NO LENGTH FIELD IN HEADER

And, some protocols may not include a header at all.

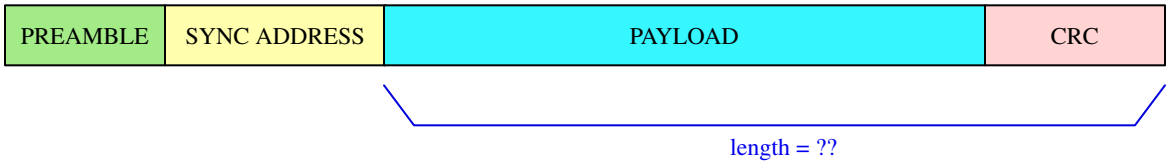

Figure 458. PACKET STRUCTURE WITH NO HEADER

In the aforementioned cases, another method of specifying length to the GENERIC_FSK Link Layer hardware must be employed. In both cases, if the length is not specified as part of the over-the-air bitstream, then GENERIC_FSK software must know the length in advance of the TX or RX operation, or know how to calculate it. So GENERIC_FSK software will provide this information to the hardware, in advance of the TX or RX operation, by programming the following registers:

- PACKET_CFG[LENGTH_SZ] = 0 : instructs the hardware that there is no LENGTH info in the packet header, and thus forces the hardware to use LENGTH_ADJ for packet length
- PACKET_CFG[LENGTH_ADJ] = ??? : program the desired (known) length of PAYLOAD + CRC
- CRC_CFG[CRC_SZ] = ??? : program the desired number of CRC octets

As an example, a packet is to be transmitted or received using the GENERIC_FSK Link Layer hardware. The packet has no header, but the length of the payload is known in advance to be 57 octets, and the number of CRC octets is 3. In this case, LENGTH_ADJ is programmed to 60 (57 + 3) and CRC_SZ is programmed to 3, as shown below.

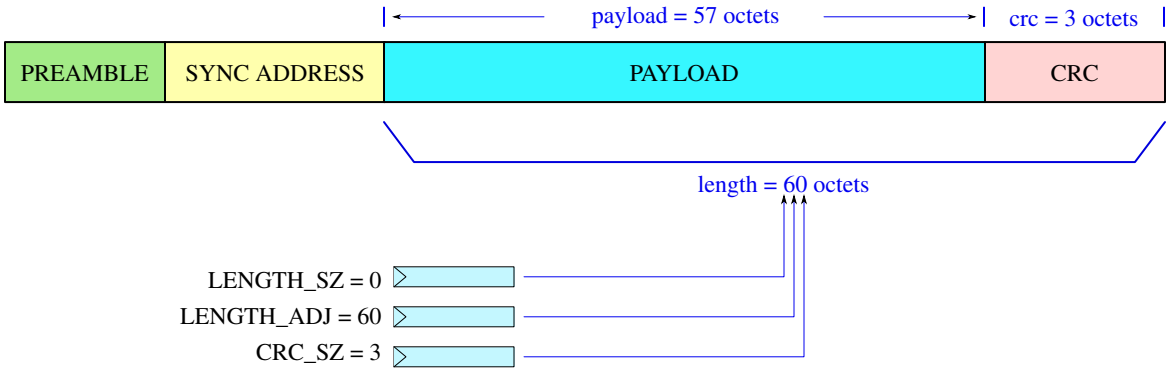

Figure 459. PACKET STRUCTURE WITH NO HEADER AND FIXED PACKET LENGTH

52.4.4.4.2.2.4 Packet Storage

The GENERIC_FSK Link Layer has access to a Packet Buffer (also known as Packet RAM), to store data to be transmitted, and to receive incoming packet data. The GENERIC_FSK Link Layer software prepares data to be transmitted, by loading the octets, in order, into the Packet Buffer. After reception, the octets received over the air are stored into the Packet Buffer, in the order they are received. The Packet Buffer contains separate spaces for TX and RX data, so incoming receive octets don't overwrite previously-loaded content intended for transmission. The Packet Buffer is large enough to accommodate the longest GENERIC_FSK packet, 2047 octets, plus header and CRC octets, for either transmit or receive.

The GENERIC_FSK Packet Buffer is contained within the multi-protocol Packet RAM. When operating in GENERIC_FSK mode, the entire Packet RAM is allocated to the GENERIC_FSK packet buffer. Separate TX and RX buffers within the consolidated RAM means that incoming RX packets don't overwrite TX packet data. Because the Packet RAM is 32/64bits wide, the GENERIC_FSK Link Layer controller hardware will address the consolidated RAM in an interleaved fashion as it stores octets to, or fetches octets from, the RAM-based packet buffer.

During packet reception, the MCU is allowed to access the RX packet buffer of the consolidated RAM, in order to download the packet while it's being received, if so desired. In cases where both the MCU and the GENERIC_FSK Link Layer controller attempt to simultaneously access the RAM during reception, internal hardware arbitration is provided to delay the MCU access until the GENERIC_FSK Link Layer completes its access to the RAM. Link Layer accesses complete in a single reference oscillator clock period, so one and only 1 wait state shall be inserted on the IPS bus whenever access attempts coincide.

During packet transmission, MCU access to the consolidated RAM is not allowed. The GENERIC_FSK software must program the TX buffer before commanding a TX operation, and must not access the RAM during the transmission.

As mentioned previously, incoming receive data lands in the RX section of the Packet Buffer. Nominally, a newly received packet will overwrite the contents of the previously received packet (the TX section of the Packet Buffer remains intact). Software can inhibit receive-packet overwriting of the RX section of the Packet Buffer contents by setting the PB_PROTECT bit in the PACKET_RAM_CTRL register. When this bit is set, incoming receive data will be blocked from overwriting the existing contents of the RX section of the Packet Buffer. This will block RX packet overwriting, but will not inhibit TX content loading of the TX section of the Packet Buffer.

GENERIC_FSK software must not attempt to access the Packet RAM unless GENERIC_FSK Link Layer is the controlling Link Layer.

When using another Link Layer, if the GENERIC_FSK Link Layer software attempts to access the Packet RAM via the GENERIC_FSK IPS bus, the access attempt will fail, as described below:

1. RAM contents shall not be altered on a GENERIC_FSK write attempt
2. Readback data on a GENERIC_FSK read attempt shall be indeterminate
3. The **ips_xfr_err** shall be asserted on the GENERIC_FSK IPS bus

52.4.4.4.2.2.5 Send and Receive multiple packets

The feature of "Send and Receive multiple packets" is enabled by setting the register MULT_PKT_EN.

To support this, the Tx and Rx RAM are divided into segments with same size. The segment size is defined by register SEG_SZ.

The first packet received is stored in the Segment 0. The second packet is stored in Segment 1, and so on. Register PKT_INDEX is initially 0 and is automatically increased by 1 after successfully received a packet. So PKT_INDEX has two meanings: the number of packet received; the segment number to store the next coming packet.

Tx is like the Rx process. The first packet to sent is placed in Segment 0. After transmitted the first packet, the PKT_INDEX is automatically increased to 1, and so on. So PKT_INDEX has two meanings in Tx: the number of packet sent; the segment number to send the next packet.

User should monitor the PKT_INDEX to avoid it moves to outside of Tx/Rx RAM.

User should write RESET_PKT_IDX to clear the PKT_INDEX to 0 before the round of packet reception.

Figure 460 shows an example of 8 packets. After received or sent 8 packets, the PKT_INDEX is increased to 8. If user wants to start another around, the PKT_INDEX should be cleared to 0.

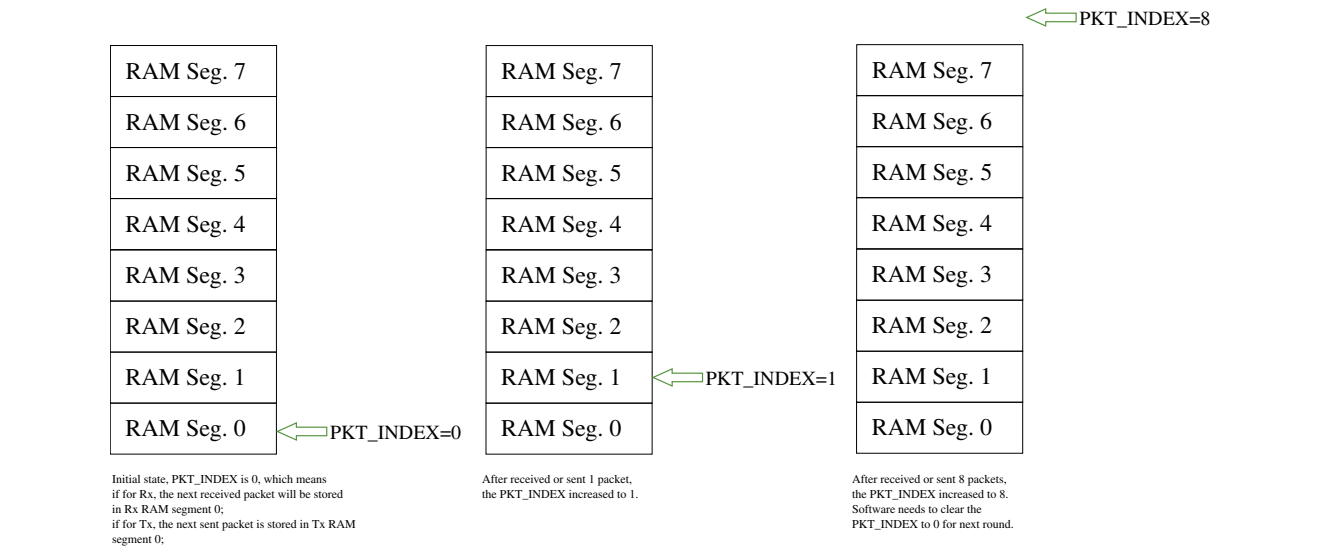

Figure 460. Send or Receive 8 packets

Notes:

1. If a packet is received with error, like CRC fail, and this fail causes the link layer to recycle, the PKT_INDEX will not be increased. This means link layer ignores the current received packet
2. For Rx with AutoACK case, the PKT_INDEX is increased after Rx is done. The AutoACK packet is not effected by PKT_INDEX. It is always in the dedicated RAM.
3. For TR case, the PKT_INDEX is increased after the TR sequence end. The T and R sequence use the same PKT_INDEX to determine the segment to send or receive a packet.

52.4.4.4.2.2.6 Timebase

The GENERIC_FSK Link Layer includes a dedicated, 32-bit multi-purpose Event Timer (EVENT_TMR), that is updated at a 1 MHz rate. The EVENT_TMR maintains the timebase for all GENERIC_FSK-related activities, except during intervals of Deep Sleep Mode. The clock source for the EVENT_TMR is a high-precision, crystal-referenced RF Oscillator, which can be either 32MHz or 26MHz. The RF Oscillator is divided down to 1MHz for GENERIC_FSK in the Clocks Generation Module (CGM). To reduce power consumption to a minimum, most of the GENERIC_FSK Link Layer Controller runs off this 1MHz clock. The exceptions are the Register IP bus interface, Command Decoder, and Interrupt Control Unit, parts of which must run at the IP bus frequency.

The 32-bit EVENT_TMR running at 1 MHz rolls over (wraps around) approximately every 4295 seconds.

The EVENT_TMR count can be read at any time, via the register of the same name. A 32-bit read is recommended to ensure coherency of the 4 bytes that make up the counter. No synchronization to the IP bus is required.

If the EVENT_TMR needs to be updated (changed), this can be done by writing the new, desired EVENT_TMR value to the register EVENT_TMR_LD. The update to EVENT_TMR will take effect at the next 1MHz clock edge.

If it is desired to increment the EVENT_TMR by a known amount, this can be done by writing the desired increment value to the EVENT_TMR_ADD register. The increment value is 32-bit signed, thus enabling a decrement function as well. The update to EVENT_TMR will take effect immediately. The EVENT_TMR_ADD avoids the necessity to perform an read-modify-write operation to the EVENT_TMR to adjust its value; this facilitates accurate restoration of the EVENT_TMR state after a period of Deep Sleep Mode.

Two 32-bit timer-compare registers are provided, T1_CMP and T2_CMP.

GENERIC_FSK software may load T1_CMP with a future EVENT_TMR count value. When EVENT_TMR reaches the T1_CMP value, either (or both) of the following events can be triggered:

1. T1_IRQ (Interrupt)
2. Sequence Command Trigger (can automatically launch or stop a transceiver operation)

Similarly, GENERIC_FSK software may load T2_CMP with a future EVENT_TMR count value. When EVENT_TMR reaches the T2_CMP value, either (or both) of the following events can be triggered:

1. T2_IRQ(Interrupt)
2. Sequence Command Trigger (can automatically launch or stop a transceiver operation)

For either type of T1-triggered events to be enabled, i.e., interrupt or sequence-launch, set T1_CMP_EN=1 after loading T1_CMP with the desired value. If T1_CMP_EN=1, the T1_IRQ interrupt status bit will always become set on a T1 timer match. (Whether or not T1_IRQ generates an GENERIC_FSK Interrupt to the MCU depends on the settings of T1_IRQ_EN and GENERIC_FSK_IRQ_EN, see section: Interrupts). If T1_CMP_EN=0, neither an interrupt nor a sequence command can be triggered by a T1 match.

For either T2-triggered events to be enabled, i.e., interrupt or sequence launch, set T2_CMP_EN=1 after loading T2_CMP with the desired value. If T2_CMP_EN=1, the T2_IRQ interrupt status bit will always become set on a T2 timer match. (Whether or not T2_IRQ generates a GENERIC_FSK Interrupt to the MCU depends on the settings of T2_IRQ_EN and GENERIC_FSK_IRQ_EN, see Section: Interrupts). If T2_CMP_EN=0, neither an interrupt nor a sequence command can be triggered by a T2 match.

See Section Interrupts for a description of how the Link Layer Controller manages the T1 and T2 interrupts, and how software can clear them.

See Section Sequence Manager for a description on how to launch and stop sequences on T1 and T2 timer matches.

52.4.4.4.2.2.7 Sequence Manager

52.4.4.4.2.2.7.1 Introduction

This Section describes the Generic Link Layer Sequence Manager (GSM).

52.4.4.4.2.2.7.1.1 Overview

The GSM is a hardware state machine which controls the timing of all transmit, receive, and CCA operations for the Link Layer.

Designed into the GSM are a variety of complex sequences, called autosequences, which are sequential concatenations of simpler, building-block sequences. The hardware autosequences provide the following advantages:

- smaller SW memory footprint: HW automates operations previously done by SW
- increases MCU sleep times, reducing current consumption
- handles timing-critical sequences (rx-to-tx), e.g., data-polling, not possible in SW

Sequences can be initiated by software directly, or alternatively, can be initiated automatically at the expiration of a hardware timer. The general parameters of the sequences can be programmed by software prior to initiating the sequences. Such parameters allow software to select, for example:

- whether CCA is required ahead of a transmit sequence
- whether an automatic Ack frame should be transmitted after a receive sequence
- slotted vs. unslotted mode
- whether the device is a PAN Coordinator or not
- whether the device resides on 2 networks simultaneously (Dual PAN mode)

52.4.4.4.2.2.7.1.2 Features

- Supports many working modes, defined by register GENLL_MODE
- Supports complex sequences
- Unburdens software by automating many transceiver operations
- Data-polling accelerator hardware enables critical-timing sequences
- Includes capability to conditionally perform CCA prior to every transmit operation
- Includes capability to conditionally transmit an Ack frame after every receive operation
- Supports software- or timer-initiated sequences
- Broad support of 2FSK/GFSK PHYs in IEEE 802.15.4-2015
- Supports slotted and unslotted modes
- Supports orderly transceiver shutdown on PLL unlock event
- Increases software visibility by making SEQ_STATE state readable
- Supports Dual PAN Mode, including on-the-fly channel changing

52.4.4.4.2.2.7.1.3 Modes and operations

The GSM controls, coordinates, and automates all transceiver operations within the 2.4GHz radio. Software selects the desired sequence, sets the general parameters, and (optionally) configures a hardware timer to trigger the sequence at a precise time in the future. Subsequently, the MCU can enter a low-power state, or tend to other activities, while the sequence manager state machine conducts the programmed transceiver operations. When the sequence completes, an interrupt alerts the MCU. At this point the MCU can check the completion status of the sequence, download received data from the packet buffer, and then prepare the next sequence. Sequences can be simple transceiver operations. For example, transmit one frame, or, perform a CCA on a channel. Alternatively, the sequence manager supports complex sequences, which use simple operations as building blocks, strung together in a back-to-back fashion, with precise timing intervals between operations. For example, a "TR" sequence calls for a transmit frame followed by a receive frame. For complex sequences, interrupts can optionally be generated at the completion of each stage of the sequence, providing greater visibility for the MCU into the timeline of the sequence. Software can determine the precise state of the sequence manager state machine at any time. Software can opt to abort a sequence at any time; when this happens, the sequence manager will return to its IDLE state in an orderly fashion.

52.4.4.4.2.2.7.2 Functional Description

The GSM provides a command set of transceiver commands, which can be used to launch and stop sequences. Software can issue sequence commands by writing to the SEQCMD(XCVSEQ) field of the XCVR_CTRL register. The SEQCMD field always reads back what was previously written by software, enabling software to quickly recall the last command written. The sequence commands are as listed in the table below:

SEQCMD[3:0]	COMMAND	DESCRIPTION
0x0	IDLE	Abort All - Cancels all pending events and abort any sequence-in-progress

Table continues on the next page...

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SEQCMD[3:0]	COMMAND	DESCRIPTION
0x1	TX_START_NOW	TX Start Now
0x2	TX_START_T1	TX Start @ T1 Timer Compare Match (EVENT_TMR = T1_CMP)
0x3	TX_START_T2	TX Start @ T2 Timer Compare Match (EVENT_TMR = T2_CMP)
0x4	TX_CANCEL	TX Cancel -- Cancels pending TX events but do not abort TX-in-progress[1]
0x5	RX_START_NOW	RX Start Now
0x6	RX_START_T1	RX Start @ T1 Timer Compare Match (EVENT_TMR = T1_CMP)
0x7	RX_START_T2	RX Start @ T2 Timer Compare Match (EVENT_TMR = T2_CMP)
0x8	RX_STOP_T1	RX Stop @ T1 Timer Compare Match (EVENT_TMR = T1_CMP)
0x9	RX_STOP_T2	RX Stop @ T2 Timer Compare Match (EVENT_TMR = T2_CMP)
0xA	RX_CANCEL	RX Cancel -- Cancels pending RX events but do not abort RX-in-progress[2]
0xB	ABORT	Abort All - Cancels all pending events and abort any sequence-in-progress
0xC	TR_START_NOW	TR Start Now
0xD	TR_START_T1	TR Start @ T1 Timer Compare Match (EVENT_TMR = T1_CMP)
0xE	TR_START_T2	TR Start @ T2 Timer Compare Match (EVENT_TMR = T2_CMP)
0xF	TR_CANCEL	TR Cancel -- Cancels pending TR events but do not abort TR-in-progress[3]
0x10	CCA_NOW	CCA Start Now
0x11	CCA_START_T1	CCA Start @ T1 Timer Compare Match (EVENT_TMR = T1_CMP)
0x12	CCA_START_T2	CCA Start @ T2 Timer Compare Match (EVENT_TMR = T2_CMP)
0x13	CCA_CANCEL	CCA Cancel -- Cancels pending CCA events but do not abort CCA-in-progress[4]

1. TX-in-progress implies TX Warmup is complete, and packet transmission is underway (i.e., command decoder state = TX_PKT)
2. RX-in-progress implies RX Warmup is complete, and Network Address search or packet reception is underway (i.e., command decoder state = RX_PKT)
3. TR-in-progress implies TX Warmup is complete, and packet transmission is underway (i.e., command decoder state = TX_PKT). For CCA+TX case, if cancel command is issued at CCA phase, then need to wait CCA complete, the following TX is cancelled.
4. CCA-in-progress implies RX Warmup is complete(i.e., command decoder state = RX_CCA1/RX_CCA2/CCA2_WAIT))

As described above, sequences can be launched immediately (actually on the next 1MHz clock edge) by issuing one of the following commands:

- TX_START_NOW
- RX_START_NOW
- TR_START_NOW
- CCA_START_NOW

Alternatively, sequences can be scheduled to launch (or stop) in the future on a T1 timer compare, by loading T1_CMP with the desired launch time (relative to the EVENT_TMR), setting T1_CMP_EN=1, and then issuing one of the following commands:

- TX_START_T1
- RX_START_T1
- RX_STOP_T1
- TR_START_T1
- CCA_START_T1

Similarly, sequences can be scheduled to launch (or stop) in the future on a T2 timer compare, by loading T2_CMP with the desired launch time (relative to the EVENT_TMR), setting T2_CMP_EN=1, and then issuing one of the following commands:

- TX_START_T2
- RX_START_T2
- RX_STOP_T2
- TR_START_T2
- CCA_START_T2

Any transceiver sequence that has been launched, either immediately (by way of the *_NOW commands), or in the future (by way of the *_T1 or *_T2 commands), can be terminated immediately by issuing the ABORT/IDLE command. This is true whether or not the sequence has actually begun, or is merely pending because the T1- (or T2-) match has not yet occurred. In either case, this is called a software abort. The ABORT/IDLE command will terminate any active sequence and cancel any pending events.

Regarding the issuance of sequence commands, both immediate and timer-triggered, software should be mindful of the following Guidelines and Restrictions:

PROGRAMING GUIDELINES AND RESTRICTIONS	
1	T1 can only be assigned to 1 function at a time {TX_START, RX_START, RX_STOP, TR_START, CCA_START}. Once assigned to a function, attempts to change the assignment will be ignored
2	T2 can only be assigned to 1 function at a time {TX_START, RX_START, RX_STOP, TR_START, CCA_START}. Once assigned to a function, attempts to change the assignment will be ignored
3	To change a T1- or T2- assignment, do one of the following first: **a.** issue an ABORT or IDLE command **b.** issue an TX_CANCEL command if T1 (or T2) is already assigned to TX_START, and the sequence has not yet started **c.** issue an RX_CANCEL command if T1 (or T2) is already assigned to RX_START or RX_STOP, and the sequence has not yet started **d.** issue an TR_CANCEL command if T1 (or T2) is already assigned to TR_START, and the sequence has not yet started **e.** issue an CCA_CANCEL command if T1 (or T2) is already assigned to CCA_START, and the sequence has not yet started
4	T1 and T2 should not be assigned to the same function (results are indeterminate)

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PROGRAMING GUIDELINES AND RESTRICTIONS	
5	If T1 and T2 are both assigned to functions, then T1_CMP shall not be equal to T2_CMP (results are indeterminate)
6	If any TX or RX or TR or CCA sequence is underway (e.g., TSM not idle), the ongoing sequence will not be interrupted or perturbed by any of the following: **a.** a T1 timer-match with T1 assigned to a function. The sequence trigger will be ignored, but the associated "pending" status bit will be cleared. **b.** a T2 timer-match with T2 assigned to a function. The sequence trigger will be ignored, but the associated "pending" status bit will be cleared. **c.** a TX_START_NOW or RX_START_NOW or TR_START_NOW or CCA_START_NOW command. Both commands will be ignored

The GSM controls high-level autosequence timing, but offloads low level warmup and warmdown tasks to a dedicated, protocol-neutral Transceiver Sequence Manager, or TSM (see TSM Chapter). The GSM initiates high-level functions, such as a CCA measurement operation or a transmit acknowledge operation, by commanding the TSM to execute an RX warmup, a TX warmup, a RX warmdown, a TX warmdown, or an RX recycle. Based on these commands, TSM generates the precise timing to control all of the digital, analog, and RF components of the TX and RX chains. The TSM is fully programmable, allowing all of the enabling and control signals to the transceiver components to be independently scheduled with 1us precision. TSM also allows all enable and control signals to be optionally overridden at any time, giving software complete control of each transceiver block, and ultimately the entire warmup/warmdown process if desired.

The GSM and TSM sequence managers operate on the same clock domain, and both have 1us resolution. The TSM is fully programmable, while the GSM is largely hardwired, with a few key exceptions. In the GSM/TSM relationship, GSM is the master and TSM is the slave. The key GSM/TSM interface signaling is shown below:

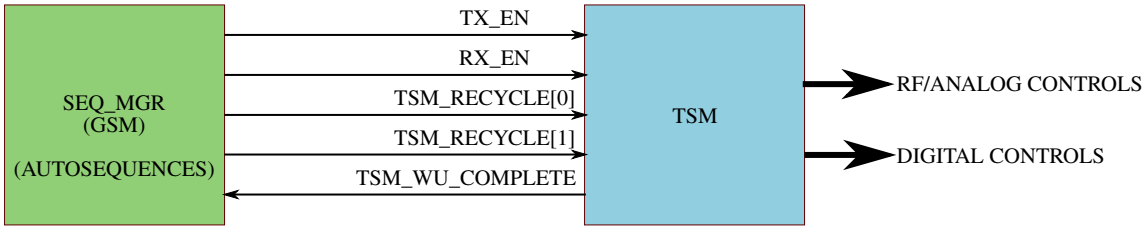

Figure 461. GSM/TSM INTERFACE SIGNALS

A description of the interface signals is provided in the table below.

GSM/TSM INTERFACE SIGNAL	DESCRIPTION
TX_EN	A low-to-high transition initiates a TSM TX warmup, starting 1us after the transition. A high-to-low transition initiates a TSM TX warmdown, starting 1us after the transition.
RX_EN	A low-to-high transition initiates a TSM RX warmup, starting 1us after the transition. A high-to-low transition initiates a TSM RX warmdown, starting 1us after the transition.
TSM_RECYCLE[0]	This signal asserts in the GSM RX_CYC state, and causes the TSM to jump from its "ON" phase, back to a point in the TSM RX warmup determined by

Table continues on the next page...

Table continued from the previous page...

GSM/TSM INTERFACE SIGNAL	DESCRIPTION
	the TSM's RECYCLE_COUNT0[7:0] register in XCVR space. This process is used to execute an RX recycle.
TSM_RECYCLE[1]	This signal asserts in the GSM RX_PAN1 state, and causes the TSM to jump from its "ON" phase, back to a point in the TSM RX warmup determined by the TSM's RECYCLE_COUNT1[7:0] register in XCVR space. This process is used to re-initialize the PLL digital on a new RF channel, during a Dual PAN mode on-the-fly channel change.
TSM_WU_COMPLETE	For the GSM states which assert TX_EN or RX_EN, this 1us-wide signal from the TSM indicates that the warmup is complete, and the GSM is now free to advance to its next state. The TSM_WU_COMPLETE is asserted 1us before the actual end of sequence, which is determined by the END_OF_TX_WU[7:0] register for TX warmup, and the END_OF_RX_WU[7:0] register for RX warmup.

The Command Decoder also maintains an set of status bits, that make it easy for Link Layer software to track, not only state, but pending events; that is, timer-linked events scheduled for future triggering. These status bits reside in the SEQ_STS register. A description of these bits is provided in the table below.

SEQSTS[12:0]	BIT	DESCRIPTION
TX_START_T1_PEND	[0]	TX Sequence will start @ next T1 Match
TX_START_T2_PEND	[1]	TX Sequence will start @ next T2 Match
TX_IN_WARMUP	[2]	TX Sequence in TSM Warmup
TX_IN_PROGRESS	[3]	TX Packet Transmission Currently Underway
TX_IN_WARMDN	[4]	TX Sequence in TSM Warmdown
RX_START_T1_PEND	[5]	RX Sequence will start @ next T1 Match
RX_START_T2_PEND	[6]	RX Sequence will start @ next T2 Match
RX_STOP_T1_PEND	[7]	RX Sequence will stop @ next T1 Match
RX_STOP_T2_PEND	[8]	RX Sequence will stop @ next T2 Match
RX_IN_WARMUP	[9]	RX Sequence in TSM Warmup
RX_IN_SEARCH	[10]	RX Sequence in Network Address Search
RX_IN_PROGRESS	[11]	RX Packet Reception Currently Underway
RX_IN_WARMDN	[12]	RX Sequence in TSM Warmdown
TR_START_T1_PEND	[13]	TR Sequence will start @ next T1 Match
TR_START_T2_PEND	[14]	TR Sequence will start @ next T2 Match
CCA_START_T1_PEND	[15]	CCA Sequence will start @ next T1 Match
CCA_START_T2_PEND	[16]	CCA Sequence will start @ next T2 Match

The GSM state diagram is shown below.

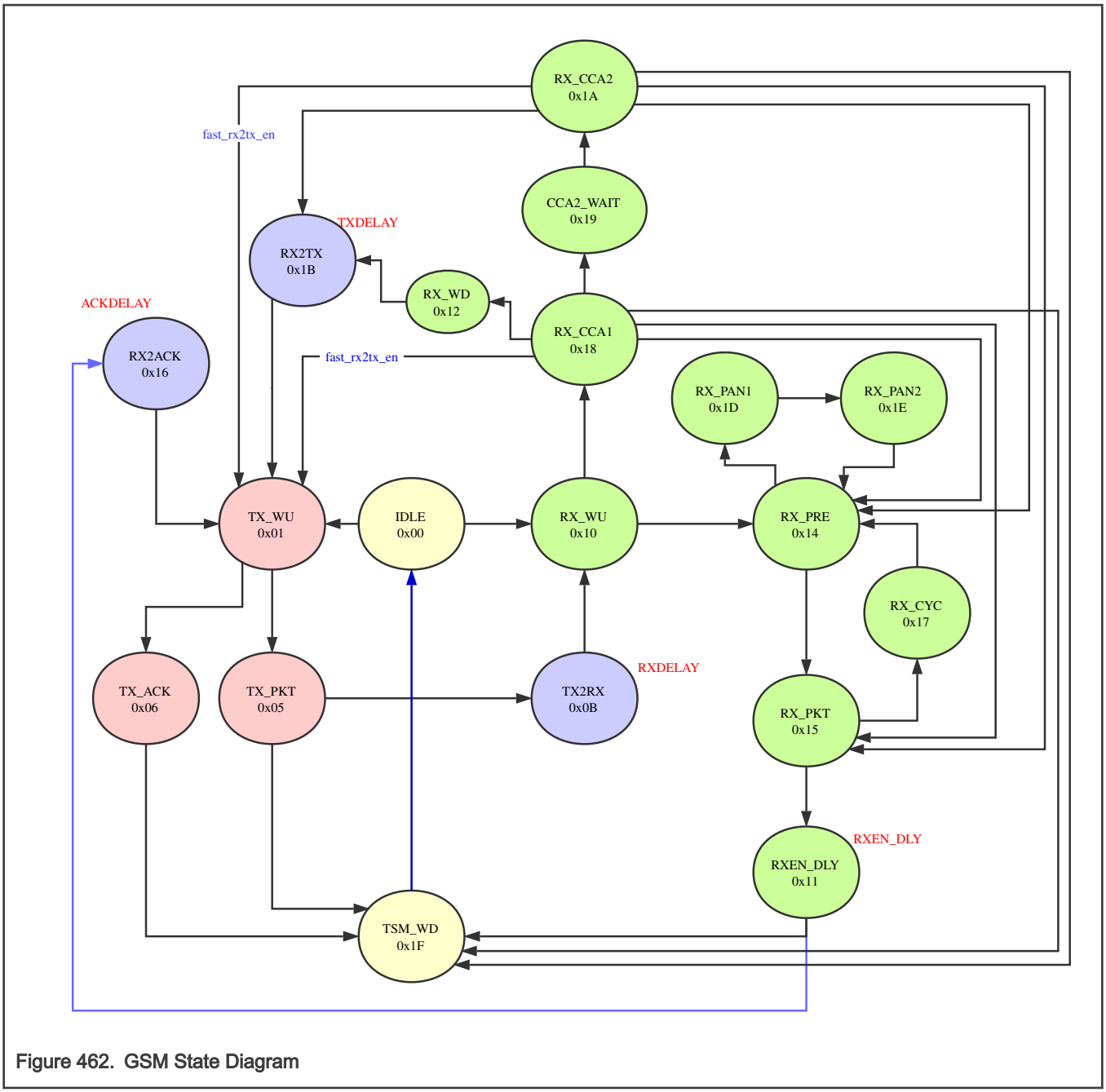

Figure 462. GSM State Diagram

Each GSM state is represented in the hardware by a 5-bit state vector. The GSM state can be monitored at any time by way of the read-only SEQ_STATE[4:0] register. The mapping of GSM state names to state vectors is shown in the table below:

GSM STATE	VECTOR
SEQ_IDLE	0x00
RX_WU	0x10
RX_PRE	0x14
RX_PKT	0x15

Table continues on the next page...

Table continued from the previous page...

GSM STATE	VECTOR
RX2ACK	0x16
RX_CYC	0x17
RX_PAN1	0x1D
RX_PAN2	0x1E
RX_CCA1	0x18
CCA2_WAIT	0x19
RX_CCA2	0x1A
RX_WD	0x12
RX2TX	0x1B
TX_WU	0x01
TX_PKT	0x05
TX_ACK	0x06
TX2RX	0x0B
TSM_WD	0x1F

52.4.4.4.2.2.7.2.1 Supported Sequences

52.4.4.4.2.2.7.2.1.1 Sequence I (Idle)

When the IDLE/ABORT value is written to XCVSEQ, the sequence manager goes to its SEQ_IDLE state. If not already in SEQ_IDLE, the sequence manager executes an orderly warmdown to return to SEQ_IDLE. A SEQIRQ interrupt is then issued. Writing IDLE/ABORT value to XCVSEQ is the proper way to abort a sequence.

When a sequence is aborted in this way (called a software abort), the SW_ABORTED bit will become set. This bit will be self-cleared at the start of the next autosequence.

52.4.4.4.2.2.7.2.1.2 Sequence R (Receive)

Sequence R can be lunched by command RX_START_*. Sequence R is the basic receive sequence.

In GLL mode, sequence R can be used to receive all frames.

In PAN mode, sequence R can be used to receive all types of PHY- and MAC-compliant frames, including reserved frame types. However, reception of Acknowledge frames is not recommended using Sequence R. This is because reception of an Acknowledge frame, usually follows a transmitted frame, with a designated Sequence Number, so that the received Acknowledge frame can be verified for the matching Sequence Number. In a standalone Sequence R, there is no Sequence Number to verify against, so any Acknowledge frame is merely transferred to the Packet RAM. (Note: the appropriate way to receive Acknowledge frames is with Sequence TR, with the RXACKRQD bit asserted). Using Sequence R, *all* frames which pass frame-filtering rules and CRC check, are transferred to the Packet RAM.

In FAN mode, sequence R can be used to receive all types of PHY- and FAN-compliant frames. Same as in PAN mode, it is recommended to use TR to receive Acknowledge frames.

The basic execution of a successful Sequence R in GLL/PAN/FAN mode is as follows:

- SEQ_MGR executes RxWarmup
- SFD Detected and received, transferred to Packet RAM
- Payload and CRC bytes received, transferred to Packet RAM.

- If no H0/H1/LENGTH violation and CRC check pass:
- And if frame-filtering rules(PAN rule) and PHR check pass:(PAN mode)
- And if frame-filtering rules(FAN rule) and PHR check pass:(FAN mode)
- ---> RXIRQ interrupt issued
- ---> SEQ_MGR executes RxWarmdown
- ---> If AUTOACK=1
- ---> And if received Frame Control Field indicates AckRequest=1 (PAN/FAN mode)
- ---- ---> SEQ_MGR executes TxWarmup
- ---- ---> an Ack frame is transmitted (programmed in Packet RAM) (GLL mode)
- ---- ---> an imm-Ack frame is transmitted using the received Sequence Number (PAN mode)
- ---- ---> an Enh-Ack frame is transmitted, with IEs and ASH field programmed in Packet RAM (FAN mode)
- ---- ---> SEQ_MGR executes TxWarmdown
- SEQIRQ interrupt issued

When Sequence R is initiated, the GSM sequence manager warms up the receiver (analog and digital elements), via the TSM (Transceiver Sequence Manager). Once a SFD is detected, the sequence manager's slot timer is activated. This is because a slotted "transmit acknowledge" frame (TxAck) may be required later in this sequence. The slot timer is loaded with the following value (in us):

Slot Timer Preload = SLOT_TIME - (PREAMBLE + SFD) + ACKDELAY

The slot timer will count down and eventually rollover at to 0, then to (SLOT_TIME-1). (There are SLOT_TIME us in a backoff slot).

The receiver receives the SFD octets . Starting with this octet, and continuing through the remainder of the frame, each octet that is received is transferred to Packet RAM. After each octet is transferred to Packet RAM, the Packet RAM address is incremented by 1.

During the reception, link layer will check the healthy of frame:

- CRC (all modes)
- H0/LENGTH_MAX/H1 violation (all modes)
- BCH/Parity fail (PAN/FAN mode)
- PAN packet-filtering rules (PAN mode)
- FAN packet-filtering rules (FAN mode)

Assuming no fail, an interrupt (RXIRQ) is issued to the MCU.

At this point, the sequence manager must determine if a TxAck is required. A TxAck is required if the following conditions are all met:

- AUTOACK=1 (register bit) (all modes)
- PROMISCUOUS=0 (register bit) (FAN and PAN mode)
- The received FrameControlField has AckRequest=1 (FAN and PAN mode)

If these conditions are met, and SLOTTED mode is not in effect, the sequence manager loads its TxAck timer with the following value (in us):

TxAck Timer Preload = TURNAROUND_TIME + ACKDELAY - TXWARMUPTIME

The TURNAROUND_TIME is the non-slotted RX-to-TX turnaround requirement in the 802.15.4 standard. The TXWARMUPTIME takes into account the fact that the TxAck timer must expire early for the Tx warmup to be complete at exactly the TURNAROUND_TIME us point. The ACKDELAY is a signed, fine-tune adjustment to the TxAck transmission time (+/-).

If SLOTTED mode is in effect, the slot timer was previously loaded (at SFD detect), but the sequence manager needs to determine how much time is left in the current backoff slot. If less than TURNAROUND_TIME remain, the sequence manager must wait an *additional* backoff slot before initiating the Ack transmission. So it sets a flag indicating it must allow the slot counter to rollover an additional iteration.

Finally, at TxAck timer expiration (in non-SLOTTED mode), or at the qualified rollover of the slot timer (in SLOTTED mode), a Tx warmup is initiated. The conclusion of the Tx warmup will coincide precisely with a backoff slot boundary if SLOTTED mode is in effect. The sequence manager will then initiate the transmission of the Ack frame.

In GLL mode, entire Ack frame should be programmed by software in Packet RAM.

In FAN mode, software should program ASH and IEs field in the Packet RAM and point out their total length in register LENGTH_ACK. The other part of the Enh-Ack frame are built up by hardware.

In PAN mode, entire Ack frame will be built up by hardware. The hardware will insert the following parameters into the Ack frame's Frame Control Field:

Table 549. Frame Control Field for Hardware-generated Auto-TxAck Frame (PAN Mode)

FCF Field	Value
FrameType	Acknowledge
SecurityEnabled	0
FramePending	Determined by the Packet Processor. (see Packet Processor Chapter, Source Address Management)
AckRequest	0
PanIDCompression	0
Reserved (bits 7-9)	000
DstAddrMode	0
FrameVersion	0
SrcAddrMode	0

The Sequence Number for the Ack packet, will be the Sequence Number obtained from the previously received frame.

Table 550shows the register bits used to control the Auto-Ack sequence in different modes.

Table 550. Auto-Ack Behavior and Register Setting(AUTOACK=1, SLOTTED=0/1)

Mode	GENLL_MODE[3:0]	SW_BUILD_ACK	ACKBUFSEL	LENGTH_ACK[10:0]	ACK Condition
GLL-ACK	0x0	0	ACK frame's SFD/H0/H1 field is from received frame. LENGTH field is from LENGTH_ACK. 0: Payload is in 64-byte dedicated RAM. 1: Payload is in TX RAM.	Payload length + CRC_SZ - LENGTH_ADJ	1. Pass CRC 2. Pass H0/H1/LENGTH_MAX check (No SAM)

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Table 550. Auto-Ack Behavior and Register Setting(AUTOACK=1, SLOTTED=0/1) (continued)

Mode	GENLL_ MODE[3:0]	SW_BUILD_ ACK	ACKBUFSEL	LENGTH_ACK[10:0]	ACK Condition
		1	ACK frame's SFD/H0/H1/LENGTH/ Payload field is from RAM 0: ACK frame is in 64-byte dedicated RAM. 1: ACK frame is in TX RAM.	Not used	
Imm-ACK	0x1 or 0x3	0	ACK frame's SFD is from received. HW build the PHR according to PHR type HW build the payload HW does not access RAM	Not used	1. Pass CRC 2. Pass H0/H1/LENGTH_MAX check 3. Pass PHR check 4. Is MAC-compliant 5. Is addressed to the device 6. Is DATA or CMD frame (Do SAM when is a data polling CMD frame)
		1	ACK frame's SFD/H0/H1/LENGTH/ Payload field is from RAM 0: ACK frame is in 64-byte dedicated RAM. 1: ACK frame is in TX RAM.	Not used	
Enh-ACK	0x2 or 0x3	0	ACK frame's SFD is from received HW build the PHR according to PHR type HW build part of the Payload 0: ASH and IEs is in 64-byte dedicated RAM. 1: ASH and IEs is in TX RAM.	ASH/IEs length	1. Pass CRC 2. Pass H0/H1/LENGTH_MAX check 3. Pass PHR check 4. Is FAN-compliant 5. Is addressed to the device (No SAM since FAN use DATA frame only.)
		1	ACK frame's SFD/H0/H1/LENGTH/ Payload field is from RAM 0: ACK frame is in 64-byte dedicated RAM. 1: ACK frame is in TX RAM.	Not used	

After the Ack frame has been transmitted, the sequence manager will issue a TXIRQ interrupt, and then perform a Tx warmdown. Finally, a SEQIRQ interrupt will be issued, and the sequence manager returns to SEQ_IDLE state.

Sequence R Timing Diagrams

The following timing diagram depicts an example of "good" packet reception, highlighting the following events:

1. AUTOACK=0, so no auto-TxAck
2. Software loads T2_CMP with desired RX start time, sets T2_CMP_EN=1
3. Software schedules RX sequence with RX_START_T2 command
4. EVENT_TMR matches T2_CMP, RX sequence starts automatically
5. Network Address search, followed by NTW_ADR_IRQ interrupt, TIMESTAMP capture
6. Packet reception, Generic_FSK LL write octets to Packet RAM
7. CRC verification passes, and no H0, H1, or LENGTH_MAX violations(GLL/PAN/FAN mode)

8. PHR verification passes(PAN/FAN mode)
9. Payload verification passes PAN rules(PAN mode)
10. Payload verification passes FAN rules(FAN mode)
11. RX_IRQ asserted, Packet RX RAM valid, RSSI valid
12. SEQ_END_IRQ asserts after TSM returns to IDLE (RX warmdown complete)

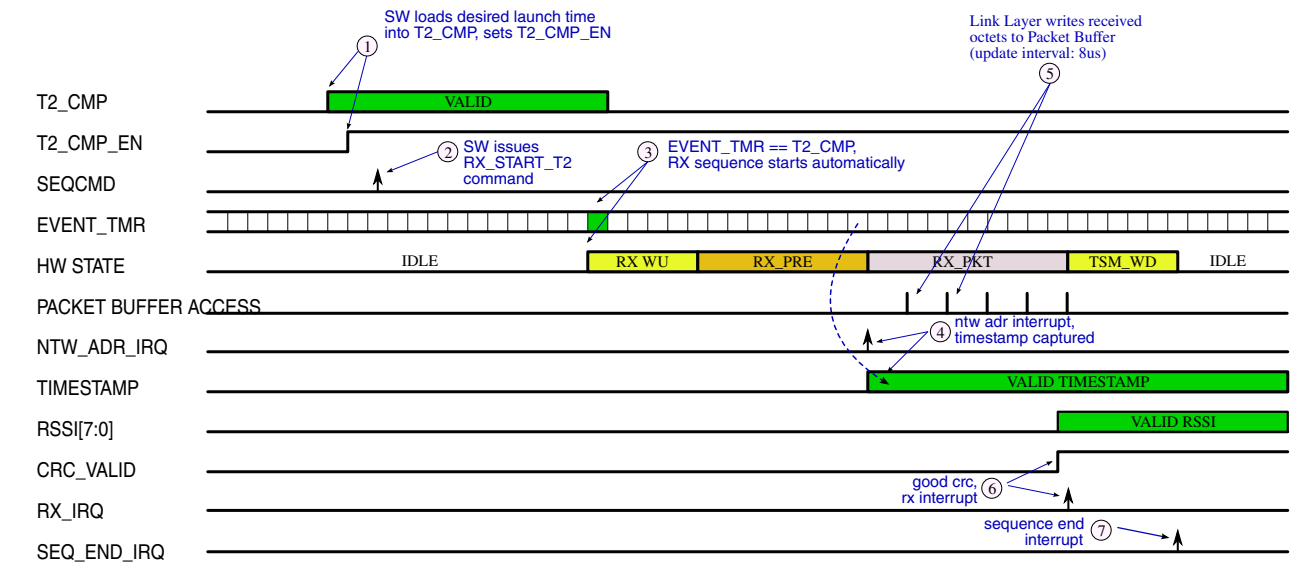


Figure 463. SEQUENCE R: LAUNCH VIA T2 TIMER, GOOD PACKET, AUTOACK=0 (All Modes)

The following timing diagram depicts an example of "good" packet reception, highlighting the following events:

1. Register RXEN_DLY is not zero and RXEN_DLY_OVERRIDE is one. After the last byte(determined by LENGTH field) of packet is received, the RX_EN signal will delay (RXEN_DLY +1) microseconds to de-assert
2. RX_IRQ asserted after the last byte(determined by LENGTH field) of packet is received.(if SEL_RXIRQ=0)
3. After extra packet received, RX_IRQ is asserted(if SEL_RXIRQ=1), GSM jumps to TSM_WD from RXEN_DLY.
4. SEQ_END_IRQ asserts after TSM returns to IDLE (RX warmdown complete)
5. **This RX mode is particularly suitable for protocols that have other fields after the CRC field. For example, the CTE(Constant Tone Extension) field in the Bluetooth LE 5.1 protocol.**

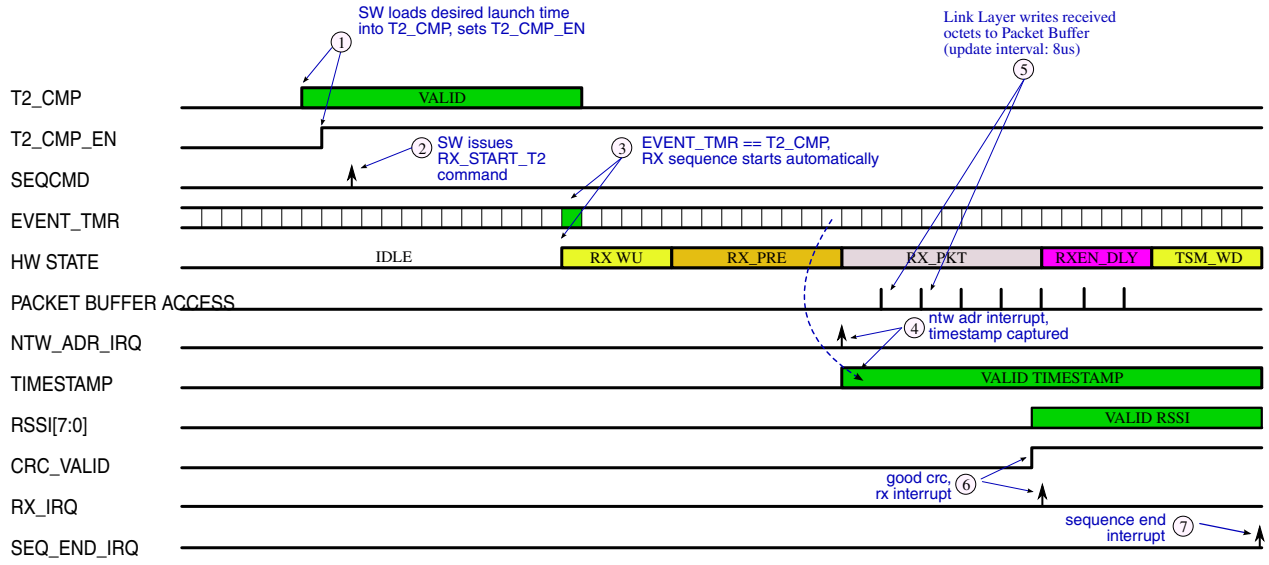


Figure 464. SEQUENCE R: RXEN DELAY (All Modes)

The following timing diagram depicts an example of "good" packet reception, highlighting the following events:

1. Register STAY_IN_RX is 1.
2. After packet received with CRC valid, GSM jumps to RX_CYC after RX_IRQ
3. This avoid the full RX re-warmup to facilitate sniffer SW.

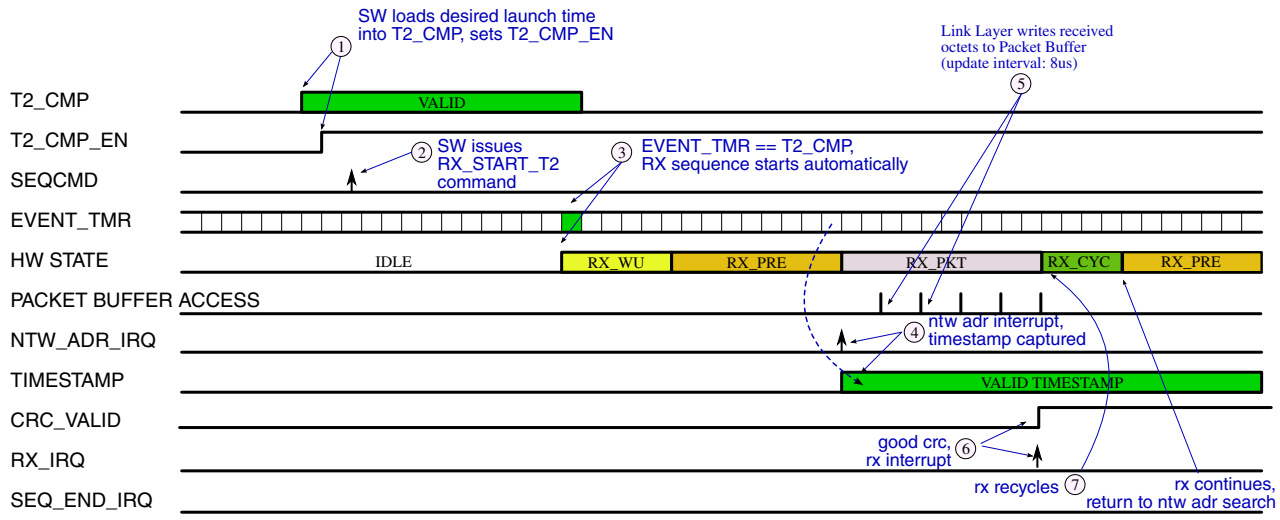


Figure 465. SEQUENCE R: STAY IN RX (All Modes)

The following timing diagram depicts an example of GENERIC_FSK "bad" packet reception, highlighting the following events:

1. Software loads T2_CMP with desired RX start time, sets T2_CMP_EN=1
2. Software schedules RX sequence with RX_START_T2 command

3. EVENT_TMR matches T2_CMP, RX sequence starts automatically
4. Network Address search, followed by NTW_ADR_IRQ interrupt, TIMESTAMP capture
5. Packet reception, Generic_FSK LL write octets to Packet RAM
6. CRC verification fails, no CRC_VALID, no RX_IRQ, RX Recycle
7. No SEQ_END_IRQ, return to Network Address Search

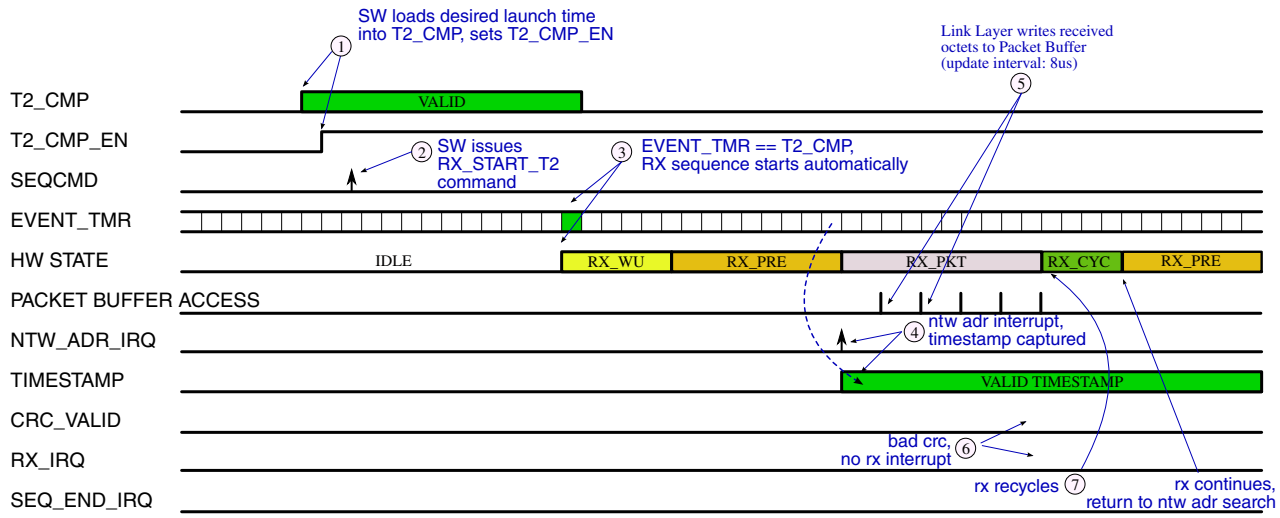


Figure 466. R SEQUENCE: LAUNCH VIA T2 TIMER, BAD PACKET, RX RECYCLE(All Modes)

The following timing diagram depicts a GENERIC_FSK RX search operation, which fails to detect a Network Address before timing out. The following events are highlighted:

1. Software loads T1_CMP with desired RX start time, sets T1_CMP_EN=1
2. Software loads T2_CMP with desired RX stop time, sets T2_CMP_EN=1
3. Software schedules RX sequence start with RX_START_T1 command
4. Software schedules RX sequence end with RX_STOP_T2 command
5. EVENT_TMR matches T1_CMP, RX sequence starts automatically
6. EVENT_TMR matches T2_CMP, RX sequence goes into warmdown automatically
7. SEQ_END_IRQ asserts to indicate TSM has returned to IDLE. No NTW_ADR_IRQ, No RX_IRQ.

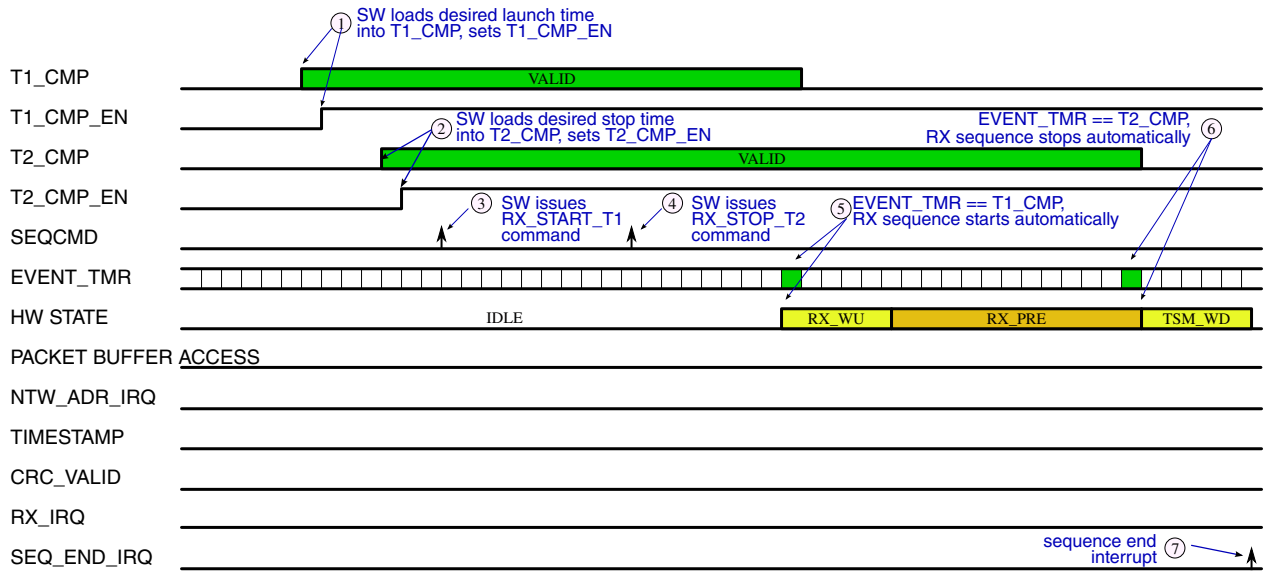


Figure 467. R SEQUENCE: SLAVE CHANNEL SEARCH, LAUNCH VIA T1, STOP VIA T2 (All Modes)

The following timing diagram depicts the GSM state transition of the Auto-Ack in PAN mode, highlighting the following events:

1. The Imm-Ack is built by hardware (SW_BUILD_ACK=0)
2. The Rx to TX time is TURNAROUND_TIME+ACKDELAY(±) (SLOTTED=0)
3. RX_IRQ is asserted when RX ends, TX_IRQ is asserted when TX ends, SEQ_END_IRQ is asserted when sequence finishes.

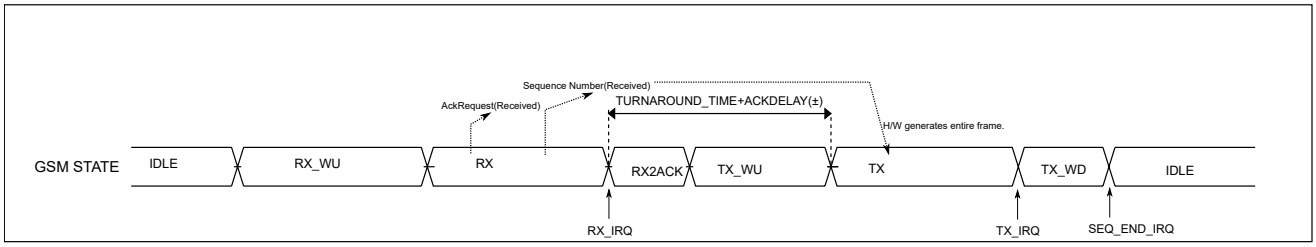


Figure 468. SEQUENCE R: Imm-Ack, SW_BUILD_ACK=0, SLOTTED=0, No SAM (PAN Mode)

The following timing diagram depicts the GSM state transition of the Auto-Ack in PAN mode, highlighting the following events:

1. The Imm-Ack is built by software in Packet RAM (SW_BUILD_ACK=1)
2. The Imm-Ack can be built by software at ACK_IRQ or any time before TX_PKT
3. ACK_IRQ are asserted when RX ends.

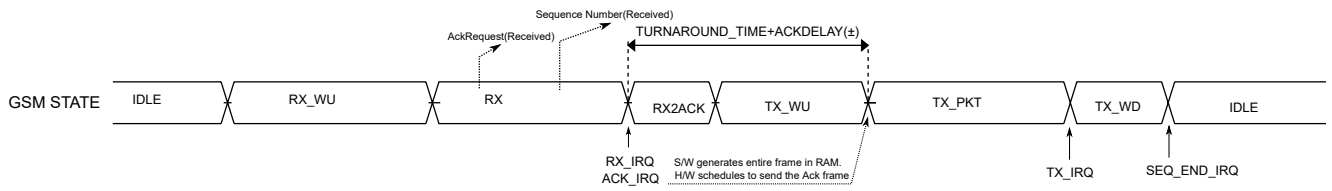


Figure 469. SEQUENCE R: Imm-Ack, SW_BUILD_ACK=1, SLOTTED=0, No SAM (PAN Mode)

The following timing diagram depicts the GSM state transition of the Auto-Ack in PAN mode, highlighting the following events:

1. The received frame is a data polling CMD frame, so Source Address Management is trigged.

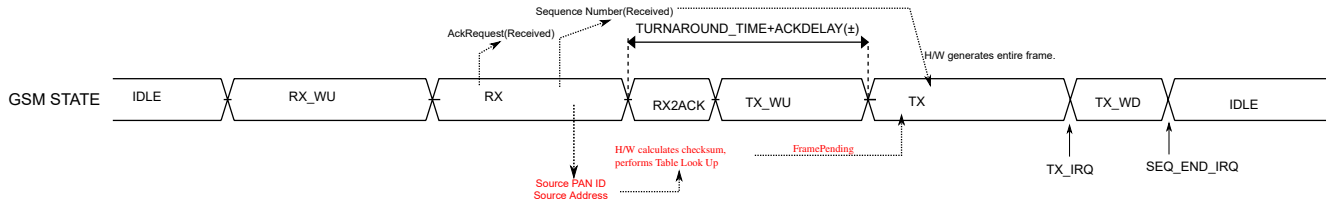


Figure 470. SEQUENCE R: Imm-Ack, SLOTTED=0, With SAM (PAN Mode)

The following timing diagram depicts the GSM state transition of the Auto-Ack in PAN mode, highlighting the following events:

1. The Slot Timer is preloaded at SFD detected with value SLOT_PRELOAD.
2. In Slot Mode, if the time between the RX END and next slot boundary is smaller than TURNAROUND_TIME, Link Layer will Tx-Ack at the next 2 slot boundary.

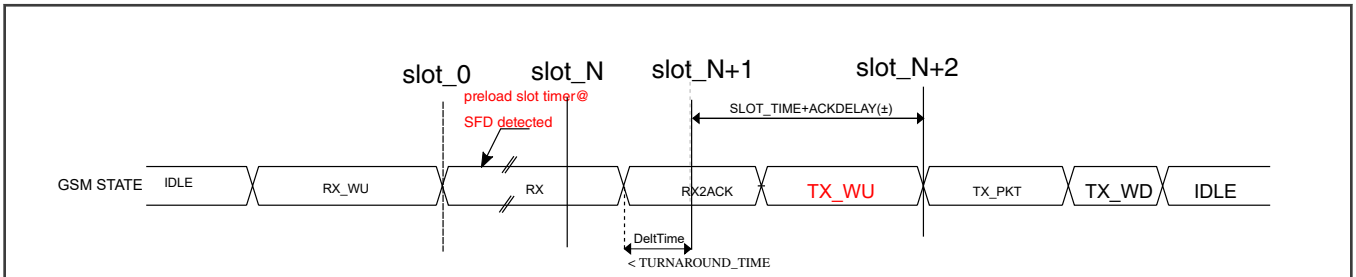


Figure 471. SEQUENCE R: Imm-Ack, SLOTTED=1, CASE 1(PAN Mode)

The following timing diagram depicts the GSM state transition of the Auto-Ack in PAN mode, highlighting the following events:

1. The Slot Timer is preloaded at SFD detected with value SLOT_PRELOAD.
2. In Slot Mode, if the time between the RX END and next slot boundary is larger than or equal to TURNAROUND_TIME, Link Layer will Tx-Ack at the next slot boundary.

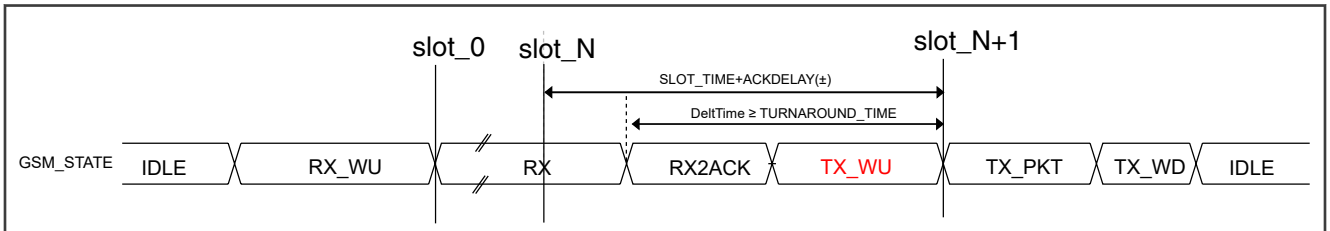


Figure 472. SEQUENCE R: Imm-Ack, SLOTTED=1, CASE 2 (PAN Mode)

52.4.4.4.2.2.7.2.1.3 Sequence T (Transmit)

Sequence T can be lunched by command TX_START_*. Sequence T is the basic, standalone transmit sequence.

Sequence T can be used to transmit all types of 802.15.4 PHY- and MAC-compliant frames. However, transmission of Acknowledge frames is not recommended using Sequence T. This is because transmission of an Acknowledge frame, usually follows a received frame, with a designated Sequence Number. The GSM sequence manager automates the transmission of an Ack frame which follows a received frame, using Sequence R with the AUTOACK bit asserted. This is the recommended method for transmitting an Ack frame. This is especially beneficial, because the transmitted Ack frame octets are generated by hardware, and so no setup of a transmit packet in Packet RAM, is required. However, sequence manager hardware does not prohibit Ack frames using Sequence T.

Sequence T allows for the insertion of 1 or 2 CCA (clear channel assessment) measurements prior to transmission, to ensure that the selected channel is idle. The CCA-before-TX feature is governed by two register bits, CCABFRTX and SLOTTED. All CCA measurements must indicate channel-idle, in order for the sequence manager to proceed to transmission; if the channel is determined by CCA to be busy, the sequence manager will terminate the sequence without a transmission. The number of CCA measurements attempted by the sequence manager, and the timing of the measurements, is shown in the following table.

Table 551. Timing of CCA Operations for Sequence T

CCABFRTX	SLOTTED	Number of CCA measurements	Timing of Initiation of CCA measurement #1	Timing of Initiation of CCA measurement #2	Timing of First Bit of Transmitted Frame (assumes channel idle)
0	X	0	-	-	Immediately follows TxWarmup
1	0	1	Immediately follows RxWarmup	-	Immediately follows RxWarmdown and TxWarmup
1	1	2	Immediately follows RxWarmup	SLOT_TIME us after Initiation of CCA measurement #1	SLOT_TIME us after Initiation of CCA measurement #2

CCA mode 1 can be used for Sequence T and Sequence TR.

The basic execution of a successful Sequence T is as follows:

- MCU sets CCABFRTX if one or more CCA's are required prior to transmit
- MCU sets SLOTTED if in slotted mode (2 CCA's will be attempted)
- MCU writes XCVSEQ = RX_START_*

- Wait for T1 or T2 match (if RX_START_T*)
- If CCABFRTX=1 :
- ---> SEQ_MGR executes RxWarmup
- ---> SEQ_MGR initiates CCA measurement (takes CCA_TIME us (CCA_TIME = SLOT_TIME - TURNAROUND_TIME))
- ---> if CCA indicates channel busy, sequence terminates, CCAIRQ & SEQIRQ issued
- ---> otherwise, if CCA indicates channel idle:
- ---- ---> if SLOTTED=0, SEQ_MGR executes a RxWarmdown, followed by a TxWarmup
- ---- ---> if SLOTTED=1, SEQ_MGR initiates a 2nd CCA, SLOT_TIME us after initiating 1st CCA.
- ---- ---> if SLOTTED=1, and channel busy, sequence terminates, CCAIRQ & SEQIRQ issued
- ---- ---> if SLOTTED=1, and channel idle, SEQ_MGR executes a RxWarmdown, followed by a TxWarmup
- if SLOTTED=1, SEQ_MGR waits until SLOT_TIME us elapse after 2nd CCA initiation
- SEQ_MGR executes TxWarmup
- Preamble transmitted
- SFD are obtained from Packet RAM and transmitted
- Payload are obtained from Packet RAM and transmitted
- After Payload octet transmitted, FCS is available from CRC engine.
- SEQ_MGR issues TXIRQ
- SEQ_MGR executes TxWarmdown
- SEQ_MGR issues SEQIRQ

When Sequence T is initiated, the sequence manager first must determine if one or more CCA measurements are required.

If CCABFRTX bit is asserted, the sequence manager warms up the receiver (analog and digital elements), via the TSM (Transceiver Sequence Manager). Immediately after the conclusion of the warmup, a CCA measurement is initiated. The CCA measurement takes CCA_TIME us. If CCA indicates the channel is busy, the sequence manager warms down the receiver, issues CCAIRQ and SEQIRQ interrupts, and terminates the sequence. If, however, CCA indicates the channel is idle, the sequence manager inspects the SLOTTED bit to determine what to do next.

If the SLOTTED bit is clear, the sequence manager issues a CCAIRQ interrupt, and then executes a warmdown of the receiver.

If, however, the SLOTTED bit is set, the sequence manager does not issue a CCAIRQ interrupt; instead, the sequence manager initiates a second CCA measurement, precisely SLOT_TIME us after the initiation of the first CCA. This SLOT_TIME us interval is timed by the slot timer, which had been preloaded with SLOT_TIME (microseconds) at the instant that Rx warmup was complete.

At the conclusion of the second CCA, the sequence manager issues a CCAIRQ. If the second CCA indicates the channel is busy, the sequence manager warms down the receiver, issues a SEQIRQ interrupt, and terminates the sequence. If, however, CCA indicates the channel is idle, the sequence manager executes a warmdown of the receiver. Prior to executing the warmdown, the sequence manager reloads the slot timer, in order to precisely schedule the ensuing transmission. This time, the slot timer is loaded with a smaller value, in order to account for the fact that the timer must expire early in order to trigger the Tx warmup, which must complete at precisely the next backoff slot boundary. Thus, this time the slot timer is preloaded with:

Slot Timer Preload = TURNAROUND_TIME - TXWARMUPTIME + TXDELAY.

The SLOT_TIME us is the duration of the backoff slot. The TXWARMUPTIME takes into account the fact that the TxAck timer must expire early for the Tx warmup to be complete at exactly the SLOT_TIME us point. The TXDELAY is a signed, fine-tune adjustment to the TxAck transmission time.

If the SLOTTED bit is asserted, once the slot timer expires, the sequence manager executes a Tx warmup. The conclusion of this warmup coincides with the backoff slot boundary. If the SLOTTED bit is deasserted, the sequence manager does not wait for the slot timer, and instead executes a Tx warmup immediately after the Rx warmdown.

At this point, the sequence manager begins the transmit operation. After the transmit operation is complete. The sequence manager issues a TXIRQ interrupt. The sequence manager then executes a complete Tx warmdown, and follows up with a SEQIRQ interrupt. The sequence manager returns to SEQ_IDLE state.

Sequence T Timing Diagrams

The following timing diagram depicts an example of packet transmission, highlighting the following events:

1. No CCA before TX
2. Software stores packet octets into Packet RAM, to be transmitted
3. Software loads T1_CMP with desired TX start time, sets T1_CMP_EN=1
4. Software schedules TX sequence with TX_START_T1 command
5. EVENT_TMR matches T1_CMP, TX sequence starts automatically
6. Link Layer reads octets from Packet RAM and sends to RBME when requested
7. Packet is transmitted at the end of TX_WU
8. TX_IRQ asserts after last bit of packet transmitted
9. SEQ_END_IRQ asserts after TSM returns to IDLE (TX warmdown complete)

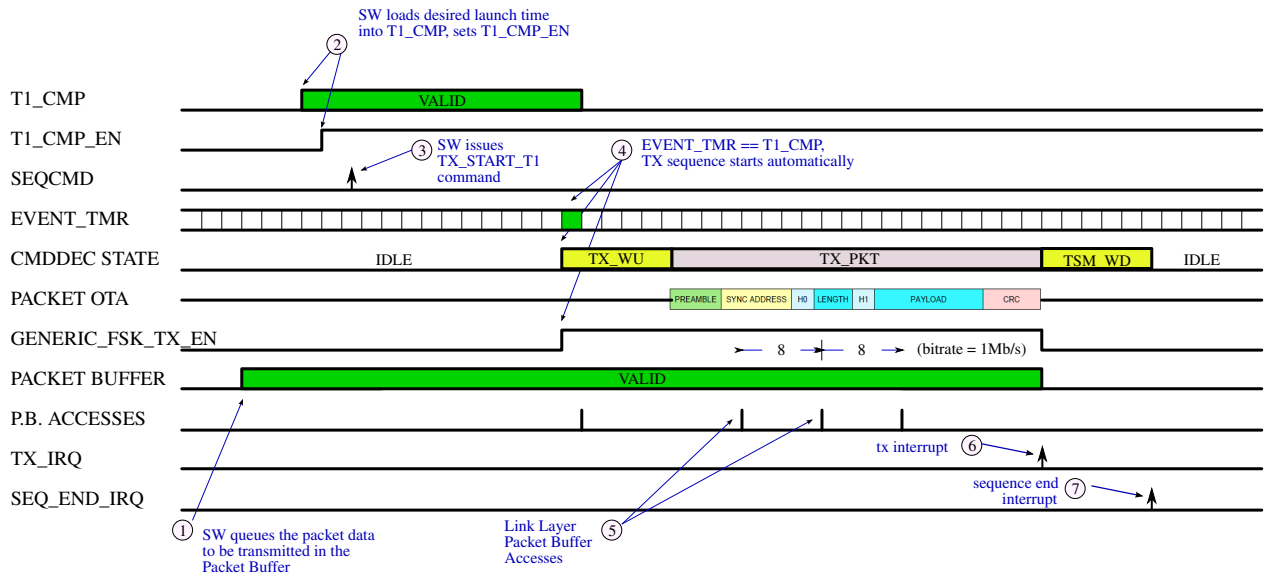


Figure 473. SEQUENCE T: LAUNCH VIA T1 TIMER

The following timing diagram depicts the GSM state transition of Tx, highlighting the following events:

1. Un-slotted mode with CCA before TX
2. The CCA measurement takes CCA_TIME us, the result shows IDLE channel
3. After CCA Rx warmdown, Link Layer inserts TXDELAY time (positive or zero) before Tx warmup
4. CCA_IRQ is asserted when CCA ends, TX_IRQ is asserted when Tx ends, SEQ_END_IRQ is asserted when sequence finishes

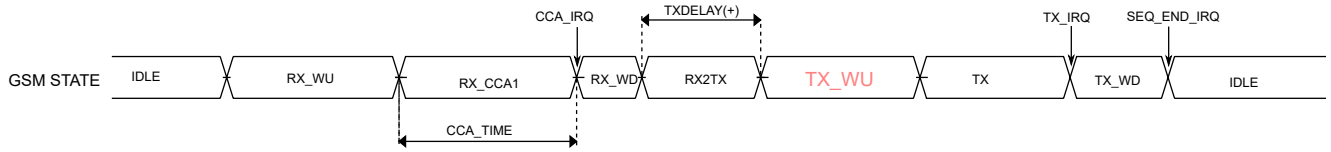


Figure 474. SEQUENCE T: Unslotted CCABFRTX, Channel is IDLE

The following timing diagram depicts the GSM state transition of Tx, highlighting the following events:

1. FAST_RX2TX_EN=1, enables TSM Fast RX-to-TX
2. Link Layer assert fast_rx2tx_wu to TSM, requests a Fast RX-to-TX warmup
3. The TSM will respond to fast_rx2tx_wu by jumping from the "ON" phase of the RX operation to the "WARMUP" phase of the TX operation at the programmed point.
4. Simultaneously, GSM jumps to its TX_WU state to wait for the TX warmup to complete.

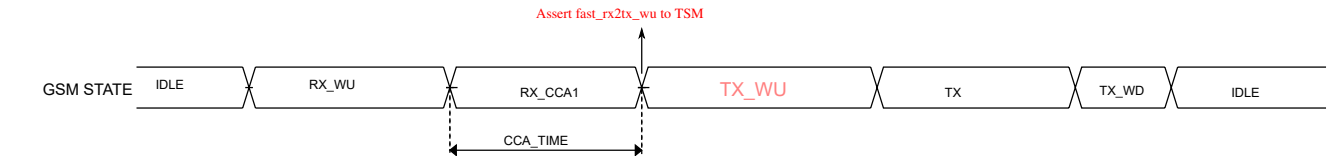


Figure 475. SEQUENCE T: Unslotted CCABFRTX, Channel is IDLE, TSM FAST RX-to-TX

The following timing diagram depicts the GSM state transition of Tx, highlighting the following events:

1. Slotted mode with CCA before TX
2. CCA_IRQ is asserted after 2nd CCA is done
3. Link Layer sends out the packet at next slot boundary(TXDELAY(±))

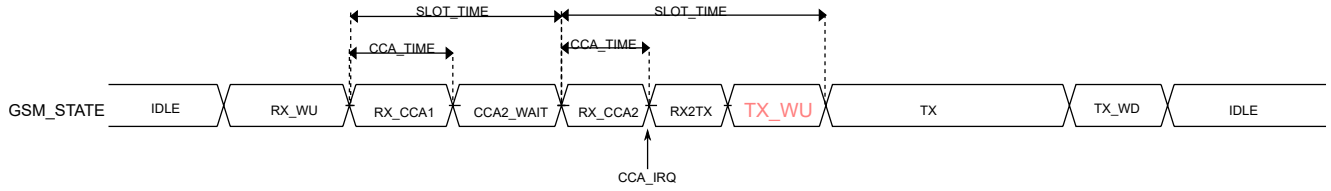


Figure 476. SEQUENCE T: Slotted CCABFRTX, Channel is IDLE

52.4.4.4.2.2.7.2.1.4 Sequence C (CCA)

CCA/ED/LQI

The CCA/ED/LQI block resides inside RX DIG. The purpose of this block is to perform the following operations:

1. Clear Channel Assessment: Modes 1
2. Energy Detection
3. Link Quality Indicator

This block takes RSSI value, as an input, for computations related to CCA modes 1, Energy Detection and LQI.

At the output, it provides a signal called (cca) to indicate if the channel of interest is busy (cca=1) or idle (cca=0), the final computed energy value (cca1_ed_fnl) and Link Quality Indicator (LQI) value.

The cca signal is further used to generate cca interrupt, according to the set interrupt mask. The cca1_ed_fnl is a signed 8 bit value that can be read back as a register. LQI is an unsigned 8 bit value that is written at the end of each valid packet that is received and is available to be read in the packet buffer.

Sequence C

Sequence C can be lunched by command CCA_START_*. Sequence C is the standalone CCA sequence.

During Sequence C, the sequence manager executes a Clear Channel Assessment (CCA). The result of the CCA measurement is reported back to software in the CCA bit. The CCA bit indicates either a busy channel (1), or an idle channel (0).

The basic execution of a Sequence C is as follows:

- MCU writes XCVSEQ=CCA_START_*
- Wait for T1 or T2 match (if CCA_START_T*)
- SEQ_MGR asserts one of **cca1_en** to CCA_DIG
- SEQ_MGR executes RxWarmup, via Transceiver Sequence Manager
- SEQ_MGR initiates CCA measurement by asserting **rx_cca_en** to CCA_DIG
- SEQ_MGR waits for CCA to complete (**CCA_TIME=SLOT_TIME - TURNAROUND_TIME**)
- CCA bit is set to the CCA status (1=busy 0=idle)
- CCAIRQ interrupt issued
- SEQ_MGR executes RxWarmdown
- SEQIRQ interrupt issued

The asserted control signal **cca1_en** will remain asserted for the duration of the Sequence C. The sequence manager warms up the receiver (analog and digital elements), via the Transceiver Sequence Manager (TSM). At the completion of the warmup, the sequence manager initiates the CCA by asserting the **rx_cca_en** signal to CCA_DIG. While CCA is enabled, the CCA_DIG measures and averages the energy or signal on the channel. At the completion of the CCA process, the CCA bit is set to the status of the channel (idle or busy). The CCAIRQ is issued, the receiver is warmed down, the SEQIRQ is issued, and the sequence manager returns to SEQ_IDLE state.

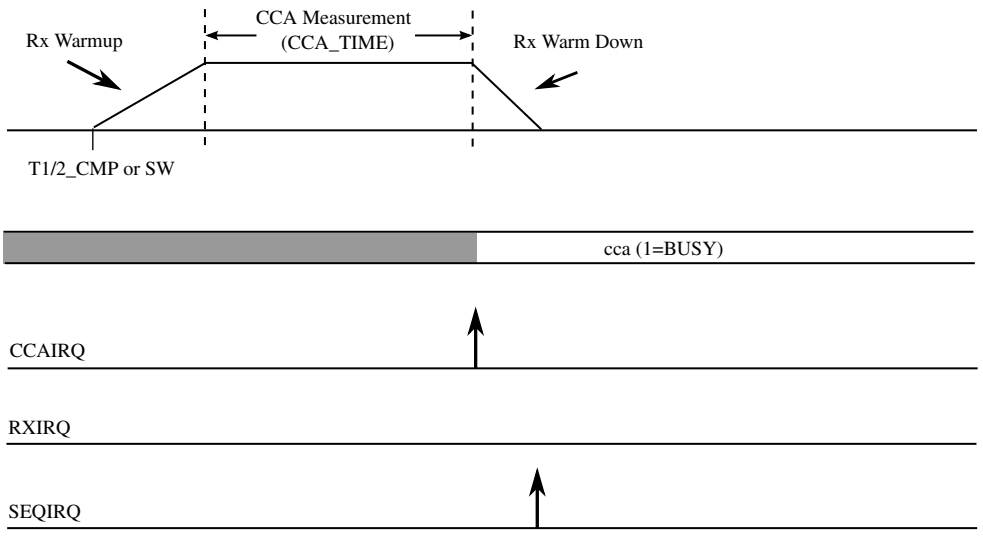


Figure 477. Sequence C Timing Diagrams

52.4.4.4.2.2.7.2.1.5 Sequence TR (Transmit/Receive)

Sequence TR can be lunched by command TR_START_*. Sequence TR is a combination Transmit/Receive sequence.

The sequence is executed as a concatenation of 1 transmit operation followed by 1 receive operation, with a minimum TX-to-RX turnaround time in between.

In PAN and FAN mode, there are 2 permutations of Sequence TR, depending on the RXACKRQD bit. For both permutations, the Sequence T which constitutes the first half of a Sequence TR, is identical to the standalone Sequence T (XCVSEQ=TX_START_*). This means that the transmit operation can be slotted or unslotted, and can be preceded by 1 or 2 CCA measurements, depending on the state of the CCABFRTX and SLOTTED bits.

If RXACKRQD=0, then Sequence TR is executed as a Sequence T followed by a Sequence R, with a minimum TX-to-RX turnaround time in between. The Sequence R, which constitutes the second half of the Sequence TR, is identical to the standalone Sequence R (XCVSEQ=RX_START_*). This means that the receive operation can be followed by an automatic, hardware-generated transmit Acknowledge frame, if all the necessary conditions are met. As with basic Sequence R, data for a successful receive operation is always transferred to Packet Buffer.

If RXACKRQD=1, then Sequence TR is executed as a Sequence T followed by a Receive-Acknowledge-Only frame. This type of receive operation is special, and not the same as a standalone Sequence R. The Ack-only receive operation filters all incoming frames, looking only for an Acknowledge frame whose Sequence Number matches the Sequence Number which was transmitted in the Sequence T portion of the sequence. All non-matching frames are discarded, and after each non-matching frame, the sequence manager will return the receiver to preamble-detect mode. This receive operation will continue until the matching Ack frame is received. Since this is a Receive-Acknowledge-Only operation, and not a Sequence R, there will be no receive octets transferred to Packet Buffer. The sequence will end with a RXIRQ interrupt, which indicates that the matching Ack frame was successfully received.

Needless to say, if during the transmit operation of a Sequence TR, an Acknowledge frame is being requested of the receiving end device (Frame Control Field: AckRequest=1), then Sequence TR with RXACKRQD=1 is the appropriate procedure. (Using Sequence TR with *RXACKREQ=0* is *not* recommended for this scenario, since there is no Sequence Number matching.)

Conversely, if during the transmit operation of a Sequence TR, an Acknowledge frame is *not* being requested of the receiving end device (Frame Control Field: AckRequest=0), then Sequence TR with RXACKRQD=1 should *never* be used, since a receive acknowledge frame will not be forthcoming. Instead, use Sequence TR with RXACKRQD=0, or simply Sequence T, if no followup receive frame is expected.

In GLL mode, there is nothing to check against to the received Acknowledge frame, so RXACKRQD is not used.

Sequence TR Timing Diagrams

The following timing diagram depicts the GSM state transition of TR, highlighting the following events:

1. Unslotted mode
2. The TX-to-RX time is TURNAROUND_TIME+RXDELAY(±)
3. TX_IRQ is asserted when TX ends, RX_IRQ is asserted when RX ends, SEQ_END_IRQ is asserted when sequence finishes.

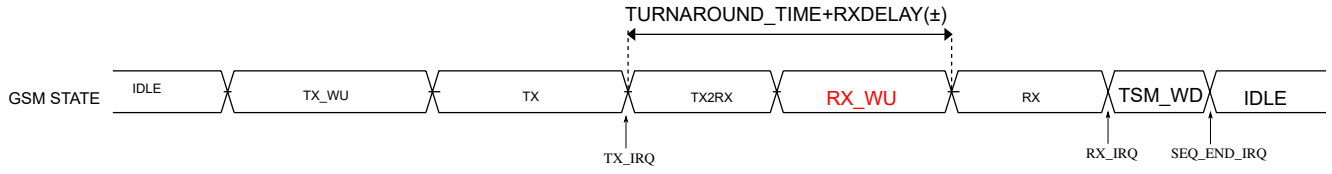


Figure 478. SEQUENCE TR: UNSLOTTED

The following timing diagram depicts the GSM state transition of TR, highlighting the following events:

1. Slotted mode

2. The time between the TX END and next slot boundary is smaller than TURNAROUND_TIME, Link Layer starts to receive at next 2 slot boundary (RXDELAY(±))

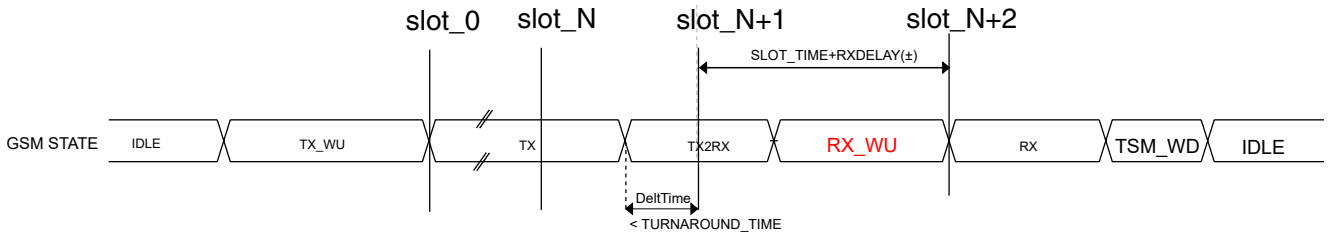


Figure 479. SEQUENCE TR: SLOTTED, CASE 1

The following timing diagram depicts the GSM state transition of TR, highlighting the following events:

1. Slotted mode
2. The time between the TX END and next slot boundary is larger than or equal to TURNAROUND_TIME, Link Layer starts to receive at next slot boundary (RXDELAY(±))

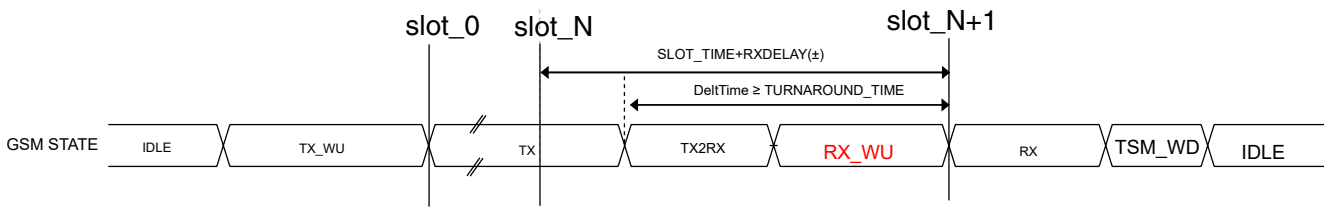


Figure 480. SEQUENCE TR: SLOTTED, CASE 2

52.4.4.4.2.2.7.2.2 Dual PAN Mode

Dual PAN On-the-fly Channel Change

The Sequence Manager (GSM) supports Dual PAN mode, which allows the device to reside on 2 networks simultaneously, switching back and forth between the 2 networks under software, or hardware control. (See Dual PAN Modefor more details on Dual PAN mode).

In Automatic Dual PAN Mode, the device must switch from one network to another under hardware control, at a software-programmed rate. Since the 2 networks often occupy different channels (frequencies), the sequence manager supports an "on-the-fly channel change", whereby, during a Sequence R, in preamble-search state (RX_PRE), the sequence manager will request the TSM to toggle **pll_dig_en** and switch to a new RF channel, wait out a PLL settling time, and then resume preamble search on the new channel. The entire on-the-fly channel change consumes 93us (based on default TSM programming), and consumes 2 GSM states. The first state (RX_PAN1) issues **tsm_recycle[1]** to the TSM, which causes TSM to jump from its "ON" phase, back to the tsm_count value which is programmed into the RECYCLE_COUNT1[7:0] register in XCVR space. Based on the default programming for RECYCLE1_COUNT, along with the default programming for the TSM timing registers, this TSM recycle will cause the TSM to jump back to the point 1us before **pll_dig_en** is asserted, resulting in a 1us-long deassertion of **pll_dig_en**. The TSM will resume counting from that point, which will re-assert **pll_dig_en**, and the GSM will simultaneously select the alternate Dual Pan channel. Meanwhile, the GSM will advance to RX_PAN2 state and wait there pending **tsm_wu_complete** from the TSM. The TSM will resume counting until it once again until it reaches END_OF_RX_WU[7:0], and then will return to its ON phase. At the end of the TSM RX warmup, TSM will issue **tsm_wu_complete** to GSM, which will return GSM to RX_PRE (preamble search) state.

Normally, during RX sequences, the PLL is monitored for unlock conditions, and if such an unlock were to occur, the GSM would abort the RX sequence by deasserting RX_EN to TSM. During RX_PAN1 and RX_PAN2 states, GSM asserts **in_pan_switch** to the transceiver, which indicates that PLL unlock detection should be temporarily suspended while the channel change and subsequent PLL re-lock takes place. Once the GSM transitions from RX_PAN2 state back to RX_PRE, GSM will deassert **in_pan_switch** to resume PLL unlock monitoring.

As mentioned, the entire on-the-fly channel change consumes 93us, based on default TSM programming. This 93us represents a short "blind spot" during which preamble detection can't occur, while the device switches from one RF frequency to another. See diagram below.

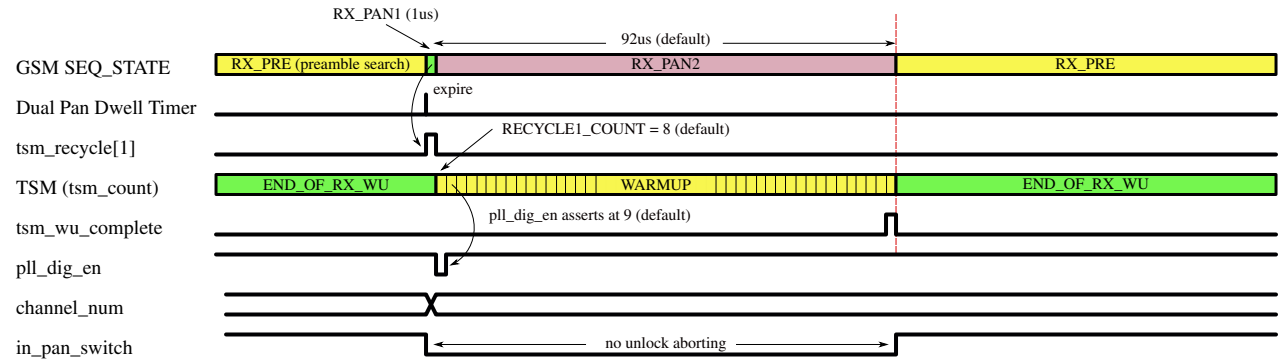


Figure 481. GSM Dual PAN on-the-fly Channel Change

Dual PAN Channel Override

When using Dual PAN mode, the channels are assigned to the 2 PAN's by programming the CHANNEL_NUM0[6:0] and CHANNEL_NUM1[6:0] registers. The channel number is processed downstream into the necessary Integer, Numerator, and Denominator components, required to generate the correct RF frequencies (see PLL Digital Chapter).

In Dual PAN mode, in case there is a need to generate a frequency which may be offset from the 16 prescribed 5MHz-spaced channels, to, for example, avoid interference on one of the Dual PAN channels, a method has been provided to do that, by designating one of the two PAN channels to use the transceiver's set of direct frequency-programming registers, instead of CHANNEL_NUMx. Programming the direct frequency-programming registers – integer, numerator, and denominator, allows an RF frequency to be selected with much more precision than the 5MHz granularity of the 802.15.4 mapped-channel registers, CHANNEL_NUM0 and CHANNEL_NUM1.

Two bits have been provided to realize this feature: DP_CHAN_OVRD_SEL and DP_CHAN_OVRD_EN. When DP_CHAN_OVRD_EN=1, this enables one of the Dual PAN channels to use the direct frequency programming. The DP_CHAN_OVRD_SEL bit determines *which* channel uses the direct programming, according to the following table:

Table 552. Dual PAN Channel Override

DP_CHAN_OVRD_EN	DP_CHAN_OVRD_SEL	PAN0 Frequency Determined by …	PAN1 Frequency Determined by …
0	X	CHANNEL_NUM0	CHANNEL_NUM1
1	0	DIRECT FREQUENCY PROGRAMMING	CHANNEL_NUM1
1	1	CHANNEL_NUM0	DIRECT FREQUENCY PROGRAMMING

Direct Frequency Programming is accomplished by setting the PLL's Integer, Numerator, and Denominator registers to the appropriate values for the desired RF frequency. These registers are in XCVR address space, and are shown in the following table:

Table 553. Direct Frequency Programming

DIRECT FREQUENCY PROGRAMMING PARAMETER	REGISTER NAME (XCVR SPACE)	REGISTER MNEMONIC
Integer	LPM_INTG[6:0]	PLL_LP_SDM_CTRL1
Numerator	LPM_NUM[27:0]	PLL_LP_SDM_CTRL2
Denominator	LPM_DENOM[27:0]	PLL_LP_SDM_CTRL3

See the PLL Digital Chapter for RF frequency programming details.

In Dual PAN automatic mode, if DP_CHAN_OVRD_EN=1, when the hardware switches to the PAN selected by DP_CHAN_OVRD_SEL as a direct-programming channel, the CHANNEL_NUMx register is ignored and the directly programmed frequency is used instead; when the hardware switches back to the other channel, the CHANNEL_NUMx register is used once again.

Hybrid Dual PAN Mode

Dual PAN Mode can be in Hybrid Mode by configuring the register GENLL_MODE. In Hybrid Mode, the two PAN can be one in PAN mode and another in FAN mode, as shown in the following table:

Table 554. Hybrid Dual PAN Mode

MODE_PAN0	MODE_PAN1	PAN0 Mode	PAN1 Mode
0	0	PAN mode	PAN mode
0	1	PAN mode	FAN mode
1	0	FAN mode	PAN mode
1	1	FAN mode	FAN mode

52.4.4.4.2.2.7.2.3 Simultaneous CCA/RX

The Link Layer controller features an autosequence that precedes a packet transmission with a CCA (Clear Channel Assessment), to ensure the channel is idle before transmitting. If the CCA indicates a busy channel, the autosequence ends after the CCA, without transmitting. In slotted mode, 2 CCA measurements take place, with the start points for the measurements SLOT_TIME apart. Both must indicate an idle channel for transmission to proceed.

During intervals of severe network congestion, high node density, and packets which are heavily fragmented, the situation can arise where Device A is preparing to transmit a packet, or fragment, and performing pre-transmit CCA, and during the CCA, Device B attempts to transmit another packet or fragment to Device A. The capability to receive-during-CCA is referred to as "Simultaneous CCA/RX".

Using Simultaneous CCA/RX, the Link Layer controller needs to be able to anticipate preamble, and even SFD detection, during the states in which it is taking CCA measurement. Those states are RX_CCA1, for non-slotted, and RX_CCA2, for slotted operation. If preamble and/or SFD is detected in those states, the sequence manager needs to transition to a packet reception state, and then receive the packet in its entirety as if the called sequence was Sequence R. To address this, these new state transitions have been added to the Sequence Manager state machine:

- RX_CCA1 -> RX_PRE (preamble detected during 1st CCA but no SFD)
- RX_CCA1 -> RX_PKT (preamble + SFD detected during 1st CCA)
- RX_CCA2 -> RX_PRE (preamble detected during 2nd CCA but no SFD)
- RX_CCA2 -> RX_PKT (preamble + SFD detected during 1st CCA)

False preambles may occur during the CCA states as well. False preambles occur when the demodulator detects a sufficient number of consecutive symbols to meet the preamble threshold, but the symbol which follows is not right SFD. False preambles

result in the demodulator signal sfd_rst asserting either during, or after, the CCA state. If a false preamble is declared within the CCA time window, then the fact that there was a false preamble has no bearing on the channel status, the CCA measurement determines channel status, as usual. If the false preamble is declared after the CCA window, the channel is assessed to be busy and the autosequence terminates without transmission, because the scheduled transmission time has been missed

In defining the Simultaneous CCA/RX operation, 9 "scenarios", or cases, were developed to help ensure correct hardware response to various permutations of preamble and SFD arrival times, preamble falsing, channel status, and RX packet goodness. These scenarios were used to guide the hardware design, for each of the 3 CCA modes, and for mode 3, both boolean combinations. The 9 scenarios are listed in the table below(**take the CCA_TIME 128us as example**), with the correct hardware response indicated. The hardware response consists of a sequence of state transitions, as well as assertion (or non-assertion) of the various 802.15.4 interrupts. The final combination of asserted interrupts assists software in determining what transpired during the autosequence, and therefore what must be done next.

Table 555. SIMUL CCA/RX SCENARIOS(*CCA_TIME is 128us in table*)

#	Scenario	Auto Sequence Ends After	Mode Switch to SFD Search Occurs At	Mode Switch to PKT Reception Occurs At	CCAIRQ?	RXIRQ?	TXIRQ?
1	Channel IDLE @ 128us	TX	--	--	Yes(CCA=0)	No	Yes
2	Channel Busy @ 128us	CCA	--	--	Yes(CCA=1)	No	No
3	Preamble Asserted During CCA SFD_RST Occurs During CCA Channel Otherwise IDLE @128us	TX	--	--	Yes(CCA=0)	No	Yes
4	Preamble Asserted During CCA SFD_RST Occurs During CCA Channel Otherwise Busy @128us	CCA	--	--	Yes(CCA=1)	No	No
5	Preamble Asserted @128us SFD Not Asserted @128us SFD_RST Asserts Later (False PRE)	SFD_RST	128us	--	Yes(CCA=1)	No	No
6	Preamble Asserted @128us SFD Not Asserted @128us SFD Asserts Later (Bad PKT)	RX	128us	--	Yes(CCA=1)	No	No
7	Preamble Asserted @128us SFD_RST Asserted @ 128us (Bad PKT)	RX	--	SFD DET	Yes(CCA=1)	No	No
8	Preamble Asserted @128us SFD Not Asserted @128us SFD Asserts Later (Good PKT)	RX	128us	--	Yes(CCA=1)	Yes	No
9	Preamble Asserted @128us SFD Asserted @128us(Good PKT)	RX	--	SFD DET	Yes(CCA=1)	Yes	No

A single register bit enables Simultaneous CCA/RX mode: SIMUL_CCA_RX. Simultaneous CCA/RX works with both nonslotted (single CCA before TX) and slotted (2 CCA before TX) modes.

Note that to use the Simultaneous CCA/RX feature, software (not just hardware) needs to anticipate packet reception during a Sequence T (not just a Sequence TR)

52.4.4.4.2.2.8 Work Modes

The Generic Link Layer work modes are controlled by register bits GENLL_MODE[3:0] . With proper setting, Generic Link Layer and RBME can support to receive and send different kinds of packet, like 802.15.4, FCP, Bluetooth LE packets.

- The default mode is called Generic Link Layer mode(**GLL mode**). GLL mode is the most basic mode, all commands and sequences can be used in GLL mode.
- The PAN, FAN modes are to support GFSK, MSK, SUN FSK, and LECIM FSK in the 802.15.4 protocol. In these modes, the PHRs are parsed and checked according to the protocol. Both modes also check whether the payload complies with the 802.15.4 MAC frame format. The difference is that in PAN mode, link layer only supports frames with frame version less than 2, and supports Imm-Ack frame sending and receiving. While in FAN mode, link layer supports FAN protocol-specific frame, and supports Enh-Ack frame only.
- The link layer can work in Dual PAN mode when in PAN or FAN mode. In this case, both PANs are in PAN mode or both PANs are in FAN mode. When configured to Hybrid Dual PAN Mode, one PAN can be in PAN mode while the other can be in FAN mode.
- Link layer can also work in FCP/Bluetooth LE mode.
- The test mode (GTM mode) is also supported.

52.4.4.4.2.2.8.1 802.15.4 Protocol Support

The link layer supports to parse the IEEE 802.15.4-2015 FSK/GFSK mode packet header when configured in PAN or FAN mode. The objective is to be able to parse the PHR field and identify when to mode switch, extract the PSDU configuration and verify the health of the header. It is intended to support the FSK/GFSK modes as specified for GFSK, MSK, SUN-FSK and LECIM-FSK PHYs.

The 4 PHR structures are shown as Figure 482

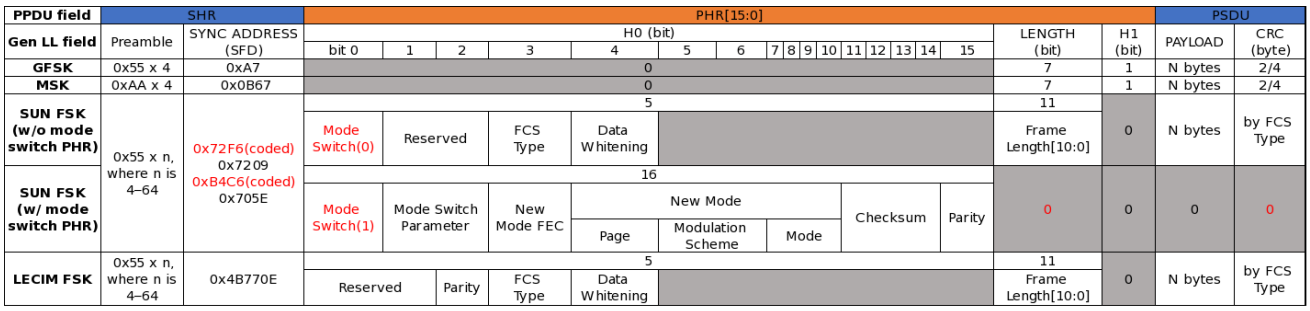


Figure 482. PPDU Mapping to Link Layer Packet Structure

Software should configure the register PHR_TYPE[2:0] to select the proper PHR type before Tx or Rx.

For SUN FSK, user should put the **uncoded network address in NTW_ADR_0 or NTW_ADR_2** and put the **coded network address in NTW_ADR_1 or NTW_ADR_3**.

And also software should configure the related registers to correctly work with different PHRs, as shown in Table 556.

Table 556. Link Layer Register Configuration for 802.15.4 Emulation

Register	GFSK/MSK	SUN FSK	LECIM FSK
GENLL_MODE[3:0]	• 0x1 - PAN Mode • 0x2 - FAN Mode • 0x3 - Hybrid Dual PAN Mode		

Table continues on the next page...

Table 556. Link Layer Register Configuration for 802.15.4 Emulation (continued)

Register	GFSK/MSK	SUN FSK	LECIM FSK
PREAMBLE_SZ[8:0]	As needed		
PREAMBLE_SEL[2:0]	• 000b - The controller hardware selects the preamble pattern based on the first transmitted bit of Network Address, such that the last bit of preamble is the opposite polarity from the first bit of Network Address, forcing a bit transition at this boundary. • 001b - Preamble is programmed by register GEN_PREAMBLE[7:0]		
GEN_PREAMBLE[7:0]	As needed		
NTW_ADR_SZ[1:0]	According to SFD length		
SYNC_ADDR_SZ[1:0]	According to SFD length		
H0_SZ[4:0]	0	• 5 (MS=0) • 16 (MS=1)	5
LENGTH_SZ[4:0]	7	• 11(MS=0) • 0 (MS=1)	11
H1_SZ[4:0]	1	0	
LENGTH_BIT_ORD	1 - MS Bit First 0 - LS Bit First		
LENGTH_ADJ[10:0]	0		
AA_PLAYBACK_CNT	0 - Access Address will not play back to Link Layer		
RXEN_DLY[9:0]	0		
PHR_TYPE[2:0]	• 000b - The packet type is GFSK • 001b - The packet type is MSK	010b - The packet type is SUN FSK	011b - The packet type is LECIM FSK

For SUN FSK PHR, there will be two cases: one is mode switch PPDU and the other is PPDU without mode switch. LL distinguishes between the two modes by the "Mode Switch (MS)" bit received. If MS=1, then link layer hardware will override the H0_SZ to 16, override LENGTH_SZ to 0. And if MS=0, then link layer hardware will override the H0_SZ to 5 and override the LENGTH_SZ to 11.

For SUN FSK PHR (MS=0) and LECIM FSK PHR type, when Rx, link layer hardware will override the CRC_SZ and WHITEN_START register according to the received FCS Type and Data Whitening bits. That is when FCS Type = 0, CRC_SZ is 4; when FCS Type = 1, CRC_SZ is 2. And when Data Whitening = 0, WHITEN_START=0; when Data Whitening = 1, WHITEN_START=3. When Tx, the PHR is programmed in Packet RAM by software. The FCS Type and Data Whitening bits in PHR should align with the CRC_SZ and WHITEN_START registers. When link layer is performing an auto-Ack sequence, the FCS Type and Data Whitening bits are automatically calculated by hardware according to the CRC_SZ and WHITEN_START registers.

When Rx, for SUN FSK(MS=1), RBME will do the BCH correction and Parity check for the PHR and it will send out the corrected result and fail/pass flag to link layer. If the flag shows pass, an interrupt flag MS_IRQ will be set in IRQ_CTRL register. If MS_IRQ_EN=1, then the interrupt will occur. The PHR[10:0] will be saved into PHR_MISC register for software read. For LECIM FSK, link layer will check the Parity bit. When either fail happens, BCH fail or Parity fail, the PHRFAIL_IRQ will be set and RX_IRQ

will not set. if PHRFAIL_IRQ_EN=1, then the fail interrupt will occur. If PHR_FAIL_IGNORE =1, RX_IRQ will be set even for a received packet which fails PHR verification.

When Tx, for SUN FSK(MS=1), RBME will do the BCH encode and Parity calculation, and fill the Checksum and Parity Check bits in PHR. For LECIM FSK, the Parity bit is calculated by software and programmed into the Packet RAM.

When auto-Ack, the Parity bit for LECIM FSK are calculated by link layer hardware.

52.4.4.4.2.2.8.1.1 Packet Processor

52.4.4.4.2.2.8.1.1.1 Introduction

The Packet Processor works in PAN or FAN mode.

In PAN mode, the Packet Processor performs sophisticated hardware filtering of the incoming received packet, to determine whether the packet is both PHY- and MAC-compliant, whether the packet is addressed to this device, and if the device is a PAN Coordinator, whether a message is pending for the sending device.

In FAN mode, the Packet Processor checks whether the received packet passes the rules in FAN standard.

The packet processor greatly reduces the packet filtering burden on software, allowing software to tend to higher-layer tasks with a lower latency and smaller software footprint.

Table 557. References

Revision	Title
IEEE Std 802.15.4 -2003	Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)
IEEE Std 802.15.4 -2006	802.15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs)
IEEE Std 802.15.4 -2011	Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)
IEEE Std 802.15.4 -2015	Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) (Amendment to IEEE Std 802.15.4-2011)
Version 1v10	Technical Profile Specification Field Area Network (FAN)

52.4.4.4.2.2.8.1.1.1.1 Overview

The Packet Processor performs aggressive hardware filtering of the incoming packet as it is being received, to increase battery life by not awakening the MCU to process packets which are non-compliant or not addressed to the device, or that violate the 802.15.4 MAC Frame structure.

The advanced frame parsing enables the sequence manager to handle complex sequences, by, for example, determining whether a receive frame requires an acknowledge, and generating the Sequence Number for that acknowledge, so that the transmit/receive combination sequence can be executed without any MCU intervention.

Finally, the packet processor includes a hardware accelerator that allows the device to handle a critical timing requirement that had been problematic for 8-bit MCU's in the past: the quick-turnaround requirement for an indirect queue-lookup to determine the correct response to an end device sending a data polling request.

The packet processor contains a register-based table of end devices which have messages pending, allowing a single-cycle hardware table lookup to be performed, and a minimum-turnaround-time acknowledge packet to be sent to the end device without MCU intervention.

The packet processor also includes support for Dual PAN mode, which allows the device to simultaneously reside on 2 networks, with 2 separate IEEE addresses.

52.4.4.4.2.2.8.1.1.1.2 Features

- Aggressive packet filtering to enable long, uninterrupted MCU sleep periods

- Fully compliant with both 2003 and 2006 versions of the 802.15.4 wireless standard
- Supports all Frame Types, including reserved types
- Enables auto-Tx Acknowledge frames (no MCU intervention) by parsing of Frame Control Field and Sequence Number
- Supports all Source and Destination Address modes, and also PAN ID Compression
- Supports Broadcast address for PAN ID and short address mode
- Supports "Promiscuous" mode, to receive all packets regardless of address- and rules-checking
- Allows Frame Type-specific filtering (e.g., reject all but Beacon frames)
- Supports SLOTTED and non-SLOTTED modes
- Includes special filtering rules for PAN Coordinator devices
- Enables minimum-turnaround TX-Acknowledge frames for data-polling requests by automatically determining message-pending status
- Assists MCU in locating pending messages in its indirect queue for data-polling end devices
- Assists MCU in determining if a poll request originated from a valid child end device
- Makes available to MCU detailed status of frames which fail address- or rules-checking
- Supports Dual PAN mode, allowing the device to exist on 2 PAN's simultaneously
- Supports 2 IEEE addresses for the device
- Includes provisions to enable software support of 802.15.4-2015 frame types and versions
- **Supports FAN standard DATA and ACK frame filter.**

52.4.4.4.2.2.8.1.1.2 Functional Description

The packet processor is responsible for receiving symbols from the demodulator, combining them into octets, assembling the octets into packets, filtering the packets in compliance with the 802.15.4 wireless MAC standard, and storing the packets into the Packet Buffer (Packet RAM).

The packet processor parses the incoming packets on-the-fly to determine:

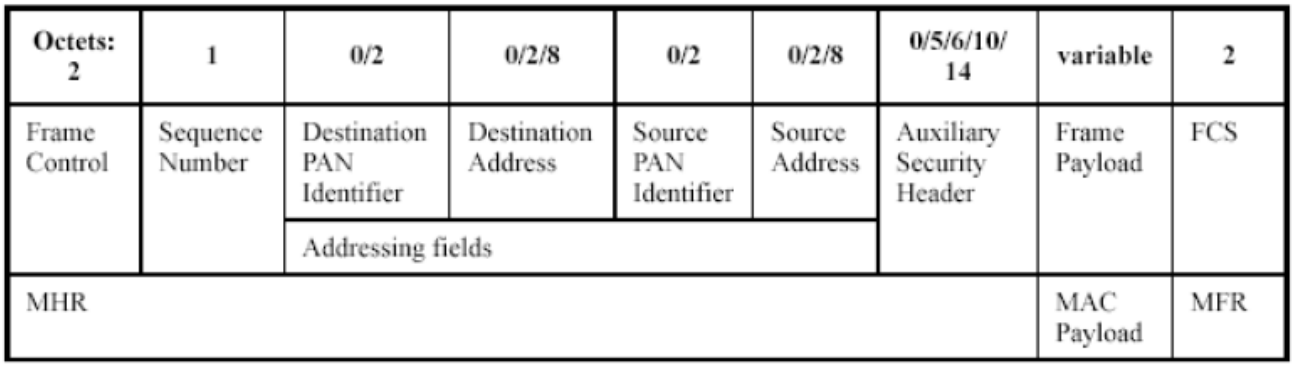
1. whether the packet is MAC-compliant, and if it is,
2. whether the packet is addressed to the end device.

The packet processor performs aggressive filtering on incoming packets, in order to reduce unnecessary MCU wake-ups, to allow longer MCU sleep durations, and to provide sufficient hardware automation so as to enable complex sequences to be executed by the sequence manager. The packet processor also includes hardware support for Dual PAN operation (allowing the device to reside on two networks simultaneously).

The packet processor also includes functionality to allow a critical-timing requirement to be met, which in the past has been problematic for low-MIPS receiving devices: the ability of a coordinator device to respond to a MAC Command data request from an end device, with an Acknowledge frame containing a FramePending bit accurately reflecting the presence of a message for the end device in the coordinator's indirect queue, or the absence of the end device in the coordinator's neighbor table, within the prescribed turnaround time window. This functionality is described in more detail in the Source Address Management

52.4.4.4.2.2.8.1.1.2.1 Packet Filtering Background

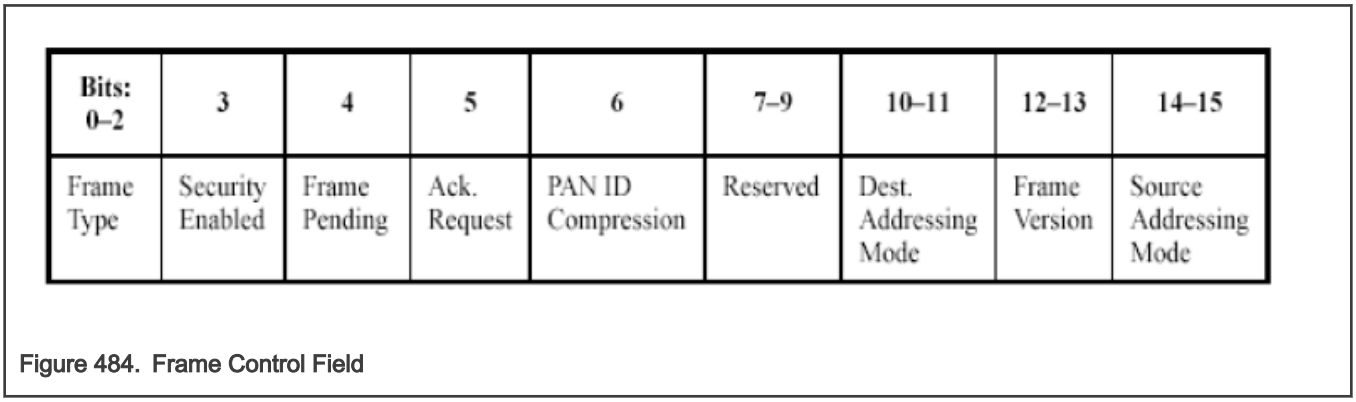
The packet processor parses packets to verify compliance with the 802.15.4 MAC frame format. The basic MAC frame format is shown in the figure below.



Octets: 2	1	0/2	0/2/8	0/2	0/2/8	0/5/6/10/14	variable	2
Frame Control	Sequence Number	Destination PAN Identifier	Destination Address	Source PAN Identifier	Source Address	Auxiliary Security Header	Frame Payload	FCS
		Addressing fields						
MHR							MAC Payload	MFR

Figure 483. MAC Frame Format

The packet processor parses the incoming octets on the fly, as they are received. The Frame Control Field, two octets in length, contains subfields which encode "instructions" on how to parse the remainder of the MHR (MAC Header). The structure of the Frame Control Field is shown in the figure below.



Bits: 0–2	3	4	5	6	7–9	10–11	12–13	14–15
Frame Type	Security Enabled	Frame Pending	Ack. Request	PAN ID Compression	Reserved	Dest. Addressing Mode	Frame Version	Source Addressing Mode

Figure 484. Frame Control Field

The packet processor utilizes the Frame Control Fields subfields in the following manner:

FCF Subfield	Utilization by Packet Processor
FrameType	Interprets the remaining MHR as specific to Beacon, Ack, Data, Command, or Reserved frame types. Each frame type has a unique MHR structure, and so different parsing rules apply.
SecurityEnabled	If SecurityEnabled=1 and FrameVersion>0 (frame versions 2006 and later), an Auxiliary Security Header field will be present in the MHR and will need to be further parsed by the packet processor if this is a MAC Command frame (see Section Source Address Management). There is no other use of SecurityEnabled by the packet processor.
FramePending	ignored by packet processor
Ack. Request	will be copied into the **pp_ack_request** signal to the sequence manager. An auto-TxAck frame will follow the incoming receive frame if necessary conditions are met
PAN ID Compression	used for addressing mode rules-checking and addressing field parsing.

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FCF Subfield	Utilization by Packet Processor
Reserved	ignored by packet processor
Destination Addressing Mode	used for addressing mode rules-checking and addressing field parsing
FrameVersion	For Beacon, Data, and MAC Command frames, FrameVersion is checked against the allowed frame versions according to FRM_VER_FILTER For Acknowledge frames, FrameVersion is ignored. If SecurityEnabled=1 and FrameVersion>0 (frame versions 2006 and later), an Auxiliary Security Header field will be present in the MHR and the MHR will need to be further parsed by the packet processor if this is a MAC Command frame (see SectionSource Address Management).
Source Addressing Mode	used for addressing mode rules-checking and addressing field parsing

The Packet Processor parses the FrameType field of the Frame Control Field per the following table:

Frame type value b_2 b_1 b_0	Description
000	Beacon
001	Data
010	Acknowledgment
011	MAC command
100–111	Reserved

Figure 485. Frame Type Field

Directly following the Frame Control Field is the Sequence Number field. The Sequence Number field of the MHR is captured by the packet processor. If an auto-TxAck frame follows the incoming receive frame, the captured Sequence Number will be copied to the transmitted Acknowledge packet, and the Packet Processor will insert FrameVersion=00 into the Frame Control Field of the transmitted frame, regardless of the received FrameVersion subfield of the original frame.

The Addressing Fields follow the Sequence Number. The format of the Addressing Fields depends upon the Source and Destination Addressing Mode subfields of the Frame Control Field. The Addressing Modes are defined in the table below:

Addressing mode value b_1 b_0	Description
00	PAN identifier and address fields are not present.
01	Reserved.
10	Address field contains a 16-bit short address.
11	Address field contains a 64-bit extended address.

Figure 486. Addressing Mode Fields

The packet processor uses these Source and Destination Address Modes shown above, to extract the Source PAN ID and Address (if present), and the Destination PAN ID and Address (if present), from the MHR, according to the table below:

FrameType	Destination Addressing Mode	Source Addressing Mode	PanID-Compression	Addressing Fields
Acknowledge only (reject all other frame types)	0	0	0	None
Data or Command (reject Ack and Beacon frames)	2 or 3	0	0	DstPanID + DstAddr
Beacon (all devices), or Data or Command (PAN Coord Only) (reject Ack frames)	0	2 or 3	0	SrcPanID + SrcAddr
Data or Command (reject Ack and Beacon frames)	2 or 3	2 or 3	0	DstPanID + DstAddr + SrcPanId + SrcAddr
Reject all frames (Illegal as per Section 7.2.2.1.5)	0	0	1	-
Reject all frames (Illegal as per Section 7.2.2.1.5)	2 or 3	0	1	-
Reject all frames	0	2 or 3	1	-

Table continues on the next page...

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FrameType	Destination Addressing Mode	Source Addressing Mode	PanID-Compression	Addressing Fields
(Illegal as per Section 7.2.2.1.5)				
Data or Command (reject Ack or Beacon frames)	2 or 3	2 or 3	1	DstPanID + DstAddr + SrcAddr
Reject all frames (Illegal as per Section 7.2.2.1.6)	1	-	-	-
Reject all frames (Illegal as per Section 7.2.2.1.8)	-	1	-	-

The Source PAN ID and Address, and Destination PAN ID and Address, extracted by the packet processor, are then checked against the MACPANID, MACSHORTADDRS, and MACLONGADDRS register settings, depending on the FrameType of the incoming packet, to determine:

1. Is the addressing mode combination valid for this frame type?
2. Do the address fields indicate that the packet is indeed addressed to the end device?

The details on how the packet processor answers those 2 questions, are described in the following sections.

52.4.4.4.2.2.8.1.1.2.2 Packet Filtering Detail

The figure below is a high-level representation of the packet filtering performed by the 802.15.4 packet processor. The sections which follow provide more detail on the packet filter implementation.

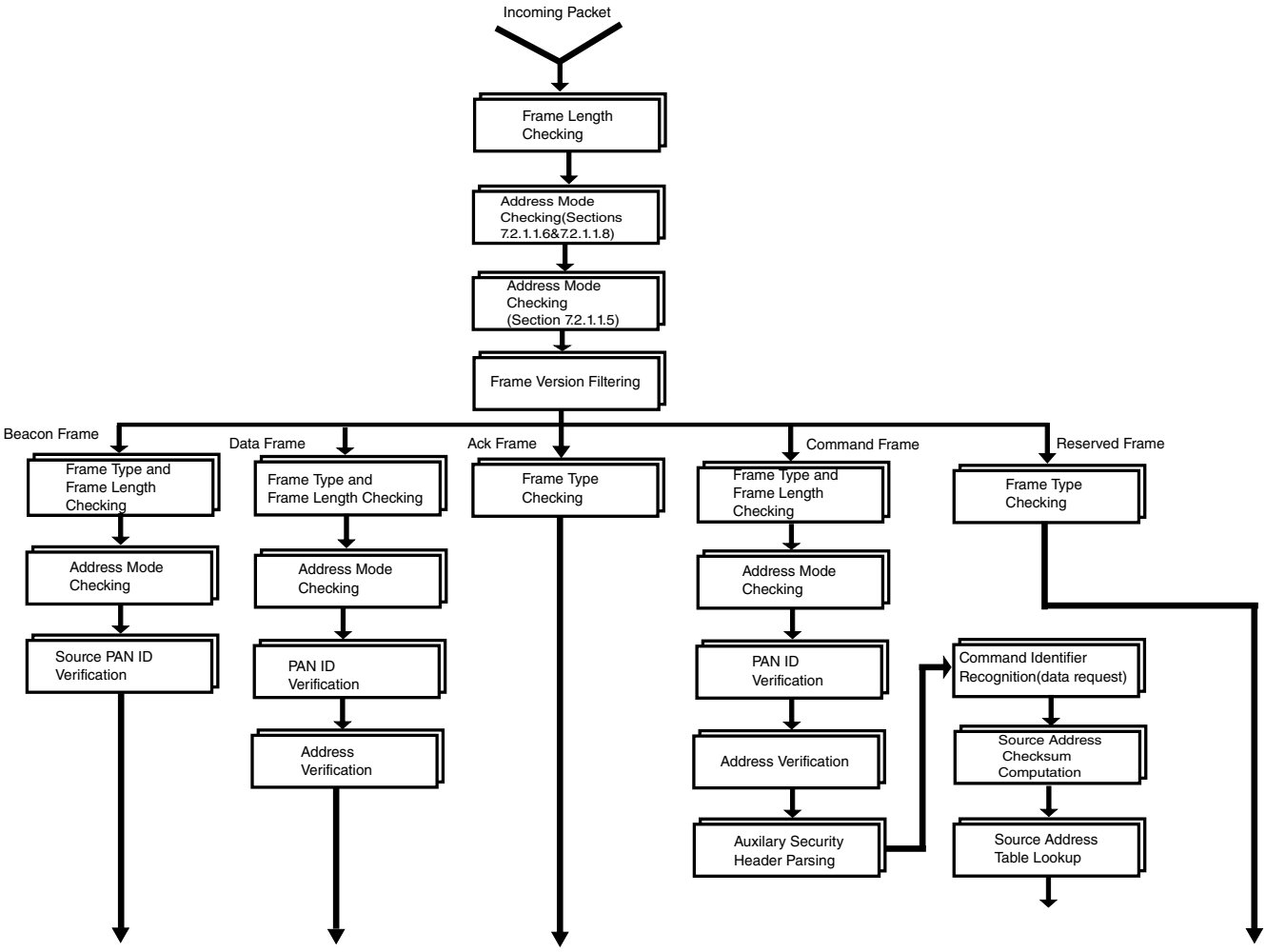

Figure 487. Packet Filtering Flow Diagram

First-Stage Packet Filtering

The first stage of packet filtering examines the incoming packet, and implements basic rule-checking, based on the 2006 version of the 802.15.4 standard, and is applied to *all* frame types. First stage rule-checking is described in the table below:

	Filtering Step	Description
1	Frame Length Checking	Check that all frames are at least 3 octets payload (not include FCS field).
2	Address Mode Checking (Sections 7.2.1.1.6 and 7.2.1.1.8)	Check that neither Source nor Destination Address Mode set to 1 (illegal addressing mode)
3	Address Mode Checking (Section 7.2.1.1.5)	Check for PAN ID Compression enabled, with either Source or Destination Address Mode set to 0 (illegal addressing mode)

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	Filtering Step	Description
4	FrameVersion Checking	Check that incoming packet's Frame Version is allowed based on FRM_VER_FILTER setting. (FRM_VER_FILTER is a programmable register, see Register Descriptions Section).

Packets which pass first stage filtering, proceed to the second stage of packet filtering, which is *frame type-specific* filtering. Packets which fail initial rule checking are marked as rejected.

Second-Stage Packet Filtering

The second stage of packet filtering is *frame type-specific*. Different variations of the MAC Header (MHR) apply to different frame types, so different parsing mechanisms apply to each.

Note: In the following section, the following references are to register bits; see Register Description Section for register descriptions: BEACON_FT, ACK_FT, DATA_FT, CMD_FT, NS_FT, PANCORDNTR, MACPANID, MACSHORTADDRS, and MACLONGADDRS.

1) For Beacon frames, these are the basic filtering steps:

- Check that Beacon frames are enabled by software (BEACON_FT)
- Check that Payload Length >= 7
- Check for illegal combinations of PAN ID Compression and Source/Destination Address Modes
- Verify the Source PAN ID matches MACPANID, or that MACPANID = 0xffff.

2) For Acknowledge frames, these are the basic filtering steps:

- Check that Ack frames are enabled by software (ACK_FT)
- If Sequence TR is active and RXACKRQD = 1, check the received Sequence Number matches the transmitted Sequence Number; FrameVersion bits are ignored, as per section 7.2.2.3.1 of the 802.15.4 standard.

Note: It is recommended to use Sequence TR to receive Acknowledge frames, not Sequence R. See Chapter Sequence Manager, Section.Sequence TR (Transmit/Receive)

3) For Data frames, these are the basic filtering steps:

- Check that Data frames are enabled by software (DATA_FT)
- Check that Payload Length >= 7
- Check for illegal combinations of Source and Destination Address Modes
- If PANCORDNTR=0, check for missing Destination Address field or present Source Address field
- If no Destination Address field (PANCORDNTR=1 only), check Source PAN ID matches MACPANID
- If Destination Address present, check Destination PAN ID matches MACPANID or broadcast (0xffff)
- If Short Destination Address field, check address matches MACSHORTADDRS or broadcast (0xffff)
- If Long Destination Address field, check address matches MACLONGADDRS.

4) For MAC Command frames, these are the basic filtering steps:

- Check that Command frames are enabled by software (CMD_FT)
- Check that Payload Length >= 7

- Check for illegal combinations of Source and Destination Address Modes
- If PANCORDNTR=0, check for missing Destination Address field or present Source Address field
- If no Destination Address field (PANCORDNTR=1 only), check Source PAN ID matches MACPANID
- If no Destination Address field (PANCORDNTR=1 only), capture Source PAN ID and Source Address for later use
- If Destination Address present, check Destination PAN ID matches MACPANID or broadcast (0xffff)
- If Short Destination Address field, check address matches MACSHORTADDRS or broadcast (0xffff)
- If Long Destination Address field, check address matches MACLONGADDRS.
- At end of the addressing field, if incoming packet's FrameVersion=0 or SecurityEnabled=0, capture the next octet (Command Identifier)
- At end of the addressing field, if incoming packet's FrameVersion!=0 and SecurityEnabled=1, parse the Auxiliary Security Header, then capture the next octet (Command Identifier)
- If Command Identifier indicates the MAC Command is a data request, compute a "Source Address Checksum" to uniquely identify the sending device.

52.4.4.4.2.2.8.1.1.2.3 Source Address Management

The 802.15.4 wireless MAC standard envisions a scenario whereby an end device may interrogate a coordinator as to whether the coordinator is storing data (i.e., a pending message) for the end device. The situation arises in a beacon-enabled network, when a coordinator includes in its transmitted beacon frame the MAC address of the end device in its "Pending Address Fields". The "Pending Address Fields" are part of the required MAC payload of the beacon frame. The "Pending Address Fields" contain a list of end device addresses for which messages are pending. In this scenario, an end device which finds its address included in the "Pending Address Fields" of the received beacon frame, must respond to the beacon (coordinator) with a MAC Command of type "data request". Alternatively, in non-beacon-enabled networks, an end device may periodically wake up and "poll" a coordinator, to determine if a message is pending for the end device. In either case, the coordinator stores messages for its end devices in its "indirect queue". The coordinator must respond to an incoming MAC Command data request (which *must* have AckRequest=1 in its Frame Control Field), with an Acknowledge frame containing a FramePending subfield indicating the presence (or absence) of a message for the requesting end device, in the coordinator's indirect queue. For a coordinator built around a low-MIPS MCU, a significant amount of MCU time is typically required, simply to ascertain whether a given end device has a message pending or not; the indirect queue can be quite large, and for 8-bit MCU's, the queue must be searched byte-by-byte. This makes it difficult, or impossible, for an underpowered MCU to establish frame-pending status within the RX-to-TX turnaround time required by the standard.

Also, coordinators may include, in software, a "Neighbor Table", the contents of which consist of all the end devices with which the coordinator is in communication. The neighbor table requires periodic maintenance by coordinator (parent) software, as end devices (children) come and go within the network, join different parents, or simply never return. Child tables have limited capacity and parents need to create space for new devices that may show up. A timeout mechanism is the only way that can guarantee that child tables will eventually be cleaned up. Coordinator software must "age out" end devices with which there has not been recent communication. In order for an end device to refresh its status within its parent's Neighbor Table, the end device may periodically send a "keepalive" message in the form of a MAC Data Poll Request. Upon receipt of such a poll request, the parent must search its neighbor table to determine if the source address of the end device is a valid table entry. If the end device exists in the table, an Acknowledgment packet must be transmitted to the end device, with the FramePending subfield set to 0, and coordinator software resets that end device's timeout counter; if the child is not present in the table, an Acknowledgment packet must be transmitted to the end device, with the FramePending subfield set to 1, and the parent device will follow up by transmitting a "Leave Packet" to the end device, instructing the end device to sever its child status with the parent. The end device may opt to rejoin at a later time. Due to the size of the parent's Neighbor table, the search a child's source address can be time consuming, and may not always be possible within the RX-to-TX turnaround time required by the standard.

To alleviate both of these problems, the 802.15.4 packet processor includes hardware acceleration to expedite the source address table search, greatly relieving the software bottleneck during the critical turnaround time. The table search acceleration consists of 2 components: 1) a search for the *presence* of a specific end device's source address, which expedites the process of determining whether a message is pending for the device; and 2) a search for the *absence* of a specific end device's source address, which expedites the process of determining whether the end device is a valid child of the parent.

The packet processor maintains a register table (128 deep, 16-bit wide). The table is divided into multiple partitions, one to perform the "Source Address Present" (SAP) search, and another to perform the "Source Address Absent" (SAA) search. In the SAP partition of the table, coordinator software will store the address of end devices for which it has a message pending; in the SAA partition of the table, coordinator software will store the address of end devices for which it is the parent. To reduce area, the address information is stored in a "compressed" format. Software compresses the address information, and stores it into the table partitions, during a non-critical time. Then, when the coordinator's packet processor receives a MAC Command data request, it extracts the source address information from the incoming packet, and compresses it using the *same* compression algorithm used by software to populate the source address table. The packet processor performs 2 steps simultaneously:

1. it compares the just-received, compressed source address information, or "checksum", against all of the enabled entries in the SAP partition of the table. If a match is found in the SAP partition, the packet processor *asserts* the **rx_frame_pending** signal to the transmit block (TX_PACKET), so that an auto-TxAck packet can be sent to the requesting end device, with the FramePending subfield set to 1, indicating that the end device has a message pending in the coordinator's indirect queue. A message packet from the coordinator to the end device will follow.
2. it compares the just-received, compressed source address information, or "checksum", against all of the enabled entries in the SAA partition of the table. If *no* match is found in the SAA partition, the packet processor *asserts* the **rx_frame_pending** signal to the transmit block (TX_PACKET), so that an auto-TxAck packet can be sent to the requesting end device, with the FramePending subfield set to 1, indicating that the end device is not a valid child of this parent, and a "Leave Packet" from the coordinator to the end device, will follow.

If neither condition is met, i.e., there is no address match in the SAP partition, and a positive match in the SAA partition, the packet processor *deasserts* the **rx_frame_pending** signal, so that an auto-TxAck packet can be sent indicating to the end device that it has no data pending, and that it remains a valid child of this parent; the end device may then deactivate its receiver immediately. For the packet processor, the entire table lookup occurs in 128 clock cycles, once the last source address octet has been received. The SAP and SAA lookups are performed simultaneously. The checksum is also computed on-the-fly by hardware as the source address octets are received, taking no more than 1 clock cycle per octet. Finally, table-search status is reported to the MCU:

1. after the packet processor completes its SAP table search, the status bit SAP0_ADDR_PRESENT will be set to 1 if a match is found in the SAP partition, and the table index which matched will be indicated in the SAP0_MATCH[6:0] register, to further assist software in locating the relevant message within its indirect queue; if no match is found in the SAP partition, the status bit SAP0_ADDR_PRESENT will be set to 0.
2. after the packet processor completes its SAA table search, the status bit SAA0_ADDR_ABSENT will be set to 1 if *no* match is found in the SAA partition; if a positive match is found in the SAA partition, the status bit SAA0_ADDR_ABSENT will be set to 0, and the table index which matched will be indicated in the SAA0_MATCH[6:0] register, to further assist software in locating the child device within its neighbor table.

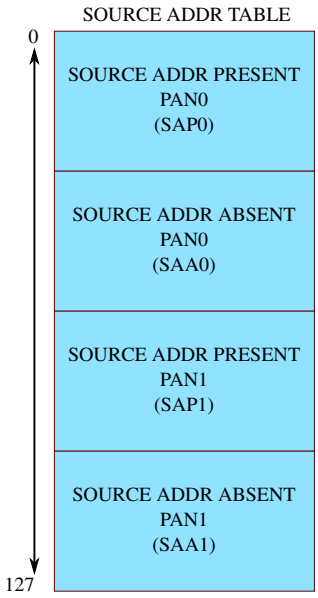
Both features, SAP and SAA acceleration, are optional, and functionally independent. Coordinator software can elect to enable both, either, or neither feature. The control bit SAP0_EN enables SAP acceleration. The control bit SAA0_EN enables SAA acceleration. If either feature is disabled, that table partition (SAP or SAA) is not searched, and so is not a factor in determining FramePending status for the transmitted Acknowledge frame. If *both* features are disabled, FramePending status defaults to software control, and merely tracks the state of the ACK_FRM_PND register bit; in this case software must manage FramePending status for all auto-TxAck frames.

Software can also take direct control of FramePending status for the next auto-TxAck frame at any time (regardless of whether SAP or SAA acceleration is enabled), by setting the ACK_FRM_PND_CTRL bit; in this case, hardware FramePending status will track the state of ACK_FRM_PND.

In order to support Dual PAN mode, a device could theoretically be a PAN Coordinator on both networks. Thus, a coordinator device may need to maintain distinct message pending lists and/or neighbor tables for the 2 PANs. Accordingly, the packet processor further subdivides the Source Address Management table into 4, instead of 2, partitions:

1. SAP0: Source Address Present Partition for PAN0
2. SAA0: Source Address Absent Partition for PAN0
3. SAP1: Source Address Present Partition for PAN1
4. SAA1: Source Address Absent Partition for PAN1

SOURCE ADDRESS TABLE PARTITIONS



Four register control bits enable each partition individually. If a partition is enabled, and a MAC poll request is received on the corresponding PAN (e.g. SAP0 or SAA0 partitions on PAN0), then the partition is searched by the packet processor, looking for a source address match (or absence), and the result of the search affects the FramePending status; if a partition is disabled, the partition is not searched, and will not influence FramePending status. The register bits are described in the table below.

REGISTER NAME	DESCRIPTION
SAP0_EN	Enables SAP0 Partition
SAA0_EN	Enables SAA0 Partition
SAP1_EN	Enables SAP1 Partition
SAA1_EN	Enables SAA1 Partition

For maximum flexibility in supporting all combinations of message-pending status, neighbor-table status, and dual PAN mode, the dividing-line between all the partitions is fully programmable. The SAP0 partition always starts at table index 0. Three registers control the starting point for the other 3 partitions. The starting point is defined the first table index (0-127) of that partition. The registers are described below, along with some software restrictions to ensure table consistency.

REGISTER NAME	DESCRIPTION	RESTRICTIONS
SAA0_START[6:0]	First Index of SAA0 partition.	If SAA0_START=0, then there is no SAP0 partition (SAP0_EN should be set to 0)
SAP1_START[6:0]	First Index of SAP1 partition.	Software must ensure that: **SAP1_START ≥ SAA0_START** If SAP1_START = SAA0_START, then there is no SAA0 partition (SAA0_EN should be set to 0)
SAA1_START[6:0]	First Index of SAA1 partition.	Software must ensure that:

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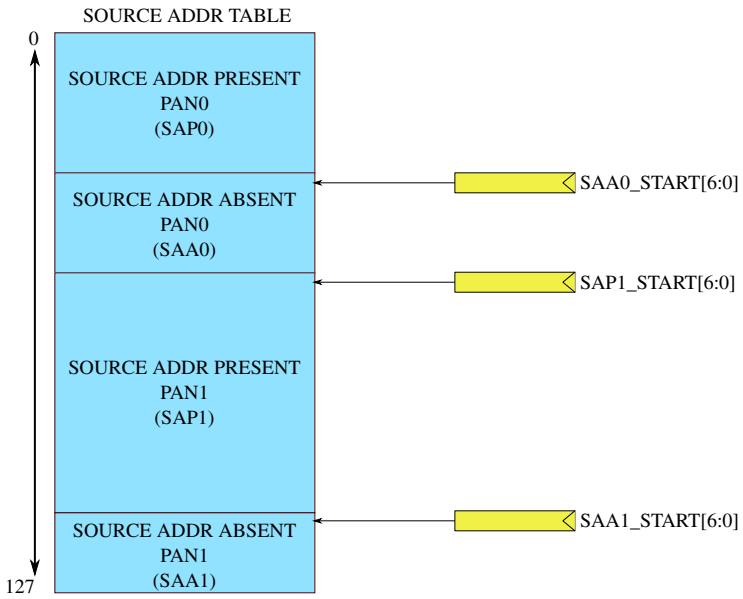
REGISTER NAME	DESCRIPTION	RESTRICTIONS
		SAA1_START ≥ SAP1_START If SAA1_START = SAP1_START, then there is no SAP1 partition (SAP1_EN should be set to 0)

A diagram which depicts one example of how the dividing-line registers affect partitioning of the table, is shown below.

SOURCE ADDRESS TABLE PARTITIONS -- NON-EQUAL SIZES (EXAMPLE)



Each table partition consists of one or more indices, which can be used to store source address checksums. The first index for any partition, is defined by the aforementioned *PARTITION*_START[6:0] register, where *PARTITION*_ is one of {SAP0, SAP1, SAA0, SAA1}. The last index for any partition, is defined by the next higher partition's *PARTITION*_START[6:0] register, minus 1. When populating the table with source address information, software must be sure to select an index that is within the defined range for the partition. For example, when installing a checksum in the SAP1 partition:

SAP1_START ≤ Selected_Index ≤ (SAA1_START – 1)

To populate the table partitions, a 7-bit register SAM_INDEX[6:0] is provided, as well as a "index enable bit", and a "index invalidate" bit. A 16-bit SAM_CHECKSUM[15:0] is provided, into which software will write the computed checksum. Installing a checksum into any partition is referred to as "Enabling an Index", and removing a checksum from any partition is referred to as "Invalidating an Index". A description of the registers is provided in the following table:

REGISTER NAME	DESCRIPTION
SAM_CHECKSUM[15:0]	Software-computed source address checksum, to be installed into a table index
SAM_INDEX[6:0]	Contains the table index to be enabled or invalidated. Software must ensure that the index is within the range of the desired partition.

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REGISTER NAME	DESCRIPTION
SAM_INDEX_WR	For 32-bit writes, this must be set to indicate that the table entry specified by SAM_INDEX[6:0] is to be written; if SAM_INDEX_WR=0, the table entry is not written, but the SAM_INDEX[6:0] register is updated. For 8-bit writes, this bit is ignored.
SAM_INDEX_EN	Enable the index selected by SAM_INDEX[6:0] for searching.
SAM_INDEX_INV	Invalidate the index selected by SAM_INDEX[6:0]
FIND_FREE_IDX	After modifying Valid bits (enabling or invalidating), write this bit to 1 to force HW to update the "First Free Index" registers to account for the changed Valid bits. This HW update process takes 4us. SW can poll SAM_BUSY to determine when the table update is complete. Write-only bit. Writing 0 to this bit has no effect. Readback value is indeterminate.
SAM_BUSY	HW is in the process of updating the Source Address table, either in response to a poll indication from the packet processor, or due to SW setting FIND_FREE_IDX=1. In the latter case, SW should poll SAM_BUSY until low before accessing the "First Free Index" registers. Read-only bit.
INVALIDATE_ALL	Writing a 1 to this bit clears all 128 Valid bits. Invalidates the entire table. Write-only bit. Writing 0 to this bit has no effect. Readback value is indeterminate.

All the index-control registers reside within a single 32-bit word, so that a single 32-bit write can store a new checksum in the table, and simultaneously enable, or invalidate, the index. For 32-bit writes, SAM_INDEX_WR must be set to 1 to cause the SAM_CHECKSUM[15:0] to be loaded into the table at the address specified by SAM_INDEX[6:0]. For 32-bit reads, it is necessary first to update SAM_INDEX[6:0] to the desired table index, if it is not already set to the desired index; this requires a write to SAM_INDEX[6:0] with SAM_INDEX_WR=0, so as to not update the table contents. Then, a subsequent 32-bit read will return the table contents at the desired index.

For systems that don't support 32-bit writes, the register fields should be written in the following order:

1. SAM_INDEX[6:0]
2. SAM_CHECKSUM (the 2 bytes can be written in either order)
3. SAM_INDEX_EN (to enable), or SAM_INDEX_INV (to invalidate)

During operation, when a packet is received and the packet processor searches the table for a source address match, only enabled indices within each partition are searched. Invalidated indices are ignored.

To assist software in finding an available index to store the next source address checksum, the packet processor makes available the following 4 read-only registers:

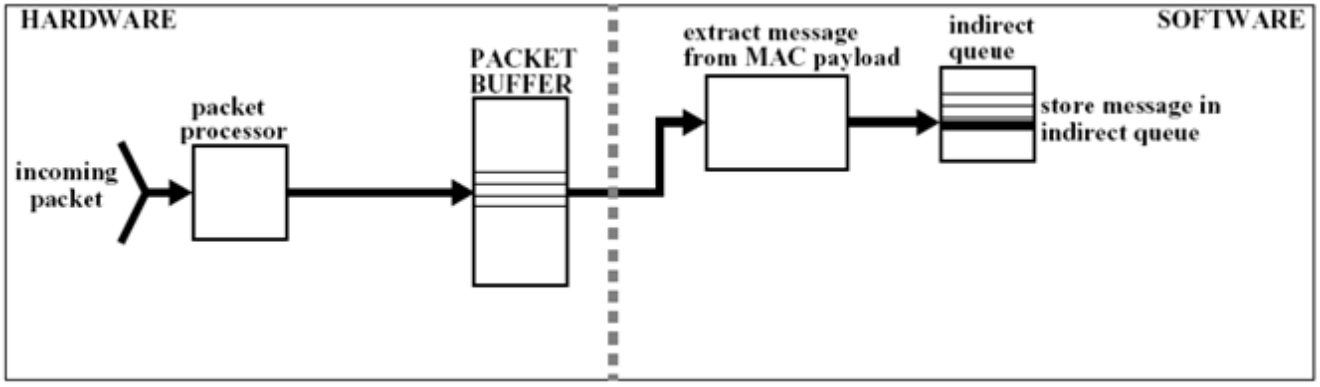
REGISTER NAME	DESCRIPTION
SAP0_1ST_FREE_IDX[6:0]	First non-enabled (invalid) index in the SAP0 partition
SAA0_1ST_FREE_IDX[6:0]	First non-enabled (invalid) index in the SAA0 partition
SAP1_1ST_FREE_IDX[6:0]	First non-enabled (invalid) index in the SAP1 partition
SAA1_1ST_FREE_IDX[6:0]	First non-enabled (invalid) index in the SAA1 partition

Operational Use

The following flow description illustrates how hardware and software interact to utilize the Source Addressing Management feature to facilitate pending-message handling and neighbor table management. This flow assumes both SAP and SAA acceleration are enabled, and Dual PAN mode is in effect. There are 11 sequential steps.

Step 1: Message Packet Reception, Extracting the Message, Indirect Queue Management

A message (data frame) is received by a coordinator. The message is received from one end device, and is intended for another end device. The coordinator's packet processor receives the packet, and stores it in the packet buffer. Coordinator software downloads the packet data from the packet buffer, extracts the message from the MAC payload, and stores the message in its indirect queue.



Step 2: Software computes address checksum

Coordinator software also extracts the destination information (Destination PANID and Destination Address), from the data packet stored in the packet buffer. Software uses this information to compute a 16-bit checksum. This checksum uniquely identifies the sending device, with a high degree of reliability. The checksum is computed according to the following rules:

Destination Addressing Mode	Rule
Mode 2 (short address)	Checksum = (Destination PAN ID + DstAddr[15:0]) % 65536
Mode 3 (long address)	Checksum = (Destination PAN ID + DstAddr[15:0]) % 65536 Checksum = (Checksum + DstAddr[31:16]) % 65536 Checksum = (Checksum + DstAddr[47:32]) % 65536 Checksum = (Checksum + DstAddr[63:48]) % 65536

Step 3: Software populates the address table

Coordinator software chooses an index in the Source Address Table in which it will store the just-computed checksum. If the data packet was received on PAN0, an index in the SAP0 partition should be chosen. Software may consult the register SAP0_1ST_FREE_IDX[6:0] to find the first available index in this partition. If the data packet was received on PAN1, an index in the SAP1 partition should be chosen. Software may consult the register SAP1_1ST_FREE_IDX[6:0] to find the first available index in this partition.

If an index is chosen which is already valid, software should first invalidate the index with the following procedure:

1. Set SAM_INDEX[6:0] to the selected index
2. Set SAM_INDEX_EN=0 and SAM_INDEX_INV=1

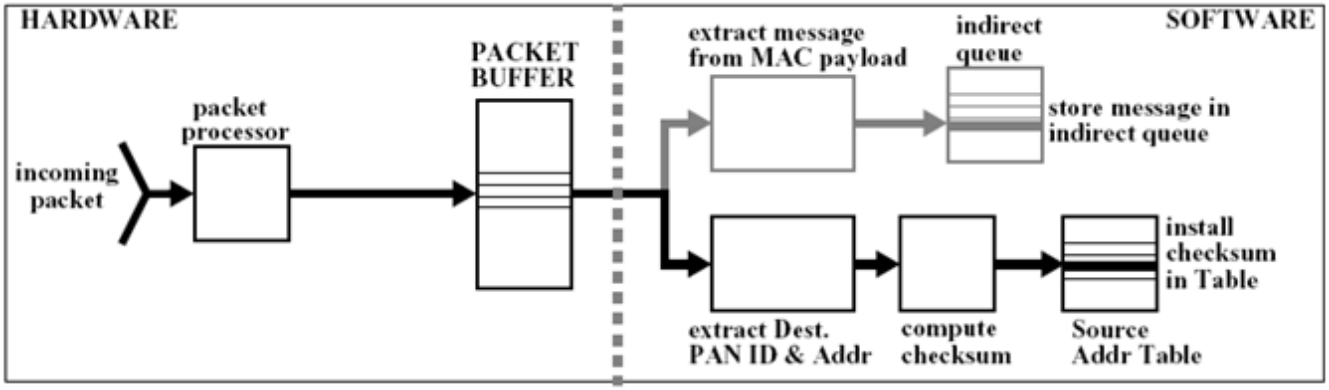
These steps can be performed in a single, 32-bit register write.

To install the source address checksum into the index and enable the index, the following procedure should be used:

1. Program SAM_CHECKSUM[15:0] to the computed checksum
2. Set SAM_INDEX[6:0] to the selected index
3. Set SAM_INDEX_EN=1 and SAM_INDEX_INV=0

These steps can be performed in a single, 32-bit register write.

The index is now enabled, and the packet processor will include it in its search when the next MAC Poll Request is received.



Step 4: Incoming Poll request, Packet Processor parses the Auxiliary Security Header

An incoming packet is received. The packet processor performs routine packet filtering. After determining that the packet is type 'MAC Command', the packet processor must perform additional packet parsing in order to locate the packet's Command Frame Identifier. This is the octet that distinguishes this commandas being of type "data request", from other MAC Command types. For the packet processor, this extra parsing is more complex, because the Command Frame Identifier is part of the MAC payload; this is the only scenario where the packet processor is required to parse the payload. This is further complicated by the fact that the revision 2006 (and subsequent) of the 802.15.4 wireless MAC standard, includes a variable-length "Auxiliary Security Header", prior to the MAC payload. This header is only present for FrameVersion > 0, and SecurityEnabled = 1. The packet processor must conditionally parse this header in order to locate the start of the MAC payload, where the Command Frame Identifier is located. The packet processor uses 2 subfields of the Frame Control Field to parse the Auxiliary Security Header (A.S.H.): FrameVersion, and SecurityEnabled. The packet processor parses the Auxiliary Security Header (A.S.H.) according to the following table:

Length of Auxiliary Security Header (Octets)	SecurityEnabled (Frame Control Field)	FrameVersion (Frame Control Field)	KeyIdentifierMode (Security Control Field)	Remarks
0	0	00 or 01	-	If !SecurityEnabled, no ASH regardless of FrameVersion
0	1	00	0	If packet is 2003-compliant, no ASH
5 Security Control (1 octet) + Frame Counter (4 octet)	1	01	0x00	ASH present. Length of ASH computed by HW.
6 Security Control (1 octet) +	1	01	0x01	ASH present. Length of ASH computed by HW.

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Length of Auxiliary Security Header (Octets)	SecurityEnabled (Frame Control Field)	FrameVersion (Frame Control Field)	KeyIdentifierMode (Security Control Field)	Remarks
Frame Counter (4 octet) + Key Identifier (1 octet)				
10 Security Control (1 octet) + Frame Counter (4 octet) + Key Identifier (5 octet)	1	01	0x2	ASH present. Length of ASH computed by HW.
14 Security Control (1 octet) + Frame Counter (4 octet) + Key Identifier (9 octet)	1	01	0x3	ASH present. Length of ASH computed by HW.
-	-	10 or 11	-	HW will handle these FrameVersion's indentically to FrameVersion 01

The contents of the A.S.H. are irrelevant to the packet processor; only its length is important. This is because the octet which immediately follows the A.S.H. is the Command Frame Identifier. This is all the packet processor needs to know.

Step 5: Hardware extracts the Command Frame Identifier

After parsing the A.S.H. (if present), the next octet in the MAC payload, in accordance with the 802.15.4 standard, is the Command Frame Identifier.

Command frame identifier	Command name	RFD		Subclause
		Tx	Rx	
0x01	Association request	X		5.3.1
0x02	Association response		X	5.3.2
0x03	Disassociation notification	X	X	5.3.3
0x04	Data request	X		5.3.4
0x05	PAN ID conflict notification	X		5.3.5
0x06	Orphan notification	X		5.3.6
0x07	Beacon request			5.3.7
0x08	Coordinator realignment		X	5.3.8
0x09	GTS request			5.3.9
0x0a–0xff	Reserved			—

The packet processor checks to see if the Command Frame Identifier = 0x4. If it is not, packet processing for this frame is complete, the remainder of the packet is received, without inspection by the packet processor, and is stored the packet buffer. If the Command Frame Identifier = 0x4, then this is a data request, and assuming the prior rules-checking and address-checking on this packet have already passed, then the Source Address Matching function will be applied to this packet, continuing in STEP 6.

Step 6: Hardware Computes the Source Address Checksum

The packet processor uses the received Source PAN ID and Source Address for this packet to compute a 16-bit Source Address checksum. This checksum uses precisely the same algorithm that software uses to compute its Address checksum (see STEP 2), except that the *Source* PAN ID and address are used, rather than the Destination PAN ID and address. This checksum uniquely identifies the sending device, with a high degree of reliability. Note if the incoming packet's Frame Control Field has the PANIDCompression subfield asserted, the packet processor will substitute "Destination PAN ID" for "Source PAN ID" in the computation, since Source PAN ID will not be present under these circumstances.

Step 7: Hardware performs "Source Address Present" Table Search

If the MAC poll request was received on PAN0, and SAP0_EN=1 to enable searches of the PAN0 "Source Address Present" partition, the packet processor uses its Source Address checksum to look for a match in the SAP0 partition of the table. Only table entries that are enabled, are compared against (see STEP 3); table indices which are not enabled, are ignored in the search.

If a single table match is found (i.e., 1 software-computed checksum in SAP0 partition matches the hardware-computed checksum for the incoming packet), this means that there is a message for this requestor in the coordinator's message queue. For a SAP0 match, the packet processor takes these 2 steps:

1. Set SAP0_ADDR_PRESENT=1
2. Set SAP0_MATCH[6:0] to the index which matched

If multiple table matches are found (i.e., more than 1 software-computed checksum in the SAP0 partition matches the hardware-computed checksum for the incoming packet), this means that there are multiple messages for this requestor in the coordinator's message queue. In this case, the packet processor takes the same steps as for a single match, with the SAP0_MATCH[6:0] register being set to the lowest-value matching index (i.e., the smallest number) within the SAP0 partition.

If no source address match is found in the SAP0 table search, the packet processor will set SAP0_ADDR_PRESENT=0.

If, on the other hand, the MAC poll request was received on PAN1, and SAP1_EN=1 to enable searches of the PAN1 "Source Address Present" partition, the packet processor uses its Source Address checksum to look for a match in the SAP1 partition of the table. Only table entries that are enabled, are compared against (see STEP 3); table indices which are not enabled, are ignored in the search.

If a single table match is found (i.e., 1 software-computed checksum in SAP1 partition matches the hardware-computed checksum for the incoming packet), this means that there is a message for this requestor in the coordinator's message queue. For a SAP1 match, the packet processor takes these 2 steps:

1. Set SAP1_ADDR_PRESENT=1
2. Set SAP1_MATCH [6:0] to the index which matched

If multiple table matches are found (i.e., more than 1 software-computed checksum in the SAP1 partition matches the hardware-computed checksum for the incoming packet), this means that there are multiple messages for this requestor in the coordinator's message queue. In this case, the packet processor takes the same steps as for a single match, with the SAP1_MATCH[6:0] register being set to the lowest-value matching index (i.e., the smallest number) within the SAP1 partition.

If no source address match is found in the SAP1 table search, the packet processor will set SAP1_ADDR_PRESENT=0.

Step 8: Hardware performs "Source Address Absent" Table Search

If the MAC poll request was received on PAN0, and SAA0_EN=1 to enable searches of the PAN0 "Source Address Absent" partition, the packet processor uses its Source Address checksum to look for a match in the SAA0 partition of the table. Only table entries that are enabled, are compared against (see STEP 3); table indices which are not enabled, are ignored in the search.

If one (or more) table match is found (i.e., a software-computed checksum in SAA0 partition matches the hardware-computed checksum for the incoming packet), this means that the end device which sent the poll request is a valid child of this parent. For a SAA0 match, the packet processor takes these 2 steps:

1. Set SAA0_ADDR_ABSENT=0
2. Set SAA0_MATCH[6:0] to the first index which matched

If *no* source address match is found in the SAA0 table search, the packet processor will set SAA0_ADDR_ABSENT=1.

If, on the other hand, the MAC poll request was received on PAN1, and SAA1_EN=1 to enable searches of the PAN1 "Source Address Absent" partition, the packet processor uses its Source Address checksum to look for a match in the SAA1 partition of the table. Only table entries that are enabled, are compared against (see STEP 3); table indices which are not enabled, are ignored in the search.

If one (or more) table match is found (i.e., a software-computed checksum in SAA1 partition matches the hardware-computed checksum for the incoming packet), this means that the end device which sent the poll request is a valid child of this parent. For a SAA1 match, the packet processor takes these 2 steps:

1. Set SAA1_ADDR_ABSENT=0
2. Set SAA1_MATCH[6:0] to the first index which matched

If *no* source address match is found in the SAA1 table search, the packet processor will set SAA0_ADDR_ABSENT=1.

Step 9: Hardware determines FramePending status

The packet processor maintains an internal flag called **rx_frame_pending**, which is sent to the TX_PACKET block after every received packet, to directly control the state of the FramePending subfield of the Frame Control Field in the upcoming auto-TxAck frame (if enabled with AUTOACK=1).

If the Source Address Management feature is completely disabled, i.e.,

SAP0_EN = SAA0_EN = SAP1_EN = SAA1_EN = 0

then the packet processor will set the **rx_frame_pending flag** to the value of the ACK_FRM_PND register, putting the state of FramePending under direct software control.

Otherwise, if *any* of the following conditions are met, the packet processor will set its **rx_frame_pending** flag to 1:

1. The MAC Poll Request was received on PAN0, SAP0_EN=1, and SAP0_ADDR_PRESENT=1
2. The MAC Poll Request was received on PAN1, SAP1_EN=1, and SAP1_ADDR_PRESENT=1
3. The MAC Poll Request was received on PAN0, SAA0_EN=1, and SAA0_ADDR_ABSENT=1
4. The MAC Poll Request was received on PAN1, SAA1_EN=1, and SAA1_ADDR_ABSENT=1

If none of the conditions are met, **rx_frame_pending** flag will be set to 0.

Step 10: Receive interrupt RXIRQ

The packet processor receives the remainder of the packet, and verifies the FCS. Assuming the CRC check passes, the RXIRQ interrupt is issued. In the coordinator software's RXIRQ Interrupt Service Routine, software can determine if the received packet was a MAC Poll Request by reading the PI bit of the IRQSTS register. If PI=0, the received packet was not a poll request, and no action relating to Source Address Matching need be taken.

Otherwise, if *either* SAP0_ADDR_PRESENT=1 or SAP1_ADDR_PRESENT=1, an auto-TxAck packet is being sent with the FramePending subfield set to 1, so software should follow up by constructing a data packet (or packets) for the requesting end device, with a payload consisting of the message for this device which had been stored in the coordinator's indirect queue.

Also, if *either* SAA0_ADDR_ABSENT=1 or SAA1_ADDR_ABSENT=1, an auto-TxAck packet is being sent with the FramePending subfield set to 1, so software should follow up by constructing a "Leave Message" for the requesting end device.

Step 11: Software disables the spent index

In the final step, coordinator software must disable (invalidate) the index which was just used to locate and send the stored message to the requesting end device. To disable the index:

1. Set SAM_INDEX[6:0] to the selected index
2. Set SAM_INDEX_EN=0 and SAM_INDEX_INV=1

At this point, the disabled index is now an available table entry, which can be used to install a new Address checksum for another message in the indirect queue.

52.4.4.4.2.2.8.1.1.2.4 Dual PAN Mode

In the past, radio transceivers designed for 802.15.4 applications allow a device to associate to one and only one PAN (Personal Area Network), at any given time. The Packet Processor includes hardware support for a device to reside on two networks simultaneously. In optional Dual PAN mode, the device will alternate between the 2 PAN's, under hardware or software control. Hardware support for Dual PAN operation consists of 2 sets of PAN and IEEE addresses for the device, 2 different channels (one for each PAN), a programmable timer to automatically switch PAN's (including on-the-fly channel-changing) without software intervention, control bits to configure and enable Dual PAN mode, and read-only bits to monitor status in Dual PAN mode. A device can be configured to be a PAN Coordinator on either network, both networks, or neither.

For the purpose of defining a "PAN" in the context of Dual PAN mode, two sets of network parameters are maintained. In this document, "PAN0" and "PAN1" will be used to refer to the 2 PAN's. Each parameter set uniquely identifies a PAN for Dual PAN mode. These parameters are:

PAN0	PAN1
CHANNEL_NUM0	CHANNEL_NUM1
MACPANID0 (16-bit register)	MACPANID1 (16-bit register)

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PAN0	PAN1
MACSHORTADDRS0 (16-bit register)	MACSHORTADDRS1 (16-bit register)
MACLONGADDRS0 (64-bit registers)	MACLONGADDRS1 (64-bit registers)
PANCORDNTR0 (1-bit register)	PANCORDNTR1 (1-bit register)

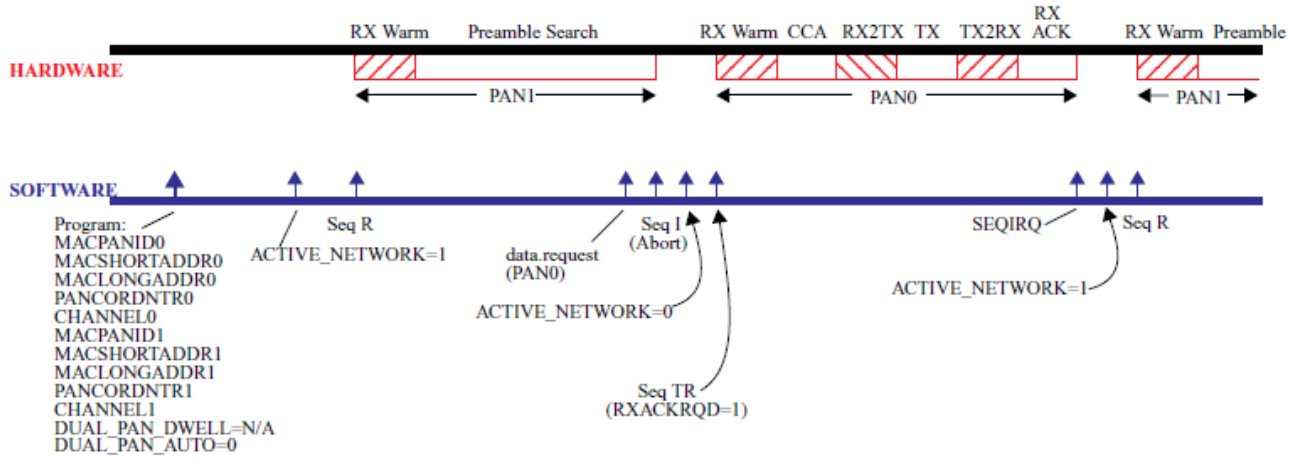
During device initialization, if Dual PAN mode is to be utilized, software will program both parameters sets, to configure the hardware for operation on two networks.

Two modes are available for Dual PAN operation: manual and automatic.

Manual Dual PAN

In manual Dual PAN mode, software controls which PAN is selected for transmission and reception, at all times. Software populates both PAN network parameter-set registers listed above. Software then selects a PAN to begin transmission or reception. A single control bit **ACTIVE_NETWORK**, selects the PAN. To select PAN0, **ACTIVE_NETWORK** should be set to 0; to select PAN1, **ACTIVE_NETWORK** should be set to 1. Software then initiates an autosequence by writing the appropriate value to XCVSEQ (PHY_CTRL1 Register). At any point, software can elect to switch to the alternate PAN. To do so, software aborts the sequence (if one is active) by writing XCVSEQ=IDLE. Software then toggles **ACTIVE_NETWORK**, and restarts a new sequence with XCVSEQ. Software is responsible for aborting and initiating sequences. Hardware is responsible for warming up the transceiver on the selected channel (CHANNEL_NUM0 or CHANNEL_NUM1), and performing address-filtering on the selected network's address parameters (PANCORDNTR, MacPanID, Short Address, and/or IEEE address). Software overhead is significantly reduced in this mode, since there is no need to re-program all of the PAN-select registers every time the PAN is toggled in Dual PAN mode; only a single bit (**ACTIVE_NETWORK**) need be written. For manual Dual PAN operation, **DUAL_PAN_AUTO** should be set to 0.

The following diagram depicts Dual PAN operation in manual mode. In this example, software populates both PAN parameters sets during initialization. In this example, software elects to initiate packet reception on PAN1, so **ACTIVE_NETWORK** is set to 1. Software initiates the Sequence R by writing to XCVSEQ. Hardware warms up the receiver on CHANNEL_NUM1 and enters preamble-search. In this example, no packet is received, but a data request from higher-level software requires a switch to PAN0. Software responds by aborting the reception by writing Sequence I to XCVSEQ. Software then sets **ACTIVE_NETWORK** to 0 to select PAN0. In the example, software initiates a Sequence TR. Hardware warms up the receiver for CCA on CHANNEL_NUM0, performs CCA (channel is idle), warms down the receiver, and warms up the transmitter on CHANNEL_NUM0, transmits the requested packet, warms down the transmitter and warms up the receiver again (as per the autosequence) on CHANNEL_NUM0, to receive the acknowledge packet. The acknowledge packet is received and the autosequence completes successfully with RXIRQ and SEQIRQ. Software elects to resume packet reception on PAN1 (which was in progress before the data request). Software toggles **ACTIVE_NETWORK** back to 1, and re-initiates Sequence R.



Auto Dual PAN

In automatic Dual PAN mode, hardware is responsible for alternating the selected PAN, at a pre-programmed interval. Software programs a "PAN dwell time", which determines the amount of time during which the hardware will receive on a given PAN. This is done by programming the **DUAL_PAN_DWELL** register. Software sets the **DUAL_PAN_AUTO** bit to 1 for automatic Dual PAN operation, and sets **ACTIVE_NETWORK** to correspond to the PAN on which it desires packet reception to begin. Software then initiates a Sequence R. Hardware warms up the receiver on the selected PAN, and begins preamble search. When the dwell time expires, assuming preamble and SFD have not been detected, hardware will switch to the alternate PAN. This includes an on-the-fly channel change. Once switched to the alternate PAN, hardware will use the address filtering parameters (PANCORDNTR, MacPanID, Short Address, and/or IEEE address) programmed for the alternate PAN. Once the dwell time expires on the alternate PAN, assuming preamble and SFD have not been detected, hardware will switch back to the original PAN. This process will repeat indefinitely, until one of the following occurs:

1. A packet is successfully received (address match and CRC valid).
2. Software aborts the Sequence R
3. A PLL unlock automatically aborts the Sequence R (if unlock aborting is enabled)

If the hardware PAN dwell timer expires *during* a packet reception (i.e., preamble and SFD have been detected during a Sequence R), the PAN-switch will be delayed until the packet is completely received. If the packet is received successfully (address match and CRC valid), the receive sequence will terminate with RXIRQ and SEQIRQ (if an auto-Acknowledge was requested and enabled, the sequence will complete after the Acknowledge packet was transmitted, and TXIRQ will also be set, in addition to RXIRQ and SEQIRQ); the PAN switch will occur at this point, after the Sequence has returned to IDLE.

If the received packet fails FCS (CRC check), or, if the packet was not intended for the device (address mismatch), the hardware will toggle the PAN, and return to preamble-search on the new PAN.

If the hardware PAN dwell timer expires during a state *other* than RX preamble search during Sequence R (i.e., if expiration occurs during TX, CCA, ED, Sequence TR, or any warmup or transitional state), PAN-switch will be delayed until either:

1. Preamble Search state is reached during a Sequence R (not Sequence TR)
2. Sequence returns to IDLE.

At any point, software can elect to interrupt the automatic Dual PAN operation, by aborting the sequence with a XCVSEQ=IDLE, and the setting the **DUAL_PAN_AUTO** bit to 0. In response, hardware will freeze the current state of the dwell timer, and capture the currently-selected PAN, so that hardware-controlled PAN alternation can resume where it left off, later. Software can then tend to that tasks that caused the Dual PAN interruption. When software wants to resume Dual PAN operation, it then sets **DUAL_PAN_AUTO**=1, and re-initiates Sequence R. Hardware will resume the dwell timer from the point it was frozen earlier, on the same PAN, and will warmup the receiver to receive on the PAN which was being monitored before

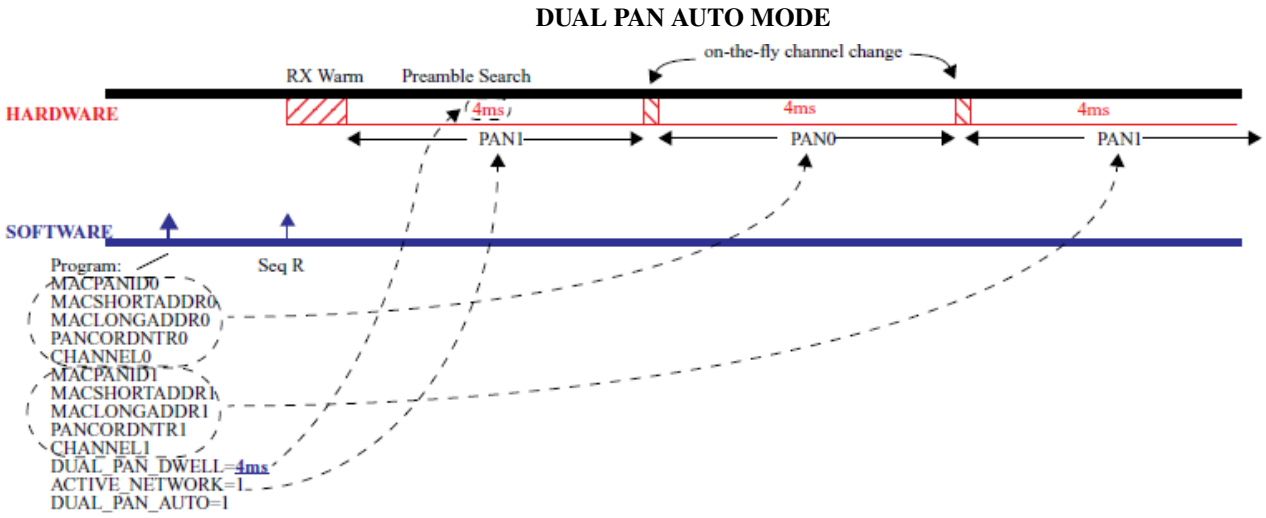
the interruption. Hardware will dwell on that PAN until the timer expires, and then switch PAN's (assuming no preamble and SFD detected, subject to the conditions listed above). Software can always determine the selected PAN at any time, in any mode, by reading **CURRENT_NETWORK** bit. If **DUAL_PAN_AUTO**=0, then **CURRENT_NETWORK** = **ACTIVE_NETWORK**. If **DUAL_PAN_AUTO**=1, then **CURRENT_NETWORK** is controlled by hardware.

To initiate auto Dual PAN operation for the first time, or to reset the dwell timer to its programmed value and allow software to select the initial PAN for auto Dual PAN operation, software should program the desired initial PAN to **ACTIVE_NETWORK** (0 for PAN0, 1 for PAN1), and then program the desired dwell time into the **DUAL_PAN_DWELL** register. Hardware always responds to a write to **DUAL_PAN_DWELL**, by resetting the dwell timer to its programmed value, and selecting the initial PAN for auto Dual PAN operation, based on the state of **ACTIVE_NETWORK**. A write to **DUAL_PAN_DWELL**, always re-initializes the DWELL TIMER to the programmed value. If a write to **DUAL_PAN_DWELL** occurs during an autosequence, the DWELL TIMER will begin counting down immediately. If a write to **DUAL_PAN_DWELL** occurs when there is no autosequence underway, the DWELL TIMER will not begin counting until the next autosequence begins; it will begin counting at the start of the autosequence warmup. Under all circumstances, **DUAL_PAN_AUTO** must be asserted to allow the DWELL TIMER to count. If **DUAL_PAN_AUTO**=0, the DWELL TIMER will freeze and hold its state, until **DUAL_PAN_AUTO**=1. However, a write to **DUAL_PAN_DWELL** will still initialize the DWELL TIMER to its programmed value, regardless of the state of **DUAL_PAN_AUTO**.

At any point during auto Dual PAN mode, software can ascertain the PAN currently being serviced by hardware, by reading the **CURRENT_NETWORK** bit. Software can also determine the time-remaining in the current dwell, by reading the **DUAL_PAN_REMAIN** Register.

In auto Dual PAN mode, software retains responsibility for initiating and aborting sequences. There is no provision for hardware-initiated sequences.

The following diagram depicts Dual PAN operation in automatic mode. In this example, software populates both PAN parameters sets during initialization. In this example, software wants to initiate packet reception in auto Dual PAN mode, on PAN1, so **ACTIVE_NETWORK** is set to 1. For auto Dual PAN operation, software programs the desired PAN-switching interval into **DUAL_PAN_DWELL** register, in this case, 4ms. Software initiates the Sequence R by writing to XCVSEQ. The dwell timer begins counting as soon as the receiver warmup begins. Hardware warms up the receiver on CHANNEL_NUM1 (since PAN1 was selected as the initial PAN in this example), and begins preamble search. If a packet is received during this interval, hardware applies PAN1 address filtering. In this example, no preamble is detected at the point at which the dwell timer expires. So, at this point, hardware executes a PAN-switch to PAN0. which includes an on-the-fly channel change. The on-the-fly channel change requires approximately 93us and no preamble detection is possible during this "blind spot". (For more details on how the hardware executes the Dual PAN on-the-fly channel change, see Chapter GSM Sequence Manager, Section Dual PAN Mode.) After the PAN switch, hardware resumes preamble search on CHANNEL_NUM0, and applies PAN0 address filtering if a packet is received. In this example, no preamble is detected at the point at which the dwell timer expires. So, at this point, hardware performs a PAN-switch back to PAN1. And so on and so forth.



Two-PAN-one-channel

A special case occurs if a device is operating in Dual PAN mode (either Auto or Manual mode), and both PAN's occupy the same channel; in other words, CHANNEL_NUM0=CHANNEL_NUM1. In this case, hardware will detect this condition automatically, and apply both sets of address-filtering parameters simultaneously. Hardware will provide Data Indication if the received packet matches either the PAN0 address parameter set {**MACPANID0, MACSHORTADDRS0, MACLONGADDRS0, PANCORDNTR0**}, or the PAN1 address parameter set {**MACPANID1, MACSHORTADDRS1, MACLONGADDRS1, PANCORDNTR1**}. At Data Indication, two status bits can be queried by software to quickly determine on which PAN the packet was received, **RECD_ON_PAN0** or **RECD_ON_PAN1**. In the "Two-PAN-one-channel" scenario, it is possible for a packet to satisfy both sets of addressing parameters (PAN0 and PAN1). When this happens, both **RECD_ON_PAN0** and **RECD_ON_PAN1** will be set. In the "Two-PAN-one-channel" scenario, the **CURRENT_NETWORK** bit should be ignored, since both networks are simultaneously active.

If Dual PAN mode is not to be utilized, **ACTIVE_NETWORK** should be maintained at 0 (default) to select the PAN0 parameters for transceiving. In single PAN operation, the PAN1 parameter registers need not be programmed, and can be used as scratchpad. CHANNEL_NUM1 should not be programmed, and should instead be left in its default state, if Dual PAN mode is not in use.

Dual PAN Channel Override

In Dual PAN mode, in case there is a need to generate a frequency which may be offset from the 16 prescribed 5MHz-spaced channels, to, for example, avoid interference on one of the Dual PAN channels, a method has been provided to do that, by designating one of the two PAN channels to use the transceiver's set of direct frequency-programming registers, instead of CHANNEL_NUMx. Programming the direct frequency-programming registers – integer, numerator, and denominator, allows an RF frequency to be selected with much more precision than the 5MHz granularity of the 802.15.4 mapped-channel registers, CHANNEL_NUM0 and CHANNEL_NUM1. This is referred to as "Dual PAN Channel Override". For more details on this feature, see Chapter GSM Sequence Manager, Section Dual PAN Channel Override.

52.4.4.4.2.2.8.1.1.2.5 Promiscuous Mode

Functional description

Promiscuous Mode are defined in PAN mode and FAN mode.

The 802.15.4 Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs) defines the following behavior for Promiscuous Mode operation:

> "In promiscuous mode, the MAC sublayer shall pass all frames received after the first filter directly to the upper layers without applying any more filtering or processing."

Where first level filtering is described as:

> "For the first level of filtering, the MAC sublayer shall discard all received frames that do not contain a correct value in their FCS field in the MFR (see 7.2.1.9)"

Promiscuous mode allows a device to receive and process all 802.15.4 frames which pass FCS check (CRC), regardless of whether or not they are addressed to the device. This allows a device to receive and process all valid traffic on a network. In Promiscuous mode, the Packet Processor will provide a Data Indication on all such packets. This capability allows a simple network sniffer to be constructed, which can display comprehensive packet data for all packets transmitted on a network within receiving range of the device.

In PAN mode, promiscuous mode will bypass the filtering rules described in Packet Filtering Detail.

In FAN mode, promiscuous mode will bypass the filtering rules described in FAN Mode Filter.

Since a device operating in promiscuous mode is designed to do so discreetly, automatic acknowledgement of all received packets is inhibited, regardless of the state of the Ack Request field in the Frame Control Field of the received packet; otherwise, the sniffing device would be acknowledging received frames for which it was not the addressee.

Special Handling for Auto Receive Acknowledge Frame

The Packet Processor features an autosequence to automatically receive, and verify, Acknowledge Frames after a Transmit frame has been sent by the device. This is accomplished by programming a Sequence TR with RXACKRQD=1. During normal operation, these receive Acknowledge Frames are not stored in the Packet Buffer. They are merely checked for matching Sequence Number and Frame Version, with a Data Indication issued for a valid match on both. Promiscuous Mode should therefore **NOT** be used with Sequence TR with RXACKRQD=1.

52.4.4.4.2.2.8.1.1.2.6 Provisions to Enable Software Support 802.15.4-2015

Legacy frame types as specified in 802.15.4, such as LLDN Frame Type, Multipurpose Frame Type, , as well as the Extended Frame Type, Fragment Frame Type, modify the format and definition of the Frame Control Field in such a way as to render parsing of the MHR by the packet processor impossible, without major upgrades to the hardware. For example, the packet processor hardware does not support 8-bit (simple) addressing, nor Sequence Number Suppression.

As in interim solution, provisions have been added to the packet processor to allow these new packet variations to be recognized and conditionally admitted (Data Indication to software). Three new Frame Type control bits, and a modification of the Frame Version Filtering bits, are included in the Packet Processor, and affect hardware packet parsing as indicated in the following table:

REGISTER	DEFINITION
FRM_VER_FILTER[3:0]	Frame Version selector. The incoming packet's Frame Control Field is parsed to obtain the FrameVersion subfield, and that value is compared against this register, in accordance with the following: xxx1: Accept received packets with FrameVersion=00 xx1x: Accept received packets with FrameVersion=01 x1xx: Accept received packets with FrameVersion=10 1xxx: Accept received packets with FrameVersion=11 These filtering rules apply to Beacon, Acknowledge, Data, and MAC Command Frame Types only, since these frame types require a 2-octet Frame Control Field which embeds a 2-bit FrameVersion subfield.
LLDN_FT	1: LLDN frame type enabled (Frame Type 4) 0: reject all LLDN frames
MULTIPURPOSE_FT	1: Multipurpose frame type enabled (Frame Type 5) 0: reject all Multipurpose frames
EXTENDED_FT	1: Extended frame type enabled (Frame Type 7) 0: reject all Extended frames
FRAGMENT_FT	1: Fragment/Frak frame type enabled (Frame Type 6) 0: reject all Fragment/Frak frames

The Extended Frame Type does not comply with the General MAC Frame Format, which is shown in the following diagram:

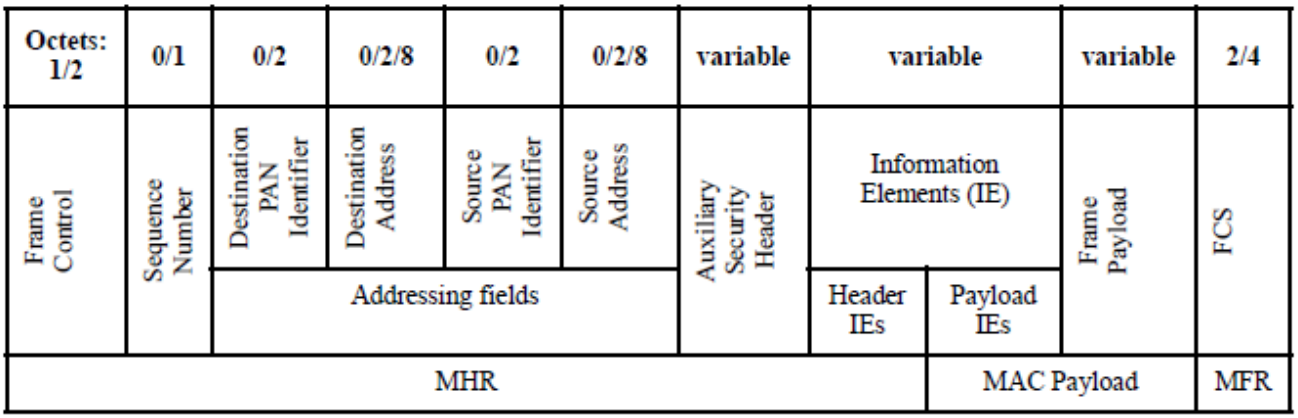


Figure 86—General MAC frame format

Figure 488. General MAC Frame Format

Instead, the Extended Frame has its own unique format, which is shown in the following diagram:

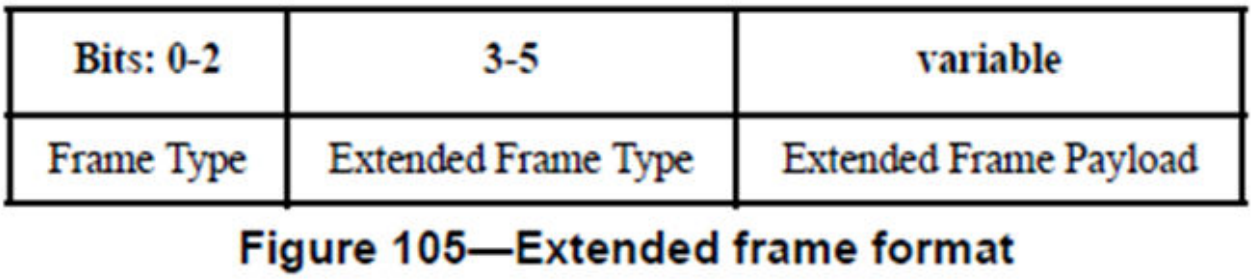


Figure 105—Extended frame format

Figure 489. Extended Frame Format

Because the Extended Frame Payload, which is not defined in the 802.15.4-2015 revision to the standard, would be intended to contain and fully specify the FCS, the Packet Processor will not be able to verify FCS on received packets with Frame Type Extended. FCS checking will need to be implemented in software.

Note: If the EXTENDED_FT bit is set to enable Data Indication on packets of Frame Type Extended, software should expect a substantial increase in the frequency of notifications, as a consequence of the lack of hardware verification of FCS, which will have implications for software workload as well as power consumption in the SoC.

When the packet processor receives any of the legacy frames, if the corresponding control bit is set, the hardware will skip Stage 2 filtering, and merely verify FCS. If FCS passes, the packet processor will notify software of the packet, without inspection of the addressing fields or payload. For such packets, software will be responsible for parsing the MHR and payload sections of the frame. If the corresponding control bit is not set, the packet processor will reject the received packet and there will be no Data Indication.

When the packet processor receives a packet of Frame Type Extended, if the EXTENDED_FT bit is set, the hardware will skip Stage 2 filtering, and after the entire packet is received, the packet processor will merely notify software of the packet, without inspection of the Extended Frame Type bits or the Extended Frame Payload. For such packets, software will be responsible for parsing the Extended Frame Type and the Extended Frame Payload sections of the frame. If the corresponding control bit is not set, the packet processor will reject the received packet and there will be no Data Indication.

Like all existing frames prior to 802.15.4-2015, a received frame may require an acknowledgement. In the case of the 802.15.4-2015 frames, the required timing for the acknowledge frame transmission, has been modified. The acknowledgement no longer immediately follows the packet reception. For this reason, upon reception of any of these 2015-compliant packets, the packet processor will cancel any auto-ACK transmission, regardless of the state of the PHY_CTRL[AUTOACK] bit and AR

field of the received packet's Frame Control Field. Software will be responsible for constructing the acknowledgment packet and transmitting it at the appropriate time using a Sequence T.

To help expedite software processsing of the 2015-compliant Frame Types and Versions, additional status bits have been added to the 802.15.4 register set, which are described in the following table:

STATUS BIT	RESIDES IN REGISTER	DEFINITION
ENH_PKT_STATUS	RX_FRAME_FILTER	1: The last packet received was 2015-compliant (SW should query the RX_FRAME_FILTER register for additional status bits) 0: The last packet received was not 2015-compliant
BEACON_FV2_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType Beacon with FrameVersion 2 0: The last packet received was not a FrameType Beacon with FrameVersion 2
DATA_FV2_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType Data with FrameVersion 2 0: The last packet received was not a FrameType Data with FrameVersion 2
ACK_FV2_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType Acknowledge with FrameVersion 2 0: The last packet received was not a FrameType Acknowledge with FrameVersion 2
CMD_FV2_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType MAC Command with FrameVersion 2 0: The last packet received was not a FrameType MAC Command with FrameVersion 2
LLDN_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType LLDN 0: The last packet received was not a FrameType LLDN
MULTIPURPOSE_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType Multipurpose with FrameVersion 2 0: The last packet received was not a FrameType Multipurpose
EXTENDED_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType Extended 0: The last packet received was not a FrameType Extended
FRAGMENT_RECD	RX_FRAME_FILTER	1: The last packet received was a FrameType Fragment 0: The last packet received was not a FrameType Fragment

52.4.4.4.2.2.8.1.1.2.7 FAN Mode Filter

The Packet Processor supports to filter the DATA and ACK frame in FAN standard which is based on 802.15.4-2015. Only Data and Enhanced Acknowledge frames are used in FAN mode.

The following table summarizes the frame format used in FAN.

	Frame Control, Octets: 2											1	8	2	8	6	Variable	4
	Bit:0-2	3	4	5	6	7	8	9	10-11	12-13	14-15							
	Frame Type	Security	Frame Pending	AR	PAN ID Compression	Reserved	Sequence Number Suppression	IEs Present	Destination Addressing Mode	Version	Source Addressing Mode	Sequence Number	Destination Address	Source PAN ID	Source Address	ASH	IE	FCS
PA	1	0	0	0	0	0	1	1	0	2	3	N	N	Y	Y	N	Y	Y
PAS	1	0	0	0	1	0	1	1	0	2	3	N	N	N	Y	N	Y	Y
PC	1	1	0	0	0	0	1	1	0	2	3	N	N	Y	Y	Y	Y	Y
PCS(same as PA)	1	0	0	0	0	0	1	1	0	2	3	N	N	Y	Y	N	Y	Y
unicast ULAD	1	1	0	0/1	1	0	0/1	1	3	2	0/3	Y/N	Y	N	Y/N	Y	Y	Y
broadcast ULAD	1	1	0	0	0	0	0	1	0	2	3	Y	N	Y	Y	Y	Y	Y
Acknowledgement	2	1	0	0	1	0	1	1	3	2	3	N	Y	N	Y	Y	Y	Y
EAPOL	1	0	0	0	1	0	0	1	3	2	3	Y	Y	N	Y	N	Y	Y

Figure 490. Frame Type in FAN

The Packet Processor checks the following rules:

1. Auto-RxAck Checking (in Sequence TR)
    a. Received Destination Address == Device's Address
    b. Received Source Address = Transmitted Destination Address
    c. Received Frame Control filed is same as WiSUN spec
2. Data or ACK frame format check
    a. Received Destination Address == Device's Address
    b. Frame Version field should be b10
    c. IEs Present field should be 1
    d. Frame Type should be DATA or ACK

52.4.4.4.2.2.8.1.1.2.8 Appendix A

FILTERFAIL CODES

A description of the FILTERFAIL_PAN codes can be found in the following table.

FILTERFAIL CODE_PAN BIT	REASON FOR FILTERFAIL
[0]	Fails Stage 1 Frame Length Checking (FL < 5) **Note:** FL < 3 will not generate an SFD, so this bit will not be set
[1]	Fails Stage 1 Section 7.2.1.1.6 or Section 7.2.1.1.8 Checking (DST_ADDR_MODE or SRC_ADDR_MODE = 1)
[2]	Fails Stage 1 Section 7.2.1.1.5 Checking (Illegal PAN_ID_COMPRESSION Usage)
[3]	Fails Stage 1 Frame Version Checking
[4]	Fails Stage 2 Auto-RxAck Checking (Illegal Ack Frame Format in Sequence TR)
[5]	Fails Stage 2 Frame Type Checking (Incorrect Frame Filter Bit setting)
[6]	Fails Stage 2 Frame Length Checking (Illegal Beacon, Data, or Cmd FL)
[7]	Fails Stage 2 Addressing Mode Checking (Illegal Addressing Mode for Beacon, Data, OR Cmd)
[8]	Fails Stage 2 Sequence Number Matching (Sequence TR Only)
[9]	Fails Stage 2 PAN ID or Address Checking (Beacon, Data, or Cmd)

A description of the FILTERFAIL_FAN codes can be found in the following table.

FILTERFAIL CODE_FAN BIT	REASON FOR FILTERFAIL
[0]	Fails Stage 2 Auto-RxAck Checking (Illegal Ack Frame Format in Sequence TR)
[1]	Fails Stage 2 Received frame has Destination Address != Device's Address or Frame Version field != b10 or IEs Present field != 1 or Frame Type != DATA or ACK

52.4.4.4.2.2.8.1.1.2.9 Appendix B

LENIENCY BITS

The Packet Processor performs filtering on all received packets, in order to determine whether the packet is intended for the device. The packet filtering is based on rules. In case any of the packet filtering rules need to be overridden, a 45-bit "leniency register" has been provided. When the leniency register is programmed to its default value (0), all hardware packet filtering rules are in effect, and if an incoming packet violates any rule, a "Filter Fail" will occur (packet will be rejected). When a given leniency register bit is asserted, the packet filtering rule assigned to that bit will not be in effect, and if any incoming packet violates that rule (but no other rules), then a "Filter Fail" will not occur, the packet will not be rejected, the packet will be treated as "intended for the device", and software will be notified of the incoming packet. The table below shows the assignment of leniency bits to packet filtering rules.

LENIENCY BIT	PACKET FILTERING RULE OVERRIDDEN
leniency[0]	Override Stage 1 Frame Length Checking (FL < 5)
leniency[1]	Override Stage 1 Section 7.2.1.1.6 Checking (DST_ADDR_MODE = 1)
leniency[2]	Override Stage 1 Section 7.2.1.1.8 Checking (SRC_ADDR_MODE = 1)
leniency[3]	Override Stage 1 Section 7.2.1.1.5 Checking (Illegal PAN_ID_COMPRESSION Usage)
leniency[4]	Override Stage 2 Auto-RxAck Checking (Illegal Ack Frame Format in Sequence TR)
leniency[5]	Override Stage 2 Frame Length Checking (Illegal Beacon, Data, or Cmd FL)
leniency[6]	Override Stage 2 Beacon Frame Address Mode Violations
leniency[7]	Override Stage 2 Data Frame Address Mode Violations
leniency[8]	Override Stage 2 MAC Command Frame Address Mode Violations
leniency[9]	Override Stage 2 Sequence Number Matching
leniency[10]	Override Stage 2 Filter for DST_ADDR_MODE_NONE/SRC_ADDR_MODE_SHORT (Beacon Only)
leniency[11]	Override Stage 2 Filter for DST_ADDR_MODE_NONE/SRC_ADDR_MODE_SHORT (Data and MAC Command Only)
leniency[12]	Override Stage 2 Dst PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_NONE (Data and MAC Command Only)

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LENIENCY BIT	PACKET FILTERING RULE OVERRIDDEN
leniency[13]	Override Stage 2 Dst Short Addr Filter for DST_ADDR_MODE_SHORT/ SRC_ADDR_MODE_NONE (Data and MAC Command Only)
leniency[14]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_SHORT/ PAN_ID_COMPRESSION (Beacon Only)
leniency[15]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_SHORT/ PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[16]	Override Stage 2 Dst Short Addr Filter for DST_ADDR_MODE_SHORT/ SRC_ADDR_MODE_SHORT/PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[17]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_SHORT/ NO_PAN_ID_COMPRESSION (Beacon Only)
leniency[18]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_SHORT/ NO_PAN_ID_COMPRESS ION (Data and MAC Command Only)
leniency[19]	Override Stage 2 Dst Addr Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_SHORT/ NO_PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[20]	Override Stage 2 Src PAN ID Filter for DST_ADDR_MODE_NONE/SRC_ADDR_MODE_LONG/ NO_PAN_ID_COMPRESSION (Beacon Only)
leniency[21]	Override Stage 2 Src PAN ID Filter for DST_ADDR_MODE_NONE/SRC_ADDR_MODE_LONG/ NO_PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[22]	Override Stage 2 Dst PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_NONE (Data and MAC Command Only)
leniency[23]	Override Stage 2 Dst Long Addr Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_NONE (Data and MAC Command Only)
leniency[24]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_LONG/ PAN_ID_COMPRESSION (Beacon Only)
leniency[25]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_LONG/ PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[26]	Override Stage 2 Dst Long Addr Filter for DST_ADDR_MODE_SHORT/ SRC_ADDR_MODE_LONG/PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[27]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_SHORT/ PAN_ID_COMPRESSION (Beacon Only)
leniency[28]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_SHORT/ PAN_ID_COMPRESSION (Data and Mac Command Only)
leniency[29]	Override Stage 2 Dst Long Addr Filter for DST_ADDR_MODE_LONG/ SRC_ADDR_MODE_SHORT/PAN_ID_COMPRESSION (Data and Mac Command Only)
leniency[30]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_LONG/ NO_PAN_ID_COMPRESSION (Beacon Only)
leniency[31]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_LONG/ NO_PAN_ID_COMPRESSION (Data and MAC Command Only)

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LENIENCY BIT	PACKET FILTERING RULE OVERRIDDEN
leniency[32]	Override Stage 2 Short Addr Filter for DST_ADDR_MODE_SHORT/SRC_ADDR_MODE_LONG/ NO_PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[33]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_SHORT/ NO_PAN_ID_COMPRESSION (Beacon Only)
leniency[34]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_SHORT/ NO_PAN_ID_COMPRESSI ON (Data and MAC Command Only)
leniency[35]	Override Stage 2 Long Addr Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_SHORT/ NO_PAN_ID_COMPRESSION (Data and MAC Command Only)
leniency[36]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_LONG (Beacon Only)
leniency[37]	Override Stage 2 PAN ID Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_LONG (Data and MAC Command Only)
leniency[38]	Override Stage 2 Long Addr Filter for DST_ADDR_MODE_LONG/SRC_ADDR_MODE_LONG (Data and MAC Command Only)
leniency[39]	Allow an auto-TxAck frame to be sent, after a receive frame which has all of the following parameters: 1. Destination PAN ID = Broadcast (0xFFFF) 2. Destination Address = !Broadcast (not 0xFFFF) 3. Destination Address Mode = Short Nominally, the SEQ_MGR inhibits auto-TxAck on such frames.
leniency[40]	Override FAN mode Ack frame filter for Received Destination Address == Device's Address
leniency[41]	Override FAN mode Ack frame filter for Received Source Address = Transmitted Destination Address
leniency[42]	Override FAN mode Ack frame filter for Received Frame Control filed is same as WiSUN spec
leniency[43]	Override FAN mode filter for Data frame Received Destination Address = Device's Address
leniency[44]	Override FAN mode filter for Frame Version field should be b10, IEs Present field should be 1 and Frame Type should be DATA or ACK

52.4.4.4.2.2.8.2 FCP(Frame delimiter before CRC Protocol) Protocol Support

The FCP package structure and its mapping relationship with the GENLL package structure is shown in Figure 491.

The Device Address, Control and Data Payload are mapping to PAYLOAD. User should set H0_SZ=0,H1_SZ=0, LENGTH_SZ=0, and use LENGTH_ADJ to inform the length of (Device Address + Control + Data Payload + CRC-CCITT). Standard fixed sized packets have a total length of 18bytes. Advanced Burst packets can be 19, 27 or 35 bytes. The sizes for all packets are pre-determined and will be specified by the FCP stack prior to each Tx/Rx.

Bit ordering when defining packets conforms to a Big Endian approach. First bit transmitted over the air is the MSB. So register LENGTH_BIT_ORD should set to 1.

Pre-amble is either 0xAA or 0x55 depending on the MSB of the Network Address. If MSB of Network Address is 1, preamble is 0xAA, otherwise the preamble is 0x55.

Network Address is programmable by FCP stack and transmitted in big-endian byte-order. This is the sync word of the RF packet in which corresponding FCP receivers are configured to sync on when trying to receive FCP packets.

Device Address specified and by FCP stack. Address configurable by host interface.

Control byte specified and controlled by FCP stack. Packet sequencing control.

Data payload specified and controlled by FCP stack. Data contents altered by host interface.

CRC-CCITT of packet calculated from Network Address (inclusive) to Data Payload (inclusive). Initial value is 0xFFFF with polynomial (X^16+X^12+X^5+1). CRC is to be transmitted in big-endian byteorder. **CRC_START_BYTE[2:0] in RBME should set to 0.**

Whitening is done to avoid long sequences of 0s or 1s and can be performed by the FCP stack SW or the HW (if it is capable). Whitening is performed by XORing against a pseudo-random number sequence generated from a 9-bit pseudo-random number generator with the following polynomial X^9+X^5+X^0.

- Whitening is only applied to the Device Address, Control and Data Payload. The other parts of the packet are not whitened. **So WHITEN_START[1:0] in RBME should set to 0x3.**
- Whitening is performed for any packet that is larger than the standard 18 byte packet (any packet where the Data Payload is larger than 8 bytes).
- Whitening is performed prior to CRC Generation and dewhitening is performed after the CRC is checked.

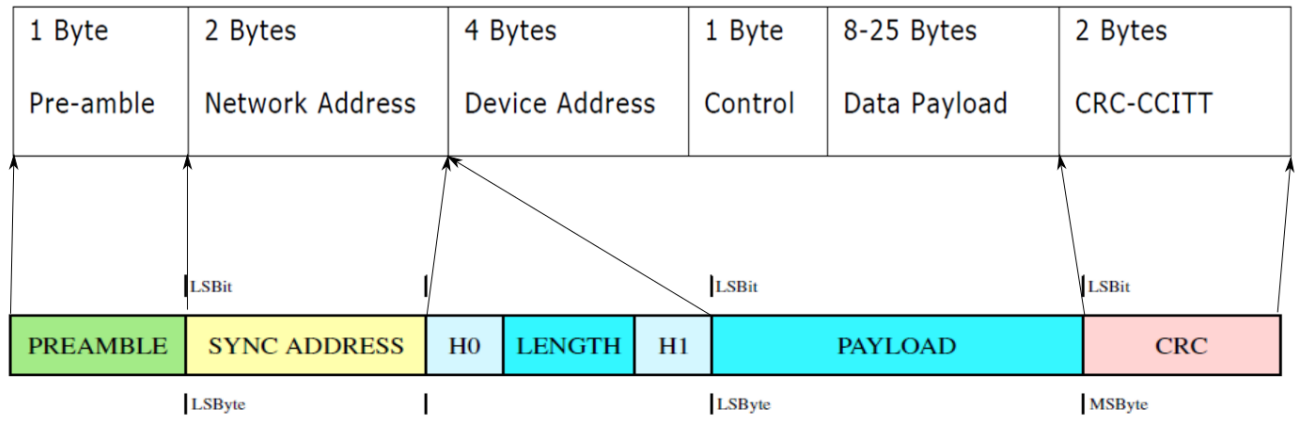

Figure 491. FCP Packet Format and Mapping to Generic Link Layer Format

Table 558 shows the register configuration for the FCP emulation.

Table 558. Link Layer Register Configuration for FCP Emulation

Register	Value
GENLL_MODE[3:0]	0x6 - FCP Mode
PREAMBLE_SZ[8:0]	0x000 - 1 octet preamble
PREAMBLE_SEL[2:0]	000b - The controller hardware selects the preamble pattern based on the first transmitted bit of Network Address, such that the last bit of preamble is the opposite polarity from the first bit of Network Address, forcing a bit transition at this boundary.
GEN_PREAMBLE[7:0]	Not used
NTW_ADR_SZ[1:0]	01b - Network Address 0/1/2/3 requires a 16-bit correlation
SYNC_ADDR_SZ[1:0]	01b - Network Address is 16-bit

Table continues on the next page...

Table 558. Link Layer Register Configuration for FCP Emulation (continued)

Register	Value
H0_SZ[4:0]	0
LENGTH_SZ[4:0]	0
H1_SZ[4:0]	0
LENGTH_BIT_ORD	0 - MS Bit First
LENGTH_ADJ[10:0]	Device Address + Control + Data Payload + CRC-CCITT
AA_PLAYBACK_CNT	1 - Access Address will play back to Link Layer
RXEN_DLY[9:0]	0

52.4.4.4.2.2.8.3 Bluetooth LE Protocol Support

- Bluetooth LE 5.0 packet format for the LE uncoded PHY

  The following packet format is defined for the LE Uncoded PHYs (LE 1M and LE 2M) and is used for both advertising channel packets and data channel packets. This packet format is shown in Figure 492. Each packet consists of four mandatory fields. The mandatory fields are Preamble, Access Address, PDU, and CRC.

  When a packet is transmitted on either the primary or secondary advertising channel, the PDU shall be the Advertising Channel PDU as defined in Figure 494. When a packet is transmitted on the data physical channel, the PDU shall be the Data Channel PDU as defined in Figure 496.

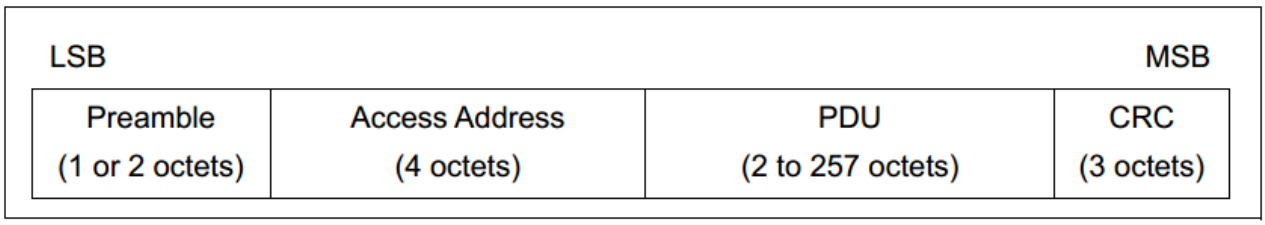

Figure 492. Link Layer packet format for the LE Uncoded PHYs

- Bluetooth LE 5.0 packet format for the LE coded PHY

  The following packet format is defined for the LE Coded PHY and is used for both advertising channel packets and data channel packets. This packet format is shown in Figure 493 .

  Each packet consists of the Preamble, FEC block 1, and FEC block 2. The Preamble is not coded. The FEC block 1 consists of three fields: Access Address, Coding Indicator (CI), and TERM1. The CI field determines which coding scheme is used for FEC block 2. The FEC block 2 consists of three fields: PDU, CRC, and TERM2.

  When a packet is transmitted on either the primary or secondary advertising channel, the PDU shall be the Advertising Channel PDU as defined in Figure 494. When a packet is transmitted on the data physical channel, the PDU shall be the Data Channel PDU as defined in Figure 496.

  When TX, RBME will pad CI, TERM1 and TERM2 into the packet.

  When RX, Link Layer will only get PDU, CRC from RBME.

  Users can also set RXEN_DLY_OVERRIDE to 1 and use RXEN_DLY to override the hardware calculation result. The waveform is show in Figure 464.

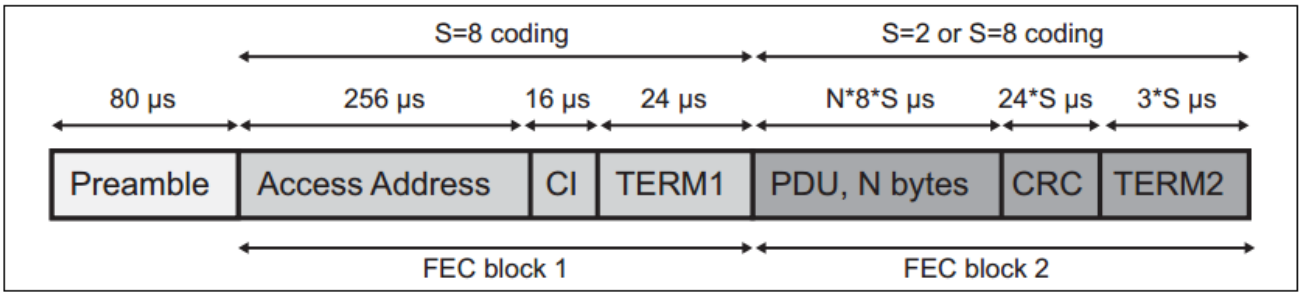

Figure 493. Link Layer packet format for the LE Coded PHY

- Advertising channel PDU

  The advertising channel PDU has a 16-bit header and a variable size payload. Its format is as shown in Figure 494. The 16-bit Header field of the advertising channel PDU is as shown in Figure 495.

  The Length field of the advertising channel PDU header indicates the payload field length in octets. The valid range of the Length field shall be 1 to 255 octets.

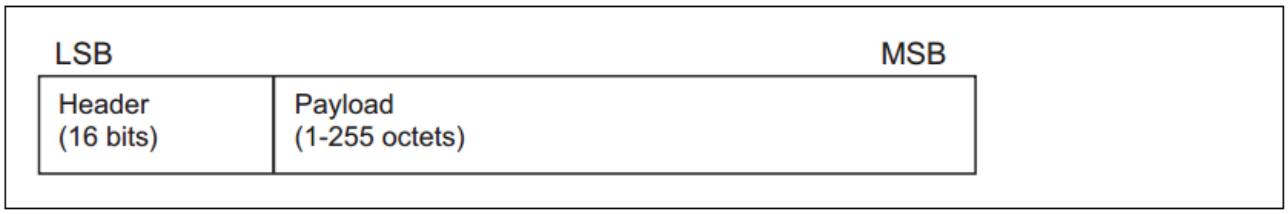

Figure 494. Advertising channel PDU

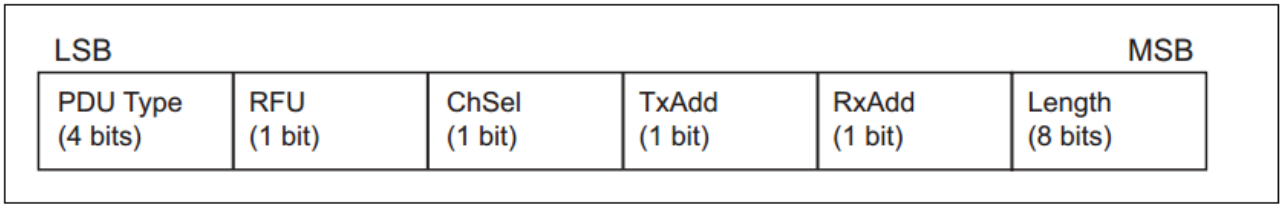

Figure 495. Advertising channel PDU Header

- Data channel PDU

  The Data Channel PDU has a 16 bit header, a variable size payload, and may include a Message Integrity Check (MIC) field. The Data Channel PDU is as shown in Figure 496. The Header field of the Data Channel PDU is as shown in Figure 497.

  The Length field of the Header indicates the length of the Payload and MIC if included. The length field has the range of 0 to 255 octets. The Payload field shall be less than or equal to 251 octets in length. The MIC is 4 octets in length.

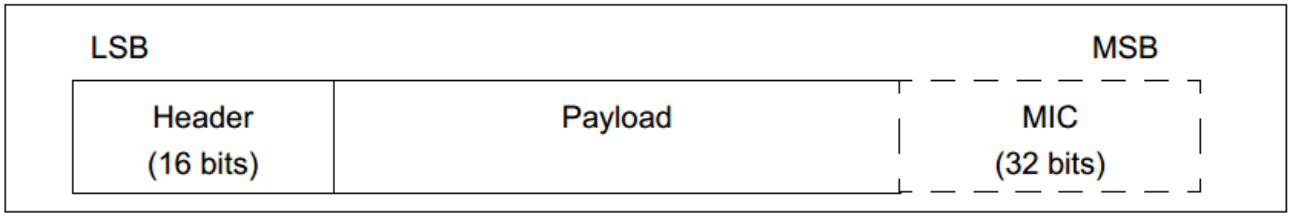

Figure 496. Data Channel PDU

Header					
LLID (2 bits)	NESN (1 bit)	SN (1 bit)	MD (1 bit)	RFU (3 bits)	Length (8 bits)

Figure 497. Data channel PDU header

- Bluetooth LE 5.1 packet format for the LE uncoded PHYs

  Be different with Bluetooth LE 5.0, the CRC is followed by an optional Constant Tone Extension field, which consists of a constantly modulated series of unwhitened 1s. The constant Tone Extension field is not included in CRC or MIC calculations.

  When TX, TX_DIG adds the CTE field.

  When RX, the CTE field can be received by Link Layer, using the RX_EN delay feature. LL hardware will recognize the uncoded packet and automatically calculate the duration of CTE according to the PDU type and CTETime field parsed, and expand the RX_EN signal accordingly. Users can also set RXEN_DLY_OVERRIDE to 1 and use RXEN_DLY to override the hardware calculation result. The waveform is shown in Figure 464.

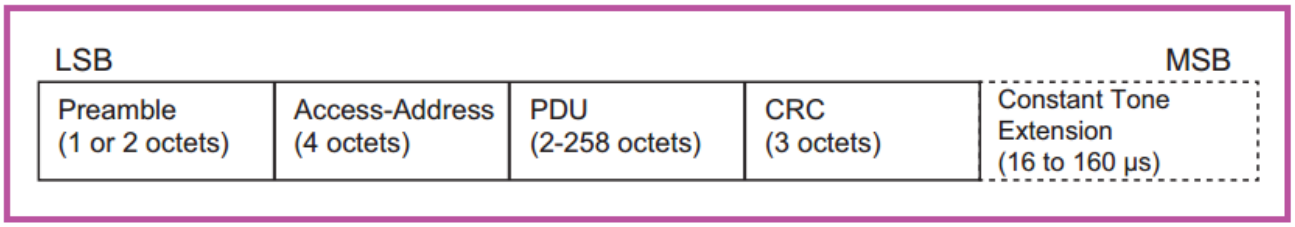

Figure 498. Link Layer packet format for the LE Uncoded PHY (Bluetooth LE 5.1)

To map the Bluetooth LE packet format to the generic packet format, just map the Length to the LENGTH field and the other 8 bits in the Header to the H0 field. Table 559 shows the register configuration for the Bluetooth LE emulation.

Table 559. Link Layer Register Configuration for Bluetooth LE Emulation

Register	Value
GENLL_MODE[3:0]	• 0x9 - Bluetooth LE Uncoded Mode • 0xA - Bluetooth LE LR Mode • 0xB - Bluetooth LE Concurrent Mode (RX configuration only; TX uses either Bluetooth LE Uncoded or Bluetooth LE LR configuration)

Table continues on the next page...

Table 559. Link Layer Register Configuration for Bluetooth LE Emulation (continued)

Register	Value
PREAMBLE_SZ[8:0]	• 0x000 - 1 octet preamble • 0x001 - 2 octets preamble
PREAMBLE_SEL[2:0]	001b - Preamble is programmed by register GEN_PREAMBLE[7:0]
GEN_PREAMBLE[7:0]	As needed
NTW_ADR_SZ[1:0]	11b - Network Address 0/1/2/3 requires a 32-bit correlation
SYNC_ADDR_SZ[1:0]	11b - Network Address is 32-bit
H0_SZ[4:0]	8
LENGTH_SZ[4:0]	8
H1_SZ[4:0]	0 or 8(TX of Bluetooth LE 5.1 Data Channel PDU with CTE)
LENGTH_BIT_ORD	0 - LS Bit First
LENGTH_ADJ[10:0]	3 - Same as CRC_SZ[2:0] (RBME register)
AA_PLAYBACK_CNT	0 - Access Address will not play back to Link Layer
BLE_V5P1_CTE_EN	When set, hardware will parse the CTE field as defined in Bluetooth LE V5.1 specification
RXEN_DLY_OVERRIDE	Override the hardware calculation result for the duration of TERM2 or CTE
RXEN_DLY[9:0]	When not zero and RXEN_DLY_OVERRIDE is set, the RX_EN signal will delay (RXEN_DLY +1) microseconds to de-assert after payload is received. The delay time range is from 2~1024 microseconds.
SEL_RXIRQ	• 0: RX_IRQ is asserted at the end of RX_PKT state • 1: RX_IRQ is asserted at the end of RXEN_DLY state(only if RX_EN is delayed).

CTE duration and parsing and signal cte_present resolve process:

- When RXEN_DLY_OVERRIDE=1, it means for all the RX process, there will be a delay defined by RXEN_DLY[9:0];
- — If BLE_V5P1_CTE_EN==1, cte_present=1 in the whole RX process
  — Otherwise, cte_present=0
- When RXEN_DLY_OVERRIDE=0, hardware will decide the RX_EN delay time.
- — If Bluetooth LE coded packet is received(i.e., internal signal phy_mode[2:0]=1), RX_EN is not delayed.
  — If Bluetooth LE uncoded packet is received(i.e., phy_mode[2:0]=2),
  — ◦ If it is Bluetooth LE 5.0 use case(BLE_V5P1_CTE_EN=0), no RX_EN delay
  ◦ If it is Bluetooth LE 5.1 use case(BLE_V5P1_CTE_EN=1),
  ◦ ▪ If received data channel PDU (ADV_CHANNEL_EN=0) , as shown in Figure 499
  ▪ • If [CP] =0, then on-the-fly change H1_SIZE to 0, no RX_EN delay
  • If [CP] =1, then on-the-fly change H1_SIZE to 8, and get the [CTETime] as the RX_EN Delay; cte_present=1 when parsed
  ▪ If received advertising channel PDU(ADV_CHANNEL_EN=1) , as shown in Figure 500
  ▪ • If the [Extended Header Length]=0, no RX_EN delay

- If the [Extended Header Length]>0, get the [CTEInfo] (if exists), and get the [CTETime] as the RX_EN Delay; cte_present=1 when parsed

NOTE

1. The [CTETime] field defines the length of the Constant Tone Extension in 8 us units. The value of the [CTETime] field shall be between 2 and 20 inclusive; all other values are reserved for future use. But LL will not check the length range.
2. Once asserted, cte_present will not be de-asserted even CRC fails. Register bit CRC_IGNORE can be used in debug cases to bypass the CRC pass condition.
3. If CRC fail and CRC_IGNORE=0, LL will recycle according to its inherent behavior.

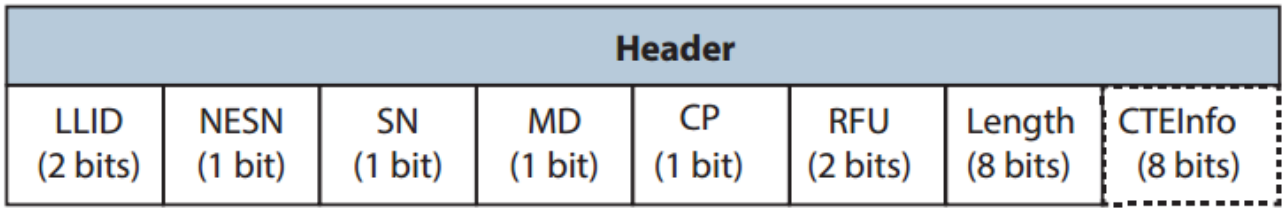

Figure 499. Bluetooth LE 5.1 Data Channel PDU Header

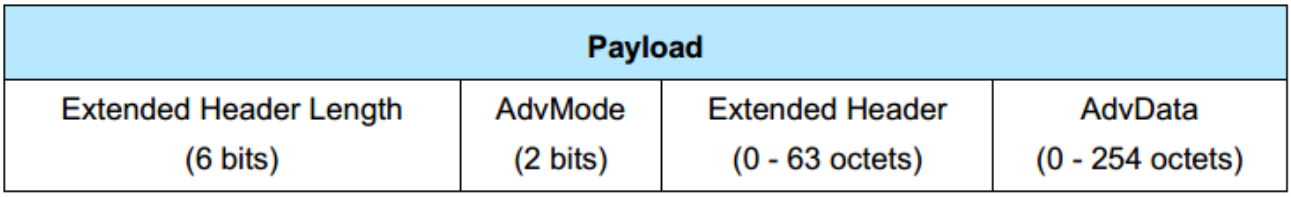

Figure 500. Bluetooth LE 5.1 Common Extended Advertising Payload

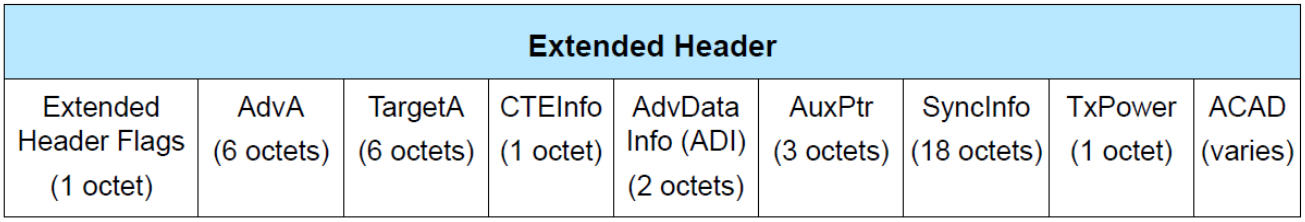

Figure 501. Bluetooth LE 5.1 Extended Header

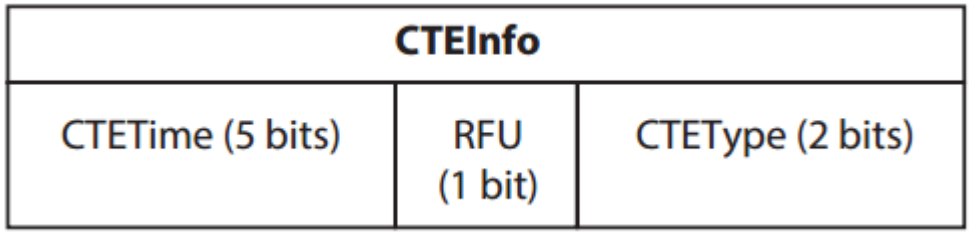

Figure 502. Bluetooth LE 5.1 CTEInfo Field

52.4.4.4.2.2.8.3.1 RPA and White List

The format of the resolvable private address is shown in Figure 503.

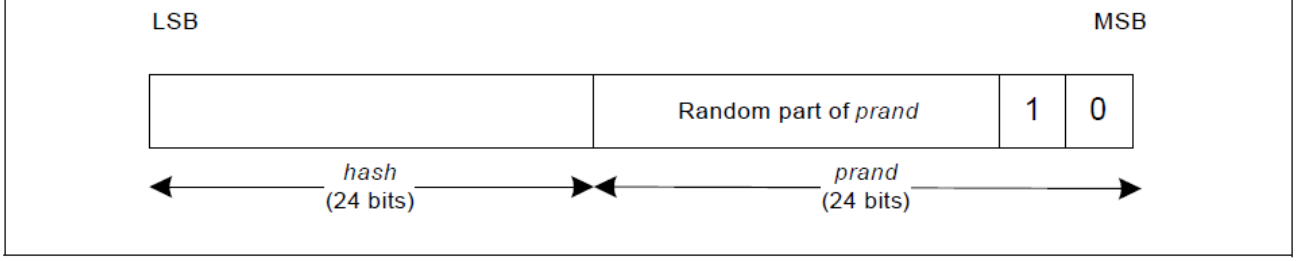

Figure 503. Format of resolvable private address

Private device address generation

The resolvable private address is generated with the Identity Resolving Key (IRK) and a randomly generated 24-bit number(prand).

The hash is generated using the function *ah* as *hash = ah(IRK, prand)*.

The prand and hash are concatenated to generate the resolvable private address in the following manner:

resolvable private address = hash || prand

The least significant octet of hash becomes the least significant octet of RPA and the most significant octet of prand becomes the most significant octet of RPA.

Private device address resolution

A resolvable private address may be resolved if the corresponding device's IRK is available using this procedure. If a resolvable private address is resolved, the device can associate this address with the peer device.

A localHash value is generated as *localHash = ah(IRK, prand)*

The localHash value is then compared with the hash value extracted from RPA. If the localHash value matches the extracted hash value, then the identity of the peer device has been resolved.

If a device has more than one stored IRK, the device repeats the above procedure for each stored IRK to determine if the received resolvable private address is associated with a stored IRK, until either address resolution is successful for one of the IRKs or all have been tried.

The RPA resolution and White List check are related with advertising channel PDUs. Register ADV_CHANNEL_EN is to indicate that it is to receive an advertising channel PDU.

Linklayer supports resolvable private address(RPA) resolution during Rx process when register RPA_EN is enabled.

There are 8 entries for the RPA resolution in RAM. Each entry includes the fields: Peer IRK[127:0], Local IRK[127:0], Peer_Identity_Address[47:0], Peer_Identity_Address_Type, Peer_RPA[47:0], Local_RPA[47:0]. The organization of these fields are shown in Figure 504.

Register RPA_VALID_ENTRY[7:0] defines that if the entry is valid or not. If the entry is not valid, it is bypassed during RPA search and resolution.

When RPA_EN is asserted, and the received Peer Address is resolvable, the address is first be searched in the PRPA list. If the address is found in the PRPA list, the address is resolved and register PEER_RESOLVED_INDEX[3:0] returns matched index of the entry. If the address is not in the PRPA list, link layer resolves the address with Peer IRK, one by one. If the address is resolved by one of the Peer IRK, register PEER_RESOLVED_INDEX[3:0] returns matched index of the entry. Link layer will also update the received peer address to the PRPA list.

If the peer address is not resolved, PEER_RESOLVED_INDEX[3:0] returns 0xF and interrupt flag PEER_RPA_FAIL_IRQ is asserted. In this case, if register PEER_RPA_FAIL_IRQ_EN is set, the interrupt is generated to the host. If register IGNORE_RPA_FAIL is set, the link layer continues to receive the whole packet; otherwise, the link layer aborts.

When RPA_EN is asserted, and the received Local Address is resolvable, the address is first be searched in the LRPA list. If the address is found in the LRPA list, the address is resolved and register LOCAL_RESOLVED_INDEX[3:0] returns matched index of the entry. If the address is not in the LRPA list, link layer resolves the address with Local IRK, one by one. If the address is resolved by one of the Local IRK, register LOCAL_RESOLVED_INDEX[3:0] returns matched index of the entry. Link layer will also update the received peer address to the LRPA list.

If the local address is not resolved, LOCAL_RESOLVED_INDEX[3:0] returns 0xF and interrupt flag LOCAL_RPA_FAIL_IRQ is asserted. In this case, if register LOCAL_RPA_FAIL_IRQ_EN is set, the interrupt is generated to the host. If register IGNORE_RPA_FAIL is set, the link layer continues to receive the whole packet; otherwise, the link layer aborts.

Entry #	Byte Address	Peer IRK	Byte Address	Local IRK	Byte Address	PEER Identity Address	Byte Address	Peer RPA	Byte Address	Local RPA
Entry[0]	PEER_IRK_BASE+0	peer_irk[0][31:0]	LOCAL_IRK_BASE+0	local_irk[0][31:0]	PEER_ID_BASE+0	peer_id_addr[0][31:0]	PRPA_BASE+0	peer_rpa[0][31:0]	LRPA_BASE+0	local_rpa[0][31:0]
	PEER_IRK_BASE+4	peer_irk[0][63:32]	LOCAL_IRK_BASE+4	local_irk[0][63:32]	PEER_ID_BASE+4	peer_id_addr_type[0], 15'h0, peer_id_addr[0][47:32]	PRPA_BASE+4	16'h0, peer_rpa[0][47:32]	LRPA_BASE+4	16'h0, local_rpa[0][47:32]
	PEER_IRK_BASE+8	peer_irk[0][95:64]	LOCAL_IRK_BASE+8	local_irk[0][95:64]						
	PEER_IRK_BASE+12	peer_irk[0][127:96]	LOCAL_IRK_BASE+12	local_irk[0][127:96]						
Entry[1]	PEER_IRK_BASE+16	peer_irk[1][31:0]	LOCAL_IRK_BASE+16	local_irk[1][31:0]	PEER_ID_BASE+8	peer_id_addr[1][31:0]	PRPA_BASE+8	peer_rpa[1][31:0]	LRPA_BASE+8	local_rpa[1][31:0]
	PEER_IRK_BASE+20	peer_irk[1][63:32]	LOCAL_IRK_BASE+20	local_irk[1][63:32]	PEER_ID_BASE+12	peer_id_addr_type[1], 15'h0, peer_id_addr[1][47:32]	PRPA_BASE+12	16'h0, peer_rpa[1][47:32]	LRPA_BASE+12	16'h0, local_rpa[1][47:32]
	PEER_IRK_BASE+24	peer_irk[1][95:64]	LOCAL_IRK_BASE+24	local_irk[1][95:64]						
	PEER_IRK_BASE+28	peer_irk[1][127:96]	LOCAL_IRK_BASE+28	local_irk[1][127:96]						
Entry[2]	PEER_IRK_BASE+32	...	LOCAL_IRK_BASE+32	...	PEER_ID_BASE+16	...	PRPA_BASE+16	...	LRPA_BASE+16	...
	PEER_IRK_BASE+36	...	LOCAL_IRK_BASE+36	...	PEER_ID_BASE+20	...	PRPA_BASE+20	...	LRPA_BASE+20	...
	PEER_IRK_BASE+40	...	LOCAL_IRK_BASE+40	...						
	PEER_IRK_BASE+44	...	LOCAL_IRK_BASE+44	...						
Entry[3]	PEER_IRK_BASE+48	...	LOCAL_IRK_BASE+48	...	PEER_ID_BASE+24	...	PRPA_BASE+24	...	LRPA_BASE+24	...
	PEER_IRK_BASE+52	...	LOCAL_IRK_BASE+52	...	PEER_ID_BASE+28	...	PRPA_BASE+28	...	LRPA_BASE+28	...
	PEER_IRK_BASE+56	...	LOCAL_IRK_BASE+56	...						
	PEER_IRK_BASE+60	...	LOCAL_IRK_BASE+60	...						
Entry[4]	PEER_IRK_BASE+64	...	LOCAL_IRK_BASE+64	...	PEER_ID_BASE+32	...	PRPA_BASE+32	...	LRPA_BASE+32	...
	PEER_IRK_BASE+68	...	LOCAL_IRK_BASE+68	...	PEER_ID_BASE+36	...	PRPA_BASE+36	...	LRPA_BASE+36	...
	PEER_IRK_BASE+72	...	LOCAL_IRK_BASE+72	...						
	PEER_IRK_BASE+76	...	LOCAL_IRK_BASE+76	...						
Entry[5]	PEER_IRK_BASE+80	...	LOCAL_IRK_BASE+80	...	PEER_ID_BASE+40	...	PRPA_BASE+40	...	LRPA_BASE+40	...
	PEER_IRK_BASE+84	...	LOCAL_IRK_BASE+84	...	PEER_ID_BASE+44	...	PRPA_BASE+44	...	LRPA_BASE+44	...
	PEER_IRK_BASE+88		LOCAL_IRK_BASE+88	...						
	PEER_IRK_BASE+92		LOCAL_IRK_BASE+92	...						
Entry[6]	PEER_IRK_BASE+96	...	LOCAL_IRK_BASE+96	...	PEER_ID_BASE+48	...	PRPA_BASE+48	...	LRPA_BASE+48	...
	PEER_IRK_BASE+100	...	LOCAL_IRK_BASE+100	...	PEER_ID_BASE+52	...	PRPA_BASE+52	...	LRPA_BASE+52	...
	PEER_IRK_BASE+104	...	LOCAL_IRK_BASE+104	...						
	PEER_IRK_BASE+108	...	LOCAL_IRK_BASE+108	...						
Entry[7]	PEER_IRK_BASE+112	...	LOCAL_IRK_BASE+112	...	PEER_ID_BASE+56	...	PRPA_BASE+56	...	LRPA_BASE+56	...
	PEER_IRK_BASE+116	...	LOCAL_IRK_BASE+116	...	PEER_ID_BASE+60	...	PRPA_BASE+60	...	LRPA_BASE+60	...
	PEER_IRK_BASE+120	...	LOCAL_IRK_BASE+120	...						
	PEER_IRK_BASE+124	...	LOCAL_IRK_BASE+124	...						

Figure 504. RPA entry organization in RAM

Link layer supports White List search and filter during Rx process when register WL_EN is enabled.

There are 2 White Lists in RAM, WL0 and WL1. Each White List has 32 entries. Register WL_SEL is used to select which White List is used for the search.

Each entry includes fields WL_Device_Address[47:0] and WL_Device_Address_Type, as shown in Figure 505.

For each White List, there is a register WL_VALID_ENTRY[31:0] to enable the 32 entries. Once disabled, the entry is skipped during the search.

If RPA is resolved, the Peer_Identity_Address[47:0] and Peer_Identity_Address_Type are searched in the White List. If RPA is not enabled or no RPA entry is valid, the received Peer Address and its type are directly searched in the White List.

After search, if there is an entry matches the address to be searched, the register WL_MATCH_INDEX[5:0] returns the matched index of the entry.

If there is no entry matched or all entries are invalid, WL_MATCH_INDEX[5:0] returns the 0x3F value, and interrupt flag WL_FAIL_IRQ is asserted. In this case, if register WL_FAIL_IRQ_EN is set, the interrupt is generated to the host. If register IGNORE_WL_FAIL is set, the link layer continues to receive the whole packet; otherwise, the link layer aborts.

Byte Addr	Entry #	White List 0
WL_BASE0+0	Entry[0]	wl_device_id_addr[0][31:0]
WL_BASE0+4		wl_addr_typ[0], 15'h0, wl_device_id_addr[0][47:32]
WL_BASE0+8	Entry[1]	wl_device_id_addr[1][31:0]
WL_BASE0+12		wl_addr_typ[1], 15'h0, wl_device_id_addr[1][47:32]
…	…	…
…		…
WL_BASE0+248	Entry[31]	wl_device_id_addr[31][31:0]
WL_BASE0+252		wl_addr_typ[31], 15'h0, wl_device_id_addr[31][47:32]

Byte Addr	Entry #	White List 1
WL_BASE1+0	Entry[0]	wl_device_id_addr[0][31:0]
WL_BASE1+4		wl_addr_typ[0], 15'h0, wl_device_id_addr[0][47:32]
WL_BASE1+8	Entry[1]	wl_device_id_addr[1][31:0]
WL_BASE1+12		wl_addr_typ[1], 15'h0, wl_device_id_addr[1][47:32]
…	…	…
…		…
WL_BASE1+248	Entry[31]	wl_device_id_addr[31][31:0]
WL_BASE1+252		wl_addr_typ[31], 15'h0, wl_device_id_addr[31][47:32]

Figure 505. White List 0 and White List 1 in RAM

For each type of PDUs that needs to do RPA check and WL check, the hardware tasks are summarized in Figure 506.

If the received PDU Type is "0011b" or "0101b" regarding to an ADV_DIRECT_IND PDU, the resolved Peer identity address and address type are not searched in WL, but are compared with register DIRECT_PEER_ADDR[47:0] and DIRECT_PEER_ADDR_TYPE. This case is indicated by set the register ADV_DIRECT_IND_SENT.

If the comparison result is a mismatch, interrupt flag DIRECT_ID_FAIL_IRQ is asserted. In this case, if register DIRECT_ID_FAIL_IRQ_EN is set, the interrupt is generated to the host. If register IGNORE_DIRECT_FAIL is set, the link layer continues to receive the whole packet; otherwise, the link layer aborts.

<table>
<tr><th>PDU Name</th><th>PDU Type</th><th colspan="7">Packet Fields</th><th>Hardware Task</th></tr>
<tr><td>ADV_DIRECT_IND</td><td>0001</td><td>AdvA</td><td>TargetA</td><td></td><td></td><td></td><td></td><td>1. Resolve AdvA
2. Check WL
3. Resolve TargetA</td></tr>
<tr><td>ADV_IND</td><td>0000</td><td>AdvA</td><td>AdvData</td><td></td><td></td><td></td><td></td><td rowspan="4">1.Resolve AdvA
2.Check WL</td></tr>
<tr><td>ADV_NONCONN_IND</td><td>0010</td><td>AdvA</td><td>AdvData</td><td></td><td></td><td></td><td></td></tr>
<tr><td>SCAN_RSP</td><td>0100</td><td>AdvA</td><td>ScanRspData</td><td></td><td></td><td></td><td></td></tr>
<tr><td>ADV_SCAN_IND</td><td>0110</td><td>AdvA</td><td>AdvData</td><td></td><td></td><td></td><td></td></tr>
<tr><td>ADV_EXT_IND</td><td rowspan="6">111</td><td rowspan="7">Extended Header Length (6 bits)+ AdvMode (2 bits)</td><td colspan="5">Extended Header (0 - 63 octets)</td><td rowspan="7">AdvData</td><td rowspan="7">1. Resolve AdvA (if exists)
2. Check WL
3. Resolve TargetA (if exists)</td></tr>
<tr><td>AUX_ADV_IND</td><td rowspan="6">Extended Header Flags (1 octet)</td><td rowspan="6">AdvA</td><td rowspan="6">TargetA</td><td rowspan="6">…</td></tr>
<tr><td>AUX_SCAN_RSP</td></tr>
<tr><td>AUX_SYNC_IND</td></tr>
<tr><td>AUX_CHAIN_IND</td></tr>
<tr><td>AUX_CONNECT_RSP</td><td>1000</td></tr>
<tr><td>SCAN_REQ
AUX_SCAN_REQ</td><td>0011</td><td>ScanA</td><td>AdvA</td><td></td><td></td><td></td><td></td><td rowspan="2">1. Resolve ScanA/InitA
2.1 If it is for ADV_DIRECT_IND, check with DIRECT_PEER_ADDR/DIRECT_PEER_ADDR_TYPE
2.2 Other cases, check WL</td></tr>
<tr><td>CONNECT_IND
AUX_CONNECT_REQ</td><td>0101</td><td>InitA</td><td>AdvA</td><td>LLData</td><td></td><td></td><td></td></tr>
</table>

Figure 506. Hardware tasks for RPA resolution and White List(WL) check

52.4.4.4.2.2.8.4 Generic Link Layer Test Mode (GTM)

Objective

Generic Test Mode (GTM) is a special test mode with the objective to facilitate time-efficient testing of the Packet Error Rate (PER) for the PHY modes available to the Generic Link Layer. The goal of this mode is to test the radio's TX and RX physical layer and front-end quality assisted by the link layer without necessarily involving complicated link layer processing.

The key objective of this test mode are as follows:

- To make PER testing on NXP radios using Generic Link Layer easy for both internal and external (customer) usage, and
- To minimize the complications in a PER test setup by reducing the need of external triggering and provision of accounting for good (passing CRC), bad (failing CRC) and missing packets on the receiving end.

Generic Test Mode (GTM) Requirements

The GTM HW will facilitate the following simplified testing of RX and TX PHY performances using either a signal analyzer (for TX), a vector signal generator (for RX) and using two NXP radios (where one is configured as TX, while the other is configured as RX). Note that it is conceived that the GTM implementation would leverage the link layer infrastructure as much as possible minimizing the need of additional register space to support GTM programming.

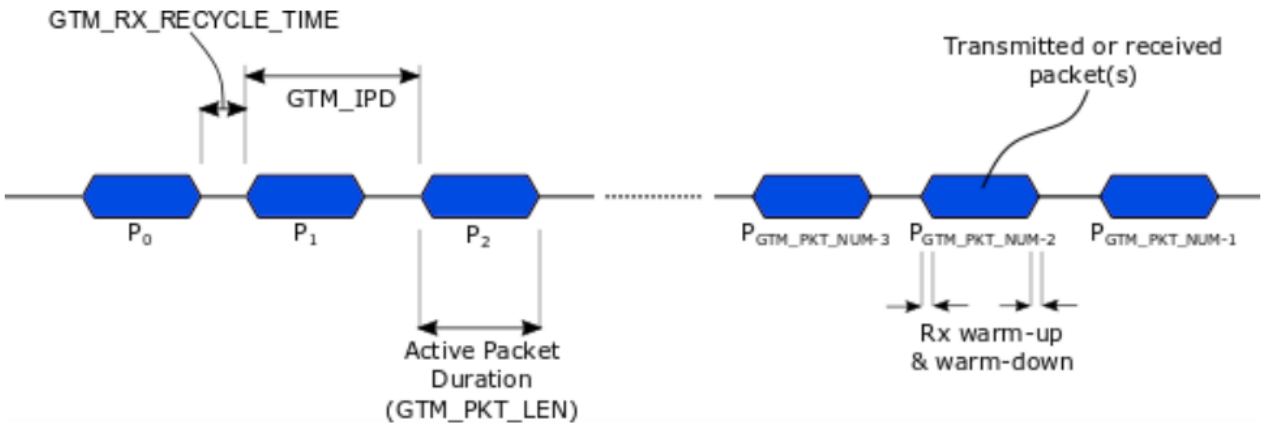

Figure 507. PACKET INTERVALS IN GTM mode

GTM Packet Structure

The packet structure in GTM mode is shown as below, where H0[7:0] = {4'h0, GTM_PDU_TYP}. So in GTM mode, register H0_SZ should be set to 8.

Figure 508. GTM PACKET STRUCTURE

Where

Table 560. GTM PACKET FIELDS

Field	Definition
PREAMBLE	Packet Preamble as supported by Gen-LL. Default size is 1 octet with preamble pattern chosen based on 1st bit of SYNC ADDRESS
SYNC ADDRESS	From registers NTW_ADR_*X*, when NTW_ADR_EN[*X*]==1. When more than one NTW_ADR_EN[*X*] is enabled, NTW_ADR_EN[0] has the highest priority. NTW_ADR*X*_SZ and SYNC_ADDR_SZ should be same value. Default size is 4 octets. It is recommended to use the same default SYNC ADDRESS value as is used by Bluetooth-LE DTM, with default transmission order of '10010100 10000010 01101110 10001110'.
GTM_PDU_TYP	From register GTM_PDU_TYPE[3:0] (reused from MACLONGADDRS1_LSB[27:24]) 0000b PRBS9 Sequence 0001b Programmable 8-bit Pattern (from register GTM_PDU[7:0], reused from MACSHORTADDRS1[7:0]) 0010b PRBS-13 Sequence 0011b PRBS-15 Sequence 0100b Programmable 32-bit Pattern (from register GTM_PDU[31:0], reused from {MACSHORTADDRS1,MACPANID1}) 0101b Programmable packet from Packet RAM (in this case, PKT_LEN is ignored) Others reserved
RES	It is reserved. (0000b)

Table continues on the next page...

Table 560. GTM PACKET FIELDS (continued)

Field	Definition
PKT_LEN	The PKT_LEN is the content of the LENGTH field. When LENGTH_ADJ=0, PKT_LEN means the length of (PAYLOAD + CRC); When LENGTH_ADJ = CRC_SZ, PKT_LEN means the length of PAYLOAD. The PKT_LEN size is controlled by register LENGTH_SZ, the value can be 8 or 16-bit. The PKT_LEN value is controlled by register GTM_PKT_LEN[10:0] (reused from LENGTH_ACK[10:0]). The GTM_PKT_LEN[10:0] value overflows the LENGTH_SZ is ignored. The default packet allocation will be 8 bits and the default value will be 39 octets (same as Bluetooth LE DTM)
GTM_PDU	A string of transmission bits as defined above by GTM_PDU_TYP, which are sent out by default in the same order as Bluetooth-LE.
CRC	All CRC computational combinations defined by Gen-LL are possible. Default size will be 3 octets and the computation will be configured to be the same as Bluetooth-LE, i.e.,

Generic Test Mode Transmit (GTM-TX)

In GTM-TX mode, Generic LL would allow for the following configurability for the radio driver SW:

- Program GENLL_MODE[3:0] to 0xF to enable the GTM mode
- Program PHY modulation parameters
- Program the type and size of the preamble to be used for the packet (PREAMBLE_SZ and PREAMBLE_SEL)
- Program a test mode Access Address (or SFD). All size of the AA/SFD supported by the Gen-LL shall be supported. (NTW_ADR_EN[*X*] , NTW_ADR_*X*, NTW_ADR_SZ and SYNC_ADDR_SZ)
- Program a fixed length for the Packet size in octets (PKT_LEN).
- Program the type of payload (GTM_PDU).
- Program the Bit manipulation engine (BME) configuration to be used, e.g., CRC, whitening, FEC, encoding, repetition or spreading, etc. blocks and processing order be configured as per the desired test configuration.
- Program the interpacket duration (register GTM_IPD[19:0], reused from MACLONGADDRS1_MSB[19:0]).
- Program the number of packets to be sent (register GTM_PKT_NUM[11:0]), reused from MACLONGADDRS1_LSB[11:0]).
- Program the delay time between 1st Tx warmup time and GTM_IN_TX asserted (register GTM_RX_RECYCLE_TIME[19:0], reused from MACLONGADDRS0_MSB[19:0]; This register has different meaning in GTM RX mode)

Once configured, GTM_TX mode will operate as follows:

- Write a "1" to register GTM_IN_TX to trigger the start of the GTM-TX mode.
  - Clear GTM_PKT_COUNT at initial
  - Gen-LL transmits the 1st sequence after GTM_RX_RECYCLE_TIME
  - Gen-LL transmits sequence after every GTM_IPD duration for GTM_PKT_NUM times.
  - Note that for each packet transmission, the TX would warm-up, transmit the packet and warm-down
- After requisite number of TX packets are sent, i.e., GTM_PKT_COUNT == GTM_PKT_NUM; the GTM_IN_TX bit would be de-asserted and GTM_TX would stop.
- The following figure shows the GTM TX timing. The GTM_PKT_PUR represents the transmitted packet duration, where *GTM_PKT_DUR = sizeof(PREAMBLE+AA+H0+LEN+GTM_PDU+CRC)*symbol_time*

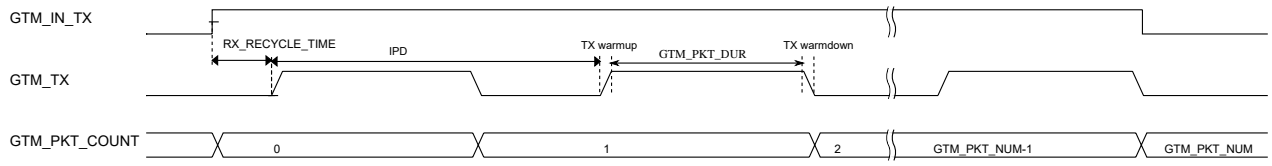

Figure 509. GTM TX Processing

Generic Test Mode Receive (GTM-RX)

For GTM-RX, it is conceived that Gen-LL and BME for the receiver are correctly configured as per the test configuration. This includes

- Program GENLL_MODE[3:0] to 0xF to enable the GTM mode
- Program the register FIRST_SFD2WD, which means the time between the force Rx warmdown and first SFD found. It is possibly the longest packet duration plus some margin.
- Program the register RX_RECYCLE_TIME, which means the time between the force Rx warmdown and Rx warmup.
- Program the register GTM_IPD, same as the GTM Tx side.
- Write a "1" to register GTM_IN_RX to trigger the start of the GTM-RX scan mode. This bit should also clear all GTM packet counters (GTM_GOOD_PKT_COUNT, GTM_BAD_PKT_COUNT and GTM_PKT_COUNT).
- The receiver will wait for the first correctly AA/SFD matched packet. This initiates the GTM-RX state machine.
- Every packet for which AA/SFD match happens should increment the GTM_PKT_COUNT.
- Once GTM_PKT_COUNT == GTM_PKT_NUM, GTM_IN_RX bit should be de-asserted and the periodic RX recycling by the GTM state machine should stop.
- If register ***GTM_PKT_COUNT_CHECK_DIS*** is programmed, then
  - The check GTM_PKT_COUNT == GTM_PKT_NUM is disabled
  - In this case the GTM test would be disabled by SW based time-out
  - As now there is no limit on the upper bound on GTM_PKT_COUNT due to a pre-programmed GTM_PKT_NUM, the counter can possibly overflow GTM_PKT_NUM. The counter will have saturation but not roll over in this case.
- If the packet is successfully received, processed by BME and passes the payload CRC. It is considered a good packet and the GTM_GOOD_PKT_COUNT is incremented.
- If the packet is not successfully received due to corrupted packet length or an unrecoverable bit error causing the packet to fail the payload CRC, or there is a header(H0/Length/H1) check fail or there is no AA matched, it is considered a bad packet and the GTM_BAD_PKT_COUNT is incremented.
- GTM_GOOD_PKT_COUNT and GTM_BAD_PKT_COUNT should be incremented based on CRC pass/fail only and setting a Gen-LL configuration such as CRC_IGNORE should not effect it.
- After receiving either a good or a bad packet, Gen-LL should recycle the receiver after GTM_RX_RECYCLE_TIME, where GTM_RX_RECYCLE_TIME is the time required by the receiver to warm-down and warm-up with some additional timing margins to receive the next packet. As an example, for a radio having a warm-up time of 110us and a warm-down time of 10us, GTM_RX_RECYCLE_TIME ≥ 150us.
- If for a packet, AA/SFD was not detected for a duration of GTM_IPD - GTM_RX_RECYCLE_TIME, it is considered that the packet was missed, GTM_PKT_COUNT is incremented and the receiver is recycled.
- In case the receiver decodes the incoming packets length incorrectly to be too long, although AA/SFD will be matched (causing the GTM_PKT_COUNT to be incremented), RX may stay in the demodulation state during the entire GTM_IPD - GTM_RX_RECYCLE_TIME duration. In this scenario, the receiver is recycled at the scheduled time and the GTM_BAD_PKT_COUNT is incremented as well.

- If register ***GTM_IPD_CHECK_DIS*** is programmed, then,
  - GTM_IPD duration enforcement is disabled
  - After each packet received, Link layer will recycle after "GTM_RX_RECYCLE_TIME"
- The packet statistics are collected as follows:
  - Number of Good CRC Packets = GTM_GOOD_PKT_COUNT
  - Number of Bad CRC Packets = GTM_BAD_PKT_COUNT
  - Number of Missed Packets = GTM_PKT_NUM - (GTM_GOOD_PKT_COUNT + GTM_BAD_PKT_COUNT)
- The following figure shows the normal GTM RX timing.

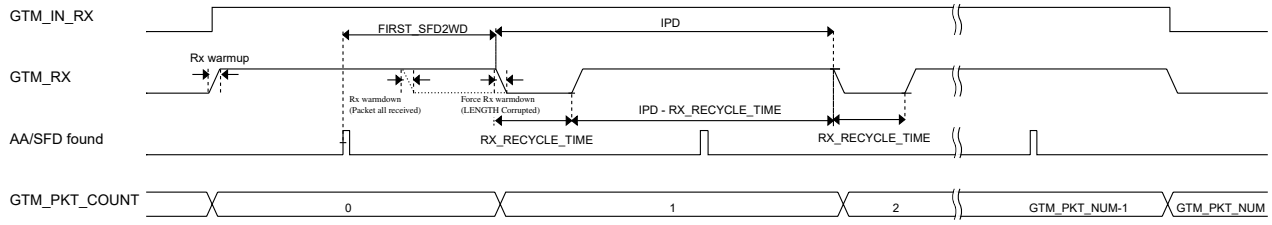

Figure 510. GTM RX Processing

The following figure shows the GTM RX timing with GTM_IPD_CHECK_DIS=1.

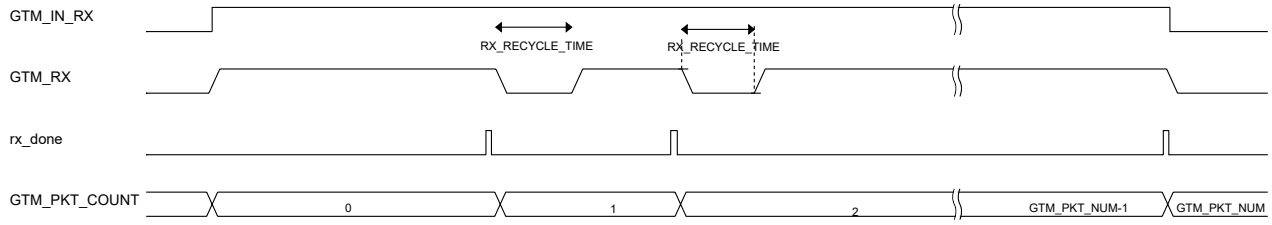

Figure 511. GTM RX Processing with GTM_IPD_CHECK_DIS=1

The following table summarizes the registers used in GTM.

Table 561. Link Layer Registers Used in GTM

Register	RX Side ?	TX Side ?	Description	Reused From
GENLL_MODE[3:0]	X	X	Link layer Mode Select, 1111b - GTM Mode	/
GTM_PDU[31:0]		X	8bits(GTM_PDU_TYP is 0001b) or 32 bits (GTM_PDU_TYP is 0100b) GTM PDU Pattern	{MACSHORTADDRS1, MACPANID1}
GTM_PDU_TYPE[3:0]		X	GTM PDU Type	MACLONGADDRS1[27:24]
GTM_IPD_CHECK_DIS	X		• GTM_IPD duration enforcement is disabled	MACLONGADDRS1[30]

Table continues on the next page...

Table 561. Link Layer Registers Used in GTM (continued)

Register	RX Side ?	TX Side ?	Description	Reused From
			• After each packet received, Link layer will recycle after "GTM_RX_RECYCLE_TIME"	
GTM_PKT_COUNT_CHECK_DIS	X		• The check GTM_PKT_COUNT == GTM_PKT_NUM is disabled; In this case the GTM test would be disabled by SW based time-out; • As now there is no limit on the upper bound on GTM_PKT_COUNT due to a pre-programmed GTM_PKT_NUM, the counter can possibly overflow GTM_PKT_NUM. The counter will have saturation but not roll over in this case.	MACLONGADDRS1[31]
GTM_PKT_NUM[11:0]	X	X	The total number of packets to be sent or received	MACLONGADDRS1[11:0]
GTM_IPD[19:0]	X	X	• In microseconds • Time slot that one packet is sent	MACLONGADDRS1[51:32]
GTM_1ST_SFD2WD[19:0]	X		• In microseconds • The time between the "force Rx warm-down" and "first SFD found", in microseconds • Possibly the longest packet duration plus some margin.	MACLONGADDRS0[19:0]
GTM_RX_RECYCLE_TIME[19:0]	X	X	• In microseconds • For TX, means the delay between "first TX warm up" and "GTM_IN_TX is asserted" • For RX, means the time between "force Rx warm-down" and "next Rx warmup"	MACLONGADDRS0[51:32]
GTM_PKT_LEN[10:0]		X	The LENGTH field	LENGTH_ACK[10:0]
LENGTH_ADJ[10:0]	X	X	• When LENGTH_ADJ=0, PKT_LEN means the length of (PAYLOAD + CRC); • When LENGTH_ADJ=CRC_SZ, PKT_LEN means the length of PAYLOAD.	/
GTM_IN_RX	X		GTM receive mode	/
GTM_IN_TX		X	GTM transmit mode	/
GTM_PKT_CNT[12:0]	X	X	• When RX, count the number of IPD slots after first AA match • When TX, count the number of packets sent.	/
GTM_BAD_PKT_CNT[12:0]	X		GTM Bad Packet Counter (CRC fail or header(H0/Length/H1) fail or no AA matched)	/

Table continues on the next page...

Table 561. Link Layer Registers Used in GTM (continued)

Register	RX Side ?	TX Side ?	Description	Reused From
GTM_GOOD_PKT_CNT[12:0]	X		GTM Good Packet Counter (CRC pass and header(H0/ Length/H1) pass)	/

52.4.4.4.2.2.9 Interrupts

Interrupt Status Bit Structure

The Generic FSK Link Layer Controller has 15 interrupt sources, each represented in the register map by an interrupt status bit. All interrupt status bits share a common, generic structure. If a particular interrupt source is enabled, a "TRIGGERING EVENT" for that interrupt source, will always set the status bit. A write-1-to-clear input from the IPS bus, will clear the status bit, but only if there is not a simultaneous triggering event. The triggering event prevails over a software clear attempt, if both events coincide. An integrated clock gate guarantees that the status bit only sees a clock when either a triggering event occurs, or a write-1-to-clear pulse arrives from the IPS bus. This reduces interrupt status bit power consumption to an absolute minimum. (Note: the TSM_IRQ does not have an associated status bit in the Link Layer Controller; its status bit resides in the Transceiver Sequence Manager, or TSM).

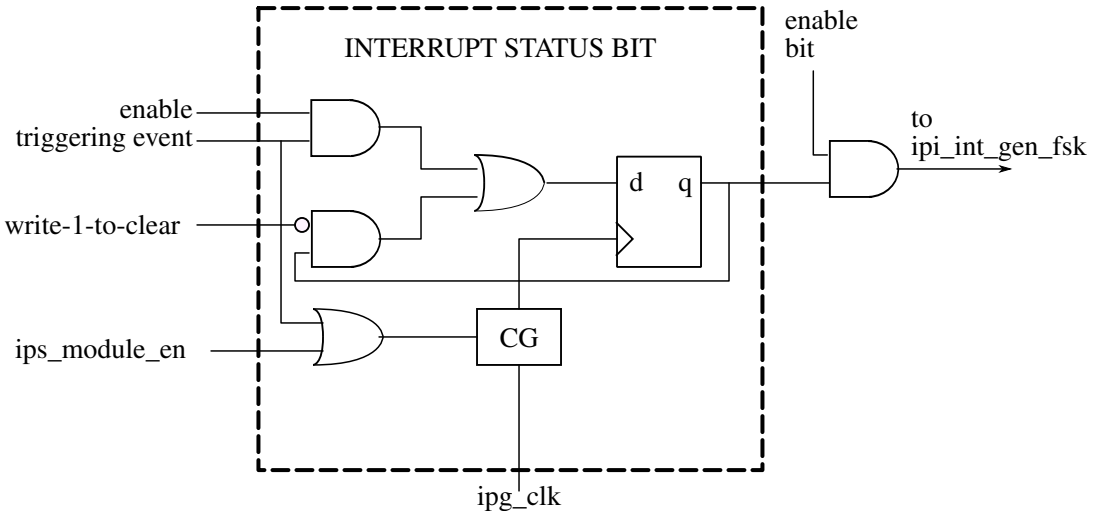

Figure 512. Interrupt Status Bit

Each GENERIC_FSK interrupt status bit, has an ENABLE bit associated with it. The name of the enable bit tracks the name of the interrupt source, with the string "_EN" appended at the end. Note that for any GENERIC_FSK interrupt source, if the triggering event occurs, the Interrupt Status Bit will be set regardless of the state of the corresponding ENABLE bit. If any of the 15 interrupts is to be ignored, software should clear the corresponding ENABLE bit, and apply the appropriate bit mask when reading the IRQ_CTRL register, to mask out the unwanted status bit.

GENERIC_FSK Interrupt Architecture

The 10 interrupt sources (status bits) are combined with their individual ENABLE bits, and then logically OR'ed together, in sum-of-products fashion, to generate single interrupt line to the MCU: **ipi_int_gen_fsk**. A global mask bit, GENERIC_FSK_IRQ_EN, can enable or disable **ipi_int_gen_fsk** altogether. There is no prioritization of interrupt sources; they have equal weight. The **ipi_int_gen_fsk** output is a level-sensitive indicator and will remain asserted until all interrupt status bits are cleared (or the corresponding ENABLE bits cleared). The following diagram depicts the GENERIC_FSK Interrupt Architecture.

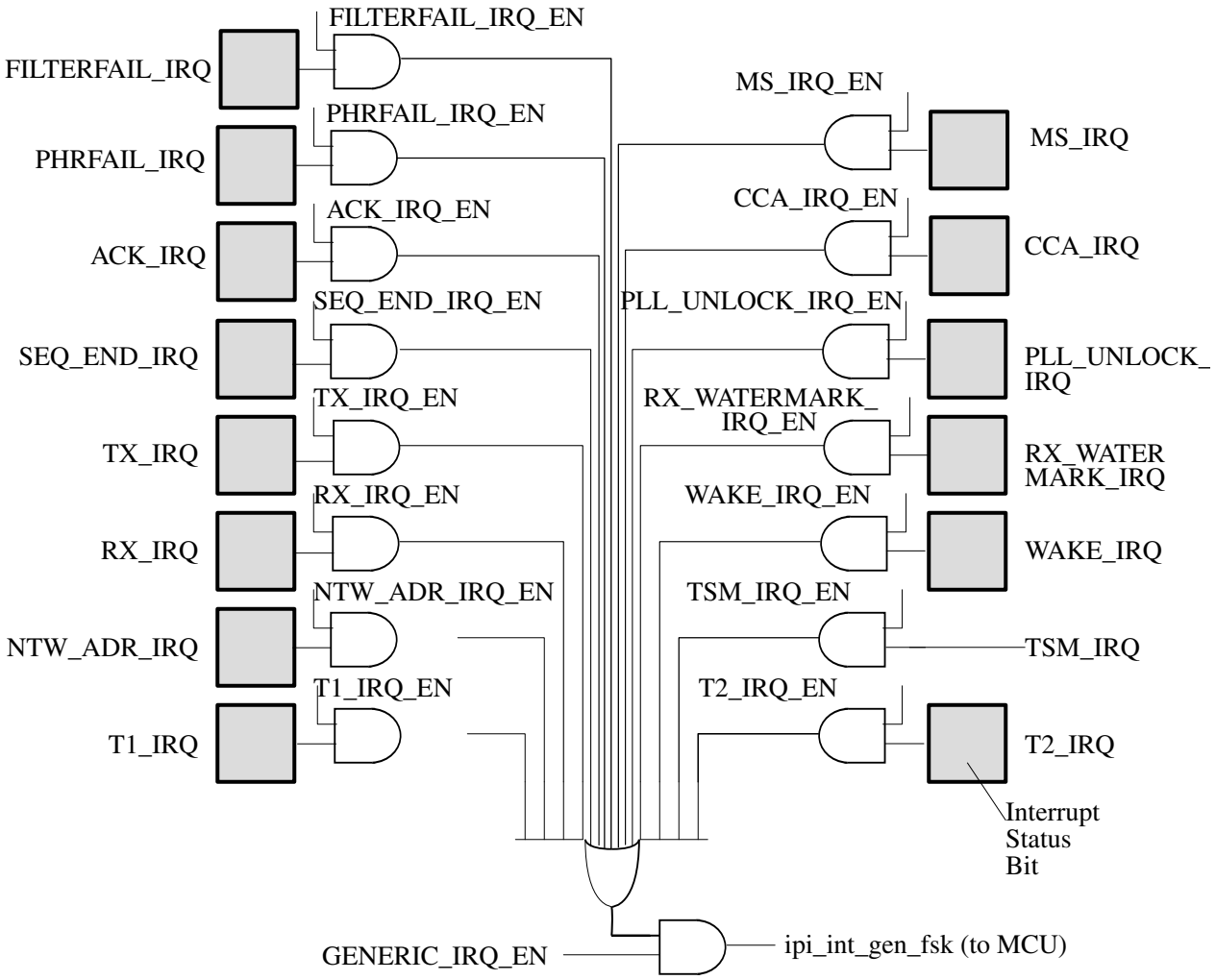

Figure 513. GENERIC_FSK Interrupt Architecture

Clearing Interrupts

All interrupt status bit use a write-1-to-clear protocol. Writing a '1' to the interrupt status bit, in the IRQ_CTRL register, clears the offending interrupt. Writing a '0' to an interrupt status bit has no effect on the bit. Interrupt status bits are not affected by reads.

GENERIC FSK Interrupt Sources

The following table describes the GENERIC_FSK Interrupt Sources

Interrupt	Description
T1_IRQ, T2_IRQ	The GENERIC_FSK Link Layer features a 24-bit Event Timer, which runs at a rate of 1MHz. The Link Layer has 2 Timer interrupts (T1_IRQ, T2_IRQ), each with its own 24-bit compare register (T1_CMP, T2_CMP), and each with its own compare enable (T1_CMP_EN, T2_CMP_EN). For each timer compare enable, if the bit is set, a match on the respective 24-bit compare value to the Event Timer will cause the corresponding interrupt status bit to become set. If the compare enable is

Table continues on the next page...

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Interrupt	Description
	not set, Event Timer matches won't cause the corresponding interrupt status bit to become set.
TX_IRQ	TX interrupt occurs at the end of a TX operation.
RX_IRQ	RX interrupt occurs at the end of a successful RX packet reception. A successful packet reception implies CRC was verified to be good, H0 matching passed, H1 matching passed, and received packet length did not violate pre-set limits. Nominally, RX interrupts are not generated on packets which fail CRC check, or which failure the H0, H1 or LENGTH limits. A received packet with a failed CRC check or a H0, H1, or LENGTH violation, results in an RX recycle back to the Network Address Search state. To receive a Data Indication (RX_IRQ) on packets which fail CRC, set the bit CRC_IGNORE=1. H0 and H1 matching, and LENGTH limiting, are under SW control.
NTW_ADR_IRQ	A Network Address Match has occurred on an enabled Network Address. At NTW_ADR_IRQ, a timestamp is captured by transferring the current contents of the EVENT_TMR into the TIMESTAMP register. Software can determined which Network Address matched by querying the NTW_ADR_MCH[3:0] field of the NTW_ADR_CTRL register.
SEQ_END_IRQ	The Sequence End Interrupt (SEQ_END_IRQ), indicates that a transceiver operation (TX or RX) has completed, and the Command Decoder State Machine, and the Transceiver Sequence Manager (TSM), have returned to their respective IDLE states. A SEQ_END_IRQ will always occur at the end of a sequence, even if the sequence terminated abnormally (such as a Software Abort, or a PLL Unlock Abort). A SEQ_END_IRQ always occurs whenever the Command Decoder FSM transitions from any non-idle to IDLE state. When SEQ_END_IRQ occurs, software can be sure that the Command Decoder and TSM are in their idle state, and a new sequence can be programmed.
RX_WATERMARK_IRQ	RX Watermark interrupt will occur during packet reception, when the number of received bytes, as indicated by the read-only BYTE_COUNTER register, matches the contents of the RX_WATERMARK register. For the purpose of defining RX_WTR_MARK, the first byte received (BYTE_COUNTER = 0) is the first byte of Network Address; the second byte received (BYTE_COUNTER = 1) is the second byte of Network Address, etc. To cause an RX Watermark Interrupt to occur after a 2-byte Network Address has been received, set RX_WTR_MARK=1. By default, RX_WATERMARK is set to a value larger than the longest supported GENERIC_FSK packet length, so an RX_WATERMARK_IRQ won't be triggered under these conditions.

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Interrupt	Description
PLL_UNLOCK_IRQ	When an PLL unlock event occurs during an transceiver operation, and the transceiver has been configured to automatically abort sequences on PLL unlock events, the PLL_UNLOCK_IRQ status bit will become set. The Transceiver Sequence Manager (TSM) will begin monitoring for PLL unlock only after the PLL has been given sufficient time to achieve lock; A PLL unlock which occurs after the warmup period, can be enabled to cause a sequence abort. Individual enables are provided for TX and RX sequences. (See the TSM Chapter for more details).
WAKE_IRQ	**For Manual DSM:** This is WAKE_IRQ. A WAKE_IRQ will be triggered when the GENERIC_FSK Link Layer Controller has awoken from a Manual DSM (Deep Sleep Mode) cycle. WAKE_IRQ indicates that the RF Oscillator has been restarted, and the GENERIC_FSK EVENT_TMR has resumed counting. **For Wake-On-Radio:**: This is WOR_IRQ. See Section Wake-On-Radio
TSM_IRQ	TSM_IRQ is a debug feature, enabling the Transceiver Sequence Manager (TSM) to generate an interrupt at any point in a TX or RX Warmup. TSM is a multipurpose hardware resource shared by all of the protocol engines in the SoC. Thus, TSM does not have its own interrupts; its interrupts are assigned to whichever link layer controller is currently executing an RF operation. TSM Interrupt Status bits reside in Transceiver (XCVR) Address Space, and can be cleared there. There is no intended mission-mode use for TSM_IRQ. See the TSM Chapter for more details.
ACK_IRQ	ACK_IRQ is asserted when RX finishes, and an auto ACK frame is scheduled to TX. At this time, software may need to write packet RAM to prepare the ACK frame or part of the ACK frame.
PHRFFAIL_IRQ	PHRFFAIL_IRQ is asserted when the received frame fails at BCH check or Parity check, for LECIM FSK and SUN FSK Mode Switch frame only.
FILTERFAIL_IRQ	FILTERFAIL_IRQ indicates that the most-recently received packet has been rejected due to elements within the packet. In Dual PAN mode, FILTERFAIL_IRQ applies to either or both networks, as follows: A: If PAN0 and PAN1 occupy different channels and CURRENT_NETWORK=0, FILTERFAIL_IRQ applies to PAN0.

Table continues on the next page...

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Interrupt	Description
	B: If PAN0 and PAN1 occupy different channels and CURRENT_NETWORK=1, FILTERFAIL_IRQ applies to PAN1. C: If PAN0 and PAN1 occupy the same channel, FILTERFAIL_IRQ is the logical 'AND' of the individual PANs' Filter Fail status.
CCA_IRQ	CCA_IRQ indicates completion of CCA operation
MS_IRQ	MS_IRQ indicates a mode switch frame is received with no BCH or Parity error.

52.4.4.4.2.2.10 Clocking

The Generic FSK has the following input signals:

Table 562.

Clock	Description
ipg_clk	IP Bus Clock, Free-running
ips_clk	IP Bus Clock, for Register I/F
ipg_clk_generic_fsk_tmr	1MHz for Generic FSK event timer
cg_1mhz_clk	cg1m_en gated ipg_clk
cg_500khz_clk	cg500k_en gated ipg_clk

52.4.4.4.2.2.11 Reset

The Generic FSK block has a single, active-low, asynchronous reset input: **ipg_hard_async_reset_b** It clears all the internal logic.

52.4.4.4.2.3 External Signal Descriptions

Signal	I/O	Function
ipg_clk	I	IP Bus Clock, Free-running
ips_clk	I	IP Bus Clock, for Register I/F
ipg_clk_generic_fsk_vbr	I	1MHz (Variable) for Generic_FSK LL
ipg_clk_generic_fsk_tmr	I	1MHz + tmrload for Generic FSK event_tmr
ipg_hard_async_reset_b	I	SoC low voltage logic asynchronous reset signal
ips_addr[11:0]	I	IP bus address
ips_byte_en[3:0]	I	IP bus byte enable

Table continues on the next page...

Table continued from the previous page...

Signal	I/O	Function
ips_module_en	I	IP bus module enable
ips_rwb	I	IP bus access
ips_wdata[31:0]	I	IP bus write data
cg1m_en	I	clock gate enable, 1MHz
cg_vbr_en	I	clock gate enable, Variable Bit Rate
end_of_tx_wu[7:0]	I	from TSM, TX warmup time
end_of_rx_wu[7:0]	I	from TSM, RX warmup time
rssi[7:0]	I	RSSI from RX_DIG
lqi[7:0]	I	LQI from RX_DIG
ntw_adr_mch[3:0]	I	from PHY, indicates which NA matched
rx_data_out	I	RX data out from CRC/whitener
rx_data_out_vld	I	RX data out valid from CRC/whitener
crc_zero	I	CRC LFSR has gone zero (good crc)
part_id[7:0]	I	Revision ID
tx_mode	I	from TSM, TX operation underway
rx_mode	I	from TSM, RX operation underway
tsm_wu_complete	I	from TSM, Warmup Complete
tsm_idle	I	from TSM, Idle Indication
rx_init	I	from TSM, RX initialization signal
pll_unlock	I	from TSM, PLL unlock indicator
xcvr_busy	I	from TSM, TSM is busy (1 of 4 Link Layers is accessing RF channel)
tsm_irq	I	from TSM, Interrupt
dsm_gen_deep_sleep_enable	I	from RFMC
scan_mode	I	Scan Mode
ipi_int_generic_fsk_async	O	Generic FSK interrupt
ips_rdata[31:0]	O	IPS bus read data
ips_xfr_err	O	IP bus access error
generic_fsk_tx_en	O	TSM control, Generic_FSK requests a TX operation
generic_fsk_rx_en	O	TSM control, Generic_FSK requests a RX operation

Table continues on the next page...

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Signal	I/O	Function
generic_fsk_tx_power[4:0]	O	To PA Ramping, Generic_FSK Desired Target Power
generic_fsk_channel_num[6:0]	O	Mapped Channel Number to PLL_DIG
ntw_adr_0[31:0]	O	Network Address #0 to PHY
ntw_adr_1[31:0]	O	Network Address #1 to PHY
ntw_adr_2[31:0]	O	Network Address #2 to PHY
ntw_adr_3[31:0]	O	Network Address #3 to PHY
ntw_adr_en[3:0]	O	Individual Enables for Network Address #N
ntw_adr0_sz[1:0]	O	3: Network Address 0 requires a 32-bit correlation 2: Network Address 0 requires a 24-bit correlation 1: Network Address 0 requires a 16-bit correlation 0: Network Address 0 requires a 8-bit correlation
ntw_adr1_sz[1:0]	O	3: Network Address 1 requires a 32-bit correlation 2: Network Address 1 requires a 24-bit correlation 1: Network Address 1 requires a 16-bit correlation 0: Network Address 1 requires a 8-bit correlation
ntw_adr2_sz[1:0]	O	3: Network Address 2 requires a 32-bit correlation 2: Network Address 2 requires a 24-bit correlation 1: Network Address 2 requires a 16-bit correlation 0: Network Address 2 requires a 8-bit correlation
ntw_adr3_sz[1:0]	O	3: Network Address 3 requires a 32-bit correlation 2: Network Address 3 requires a 24-bit correlation

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Table continued from the previous page...

Signal	I/O	Function
		1: Network Address 3 requires a 16-bit correlation 0: Network Address 3 requires a 8-bit correlation
ntw_adr_thr0[2:0]	O	Number of Tolerated bit errors for Network Address 0
ntw_adr_thr1[2:0]	O	Number of Tolerated bit errors for Network Address 1
ntw_adr_thr2[2:0]	O	Number of Tolerated bit errors for Network Address 2
ntw_adr_thr3[2:0]	O	Number of Tolerated bit errors for Network Address 3
generic_fsk_recycle	O	to TSM, RX recycle due to CRC, H0, H1, or Length violation
tx_data_in	O	TX data in to CRC/whitener
tx_data_in_vld	O	TX data in valid to CRC/whitener
tmrload	O	to CGM, load Generic_FSK Event_tmr
rx_watermark_irq	O	for DTEST
wake_irq	O	for DTEST
pll_unlock_irq	O	for DTEST
t2_irq	O	for DTEST
t1_irq	O	for DTEST
ntw_adr_irq	O	for DTEST
rx_irq	O	for DTEST
tx_irq	O	for DTEST
seq_end_irq	O	for DTEST
crcw_init	O	Init both CRC & Whitener
crc_en	O	to CRC/Whitener, Enable CRC
crc_comp	O	to CRC/Whitener, TX packet data from LL is complete
whiten_en	O	to CRC/Whitener, Enable Whitening/de-whitening
crc_sz[2:0]	O	to CRC/Whitener, CRC Size, in octets
crc_seed[31:0]	O	to CRC/Whitener, CRC Initialization Value

Table continues on the next page...

Table continued from the previous page...

Signal	I/O	Function
crc_poly[31:0]	O	to CRC/Whitener, CRC Polynomial
crc_byte_ord	O	to CRC/Whitener, CRC Byte Order
crc_ref_out	O	to CRC/Whitener, CRC result is to be manipulated bitwise
crc_ref_in	O	to CRC/Whitener, Reflect each byte in the input stream bytewise
crc_xor_out[31:0]	O	to CRC/Whitener, XOR mask for CRC result
whiten_b4_crc	O	to CRC/Whitener, Whiten before CRC
whiten_seed[8:0]	O	to CRC/Whitener, Whitener Initialization Value
whiten_poly[8:0]	O	to CRC/Whitener, Whitening Shift Register Polynomial
whiten_poly_type	O	to CRC/Whitener, see CRC/Whitener Block Guide
whiten_ref_in	O	to CRC/Whitener, see CRC/Whitener Block Guide
whiten_size[3:0]	O	to CRC/Whitener, Whitener Length
bitrate[1:0]	O	Bit Rate (Variable). Several options available. Default: 1Mb/sec
encode_en	O	to Manchester, Encode Enable
manchester_inv	O	to Manchester, Invert Coding Signal
generic_fsk_sleep_en	O	to RFMC, Generic_FSK requests DSM entry
bsm_clk	O	not currently supported
bsm_data	O	not currently supported
bsm_frame	O	not currently supported

52.4.4.4.2.4 Register Descriptions

52.4.4.4.2.4.1 Memory Mapping

In the SoC memory map, space has been allocated to GENERIC_FSK. Within the SoC, peripherals are allocated memory space in 4KB blocks, called IPS slots. GENERIC_FSK occupies one such slot. GENERIC_FSK address space consists of the GENERIC_FSK registers. The partitioning of address space for GENERIC_FSK is shown in the diagram below.

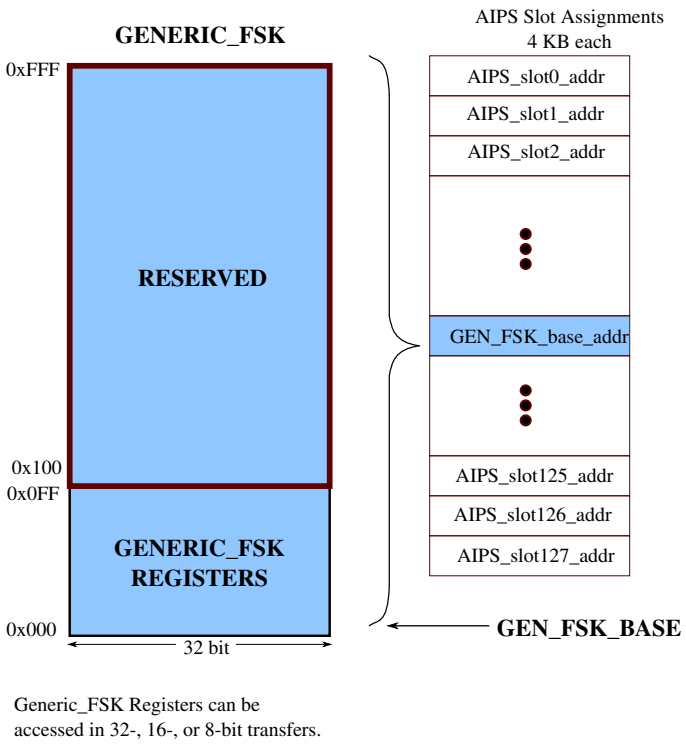

Figure 514. GENERIC_FSK MEMORY MAPPING

NOTE

See AIPS Memory Map for specific memory assignments details.

All registers within GENERIC_FSK memory space, are accessible by the MCU in 8-, 16-, or 32-bit accesses. For efficiency, 32-bit accesses are recommended.

52.4.4.4.2.4.2 GENERIC FSK register descriptions

52.4.4.4.2.4.2.1 FSK memory map

RADIO.GENFSK base address: 48A0_2000h

Offset	Register	Width (In bits)	Access	Reset value
0h	IRQ CONTROL (IRQ_CTRL)	32	RW	0000_0000h
4h	EVENT TIMER (EVENT_TMR)	32	R	See section
8h	T1 COMPARE (T1_CMP)	32	RW	FFFF_FFFFh
Ch	T2 COMPARE (T2_CMP)	32	RW	FFFF_FFFFh
10h	TIMESTAMP (TIMESTAMP)	32	R	See section
14h	TRANSCEIVER CONTROL (XCVR_CTRL)	32	RW	0007_FF00h
18h	TRANSCEIVER STATUS (XCVR_STS)	32	R	0080_0000h

Table continues on the next page...

Table continued from the previous page...

Offset	Register	Width (In bits)	Access	Reset value
1Ch	TRANSCEIVER CONFIGURATION (XCVR_CFG)	32	RW	0000_0000h
20h	CHANNEL NUMBER 0 (CHANNEL_NUM0)	32	RW	0000_0000h
24h	TRANSMIT POWER (TX_POWER)	32	RW	0000_0000h
28h	NETWORK ADDRESS CONTROL (NTW_ADR_CTRL)	32	RW	0000_0100h
2Ch	NETWORK ADDRESS 0 (NTW_ADR_0)	32	RW	5555_5555h
30h	NETWORK ADDRESS 1 (NTW_ADR_1)	32	RW	5555_5555h
34h	NETWORK ADDRESS 2 (NTW_ADR_2)	32	RW	5555_5555h
38h	NETWORK ADDRESS 3 (NTW_ADR_3)	32	RW	5555_5555h
3Ch	RECEIVE WATERMARK (RX_WATERMARK)	32	RW	1FFF_0FFFh
40h	DSM CONTROL (DSM_CTRL)	32	RW	0000_0000h
44h	PART ID (PART_ID)	32	R	0000_0002h
48h	SLOT PRELOAD (SLOT_PRELOAD)	32	RW	0000_02A8h
4Ch	SLOT TIME (SLOT_TIME)	32	RW	0000_08E8h
50h	TURNAROUND TIME (TURNAROUND_TIME)	32	RW	0000_03E8h
54h	ACK DELAY (ACKDELAY)	32	RW	0000_0000h
58h	RX DELAY (RXDELAY)	32	RW	0000_0000h
5Ch	TX DELAY (TXDELAY)	32	RW	0000_0000h
60h	PACKET CONFIGURATION (PACKET_CFG)	32	RW	00C0_0040h
64h	H0 CONFIGURATION (H0_CFG)	32	RW	0000_0000h
68h	H1 CONFIGURATION (H1_CFG)	32	RW	0000_0000h
6Ch	CRC CONFIGURATION (CRC_CFG)	32	RW	E000_0000h
70h	LENGTH ADJUSTMENT (LENGTH_ADJ)	32	RW	0000_0000h
74h	TIMESTAMP_RX_DONE (TIMESTAMP_RX_DONE)	32	R	See section
78h	TIMESTAMP_TX_DONE (TIMESTAMP_TX_DONE)	32	R	See section
7Ch	MULT_PKT_CTRL (MULT_PKT_CTRL)	32	RW	0000_0000h
80h	RPA AND WHITE LIST STATUS (RPA_WL_STATUS)	32	RW	0F0F_003Fh
84h	MAXIMUM LENGTH (LENGTH_MAX)	32	RW	0000_0000h
88h	EVENT TIMER LOAD (EVENT_TMR_LD)	32	W	0000_0000h
8Ch	EVENT TIMER ADD (EVENT_TMR_ADD)	32	W	0000_0000h
90h	ENHANCED FEATURES (ENH_FEATURE)	32	RW	0000_0000h
94h	RECEIVE FRAME FILTER (RX_FRAME_FILTER)	32	RW	0000_060Fh

Table continues on the next page...

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Offset	Register	Width (In bits)	Access	Reset value
98h	FILTER FAIL CODE (FILTERFAIL_CODE)	32	RW	0000_0000h
9Ch	LENIENCY LSB (LENIENCY_LSB)	32	RW	0000_0000h
9Ch	RPA CONTROL (RPA_CTRL)	32	RW	0000_0000h
A0h	LENIENCY MSB (LENIENCY_MSB)	32	RW	0000_0000h
A0h	WHITE LIST CONTROL (WL_CTRL)	32	RW	0000_0000h
A4h	DUAL PAN CONTROL (DUAL_PAN_CTRL)	32	RW	0001_0000h
A8h	GTM MODE PDU (GTM_PDU)	32	RW	FFFF_FFFFh
A8h	MAC SHORT ADDRESS FOR PAN1 (MACSHORTADDRS1)	32	RW	FFFF_FFFFh
A8h	VALID ENTRY OF WHITE LIST 1 (WL_VALID_ENTRY1)	32	RW	FFFF_FFFFh
ACh	DIRECT_PEER_ADDR[31:0] (DIRECT_PEER_ADDR_LSB)	32	RW	FFFF_FFFFh
ACh	GTM MODE CONFIGURATION (GTM_CFG)	32	RW	FFFF_FFFFh
ACh	MAC LONG ADDRESS 1 LSB (MACLONGADDRS1_LSB)	32	RW	FFFF_FFFFh
B0h	DIRECT_PEER_ADDR[47:32] (DIRECT_PEER_ADDR_MSB)	32	RW	FFFF_FFFFh
B0h	GTM MODE INTER-PACKET DURATION (GTM_IPD)	32	RW	FFFF_FFFFh
B0h	MAC LONG ADDRESS 1 MSB (MACLONGADDRS1_MSB)	32	RW	FFFF_FFFFh
B4h	CHANNEL NUMBER 1 (CHANNEL_NUM1)	32	RW	0000_0000h
B8h	MAC SHORT ADDRESS 0 (MACSHORTADDRS0)	32	RW	FFFF_FFFFh
B8h	VALID ENTRY OF WHITE LIST 0 (WL_VALID_ENTRY0)	32	RW	FFFF_FFFFh
BCh	GTM MODE TIME OF FIRST SFD FOUND TO FORCE RX WARM-DOWN (GTM_FIRST_SFD2WD)	32	RW	FFFF_FFFFh
BCh	MAC LONG ADDRESS 0 LSB (MACLONGADDRS0_LSB)	32	RW	FFFF_FFFFh
BCh	WL_SEARCH_ADDR[31:0] (WL_SEARCH_ADDR_LSB)	32	RW	FFFF_FFFFh
C0h	GTM MODE RX RECYCLE TIME (GTM_RX_RECYCLE_TIME)	32	RW	FFFF_FFFFh
C0h	MAC LONG ADDRESS 0 MSB (MACLONGADDRS0_MSB)	32	RW	FFFF_FFFFh
C0h	WL_SEARCH_ADDR[47:32] (WL_SEARCH_ADDR_MSB)	32	RW	FFFF_FFFFh
C4h	CCA AND LQI CONTROL (CCA_LQI_CTRL)	32	RW	0000_4B00h
C8h	TX/RX WARMUP TIME (WARMUP_TIME)	32	R	0070_005Ah
CCh	RX_EN Delay Time (RXEN_DLY)	32	RW	0000_0000h
D4h	SAM CONTROL (SAM_CTRL)	32	RW	8080_4000h
D8h	SOURCE ADDRESS MANAGEMENT TABLE (SAM_TABLE)	32	RW	0000_0000h
DCh	SOURCE ADDRESS MANAGEMENT MATCH (SAM_MATCH)	32	R	FF7F_FF7Fh

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Offset	Register	Width (In bits)	Access	Reset value
E0h	SAM FREE INDEX (SAM_FREE_IDX)	32	R	8080_8080h
E4h	MISCELLANEOUS(1) (MISC1)	32	RW	0000_0000h
E8h	SEQUENCE STATUS (SEQ_STS)	32	R	0000_0000h
ECh	PHR MISCELLANEOUS (PHR_MISC)	32	RW	0000_0000h
F0h	GTM CONTROL (GTM_CTRL)	32	RW	0000_0000h
F4h	GTM BAD PACKET COUNTER (GTM_BAD_CNT)	32	R	0000_0000h
F8h	GTM GOOD PACKET COUNTER (GTM_GOOD_CNT)	32	R	0000_0000h
FCh	GTM PACKET COUNTER (GTM_PKT_CNT)	32	R	0000_0000h
100h	COEXISTENCE CONTROL (COEX_CTRL)	32	RW	0000_0300h
104h	COEXISTENCE PRIORITY (COEX_PRIORITY)	32	RW	0000_0000h
108h	IRQ CONTROL 2 (IRQ_CTRL2)	32	RW	0000_0000h

52.4.4.4.2.4.2.2 IRQ CONTROL (IRQ_CTRL)

Offset

Register	Offset
IRQ_CTRL	0h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	MS_IRQ_...	CCA_IRQ...	FILTERF...	PHRFAIL...	ACK_IRQ...	GENERIC...	TSM_IRQ...	RX_WATE...	WAKE_IR...	PLL_UNL...	T2_IRQ_...	T1_IRQ_...	NTW_ADR...	RX_IRQ_...	TX_IRQ_...	SEQ_END...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	MS_IRQ	CCA_IRQ	FILTERF...	PHRFFAI...	ACK_IRQ	CRC_VAL...	TSM_IRQ	RX_WATE...	WAKE_IRQ	PLL_UNL...	T2_IRQ	T1_IRQ	NTW_ADR...	RX_IRQ	TX_IRQ	SEQ_END...
W	W1C	W1C	W1C	W1C	W1C			W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31 MS_IRQ_EN	MS_IRQ Enable 0b - MS Interrupt is not enabled. 1b - MS Interrupt is enabled.
30 CCA_IRQ_EN	CCA_IRQ Enable 0b - CCA Interrupt is not enabled. 1b - CCA Interrupt is enabled.
29 FILTERFAIL_IRQ_EN	FILTERFAIL_IRQ Enable 0b - FILTERFAIL Interrupt is not enabled. 1b - FILTERFAIL Interrupt is enabled.
28 PHRFAIL_IRQ_EN	PHRFAIL_IRQ Enable 0b - PHRFAIL Interrupt is not enabled. 1b - PHRFAIL Interrupt is enabled.
27 ACK_IRQ_EN	ACK_IRQ Enable 0b - Auto ACK Interrupt is not enabled. 1b - Auto ACK Interrupt is enabled.
26 GENERIC_FSK_IRQ_EN	GENERIC_FSK_IRQ Master Enable Master enable for the GENERIC_FSK_IRQ interrupt line to the MCU. 0b - All GENERIC_FSK Interrupts are disabled. 1b - All GENERIC_FSK Interrupts can be enabled.
25 TSM_IRQ_EN	TSM_IRQ Enable 0b - TSM Interrupt is not enabled. 1b - TSM Interrupt is enabled.
24 RX_WATERMARK_IRQ_EN	RX_WATERMARK_IRQ Enable 0b - RX Watermark Interrupt is not enabled. 1b - RX Watermark Interrupt is enabled.
23 WAKE_IRQ_EN	WAKE_IRQ Enable 0b - Wake Interrupt is not enabled. 1b - Wake Interrupt is enabled.
22 PLL_UNLOCK_IRQ_EN	PLL_UNLOCK_IRQ Enable 0b - PLL Unlock Interrupt is not enabled. 1b - PLL Unlock Interrupt is enabled.
21	T2_IRQ Enable

Table continues on the next page...

Table continued from the previous page...

Field	Function
T2_IRQ_EN	0b - Timer1 (T2) Compare Interrupt is not enabled. 1b - Timer1 (T2) Compare Interrupt is enabled.
20 T1_IRQ_EN	T1_IRQ Enable 0b - Timer1 (T1) Compare Interrupt is not enabled. 1b - Timer1 (T1) Compare Interrupt is enabled.
19 NTW_ADR_IRQ_EN	NTW_ADR_IRQ Enable 0b - Network Address Match Interrupt is not enabled. 1b - Network Address Match Interrupt is enabled.
18 RX_IRQ_EN	RX_IRQ Enable 0b - RX Interrupt is not enabled. 1b - RX Interrupt is enabled.
17 TX_IRQ_EN	TX_IRQ Enable 0b - TX Interrupt is not enabled. 1b - TX Interrupt is enabled.
16 SEQ_END_IRQ_EN	SEQ_END_IRQ Enable 0b - Sequence End Interrupt is not enabled. 1b - Sequence End Interrupt is enabled.
15 MS_IRQ	Mode Switch Interrupt SUN FSK Mode Switch Interrupt Status bit. A '1' indicates a mode switch frame is received. 0b - A Mode Switch frame is not received 1b - A Mode Switch frame is received
14 CCA_IRQ	CCA Interrupt Clear Channel Assessment Interrupt Status bit. A '1' indicates completion of CCA operation. 0b - A CCA Interrupt has not occurred 1b - A CCA Interrupt has occurred
13 FILTERFAIL_IRQ	Received Frame Filter Fail Interrupt Receiver Packet Filter Fail Interrupt Status bit. A '1' indicates that the most-recently received packet has been rejected due to elements within the packet. This is write a '1' to clear bit. In Dual PAN mode, FILTERFAIL_IRQ applies to either or both networks, as follows: A: If PAN0 and PAN1 occupy different channels and CURRENT_NETWORK=0, FILTERFAIL_IRQ applies to PAN0. B: If PAN0 and PAN1 occupy different channels and CURRENT_NETWORK=1, FILTERFAIL_IRQ applies to PAN1.

Table continues on the next page...

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Field	Function
	C: If PAN0 and PAN1 occupy the same channel, FILTERFAIL_IRQ is the logical 'AND' of the individual PANs' Filter Fail status. 0b - A Filter Fail Interrupt has not occurred. 1b - A Filter Fail Interrupt has occurred.
12 PHRFFAIL_IRQ	Received Frame PHR Fail Interrupt Asserts when the received frame fails at BCH check or Parity check, for LECIM FSK and SUN FSK Mode Switch frame only. 0b - Received frame PHR Fail Interrupt is not asserted. 1b - Received frame PHR Fail Interrupt is asserted.
11 ACK_IRQ	Auto ACK Interrupt Asserts when RX finishes, and an auto ACK frame is needed. Software may need to write packet RAM to prepare the ACK frame. 0b - Auto ACK Interrupt is not asserted. 1b - Auto ACK Interrupt is asserted.
10 CRC_VALID	CRC Valid CRC Valid indicator for RX packets. This bit becomes valid at RX_IRQ, and remains valid until the start of the next RX TSM sequence.
9 TSM_IRQ	TSM Interrupt Indicates TSM0_IRQ or TSM1_IRQ is set in XCVR_STATUS. Clear the bits there. For debug purposes. 0b - TSM0_IRQ and TSM1_IRQ are both clear. 1b - Indicates TSM0_IRQ or TSM1_IRQ is set in XCVR_STATUS.
8 RX_WATERMARK_IRQ	RX Watermark Interrupt Asserts when RX Byte Counter == RX_WATERMARK[12:0] 0b - RX Watermark Interrupt is not asserted. 1b - RX Watermark Interrupt is asserted.
7 WAKE_IRQ	Wake Interrupt **For Manual DSM:** This is WAKE_IRQ. A WAKE_IRQ will be triggered when the GENERIC_FSK Link Layer Controller has awoken from a Manual DSM (Deep Sleep Mode) cycle. WAKE_IRQ indicates that the RF Oscillator has been restarted, and the GENERIC_FSK EVENT_TMR has resumed counting. **For Wake-On-Radio:** This is WOR_IRQ. See Section **Wake-On-Radio** . 0b - Wake Interrupt is not asserted. 1b - Wake Interrupt is asserted.
6	PLL Unlock Interrupt

Table continues on the next page...

Table continued from the previous page...

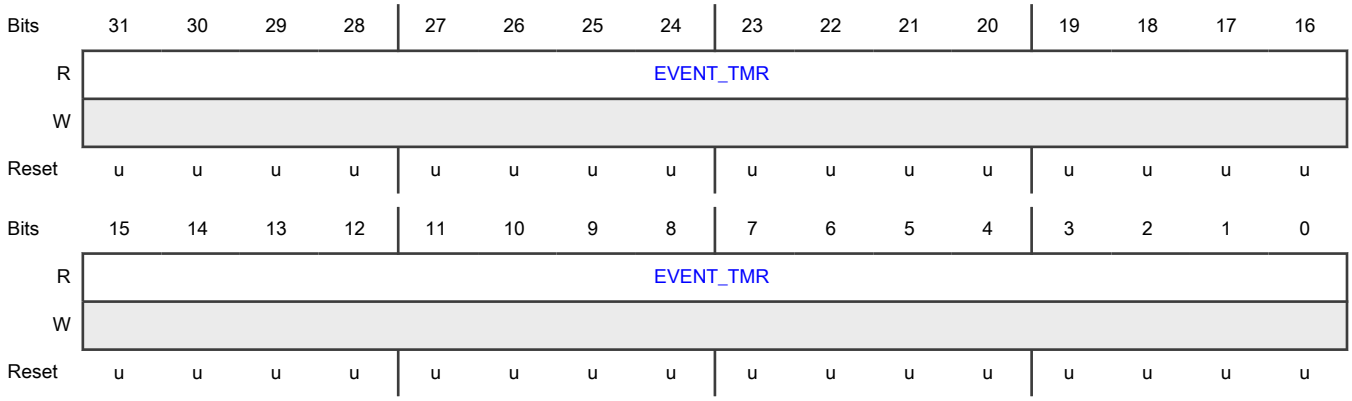
Field	Function
PLL_UNLOCK_IRQ	An unlock event has occurred. 0b - PLL Unlock Interrupt is not asserted. 1b - PLL Unlock Interrupt is asserted.
5 T2_IRQ	Timer2 (T2) Compare Interrupt 0b - Timer2 (T2) Compare Interrupt is not asserted. 1b - Timer2 (T2) Compare Interrupt is asserted.
4 T1_IRQ	Timer1 (T1) Compare Interrupt 0b - Timer1 (T1) Compare Interrupt is not asserted. 1b - Timer1 (T1) Compare Interrupt is asserted.
3 NTW_ADR_IRQ	Network Address Match Interrupt A Network Address Match has occurred. 0b - Network Address Match Interrupt is not asserted. 1b - Network Address Match Interrupt is asserted.
2 RX_IRQ	RX Interrupt The RX sequence has completed with a successful packet reception. 0b - RX Interrupt is not asserted. 1b - RX Interrupt is asserted.
1 TX_IRQ	TX Interrupt The TX sequence has completed with a successful packet transmission. 0b - TX Interrupt is not asserted. 1b - TX Interrupt is asserted.
0 SEQ_END_IRQ	Sequence End Interrupt Will assert when any TX or RX sequence ends for any reason. 0b - Sequence End Interrupt is not asserted. 1b - Sequence End Interrupt is asserted.

52.4.4.4.2.4.2.3 EVENT TIMER (EVENT_TMR)

Offset

Register	Offset
EVENT_TMR	4h

Diagram



Fields

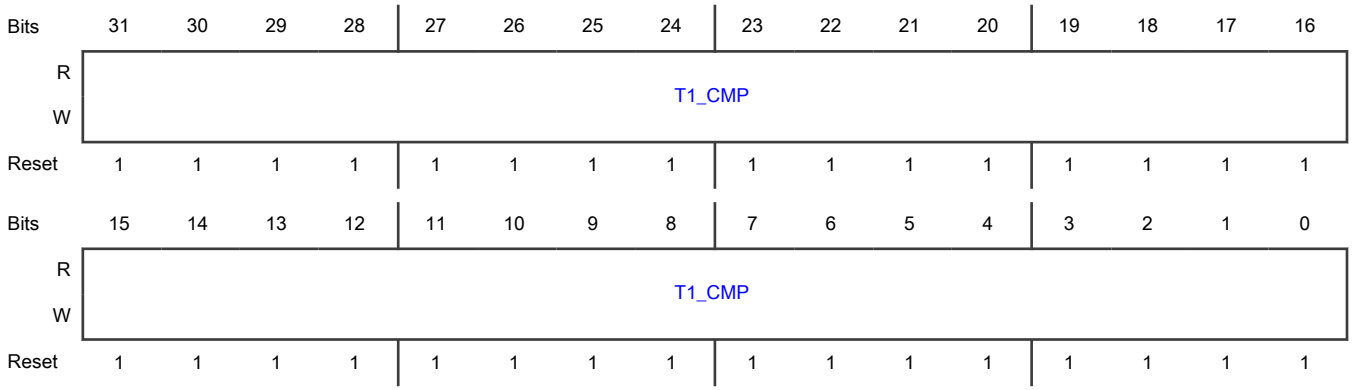
Field	Function
31-0 EVENT_TMR	Event Timer Event Timer can be read in these byte locations. To update the Event Timer, either: 1. Write the desired EVENT_TMR to register EVENT_TMR_LD[31:0], or, 2. Write the desired EVENT_TMR increment amount to register EVENT_TMR_ADD[31:0]. **Note:** for EVENT_TMR_ADD, EVENT_TMR[31:0] is a signed, two's-complement value.

52.4.4.4.2.4.2.4 T1 COMPARE (T1_CMP)

Offset

Register	Offset
T1_CMP	8h

Diagram



Fields

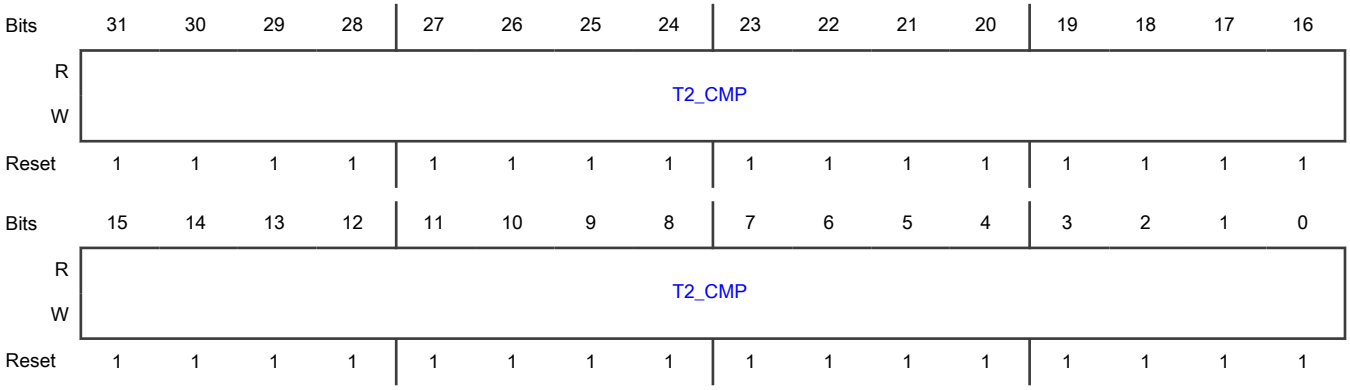
Field	Function
31-0 T1_CMP	Timer1 (T1) Compare Value Timer1 (T1) Compare Value. Can be used to generate T1_IRQ and/or launch Sequence Commands

52.4.4.4.2.4.2.5 T2 COMPARE (T2_CMP)

Offset

Register	Offset
T2_CMP	Ch

Diagram



Fields

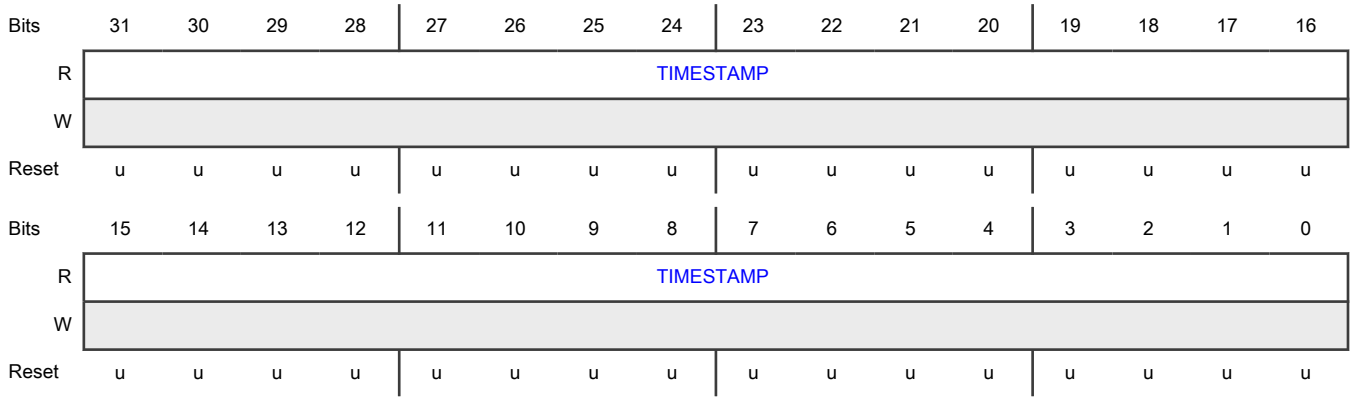
Field	Function
31-0 T2_CMP	Timer2 (T2) Compare Value Timer2 (T2) Compare Value. Can be used to generate T2_IRQ and/or launch Sequence Commands

52.4.4.4.2.4.2.6 TIMESTAMP (TIMESTAMP)

Offset

Register	Offset
TIMESTAMP	10h

Diagram



Fields

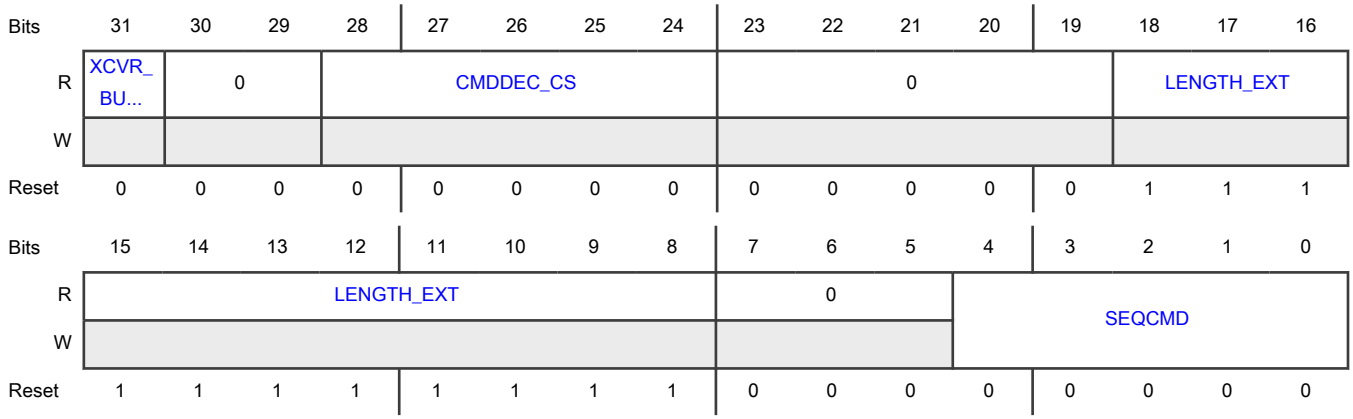
Field	Function
31-0 TIMESTAMP	Received Packet Timestamp Received Packet Timestamp. Captured at NTW_ADR_IRQ.

52.4.4.4.2.4.2.7 TRANSCEIVER CONTROL (XCVR_CTRL)

Offset

Register	Offset
XCVR_CTRL	14h

Diagram



Fields

Field	Function
31 XCVR_BUSY	Transceiver Busy For multi-protocol arbitration, XCVR_BUSY=1 indicates an RX or TX operation is underway, by either GENERIC_FSK, or some other protocol. 0b - IDLE 1b - BUSY
30-29 —	Reserved
28-24 CMDDEC_CS	Command Decode Current State of the Command Decoder FSM (debug only). Also named as SEQ_STATE.
23-19 —	Reserved
18-8 LENGTH_EXT	Extracted Length Field The read-only register reflects the contents of the LENGTH field of the Header of the most-recently received packet. This is the raw, unmodified LENGTH field, as it appears in the received bit stream, unmodified by LENGTH_ADJ or any other parameter.
7-5 —	Reserved
4-0 SEQCMD	Sequence Commands, also named as "XCVSEQ(Transceiver Sequence)" 0_0000b - Same as command ABORT 0_0001b - TX Start Now 0_0010b - TX Start @ T1 Timer Compare Match (EVENT_TMR = T1_CMP) 0_0011b - TX Start @ T2 Timer Compare Match (EVENT_TMR = T2_CMP) 0_0100b - TX Cancel -- Cancels pending TX events but do not abort a TX-in-progress 0_0101b - RX Start Now 0_0110b - RX Start @ T1 Timer Compare Match (EVENT_TMR = T1_CMP) 0_0111b - RX Start @ T2 Timer Compare Match (EVENT_TMR = T2_CMP) 0_1000b - RX Stop @ T1 Timer Compare Match (EVENT_TMR = T1_CMP) 0_1001b - RX Stop @ T2 Timer Compare Match (EVENT_TMR = T2_CMP) 0_1010b - RX Cancel -- Cancels pending RX events but do not abort a RX-in-progress 0_1011b - Abort All - Cancels all pending events and abort any sequence-in-progress 0_1100b - TR Start Now 0_1101b - TR Start @ T1 Timer Compare Match (EVENT_TMR = T1_CMP)

Table continues on the next page...

Table continued from the previous page...

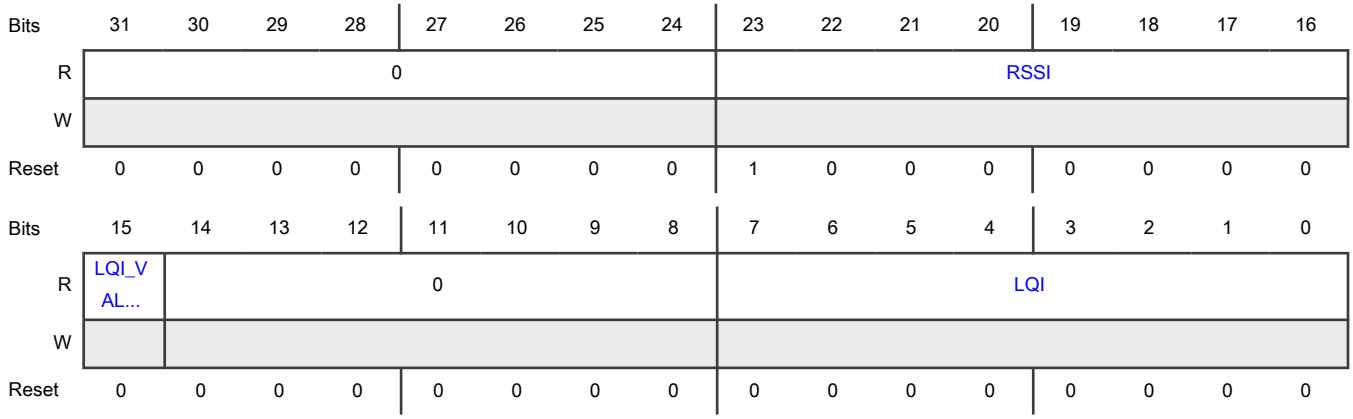
Field	Function
	0_1110b - TR Start @ T2 Timer Compare Match (EVENT_TMR = T2_CMP) 0_1111b - TR Cancel -- Cancels pending TR events but do not abort a TR-in-progress 1_0000b - CCA Start Now 1_0001b - CCA Start @ T1 Timer Compare Match (EVENT_TMR = T1_CMP) 1_0010b - CCA Start @ T2 Timer Compare Match (EVENT_TMR = T2_CMP) 1_0011b - CCA Cancel -- Cancels pending CCA events but do not abort a CCA-in-progress

52.4.4.4.2.4.2.8 TRANSCEIVER STATUS (XCVR_STS)

Offset

Register	Offset
XCVR_STS	18h

Diagram



Fields

Field	Function
31-24 —	Reserved
23-16 RSSI	RSSI Value Received Signal Strength Indicator, in dBm
15 LQI_VALID	LQI Valid Indicator

Table continues on the next page...

Table continued from the previous page...

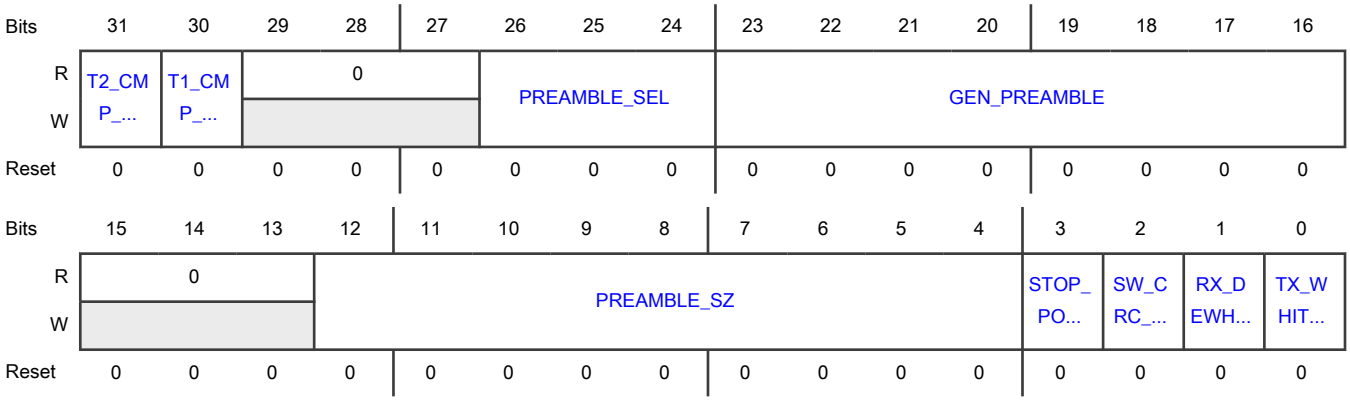
Field	Function
	LQI Valid indicator for RX packets. This bit becomes set when the LQI computation completes for the packet currently being received, and remains set for the remainder of the packet. 0b - LQI is not yet valid for RX packet. 1b - LQI is valid for RX packet.
14-8 —	Reserved
7-0 LQI	Link Quality Indicator This field is valid when LQI_VALID=1. LQI is a unsigned, unit-less value.

52.4.4.4.2.4.2.9 TRANSCEIVER CONFIGURATION (XCVR_CFG)

Offset

Register	Offset
XCVR_CFG	1Ch

Diagram



Fields

Field	Function
31 T2_CMP_EN	Timer2 (T2) Compare Enable Enable Timer Compare #2 (T2_CMP) to generate T2_IRQ and/or execute Sequence Commands.
30 T1_CMP_EN	Timer1 (T1) Compare Enable Enable Timer Compare #1 (T1_CMP) to generate T1_IRQ and/or execute Sequence Commands.

Table continues on the next page...

Table continued from the previous page...

Field	Function
29-27 —	Reserved
26-24 PREAMBLE_SEL	Preamble Select Select the Preamble pattern. 000b - The controller hardware selects the preamble pattern based on the first transmitted bit of Network Address, such that the last bit of preamble is the opposite polarity from the first bit of Network Address, forcing a bit transition at this boundary. 001b - Preamble is programmed by register GEN_PREAMBLE[7:0] 010b - Preamble is 0b01 011b - Preamble is 0b10
23-16 GEN_PREAMBLE	Preamble pattern The repeated byte of the preamble when PREAMBLE_SEL[2:0] is 001b.
15-13 —	Reserved
12-4 PREAMBLE_SZ	Preamble Size Number of Octets(PREAMBLE_SEL is 0 or 1) or two-bits(PREAMBLE_SEL is 2 or 3) = PREAMBLE_SZ + 1, where 0 <= PREAMBLE_SZ <= 511
3 STOP_POSTPONE_ON_AA	Postpone Stop Command Timeout On Access Address Match Enable If this bit is set, if a RX STOP condition occurs, due to an Event Timer match to a previously issued RX_STOP_T1 or RX_STOP_T2 sequence command, while a packet is being received (*NTW_ADR_MCH* = 1), the timeout-related abort will be deferred until the packet reception is completed. If the packet is good, HW will signal Data Indication; otherwise the Sequence Manager will return to IDLE and await further commanding. 0b - STOP Abort will occur on RX_STOP_T1 or RX_STOP_T1 Event Timer match, regardless of NTW_ADR_MCH 1b - STOP Abort will be deferred on RX_STOP_T1 or RX_STOP_T1 Event Timer match, if NTW_ADR_MCH is asserted; otherwise the RX_STOP Abort will occur immediately
2 SW_CRC_EN	Software CRC Enable Software override of the HW-computed CRC for TX. Software must write CRC to Packet Buffer (RAM)
1 RX_DEWHITEN_DIS	RX De-Whitening Disable Disable all de-whitening on RX packets
0	TX Whitening Disable

Table continues on the next page...

Table continued from the previous page...

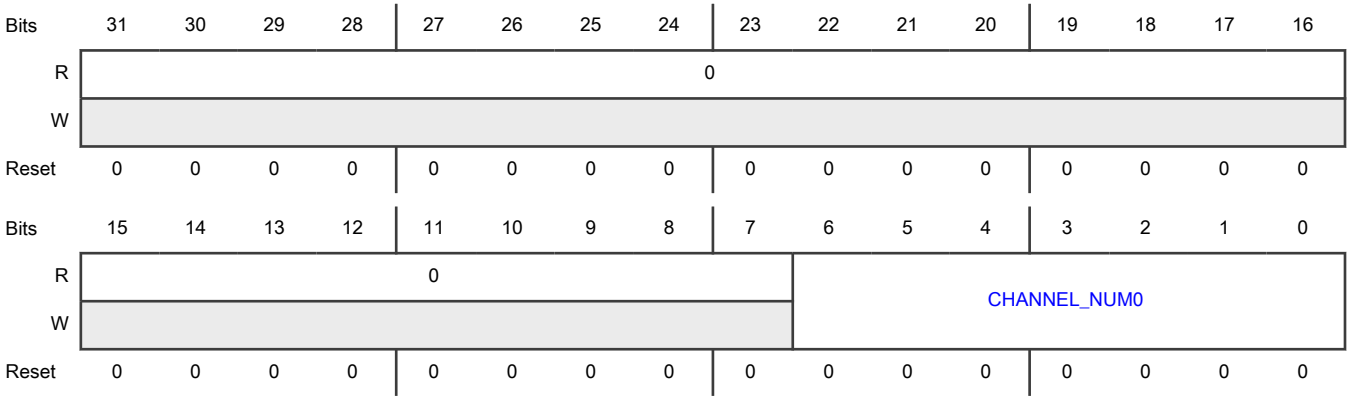
Field	Function
TX_WHITEN_DIS	Disable all whitening on TX packets

52.4.4.4.2.4.2.10 CHANNEL NUMBER 0 (CHANNEL_NUM0)

Offset

Register	Offset
CHANNEL_NUM0	20h

Diagram



Fields

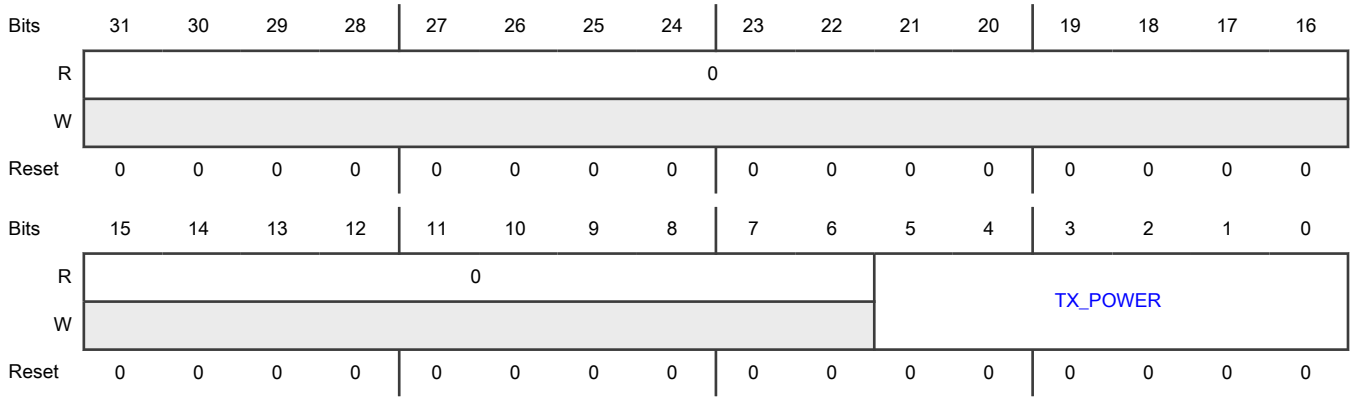
Field	Function
31-7 —	Reserved
6-0 CHANNEL_NUM0	Channel Number for PAN0 This is the mapped channel number used to transmit and receive packets. If Dual PAN is engaged, this register applies to PAN0. Formula: F = (2360 + CHANNEL_NUM0) [in MHz]

52.4.4.4.2.4.2.11 TRANSMIT POWER (TX_POWER)

Offset

Register	Offset
TX_POWER	24h

Diagram



Fields

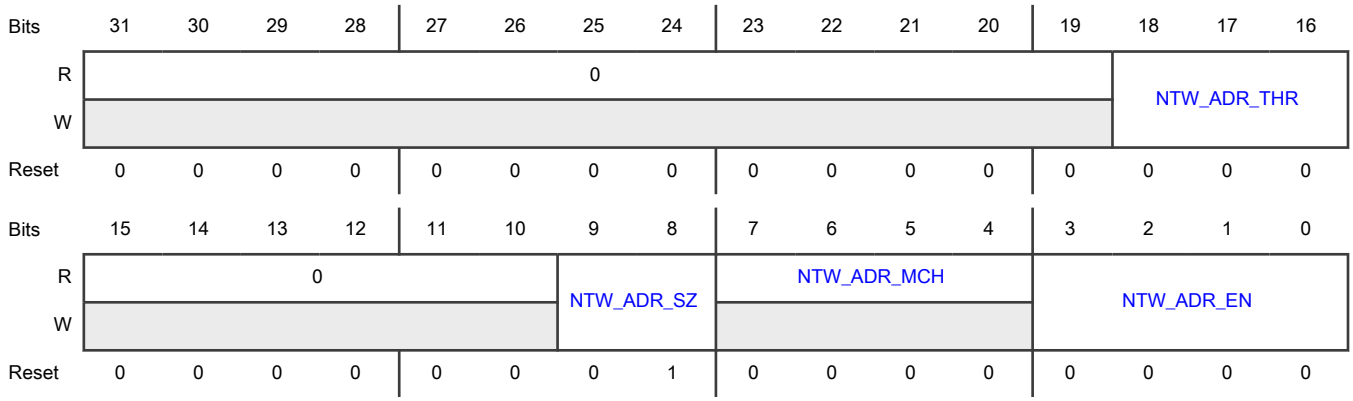
Field	Function
31-6 —	Reserved
5-0 TX_POWER	Transmit Power PA Power Level.

52.4.4.4.2.4.2.12 NETWORK ADDRESS CONTROL (NTW_ADR_CTRL)

Offset

Register	Offset
NTW_ADR_CTRL	28h

Diagram



Fields

Field	Function
31-19 —	Reserved
18-16 NTW_ADR_THR	Network Address Threshold Number of Tolerated bit errors for Network Address 0/1/2/3
15-10 —	Reserved
9-8 NTW_ADR_SZ	Network Address Size 00b - Network Address 0/1/2/3 requires a 8-bit correlation 01b - Network Address 0/1/2/3 requires a 16-bit correlation 10b - Network Address 0/1/2/3 requires a 24-bit correlation 11b - Network Address 0/1/2/3 requires a 32-bit correlation
7-4 NTW_ADR_MCH	Network Address Match Indicates which of the 4 Network Addresses has matched in the PHY. Valid during an RX sequence at the point of match, and remains asserted until either: 1. The next RX sequence begins (if the current packet passed CRC and header filtering), or, 2. An RX recycle to Network Address search (if the current packet failed CRC or header filtering) 0001b - Network Address 0 has matched 0010b - Network Address 1 has matched 0100b - Network Address 2 has matched 1000b - Network Address 3 has matched
3-0 NTW_ADR_EN	Network Address Enable Enable Network Address N for PHY correlation, where 0 ≤ N ≤ 3. Any bit combination can be set. 0001b - Enable Network Address 0 for correlation 0010b - Enable Network Address 1 for correlation 0100b - Enable Network Address 2 for correlation 1000b - Enable Network Address 3 for correlation

52.4.4.4.2.4.2.13 NETWORK ADDRESS 0 (NTW_ADR_0)

Offset

Register	Offset
NTW_ADR_0	2Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	NTW_ADR_0															
Reset	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	NTW_ADR_0															
Reset	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

Fields

Field	Function
31-0 NTW_ADR_0	Network Address 0 The PHY will search for this Network Address if NTW_ADR_CTRL[NTW_ADR_EN[0]] = 1

52.4.4.4.2.4.2.14 NETWORK ADDRESS 1 (NTW_ADR_1)

Offset

Register	Offset
NTW_ADR_1	30h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	NTW_ADR_1															
Reset	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	NTW_ADR_1															
Reset	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

Fields

Field	Function
31-0 NTW_ADR_1	Network Address 1 The PHY will search for this Network Address if NTW_ADR_CTRL[NTW_ADR_EN[1]] = 1

52.4.4.4.2.4.2.15 NETWORK ADDRESS 2 (NTW_ADR_2)

Offset

Register	Offset
NTW_ADR_2	34h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	NTW_ADR_2															
Reset	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	NTW_ADR_2															
Reset	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

Fields

Field	Function
31-0 NTW_ADR_2	Network Address 2 The PHY will search for this Network Address if NTW_ADR_CTRL[NTW_ADR_EN[2]] = 1

52.4.4.4.2.4.2.16 NETWORK ADDRESS 3 (NTW_ADR_3)

Offset

Register	Offset
NTW_ADR_3	38h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	NTW_ADR_3															
Reset	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	NTW_ADR_3															
Reset	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

Fields

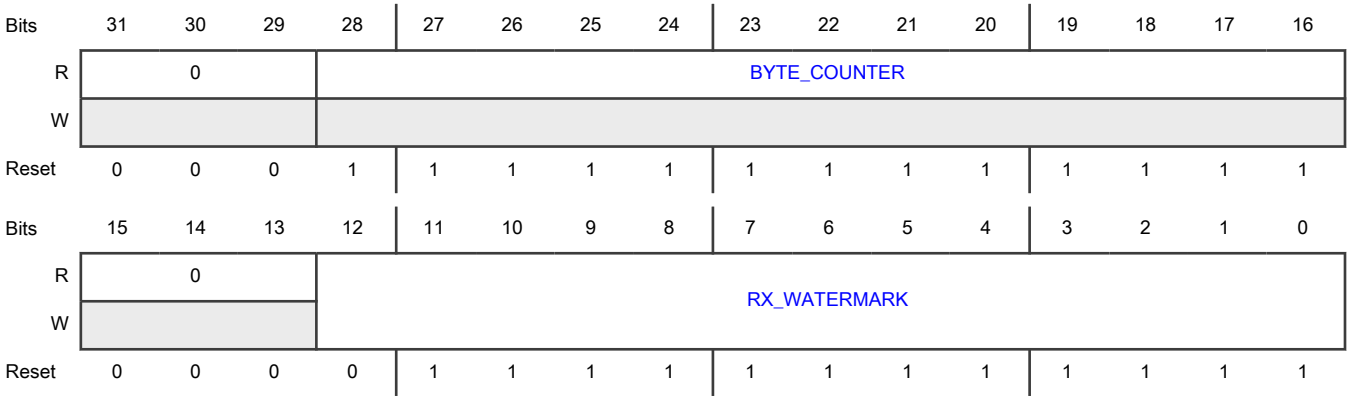
Field	Function
31-0 NTW_ADR_3	Network Address 2 The PHY will search for this Network Address if NTW_ADR_CTRL[NTW_ADR_EN[3]] = 1

52.4.4.4.2.4.2.17 RECEIVE WATERMARK (RX_WATERMARK)

Offset

Register	Offset
RX_WATERMARK	3Ch

Diagram



Fields

Field	Function
31-29 —	Reserved
28-16 BYTE_COUNTER	Byte Counter Reflects the current Byte Count, for TX and RX. This is a signed, twos-complement value. For values less than zero, indicates the preamble transmission is underway (TX only). A value of 0 indicates the first octet of Network Address is being transmitted or received. A value of 1 indicates the second octet of Network Address is being transmitted or received. Etc. When AA_PLAYBACK_CNT is 0, there is no Network Address sent to link layer, so a value of 0 indicates the first octet of H0 or LENGTH field; for TX, AA_PLAYBACK_CNT does not effect.
15-13 —	Reserved
12-0	Receive Watermark

Table continues on the next page...

Table continued from the previous page...

Field	Function
RX_WATERMARK	Sets the trigger for RX_WATERMARK_IRQ. Trigger the RX_WATERMARK_IRQ when: RX Byte Counter == RX_WATERMARK[12:0]

52.4.4.4.2.4.2.18 DSM CONTROL (DSM_CTRL)

Offset

Register	Offset
DSM_CTRL	40h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															GEN_SLE...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-1 —	Reserved
0 GEN_SLEEP_REQUEST	GENERIC_FSK Deep Sleep Mode Request If GENERIC_FSK is assigned to Manual DSM, setting GEN_SLEEP_REQUEST to 1 enables Deep Sleep Mode (DSM) to be entered when the RFMC TIMER matches the RFMC ENTER_TIME register.

52.4.4.4.2.4.2.19 PART ID (PART_ID)

Offset

Register	Offset
PART_ID	44h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								PART_ID							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Fields

Field	Function
31-8 —	Reserved
7-0 PART_ID	Part ID Part ID to identify HW revision of the Generic FSK Link Layer

52.4.4.4.2.4.2.20 SLOT PRELOAD (SLOT_PRELOAD)

Offset

Register	Offset
SLOT_PRELOAD	48h

Function

Slotted Mode Preload

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SLOT_PRELOAD															
Reset	0	0	0	0	0	0	1	0	1	0	1	0	1	0	0	0

Fields

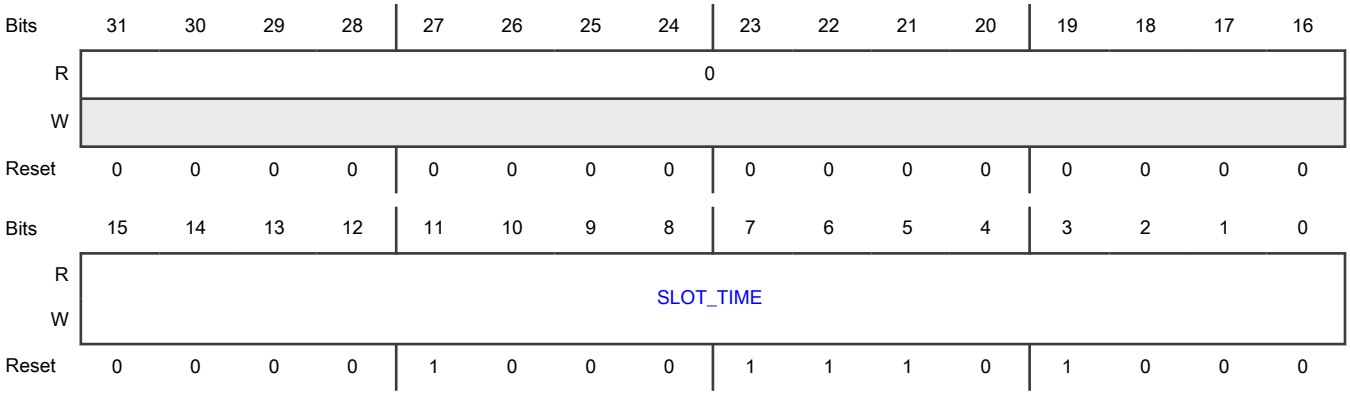
Field	Function
31-16 —	Reserved
15-0 SLOT_PRELOAD	Slotted Mode Preload This register represents the number that gets loaded into the slot_timer at SFD detect, which ultimately determines when the next slot boundary will occur. Due to processing delays within the analog front-end and digital modem, the point at which SFD is detected by the modem, is delayed relative to over-the-air timing. This register setting compensates for that delay. This timing parameter is critical for the Sequence R auto-sequence in slotted mode, when an automatic TxAck is required.

52.4.4.4.2.4.2.21 SLOT TIME (SLOT_TIME)

Offset

Register	Offset
SLOT_TIME	4Ch

Diagram



Fields

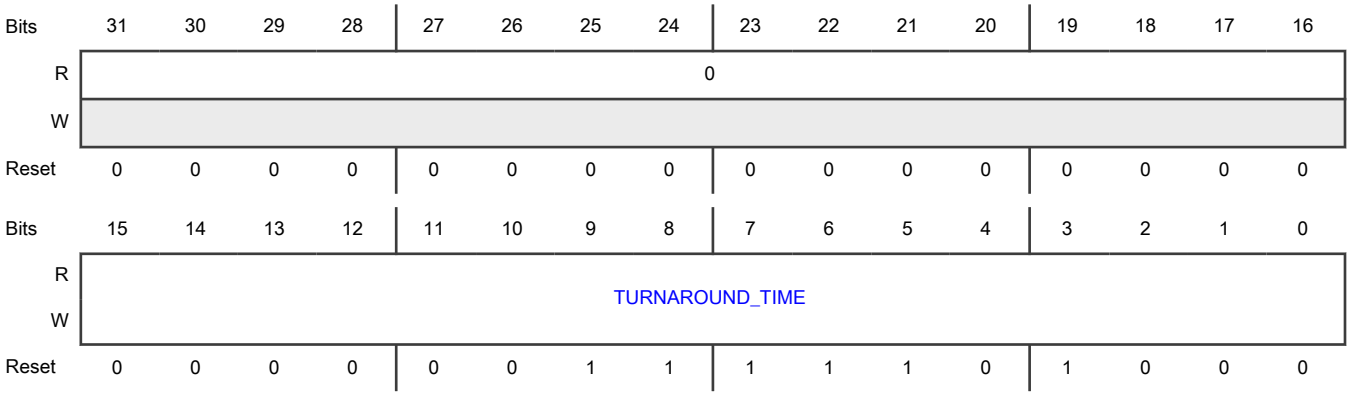
Field	Function
31-16 —	Reserved
15-0 SLOT_TIME	Duration of the Backoff Slot This register represents the time duration of the backoff slot, which is calculated by the constant *aUnitBackoffPeriod* in IEEE Std 802.15.4-2015. For all PHYs except SUN PHYs operating in the 920 MHz band, *aTurnaroundTime* + *aCcaTime* . For SUN PHYs operating in the 920 MHz band, *aTurnaroundTime* + *phyCCADuration* .

52.4.4.4.2.4.2.22 TURNAROUND TIME (TURNAROUND_TIME)

Offset

Register	Offset
TURNAROUND_TIME	50h

Diagram



Fields

Field	Function
31-16 —	Reserved
15-0 TURNAROUND_TIME	RX-to-TX or TX-to-RX turnaround time This register represents the RX-to-TX or TX-to-RX turnaround time, which is calculated by the constant *aTurnaroundTime* in IEEE Std 802.15.4-2015.

52.4.4.4.2.4.2.23 ACK DELAY (ACKDELAY)

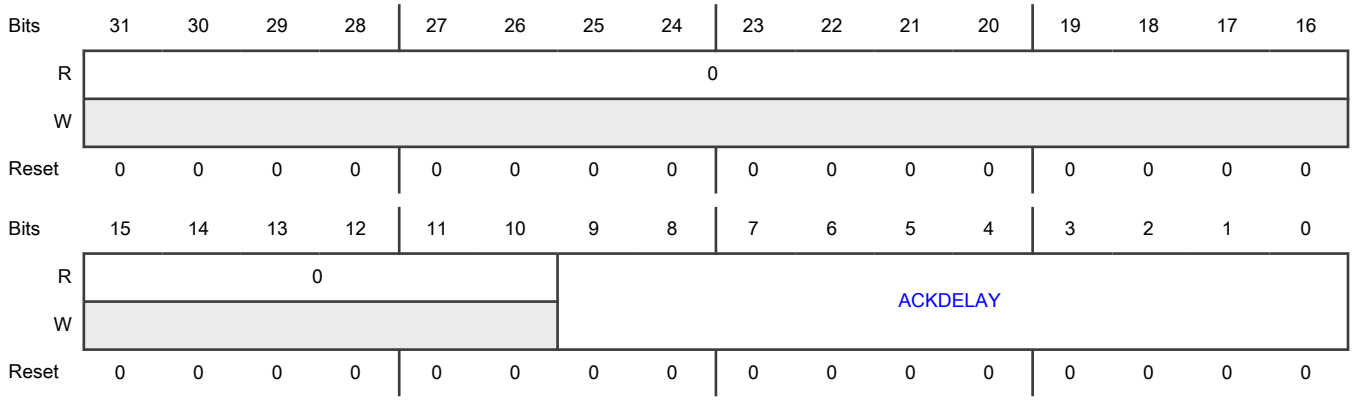
Offset

Register	Offset
ACKDELAY	54h

Function

Provides a fine-tune adjustment of the time delay between Rx warm-down and the beginning of Tx warmup for an autoTxAck packet.

Diagram



Fields

Field	Function
31-10 —	Reserved
9-0 ACKDELAY	ACK Delay Provides a fine-tune adjustment of the time delay between Rx warm-down and the beginning of Tx warmup for an Tx Acknowledge packet. ACKDELAY register will apply to both SLOTTED and UNSLOTTED TxAck, but only to TxAck (not T sequences). This is a two's complement value. Resolution = 1us.

52.4.4.4.2.4.2.24 RX DELAY (RXDELAY)

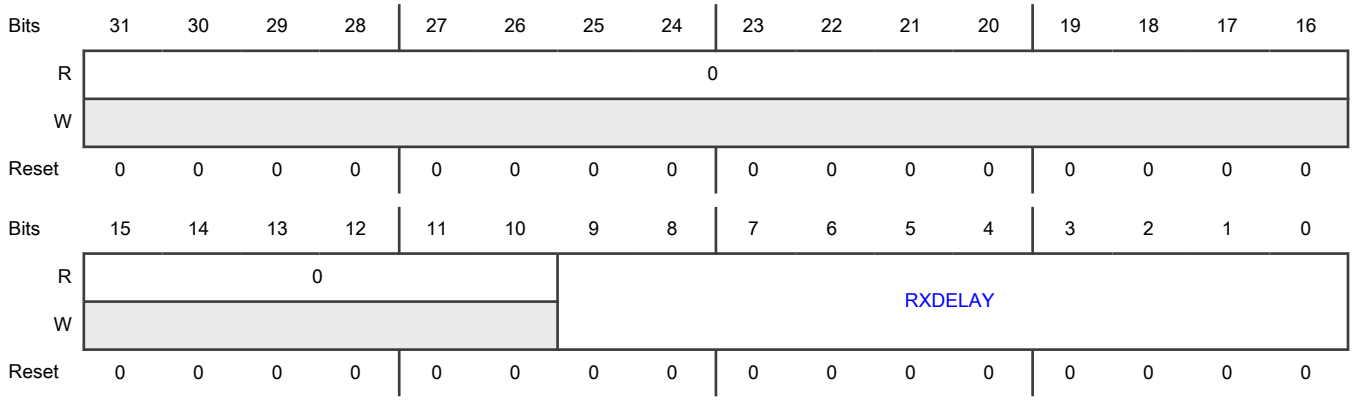
Offset

Register	Offset
RXDELAY	58h

Function

Provides a fine-tune adjustment of the time delay between Tx warm-down and the beginning of Rx warmup in a TR sequence.

Diagram



Fields

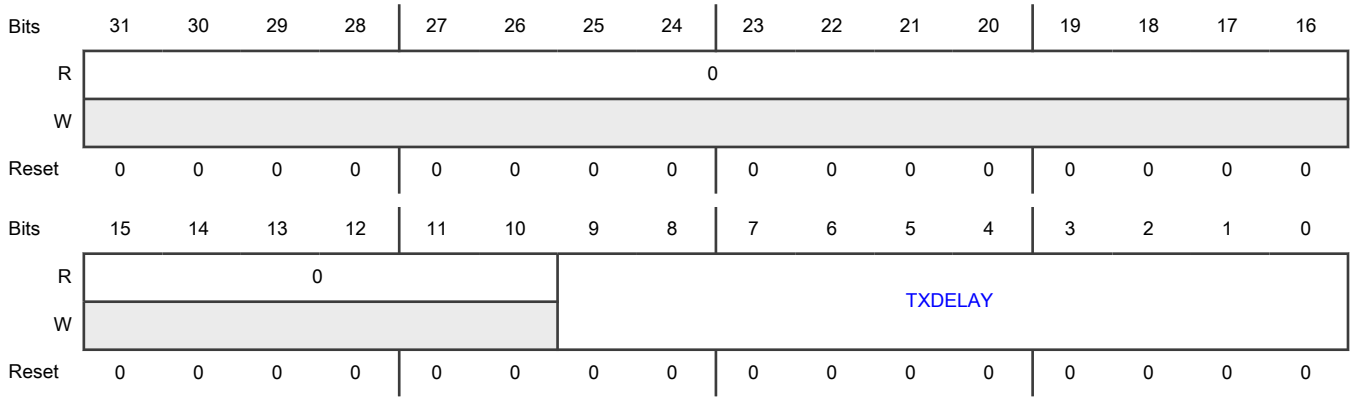
Field	Function
31-10 —	Reserved
9-0 RXDELAY	RX Delay Provides a fine-tune adjustment of the time delay between Tx warm-down and the beginning of Rx warm-up in a TR sequence. RXDELAY register will apply in both SLOTTED and UNSLOTTED modes. This is a two's complement value. Resolution = 1us.

52.4.4.4.2.4.2.25 TX DELAY (TXDELAY)

Offset

Register	Offset
TXDELAY	5Ch

Diagram



Fields

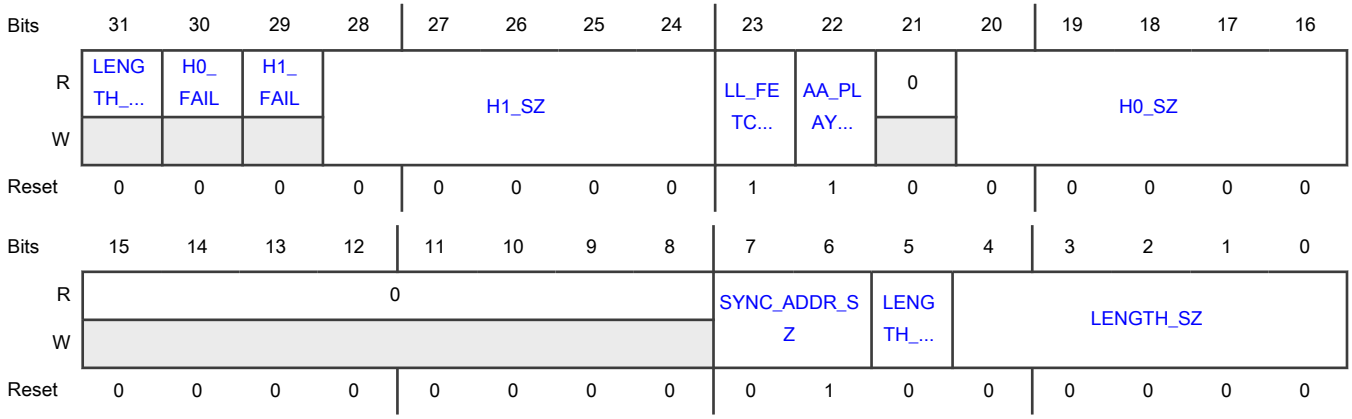
Field	Function
31-10 —	Reserved
9-0 TXDELAY	TX Delay Provides a fine-tune adjustment of the time delay between post-CCA Rx warm-down and the beginning of Tx warm-up for an Tx (non-Ack) packet. TXDELAY register will apply in both SLOTTED and UNSLOTTED modes, but only to T sequences (e.g., T, TR, and T(R)), not TxAck operations. This is a two's complement value. Resolution = 1us.

52.4.4.4.2.4.2.26 PACKET CONFIGURATION (PACKET_CFG)

Offset

Register	Offset
PACKET_CFG	60h

Diagram



Fields

Field	Function
31 LENGTH_FAIL	Maximum Length Violated Status Bit For packets received with REC_BAD_PKT=1, LENGTH_FAIL indicates the extracted LENGTH header field exceeded LENGTH_MAX
30 H0_FAIL	H0 Violated Status Bit For packets received with REC_BAD_PKT=1, H0_FAIL indicates the received H0 header field violates the H0_MASK/H0_MATCH pattern

Table continues on the next page...

Table continued from the previous page...

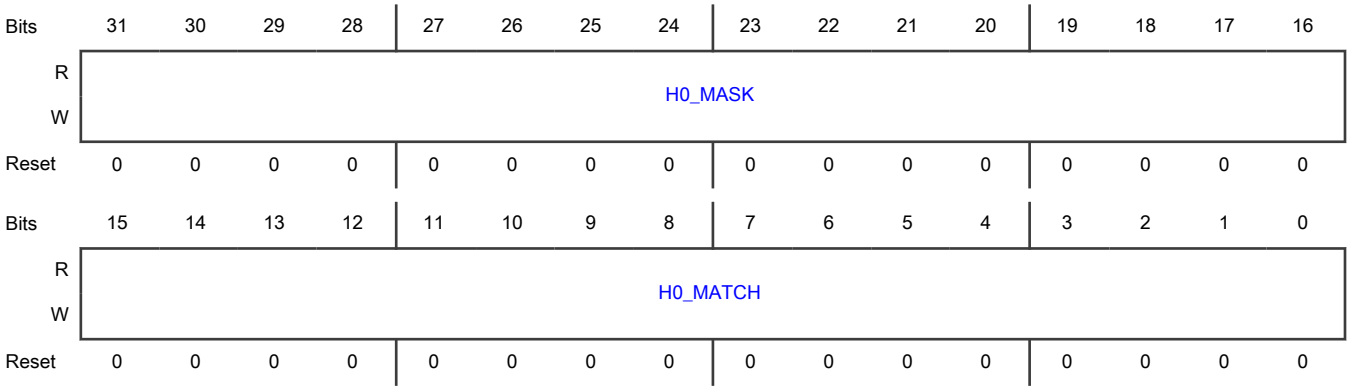
Field	Function
29 H1_FAIL	H1 Violated Status Bit For packets received with REC_BAD_PKT=1, H1_FAIL indicates the received H1 header field violates the H1_MASK/H1_MATCH pattern
28-24 H1_SZ	H1 Size Length of H1 in bits; 0 ≤ H1_SZ ≤ 16
23 LL_FETCH_AA	Link layer fetches AA from PHY When AA_PLAYBACK_CNT is 0, link layer can fetch AA from PHY 0b - Link layer does not fetch AA from PHY 1b - Link layer fetches AA from PHY when AA_PLAYBACK_CNT is 0
22 AA_PLAYBACK_CNT	AA PLAYBACK COUNT AA is playback to Link layer 0b - AA is not through CRC and not playback to Link layer. 1b - AA is through CRC and palayback to Link Layer.
21 —	Reserved
20-16 H0_SZ	H0 Size Size of H0 in bits; 0 ≤ H0_SZ ≤ 16
15-8 —	Reserved
7-6 SYNC_ADDR_SZ	Sync Address Size Number of Octets = SYNC_ADDR_SZ + 1, 0 ≤ SYNC_ADDR_SZ ≤ 3. **NOTE** When AA_PLAYBACK_CNT = 0, the Sync Address is not played out when receive. At this case, SYNC_ADDR_SZ is ignored by link layer.
5 LENGTH_BIT_ORD	LENGTH Bit Order Bit order for the LENGTH field of the header 0b - LS Bit First 1b - MS Bit First
4-0 LENGTH_SZ	LENGTH Size Size of LENGTH field of the header, in bits; 0 ≤ LENGTH_SZ ≤ 16

52.4.4.4.2.4.2.27 H0 CONFIGURATION (H0_CFG)

Offset

Register	Offset
H0_CFG	64h

Diagram



Fields

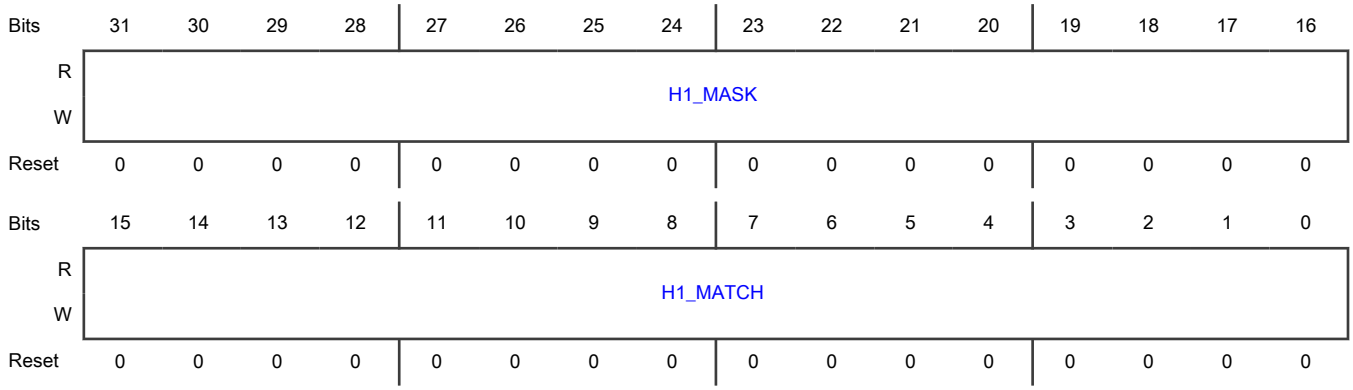
Field	Function
31-16 H0_MASK	H0 Mask Register For each bit that is set to 1, the received H0 field must match the corresponding bit of H0_MATCH[15:0], else the received packet is rejected.
15-0 H0_MATCH	H0 Match Register For each bit of H0_MASK[15:0] that is set to 1, the received H0 field must match this register, else the received packet is rejected.

52.4.4.4.2.4.2.28 H1 CONFIGURATION (H1_CFG)

Offset

Register	Offset
H1_CFG	68h

Diagram



Fields

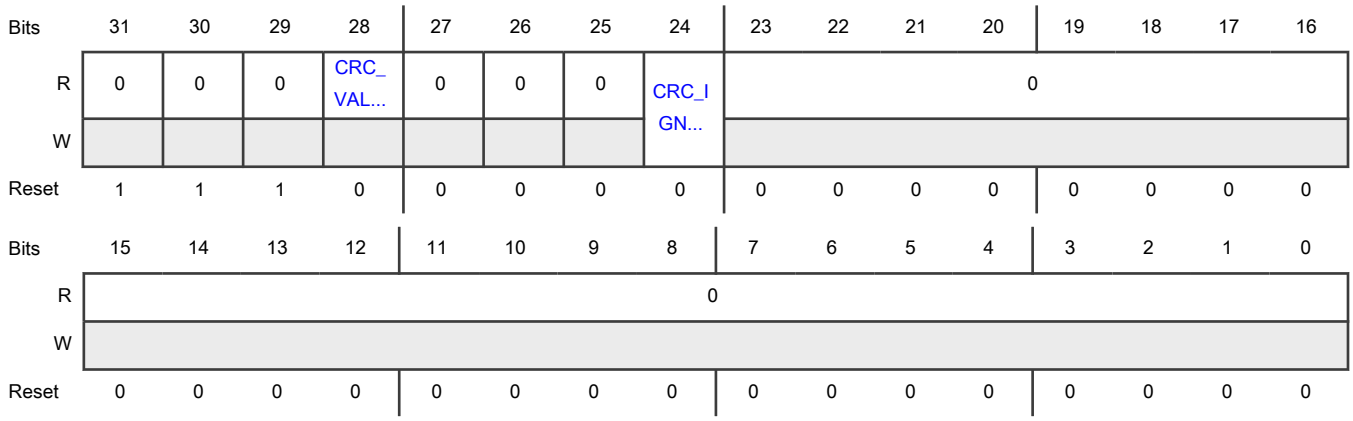
Field	Function
31-16 H1_MASK	H1 Mask Register For each bit that is set to 1, the received H1 field must match the corresponding bit of H1_MATCH[15:0], else the received packet is rejected.
15-0 H1_MATCH	H1 Match Register For each bit of H1_MASK[15:0] that is set to 1, the received H1 field must match this register, else the received packet is rejected.

52.4.4.4.2.4.2.29 CRC CONFIGURATION (CRC_CFG)

Offset

Register	Offset
CRC_CFG	6Ch

Diagram



Fields

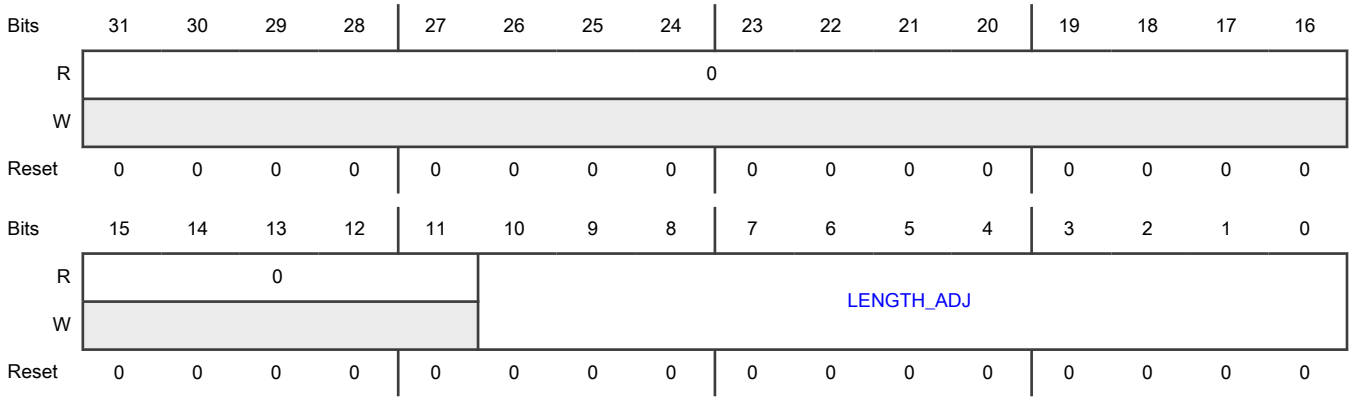
Field	Function
31 —	Reserved
30 —	Reserved
29 —	Reserved
28 CRC_VALID	CRC Valid CRC Valid indicator for RX packets. This bit becomes valid at RX_IRQ, and remains valid until the start of the next RX TSM sequence. 0b - CRC of RX packet is not valid. 1b - CRC of RX packet is valid.
27 —	Reserved
26 —	Reserved
25 —	Reserved
24 CRC_IGNORE	CRC Ignore If set, assert RX_IRQ even for a received packet which fails CRC verification. 0b - RX_IRQ will not be asserted for a received packet which fails CRC verification. 1b - RX_IRQ will be asserted even for a received packet which fails CRC verification.
23-0 —	Reserved

52.4.4.4.2.4.2.30 LENGTH ADJUSTMENT (LENGTH_ADJ)

Offset

Register	Offset
LENGTH_ADJ	70h

Diagram



Fields

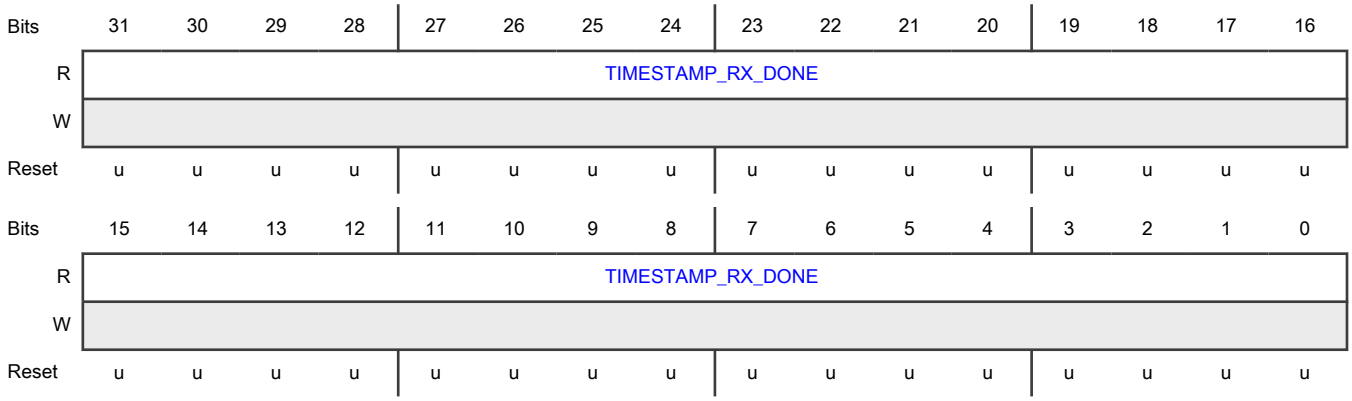
Field	Function
31-11 —	Reserved
10-0 LENGTH_ADJ	Length Adjustment Signed Adjustment to the LENGTH field for TX and RX. A value of 0 (default) means LENGTH is interpreted as PAYLOAD + CRC. **NOTE** When used as negative number, it is a two's complement value. And user should ensure, 0 <= (LENGTH + LENGTH_ADJ) <= 2047

52.4.4.4.2.4.2.31 TIMESTAMP_RX_DONE (TIMESTAMP_RX_DONE)

Offset

Register	Offset
TIMESTAMP_RX_DONE	74h

Diagram



Fields

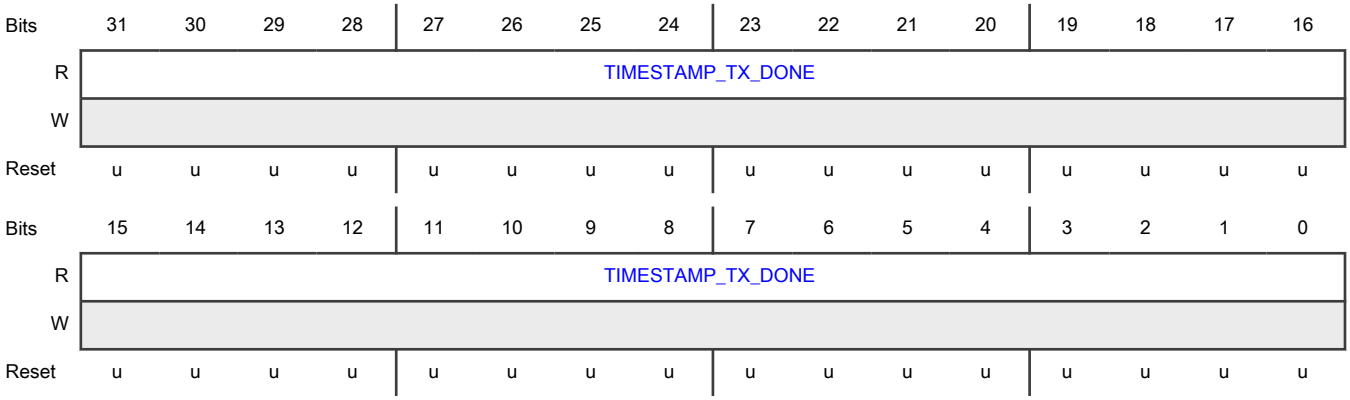
Field	Function
31-0 TIMESTAMP_RX_DONE	Received Packet Timestamp. Captured at Rx done.

52.4.4.4.2.4.2.32 TIMESTAMP_TX_DONE (TIMESTAMP_TX_DONE)

Offset

Register	Offset
TIMESTAMP_TX_DONE	78h

Diagram



Fields

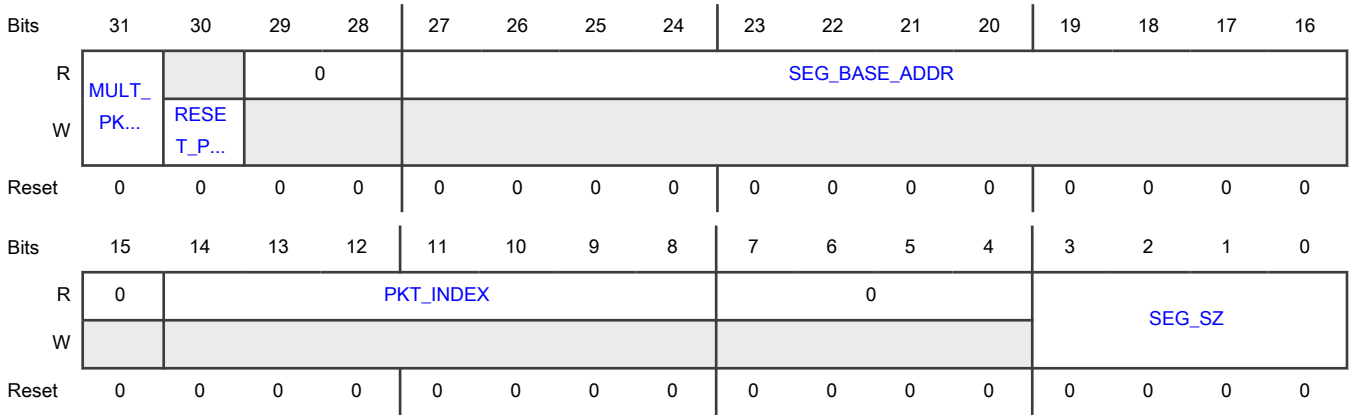
Field	Function
31-0 TIMESTAMP_TX_DONE	Received Packet Timestamp. Captured at Tx done.

52.4.4.4.2.4.2.33 MULT_PKT_CTRL (MULT_PKT_CTRL)

Offset

Register	Offset
MULT_PKT_CTRL	7Ch

Diagram



Fields

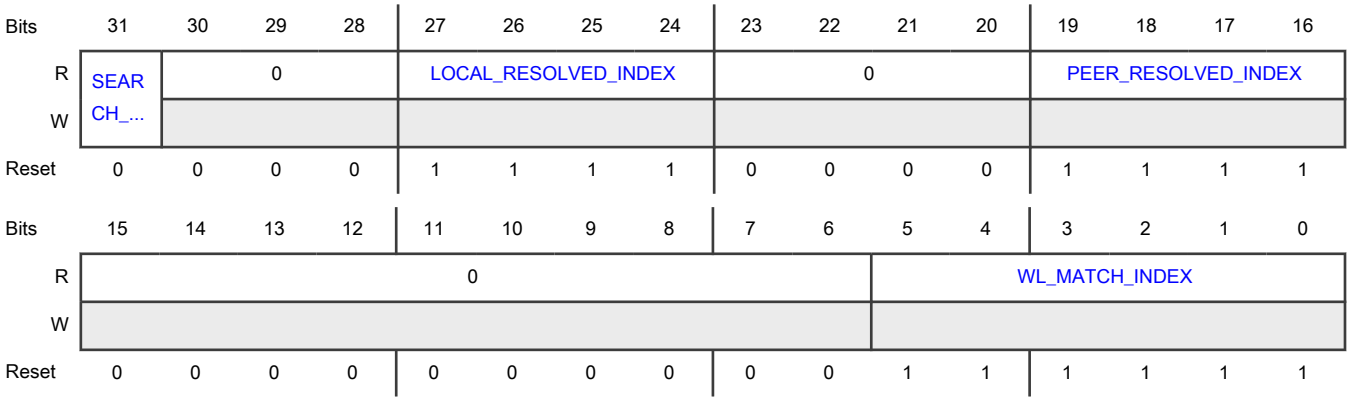
Field	Function
31 MULT_PKT_EN	Enable to send or receive multiple packets 0b - Send or receive multiple packets is not enabled. 1b - Send or receive multiple packets is enabled.
30 RESET_PKT_IDX	Reset the PKT_INDEX to zero This bit is used to reset the PKT_INDEX before a new round of packet reception.
29-28 —	Reserved
27-16 SEG_BASE_ADDR	Segment Offset Address Shows the current RAM segment offset address(regarding to the base address).
15 —	Reserved
14-8 PKT_INDEX	Packet Index Shows the current RAM segment index number.
7-4 —	Reserved
3-0 SEG_SZ	RAM Segment Size Define the RAM segment size for each packet: (SEG_SZ+1)*32 Bytes. For example, when SEG_SZ is 0, the segment size is 32 Bytes; when SEG_SZ is 1, the segment size is 64 Bytes, etc.

52.4.4.4.2.4.2.34 RPA AND WHITE LIST STATUS (RPA_WL_STATUS)

Offset

Register	Offset
RPA_WL_STATUS	80h

Diagram



Fields

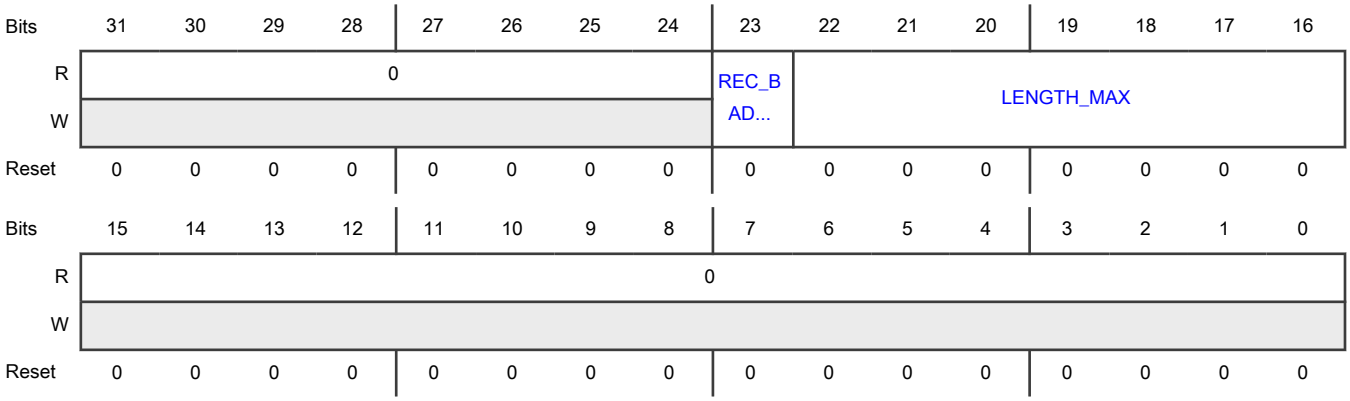
Field	Function
31 SEARCH_WL	Search Identity Address in White List Write 1 to SEARCH_WL will trigger the hardware to search for the identity address in the selected white list. After the search operation completes, SEARCH_WL is cleared by hardware.
30-28 —	Reserved
27-24 LOCAL_RESOLVED_INDEX	The matched RPA index of local address If the value is not 0xF, this register shows the matched RPA index of the local address in the received packet.
23-20 —	Reserved
19-16 PEER_RESOLVED_INDEX	The matched RPA index of peer address If the value is not 0xF, this register shows the matched RPA index of the peer address in the received packet.
15-6 —	Reserved
5-0 WL_MATCH_INDEX	The matched white list index of the identity address resolved(RPA is enabled) or peer address received(RPA is not enabled) If the value is not 0x3F, this register shows the matched white list index.

52.4.4.4.2.4.2.35 MAXIMUM LENGTH (LENGTH_MAX)

Offset

Register	Offset
LENGTH_MAX	84h

Diagram



Fields

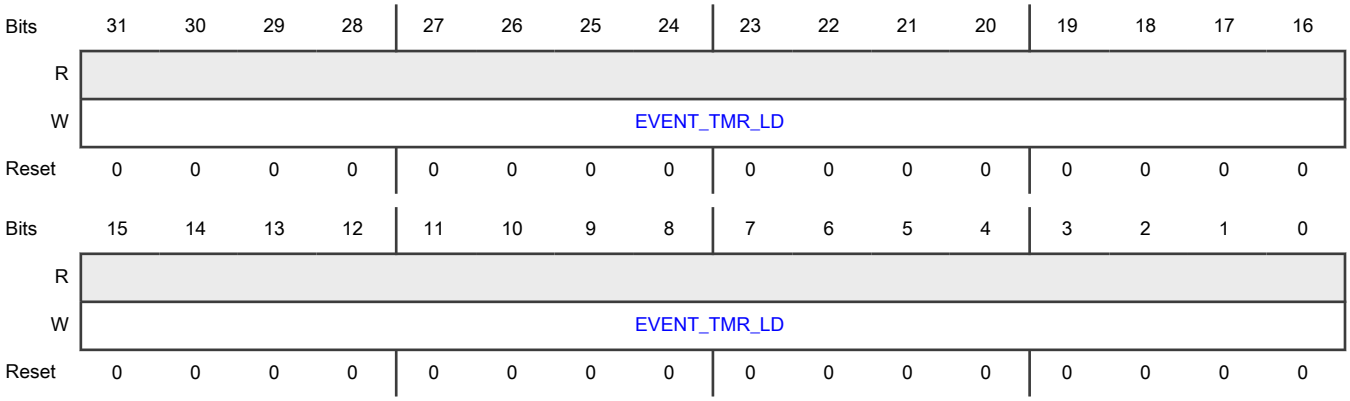
Field	Function
31-24 —	Reserved
23 REC_BAD_PKT	Receive Bad Packets Enable Packets which fail H0-filtering, H1-filtering, or Maximum Length-filtering, to be fully received without an RX recycle (intended for debug purposes) 0b - packets which fail H0, H1, or LENGTH_MAX result in an automatic recycle after the header is received and parsed 1b - packets which fail H0, H1, or LENGTH_MAX are received in their entirety
22-16 LENGTH_MAX	Maximum Length for Received Packets Sets the Maximum Length Packet that can be received, in multiples of 16 bytes. LENGTH_MAX is compared directly against the extracted LENGTH field of the header (not the adjusted length). LENGTH_MAX=0 (default) is a special case that implies no limit.
15-0 —	Reserved

52.4.4.4.2.4.2.36 EVENT TIMER LOAD (EVENT_TMR_LD)

Offset

Register	Offset
EVENT_TMR_LD	88h

Diagram



Fields

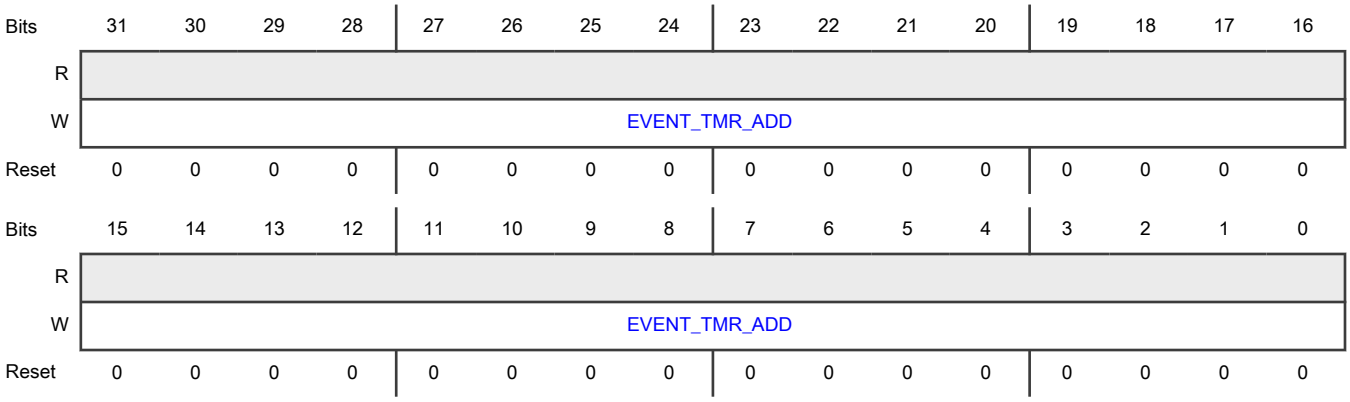
Field	Function
31-0 EVENT_TMR_LD	Event Timer Load A write access to this register loads EVENT_TMR with the contents of EVENT_TMR_LD[31:0]

52.4.4.4.2.4.2.37 EVENT TIMER ADD (EVENT_TMR_ADD)

Offset

Register	Offset
EVENT_TMR_ADD	8Ch

Diagram



Fields

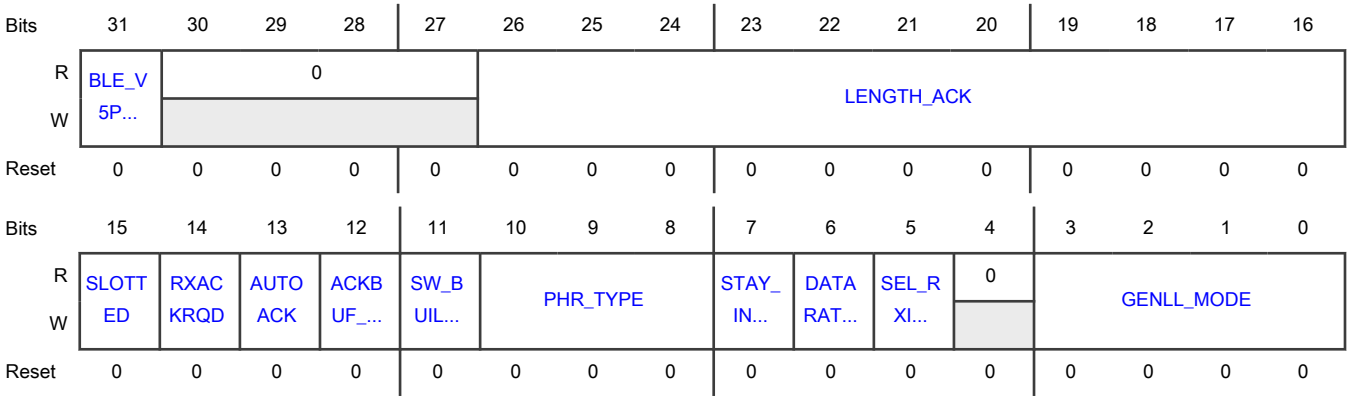
Field	Function
31-0 EVENT_TMR_ADD	Event Timer Add A write access of this register increments EVENT_TMR by the contents of EVENT_TMR_ADD[31:0]. This is a signed addition.

52.4.4.4.2.4.2.38 ENHANCED FEATURES (ENH_FEATURE)

Offset

Register	Offset
ENH_FEATURE	90h

Diagram



Fields

Field	Function
31 BLE_V5P1_CTE_EN	Bluetooth LE version 5.1 CTE feature enable 0b - Do not support Bluetooth LE version 5.1 CTE feature. 1b - Support Bluetooth LE version 5.1 CTE feature, which means the link layer hardware can parse the CTE field length and extend the RX_EN signal accordingly.
30-27 —	Reserved
26-16 LENGTH_ACK	Length of the ACK frame(or part of the ACK frame) in RAM In GLL mode, it is programed into the LENGTH field in PHR. So, if ACK's payload length is Payload_length, LENGTH_ACK = Payload_length + CRC_SZ - LENGTH_ADJ. In FAN-LL mode, when SW_BUILD_ACK=0, it is the length of ASH and IEs field in PHR.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	In GTM mode, it is the length of the test packet payload.
15 SLOTTED	Slotted Mode Slotted Mode, for beacon-enabled networks. Applies only to Sequences T, TR, and R, ignored during all other sequences. Used, in concert with CCABFRTX, to determine how many CCA measurements are required prior to a transmit operation. Also used during R sequence to determine whether the ensuing transmit acknowledge frame (if any) needs to be synchronized to a backoff slot boundary.
14 RXACKRQD	Receive Acknowledge Frame required Applies only to Sequence TR, ignored during all other sequences. 0b - An ordinary receive frame (any type of frame) follows the transmit frame. 1b - A receive Ack frame is expected to follow the transmit frame (non-Ack frames are rejected).
13 AUTOACK	Auto Acknowledge Enable Applies only to Sequence R and Sequence TR, ignored during other sequences 0b - sequence manager will not follow a receive frame with a Tx Ack frame, under any conditions; the auto-sequence will terminate after the receive frame. 1b - sequence manager will follow a receive frame with an automatic hardware-generated Tx Ack frame, assuming other necessary conditions are met.
12 ACKBUF_SEL	ACK frame is in 64-byte dedicated RAM or TX buffer RAM 0b - ACK frame is in 64-byte dedicated RAM 1b - ACK frame is in TX buffer RAM
11 SW_BUILD_ACK	Software builds the ACK packet in RAM 0b - Hardware builds part of or the whole of the auto ACK frame 1b - Software builds the whole auto ACK frame in RAM.
10-8 PHR_TYPE	PHR Type Specify the PHR type in PAN or FAN mode 000b - The packet type is GFSK 001b - The packet type is MSK 010b - The packet type is SUN FSK 011b - The packet type is LECIM FSK
7 STAY_IN_RX	Stay in receive Enable the ability to recycle and stay in receive even after an RX_IRQ, to avoid the full RX re-warmup. 0b - Link layer will warm-down after an RX_IRQ 1b - Link layer will recycle and stay in receive even after an RX_IRQ.
6	Select the data rate configuration bank

Table continues on the next page...

Table continued from the previous page...

Field	Function
DATARATE_CONFIG_SEL	0b - Select the data rate as per configuration bank 0 1b - Select the data rate as per configuration bank 1
5 SEL_RXIRQ	Select the RX IRQ assert time **NOTE** This bit must not be changed when RX or TX are active. Unpredictable behavior will ensue. 0b - RX_IRQ is asserted at the end of RX_PKT state. 1b - RX_IRQ is asserted at the end of RXEN_DLY state. This to be used for delaying RX_IRQ to accept TERM2 bits in Bluetooth LE-LR and CTE bits as needed.
4 —	Reserved
3-0 GENLL_MODE	Link layer Mode Select 0000b - GLL Mode 0001b - PAN Mode 0010b - FAN Mode 0011b - Hybrid Dual PAN Mode 0100b - Reserved 0101b - Reserved 0110b - FCP Mode 0111b - Reserved 1000b - Reserved 1001b - Bluetooth LE Uncoded Mode 1010b - Bluetooth LE LR Mode 1011b - Bluetooth LE Concurrent Mode (RX configuration only; TX uses either Bluetooth LE UNCODED or Bluetooth LE LR configuration) 1100b - Reserved 1101b - Reserved 1110b - Reserved 1111b - GTM Mode

52.4.4.4.2.4.2.39 RECEIVE FRAME FILTER (RX_FRAME_FILTER)

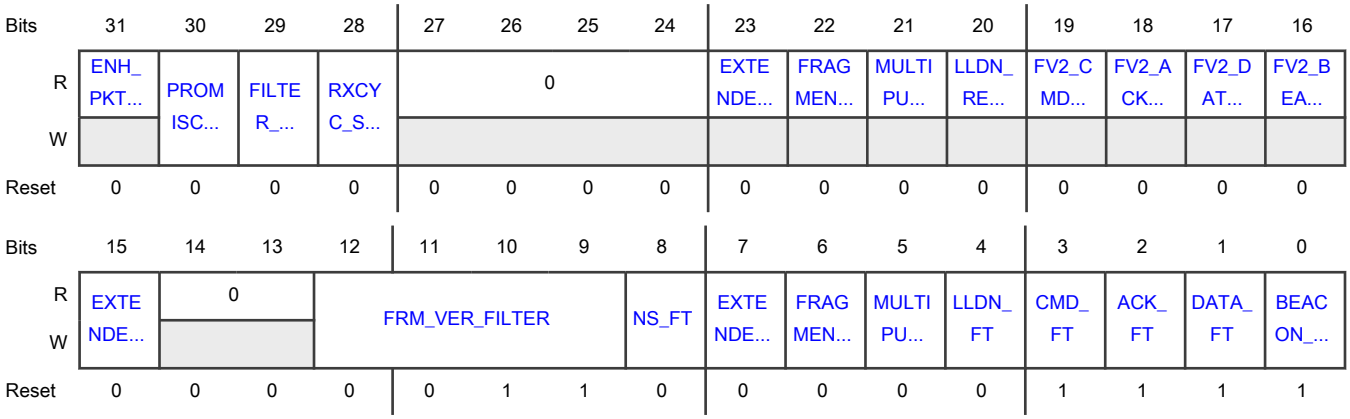
Offset

Register	Offset
RX_FRAME_FILTER	94h

Function

RECEIVE FRAME FILTER

Diagram



Fields

Field	Function
31 ENH_PKT_STATUS	Enhanced Packet Status 0b - The last packet received was not 2015-compliant 1b - The last packet received was 2015-compliant (RX_FRAME_FILTER register should be queried for additional status bits)
30 PROMISCUOUS	Promiscuous Mode Enable Bypasses most packet filtering. 0b - normal mode 1b - all packet filtering except frame length checking (FrameLength>=5) is bypassed.
29 FILTER_FAIL_IGNORE	Filter Fail Ignore If set, assert RX_IRQ even when filter fail. 0b - RX_IRQ will not be asserted when filter fail. 1b - RX_IRQ will be asserted when filter fail.
28 RXCYC_SEL	Rx Recycle Time Select 0b - Recycle when fail happens. 1b - Recycle when Rx done and fail happens.
27-24 —	Reserved
23 EXTENDED_RECD	Extended Packet Received 0b - The last packet received was not Frame Type EXTENDED

Table continues on the next page...

Table continued from the previous page...

Field	Function
	1b - The last packet received was Frame Type EXTENDED, and EXTENDED_FT=1 to allow such packets.
22 FRAGMENT_RECD	Fragment Packet Received 0b - last packet received was not Frame Type FRAGMENT 1b - The last packet received was Frame Type FRAGMENT, and FRAGMENT_FT=1 to allow such packets.
21 MULTIPURPOSE_RECD	Multipurpose Packet Received 0b - last packet received was not Frame Type MULTIPURPOSE 1b - The last packet received was Frame Type MULTIPURPOSE, and MULTIPURPOSE_FT=1 to allow such packets.
20 LLDN_RECD	LLDN Packet Received 0b - The last packet received was not Frame Type LLDN 1b - The last packet received was Frame Type LLDN, and LLDN_FT=1 to allow such packets.
19 FV2_CMD_RECD	Frame Version 2 MAC Command Packet Received 0b - The last packet received was not Frame Type MAC Command with Frame Version 2 1b - The last packet received was Frame Type MAC Command with Frame Version 2, and FRM_VER_FILTER[2]=1 to allow such packets
18 FV2_ACK_RECD	Frame Version 2 Acknowledge Packet Received 0b - The last packet received was not Frame Type Ack with Frame Version 2 1b - The last packet received was Frame Type Ack with Frame Version 2, and FRM_VER_FILTER[2]=1 to allow such packets
17 FV2_DATA_RECD	Frame Version 2 Data Packet Received 0b - The last packet received was not Frame Type Data with Frame Version 2 1b - The last packet received was Frame Type Data with Frame Version 2, and FRM_VER_FILTER[2]=1 to allow such packets
16 FV2_BEACON_RECD	Frame Version 2 Beacon Packet Received 0b - The last packet received was not Frame Type Beacon with Frame Version 2 1b - The last packet received was Frame Type Beacon with Frame Version 2, and FRM_VER_FILTER[2]=1 to allow such packets
15 EXTENDED_FCS_CHK	Verify FCS on Frame Type Extended 0b - Packet Processor will not check FCS for Frame Type EXTENDED (default) 1b - Packet Processor will check FCS at end-of-packet based on packet length derived from PHR, for Frame Type EXTENDED
14-13	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
12-9 FRM_VER_FILTER	Frame Version selector. The incoming packet's Frame Control Field is parsed to obtain the FrameVersion subfield, and that value is compared against this register, in accordance with the following: xxx1: Accept received packets with FrameVersion=00 xx1x: Accept received packets with FrameVersion=01 x1xx: Accept received packets with FrameVersion=10 1xxx: Accept received packets with FrameVersion=11 These filtering rules apply to Beacon, Acknowledge, Data, and MAC Command Frame Types only, since these frame types require a 2-octet Frame Control Field which embeds a 2-bit FrameVersion subfield. For Acknowledge frames, FrameVersion bits are ignored by the Packet Processor, irrespective of FRM_VER_FILTER.
8 NS_FT	"Not Specified" Frame Type Enable This bit enables reception of all Frame Types not covered by the other _FT bits in this register. 0b - reject all "Not Specified" frames 1b - Not-specified (reserved) frame type enabled. Applies to Frame Type 6. No packet filtering is performed, except for frame length checking (FrameLength>=5 and FrameLength<=127). No AUTOACK is transmitted for this Frame Type
7 EXTENDED_FT	Extended Frame Type Enable 0b - reject all Extended frames 1b - Extended frame type enabled (Frame Type 7).
6 FRAGMENT_FT	Fragment Frame Type Enable 0b - reject all Fragment frames 1b - Fragment frame type enabled (Frame Type 6).
5 MULTIPURPOSE_FT	Multipurpose Frame Type Enable 0b - reject all Multipurpose frames 1b - Multipurpose frame type enabled (Frame Type 5).
4 LLDN_FT	LLDN Frame Type Enable 0b - reject all LLDN frames 1b - LLDN frame type enabled (Frame Type 4).
3 CMD_FT	MAC Command Frame Type Enable 0b - reject all MAC Command frames 1b - MAC Command frame type enabled.

Table continues on the next page...

Table continued from the previous page...

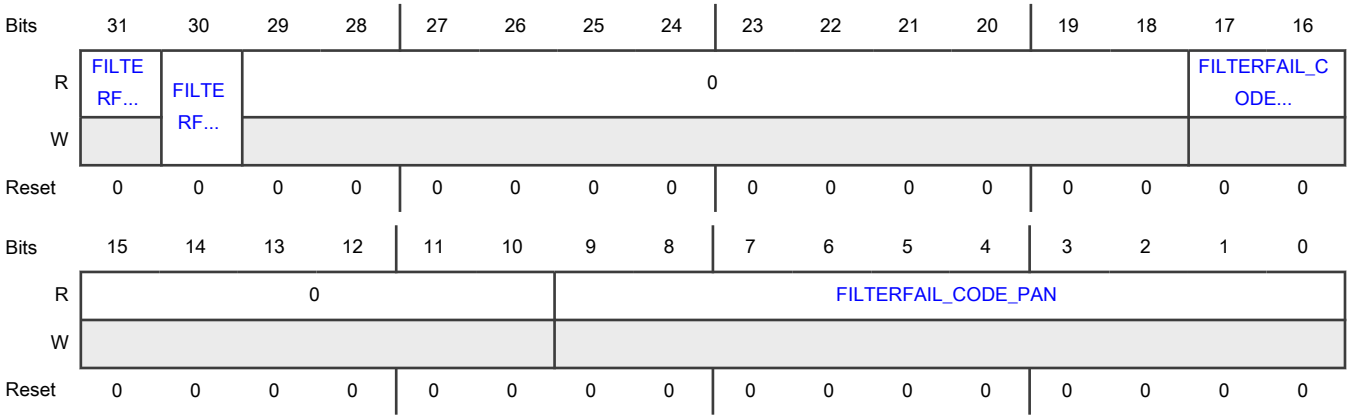
Field	Function
2 ACK_FT	Ack Frame Type Enable 0b - reject all Acknowledge frames 1b - Acknowledge frame type enabled.
1 DATA_FT	Data Frame Type Enable 0b - reject all Beacon frames 1b - Data frame type enabled.
0 BEACON_FT	Beacon Frame Type Enable 0b - reject all Beacon frames 1b - Beacon frame type enabled.

52.4.4.4.2.4.2.40 FILTER FAIL CODE (FILTERFAIL_CODE)

Offset

Register	Offset
FILTERFAIL_CODE	98h

Diagram



Fields

Field	Function
31 FILTERFAIL_FLAG_SEL	Consolidated Filter Fail Flag 0: The incoming, or just-received packet, passed packet filtering rules. 1: The incoming, or just-received packet, failed packet filtering rules

Table continues on the next page...

Table continued from the previous page...

Field	Function
	When FILTERFAIL_FLAG_SEL=1, a non-zero FILTERFAIL_CODE is present (see FILTERFAIL_CODE registers). In Dual PAN mode, FILTERFAIL_FLAG_SEL applies to either or both networks, as follows: **A:** If PAN0 and PAN1 occupy different channels and CURRENT_NETWORK=0, FILTERFAIL_FLAG_SEL applies to PAN0. **B:** If PAN0 and PAN1 occupy different channels and CURRENT_NETWORK=1, FILTERFAIL_FLAG_SEL applies to PAN1. **C:** If PAN0 and PAN1 occupy the same channel, FILTERFAIL_FLAG_SEL is the logical 'AND' of the individual PANs' FILTERFAIL_FLAG bits.
30 FILTERFAIL_PAN_SEL	PAN Selector for Filter Fail Code 0b - FILTERFAIL_CODE_PAN/FILTERFAIL_CODE_FAN will report the FILTERFAIL status of PAN0 1b - FILTERFAIL_CODE_PAN/FILTERFAIL_CODE_FAN will report the FILTERFAIL status of PAN1
29-18 —	Reserved
17-16 FILTERFAIL_CODE_FAN	Filter Fail Code When in FAN Mode Code indicating what condition, or conditions, caused the Packet Processor to reject the just-received packet in FAN mode. The bits of FILTERFAIL_CODE_FAN indicate the reason for packet rejection.
15-10 —	Reserved
9-0 FILTERFAIL_CODE_PAN	Filter Fail Code When in PAN Mode Code indicating what condition, or conditions, caused the Packet Processor to reject the just-received packet in PAN mode. The bits of FILTERFAIL_CODE_PAN indicate the reason for packet rejection.

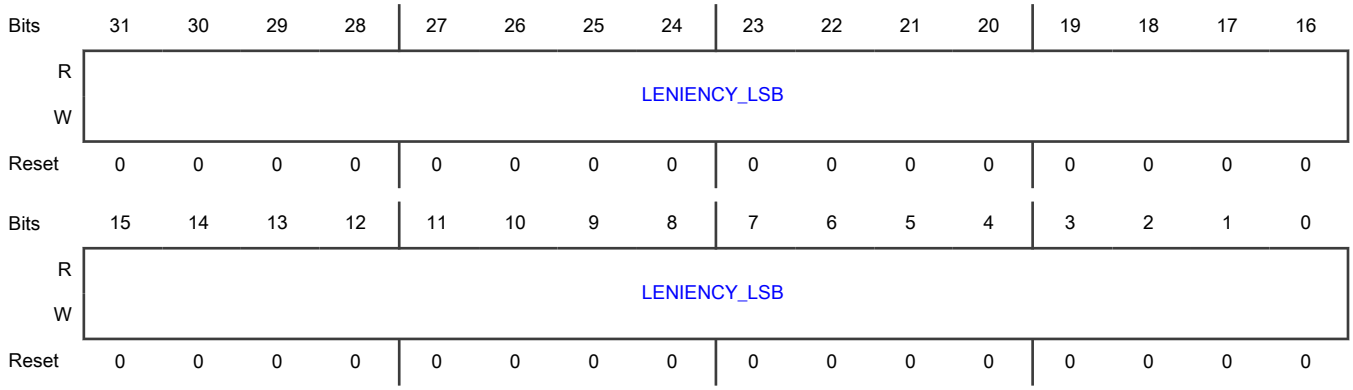
52.4.4.4.2.4.2.41 LENIENCY LSB (LENIENCY_LSB)

Offset

Register	Offset
LENIENCY_LSB	9Ch

Function
Packet Processor Leniency Bits (LSB)

Diagram



Fields

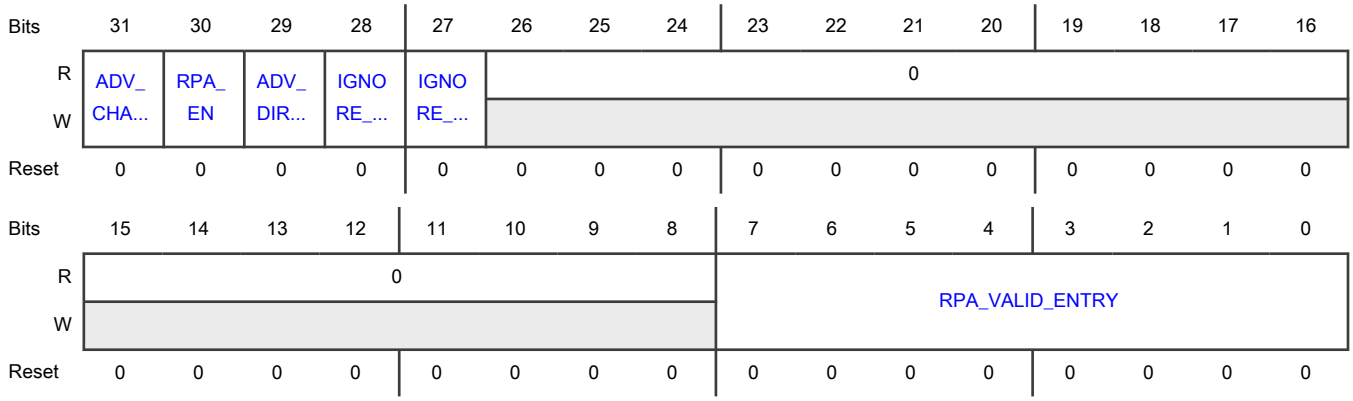
Field	Function
31-0 LENIENCY_LSB	Leniency LSB Register The Packet Processor performs filtering on all received packets, in order to determine whether the packet is intended for the device. The packet filtering is based on rules. In case any of the packet filtering rules need to be overridden, a 45-bit "leniency register" has been provided. When the leniency register is programmed to its default value (0), all hardware packet filtering rules are in effect, and if an incoming packet violates any rule, a "Filter Fail" will occur (packet will be rejected). When a given leniency register bit is asserted, the packet filtering rule assigned to that bit will not be in effect, and if any incoming packet violates that rule (but no other rules), then a "Filter Fail" will not occur, the packet will not be rejected, the packet will not be treated as "intended for the device", and software will be notified of the incoming packet.

52.4.4.4.2.4.2.42 RPA CONTROL (RPA_CTRL)

Offset

Register	Offset
RPA_CTRL	9Ch

Diagram



Fields

Field	Function
31 ADV_CHANNEL_EN	0b - The packet to be received is in Data Channel PDU. 1b - The packet to be received is in Advertising Channel PDU.
30 RPA_EN	0b - The RPA check is disabled. 1b - The RPA check is enabled.
29 ADV_DIRECT_IND_SENT	When set, it means the link layer is advertiser who has sent an ADV_DIRECT_IND. This bit is used by hardware to bypass the white list check when received a CONNECT_IND or SCAN_REQ. In this case, the peer address and peer address type are to be compared with the register DIRECT_PEER_ADDRESS and DIRECT_PEER_ADDRESS_TYPE.
28 IGNORE_DIRECT_FAIL	0b - link layer aborts the Rx process when DIRECT_ID_FAIL_IRQ 1b - link layer ignores DIRECT_ID_FAIL_IRQ.
27 IGNORE_RPA_FAIL	0b - link layer aborts the Rx process when LOCAL_RPA_FAIL_IRQ or PEER_RPA_FAIL_IRQ 1b - link layer ignores LOCAL_RPA_FAIL_IRQ and PEER_RPA_FAIL_IRQ.
26-8 —	Reserved
7-0 RPA_VALID_ENTRY	Here bits [7:0] corresponds to validity of 8th to 1st entry in RPA list respectively. Value "1" means the entry is valid, "0" means invalid.

52.4.4.4.2.4.2.43 LENIENCY MSB (LENIENCY_MSB)

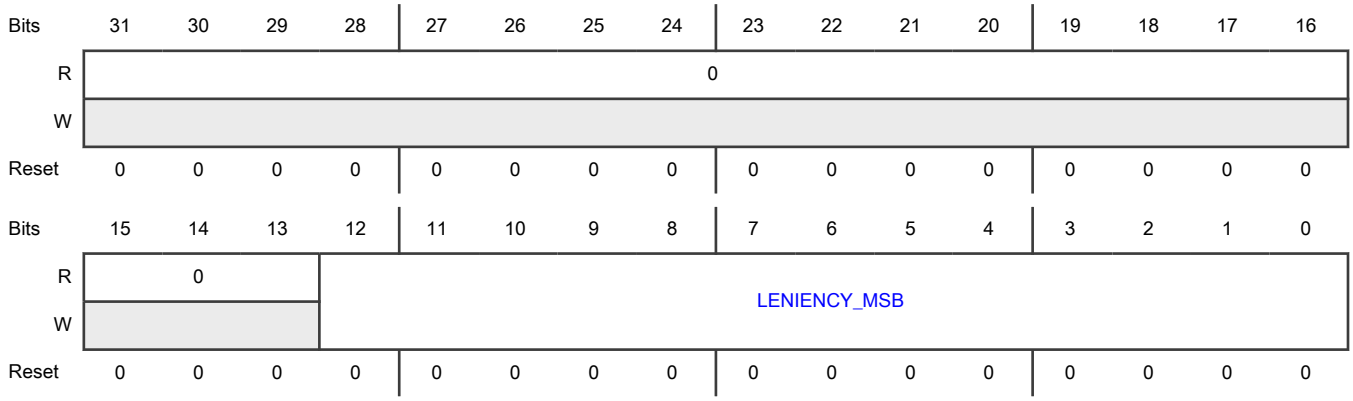
Offset

Register	Offset
LENIENCY_MSB	A0h

Function

Packet Processor Leniency Bits (MSB)

Diagram



Fields

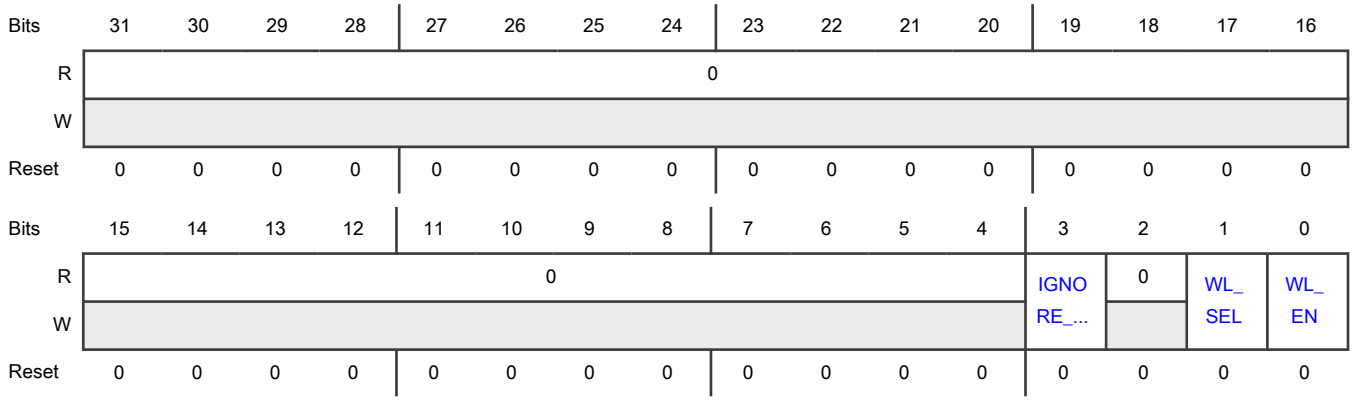
Field	Function
31-13 —	Reserved
12-0 LENIENCY_MSB	Leniency MSB Register The Packet Processor performs filtering on all received packets, in order to determine whether the packet is intended for the device. The packet filtering is based on rules. In case any of the packet filtering rules need to be overriden, a 45-bit "leniency register" has been provided. When the leniency register is programmed to its default value (0), all hardware packet filtering rules are in effect, and if an incoming packet violates any rule, a "Filter Fail" will occur (packet will be rejected). When a given leniency register bit is asserted, the packet filtering rule assigned to that bit will not be in effect, and if any incoming packet violates that rule (but no other rules), then a "Filter Fail" will not occur, the packet will not be rejected, the packet will be treated as "intended for the device", and software will be notified of the incoming packet.

52.4.4.4.2.4.2.44 WHITE LIST CONTROL (WL_CTRL)

Offset

Register	Offset
WL_CTRL	A0h

Diagram



Fields

Field	Function
31-4 —	Reserved
3 IGNORE_WL_FAIL	0b - link layer aborts the Rx process when WL_FAIL_IRQ 1b - link layer ignores WL_FAIL_IRQ.
2 —	Reserved
1 WL_SEL	0b - Select white list 0 1b - Select white list 1
0 WL_EN	0b - White list search is not enabled 1b - White list search is enabled

52.4.4.4.2.4.2.45 DUAL PAN CONTROL (DUAL_PAN_CTRL)

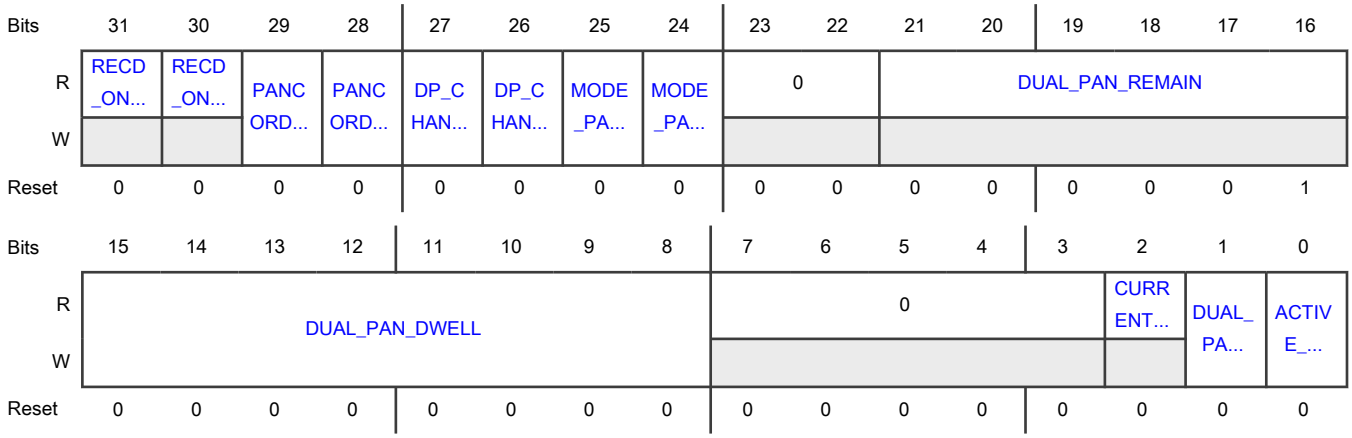
Offset

Register	Offset
DUAL_PAN_CTRL	A4h

Function

Dual PAN Control Register

Diagram



Fields

Field	Function
31 RECD_ON_PAN1	Last Packet was Received on PAN1 Indicates the packet which was just received, was received on PAN1. In Dual PAN mode operating on 2 different channels, RECD_ON_PAN1 will be set if CURRENT_NETWORK=1 when the packet was received, regardless of FILTERFAIL status. In DUAL PAN mode operating with same channel on both networks, CURRENT_NETWORK will be ignored and RECD_ON_PAN1 will be set only if a valid packet was received on PAN1 (PAN1's FILTERFAIL_FLAG is de-asserted). RECD_ON_PAN1 remains valid until the start of the next autoseqeuence.
30 RECD_ON_PAN0	Last Packet was Received on PAN0 Indicates the packet which was just received, was received on PAN0. In Dual PAN mode operating on 2 different channels, RECD_ON_PAN0 will be set if CURRENT_NETWORK=0 when the packet was received, regardless of FILTERFAIL status. In DUAL PAN mode operating with same channel on both networks, CURRENT_NETWORK will be ignored and RECD_ON_PAN0 will be set only if a valid packet was received on PAN0 (PAN0's FILTERFAIL_FLAG is de-asserted). RECD_ON_PAN0 remains valid until the start of the next autoseqeuence.
29 PANCORDNTR1	Device is a PAN Coordinator on PAN1 Device is a PAN Coordinator on PAN1. Allows device to receive packets with no destination address, if Source PAN ID matches.
28 PANCORDNTR0	Device is a PAN Coordinator on PAN0 Device is a PAN Coordinator on PAN0. Allows device to receive packets with no destination address, if Source PAN ID matches.
27 DP_CHAN_OVRD_SEL	Dual PAN Channel Override Selector This bit works with **DP_CHAN_OVRD_EN** to allow one of the two Dual PAN channels to use Direct Frequency programming. See description for **DP_CHAN_OVRD_EN** .
26	Dual PAN Channel Override Enable

Table continues on the next page...

Table continued from the previous page...

Field	Function
DP_CHAN_OVRD_EN	In Dual PAN mode, in case there is a need to generate a frequency which may be offset from the 16 prescribed 5MHz-spaced channels, to, for example, avoid interference on one of the Dual PAN channels, a method has been provided to accomplish that, by designating one of the two PAN channels to use the transceiver's set of direct frequency-programming registers, instead of CHANNEL_NUMx. Programming the direct frequency-programming registers -- integer, numerator, and denominator, allows an RF frequency to be selected with much more precision than the 5MHz granularity of the Zigbee mapped-channel registers, CHANNEL_NUM0 and CHANNEL_NUM1. Two bits have been provided in 802.15.4 space to realize this feature: DP_CHAN_OVRD_SEL and DP_CHAN_OVRD_EN. When DP_CHAN_OVRD_EN=1, this enables one of the Dual PAN channels to use the direct frequency programming. The DP_CHAN_OVRD_SEL bit determines which channel uses the direct programming, according to the following: If DP_CHAN_OVRD_EN=0, then PAN0 frequency is determined by register CHANNEL_NUM0[6:0] and PAN1 frequency is determined by register CHANNEL_NUM1[6:0]. If DP_CHAN_OVRD_EN=1 and DP_CHAN_OVRD_SEL=0, then PAN0 frequency is determined by DIRECT FREQUENCY PROGRAMMING and PAN1 frequency is determined by register CHANNEL_NUM1[6:0]. If DP_CHAN_OVRD_EN=1 and DP_CHAN_OVRD_SEL=1, then PAN0 frequency is determined by register CHANNEL_NUM0[6:0] and PAN1 frequency is determined by DIRECT FREQUENCY PROGRAMMING. **NOTE** Direct Frequency Programming is accomplished by setting the PLL's Integer, Numerator, and Denominator registers to the appropriate values for the desired RF frequency.
25 MODE_PAN1	PAN1 Mode Select For Hybrid Dual PAN Mode, select the PAN1 Mode 0b - PAN1 is in PAN mode 1b - PAN1 is in FAN mode
24 MODE_PAN0	PAN0 Mode Select For Hybrid Dual PAN Mode, select the PAN0 Mode 0b - PAN0 is in PAN mode 1b - PAN0 is in FAN mode
23-22 —	Reserved
21-16 DUAL_PAN_REMAIN	Time Remaining before next PAN switch in auto Dual PAN mode This read-only register indicates time remaining before next PAN switch in auto Dual PAN mode. The units for this register, depend on the PRESCALER setting (bits [1:0]) in the DUAL_PAN_DWELL register. The units are the same as the TIMEBASE determined by the prescaler, as per the following table: DUAL_PAN_DWELL[1:0]=0b00 (TIMEBASE=0.5ms) DUAL_PAN_REMAIN UNITS=0.5ms

Table continues on the next page...

Table continued from the previous page...

Field	Function
	DUAL_PAN_DWELL[1:0]=0b01 (TIMEBASE=2.5ms) DUAL_PAN_REMAIN UNITS=2.5ms DUAL_PAN_DWELL[1:0]=0b10 (TIMEBASE=10ms) DUAL_PAN_REMAIN UNITS=10ms DUAL_PAN_DWELL[1:0]=0b11 (TIMEBASE=50ms) DUAL_PAN_REMAIN UNITS=50ms The readback value indicates that between N-1 and N timebase units remain until the next PAN switch. For example, a DUAL_PAN_REMAIN readback value of 3, with a DUAL_PAN_DWELL PRESCALER setting of 2 (10ms), indicates that between 20ms (2*10ms) and 30ms (3*10ms), remain until the next automatic PAN switch.
15-8 DUAL_PAN_DWELL	Dual PAN Channel Frequency Dwell Time Channel Frequency Dwell Time. In Auto Dual PAN mode, hardware will toggle the PAN, after dwelling on the current PAN for the interval described below (assuming Preamble/SFD not detected). A write to DUAL_PAN_DWELL, always reinitializes the DWELL TIMER to the programmed value. If a write to DUAL_PAN_DWELL occurs during an autosequence, the DWELL TIMER will begin counting down immediately. If a write to DUAL_PAN_DWELL occurs when there is no autosequence underway, the DWELL TIMER will not begin counting until the next autosequence begins; it will begin counting at the start of the sequence warmup. DUAL_PAN_DWELL[1:0] select the timebase for the dwell time. There are 4 options: DUAL_PAN_DWELL[1:0]=0b00 --> TIMEBASE=0.5ms DUAL_PAN_DWELL[1:0]=0b01 --> TIMEBASE=2.5ms DUAL_PAN_DWELL[1:0]=0b10 --> TIMEBASE=10ms DUAL_PAN_DWELL[1:0]=0b11 --> TIMEBASE=50ms DUAL_PAN_DWELL[7:2] select how many multiples of the time base to use, from 1 (DUAL_PAN_DWELL[7:2]=0) to 64 (DUAL_PAN_DWELL[7:2]=63). Given those definitions, the table below specifies the minimum and maximum dwell times for each TIMEBASE option: DUAL_PAN_DWELL[1:0]=0b00 --> MIN_DWELL=0.5ms MAX_DWELL=32ms DUAL_PAN_DWELL[1:0]=0b01 --> MIN_DWELL=2.5ms MAX_DWELL=160ms DUAL_PAN_DWELL[1:0]=0b10 --> MIN_DWELL=10ms MAX_DWELL=640ms DUAL_PAN_DWELL[1:0]=0b11 --> MIN_DWELL=50ms MAX_DWELL=3.2seconds A write to DUAL_PAN_DWELL also causes the value of ACTIVE_NETWORK to get latched into the hardware. This latched value will be the starting point for the automatic dual-pan mode (i.e., start on PAN0 or on PAN1). The starting value takes effect immediately (if sequence is underway and DUAL_PAN_AUTO=1), or is otherwise delayed until sequence starts and DUAL_PAN_AUTO=1.
7-3 —	Reserved
2 CURRENT_NETWORK	Indicates which PAN is currently selected by hardware This read-only bit indicates which PAN is currently selected by hardware in automatic Dual PAN mode 0b - PAN0 is selected

Table continues on the next page...

Table continued from the previous page...

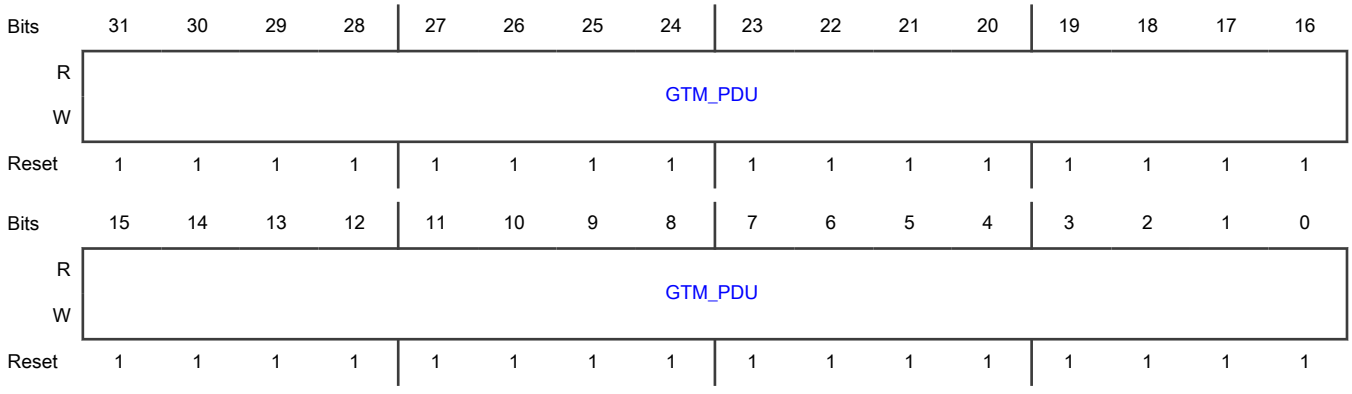
Field	Function
	1b - PAN1 is selected
1 DUAL_PAN_AUTO	Activates automatic Dual PAN operating mode Activates automatic Dual PAN operating mode. In this mode, PAN-switching is controlled by hardware at a pre-programmed rate, determined by DUAL_PAN_DWELL. 0: Manual Dual PAN mode (or Single PAN mode). 1: Auto Dual PAN Mode Whenever DUAL_PAN_AUTO=0, CURRENT_NETWORK=ACTIVE_NETWORK at all times. In other words, software directly controls which PAN is selected. Whenever DUAL_PAN_AUTO=1, CURRENT_NETWORK is controlled by hardware.
0 ACTIVE_NETWORK	Active Network Selector Selects the PAN on which to transceive, by activating a PAN parameter set (PAN0 or PAN1). In Manual Dual PAN mode (or Single PAN mode), this bit selects the active PAN parameter set (channel and addressing parameters) which governs all autosequences. In Auto Dual PAN mode, this bit selects the PAN on which to begin transceiving, latched at the point at which DUAL_PAN_DWELL register is written. 0b - Select PAN0 1b - Select PAN1

52.4.4.4.2.4.2.46 GTM MODE PDU (GTM_PDU)

Offset

Register	Offset
GTM_PDU	A8h

Diagram



Fields

Field	Function
31-0 GTM_PDU	GTM MODE PDU Used in GTM mode, the 8/32-bit Pattern selected by register GTM_PDU_TYPE.

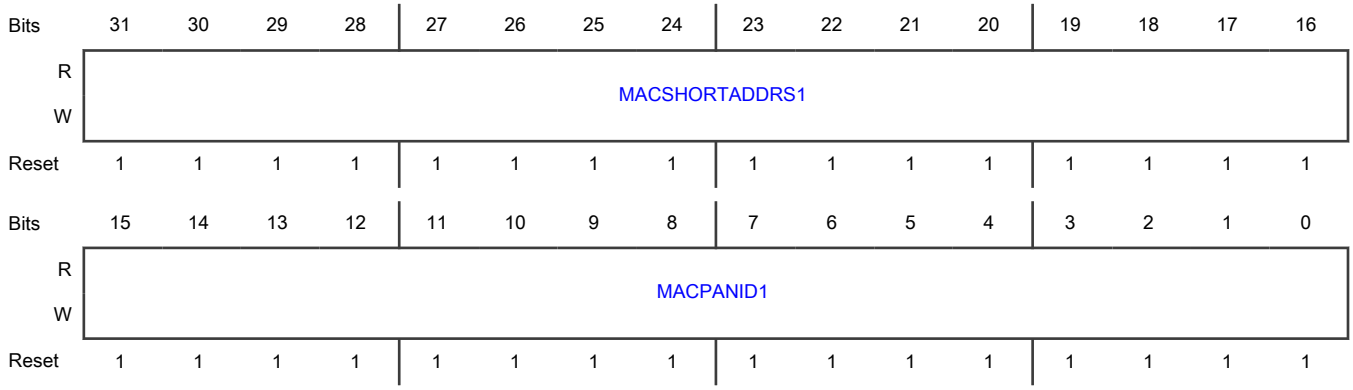
52.4.4.4.2.4.2.47 MAC SHORT ADDRESS FOR PAN1 (MACSHORTADDRS1)

Offset

Register	Offset
MACSHORTADDRS1	A8h

Function
The MACSHORTADDRS1 register .

Diagram



Fields

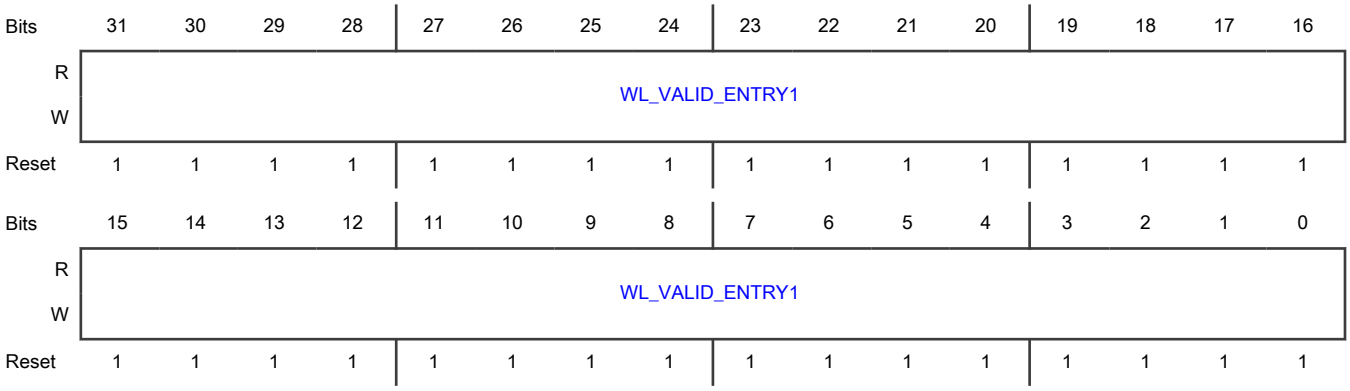
Field	Function
31-16 MACSHORTADDRS1	MAC SHORT ADDRESS for PAN1 MAC Short Address for PAN1, for 16-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.
15-0 MACPANID1	MAC PAN ID for PAN1 MAC PAN ID for PAN1. The packet processor compares the incoming packet's Destination PAN ID against the contents of this register to determine if the packet is addressed to this device; or if the incoming packet is a Beacon frame, the packet processor compares the incoming packet Source PAN ID against this register. Also, if PANCORDNTR1=1, and the incoming packet has no Destination Address field, and if the incoming packet is a Data or MAC Command frame, the packet processor compares the incoming packet Source PAN ID against this register.

52.4.4.4.2.4.2.48 VALID ENTRY OF WHITE LIST 1 (WL_VALID_ENTRY1)

Offset

Register	Offset
WL_VALID_ENTRY1	A8h

Diagram



Fields

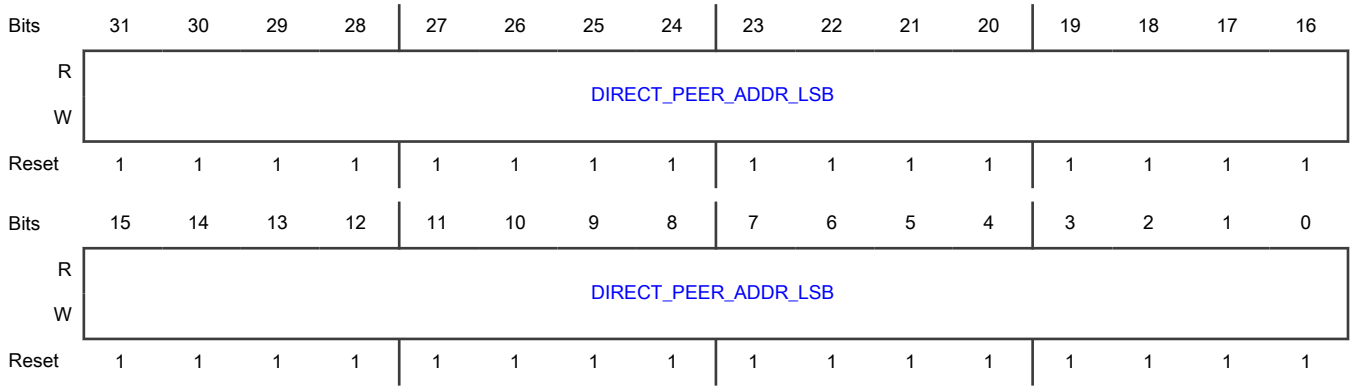
Field	Function
31-0 WL_VALID_ENTRY1	Here bits [31:0] corresponds to validity of 32th to 1st entry in white list 1 respectively. Value "1" means the entry is valid, "0" means invalid.

52.4.4.4.2.4.2.49 DIRECT_PEER_ADDR[31:0] (DIRECT_PEER_ADDR_LSB)

Offset

Register	Offset
DIRECT_PEER_ADDR_LSB	ACh

Diagram



Fields

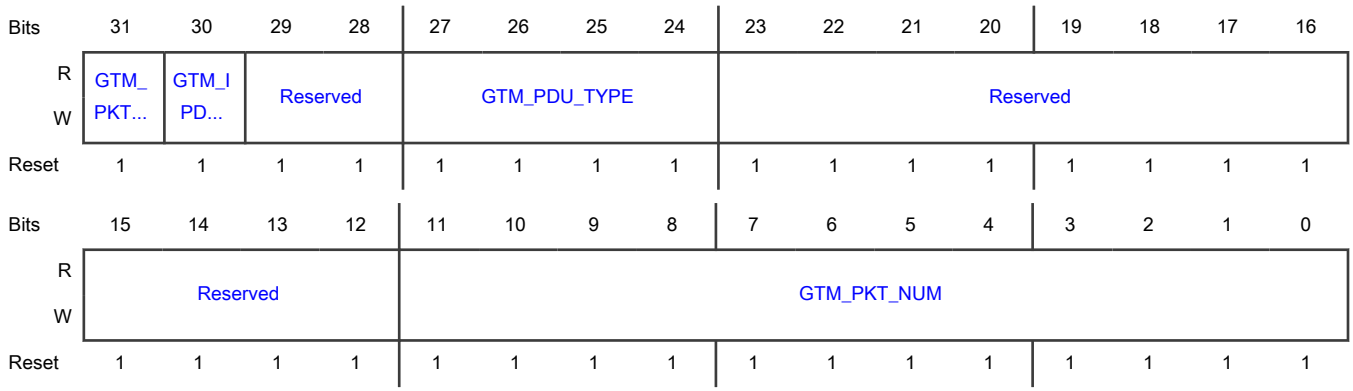
Field	Function
31-0 DIRECT_PEER_ADDR_LSB	Lower 32 bit of 48-bit address of the direct peer device.

52.4.4.4.2.4.2.50 GTM MODE CONFIGURATION (GTM_CFG)

Offset

Register	Offset
GTM_CFG	ACh

Diagram



Fields

Field	Function
31	GTM MODE PACKET NUMBER CHECK DISABLE

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Table continued from the previous page...

Field	Function
GTM_PKT_COUNT_CHECK_DIS	Used in GTM mode, disable the packet number check.
30 GTM_IPD_CHECK_DIS	GTM MODE INTER-PACKET DURATION CHECK DISABLE Used in GTM mode, disable the IPD check.
29-28 —	Reserved
27-24 GTM_PDU_TYPE	GTM MODE PDU TYPE SELECTION 0000b - PRBS9 Sequence 0001b - Programmable 8-bit Pattern (from register GTM_PDU[7:0], reused from MACSHORTADDRS1[7:0]) 0010b - PRBS-13 Sequence 0011b - PRBS-15 Sequence 0100b - Programmable 32-bit Pattern (from register GTM_PDU[31:0], reused from {MACSHORTADDRS1,MACPANID1}) 0101b - Programmable packet from Packet RAM (in this case, PKT_LEN is ignored)
23-12 —	Reserved
11-0 GTM_PKT_NUM	GTM MODE PACKET NUMBER Used in GTM mode, the total number of packets to be sent or received.

52.4.4.4.2.4.2.51 MAC LONG ADDRESS 1 LSB (MACLONGADDRS1_LSB)

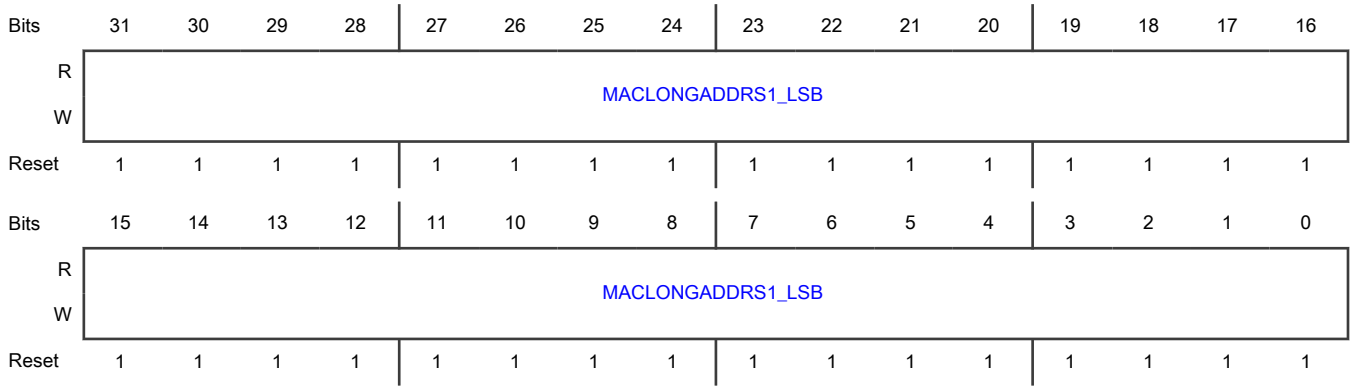
Offset

Register	Offset
MACLONGADDRS1_LSB	ACh

Function

MAC Long Address for PAN1, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.

Diagram



Fields

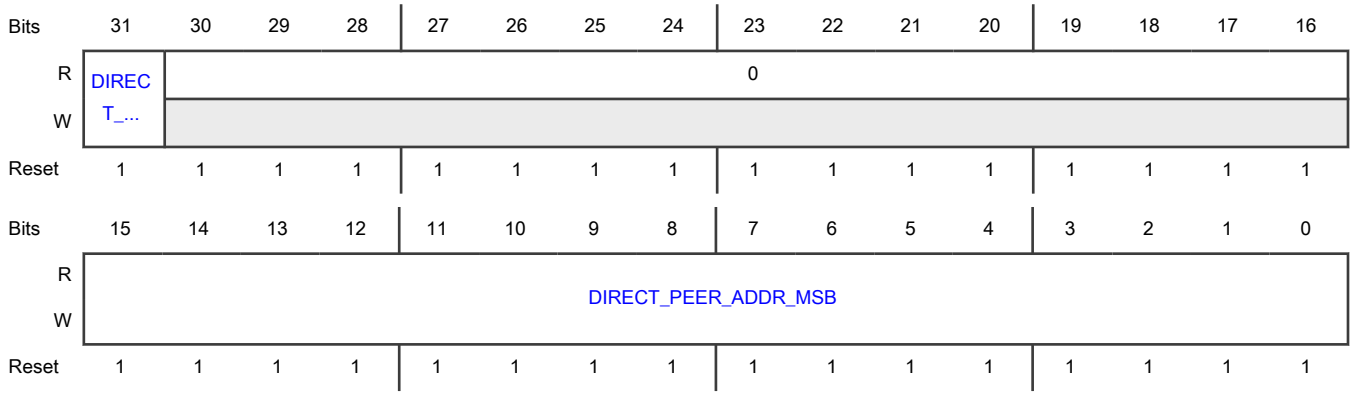
Field	Function
31-0 MACLONGADDRS1_LSB	MAC LONG ADDRESS for PAN1 LSB MAC Long Address for PAN1, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.

52.4.4.4.2.4.2.52 DIRECT_PEER_ADDR[47:32] (DIRECT_PEER_ADDR_MSB)

Offset

Register	Offset
DIRECT_PEER_ADDR_MSB	B0h

Diagram



Fields

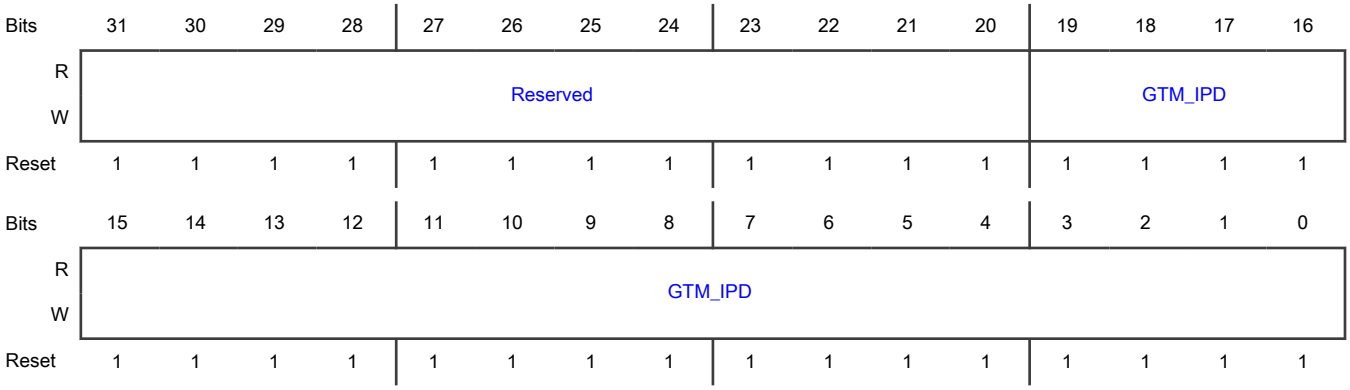
Field	Function
31 DIRECT_PEER_ADDR_TYPE	0b - Direct peer device address type is public. 1b - Direct peer device address type is random.
30-16 —	Reserved
15-0 DIRECT_PEER_ADDR_MSB	Higher 16 bit of 48-bit address of the direct peer device.

52.4.4.4.2.4.2.53 GTM MODE INTER-PACKET DURATION (GTM_IPD)

Offset

Register	Offset
GTM_IPD	B0h

Diagram



Fields

Field	Function
31-20 —	Reserved
19-0 GTM_IPD	GTM MODE INTER-PACKET DURATION Used in GTM mode, in microseconds unit; indicates the time slot that one packet is sent.

52.4.4.4.2.4.2.54 MAC LONG ADDRESS 1 MSB (MACLONGADDRS1_MSB)

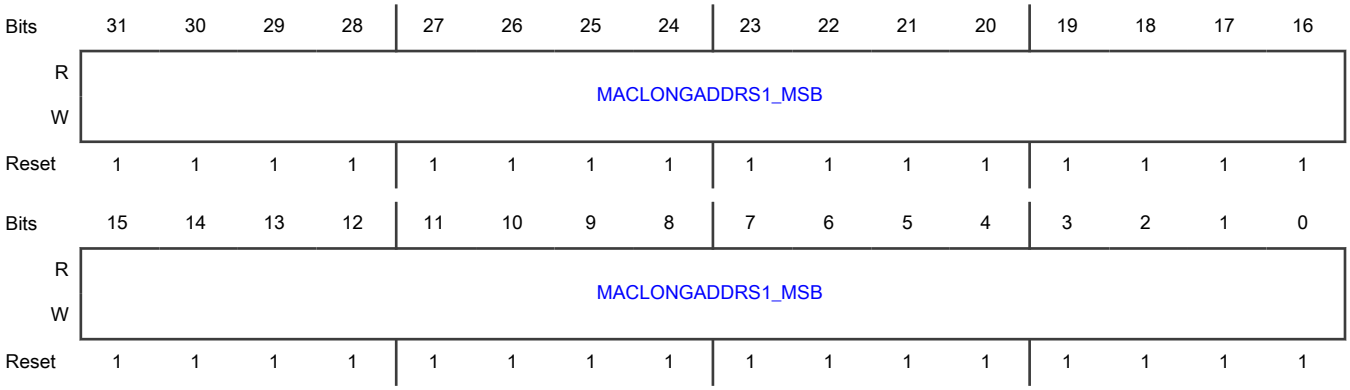
Offset

Register	Offset
MACLONGADDRS1_MSB	B0h

Function

MAC Long Address for PAN1, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.

Diagram



Fields

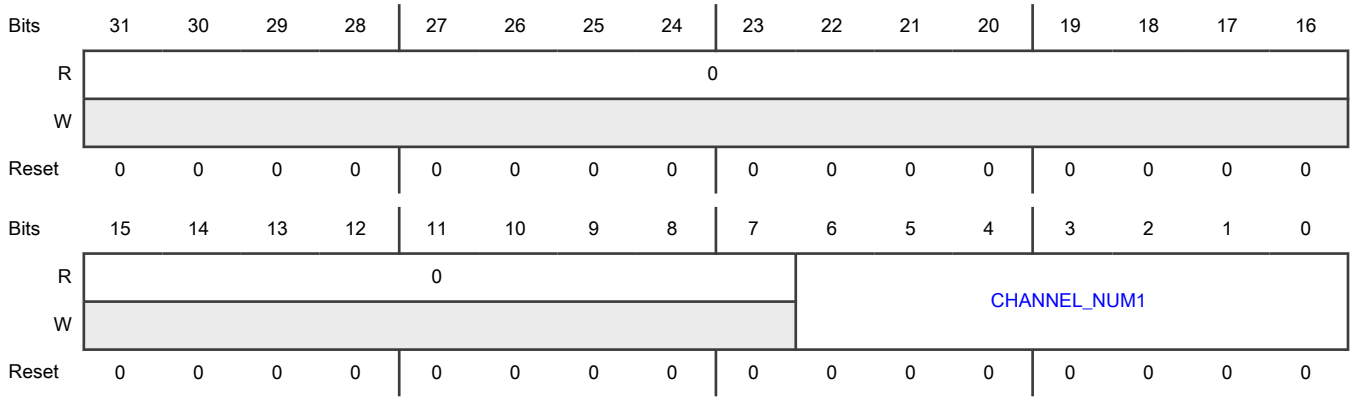
Field	Function
31-0 MACLONGADDRS1_MSB	MAC LONG ADDRESS for PAN1 MSB MAC Long Address for PAN1, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.

52.4.4.4.2.4.2.55 CHANNEL NUMBER 1 (CHANNEL_NUM1)

Offset

Register	Offset
CHANNEL_NUM1	B4h

Diagram



Fields

Field	Function
31-7 —	Reserved
6-0 CHANNEL_NUM1	Channel Number for PAN1 This is the mapped channel number used to transmit and receive packets. If Dual PAN is engaged, this register applies to PAN1. Formula: F = (2360 + CHANNEL_NUM1) [in MHz]

52.4.4.4.2.4.2.56 MAC SHORT ADDRESS 0 (MACSHORTADDRS0)

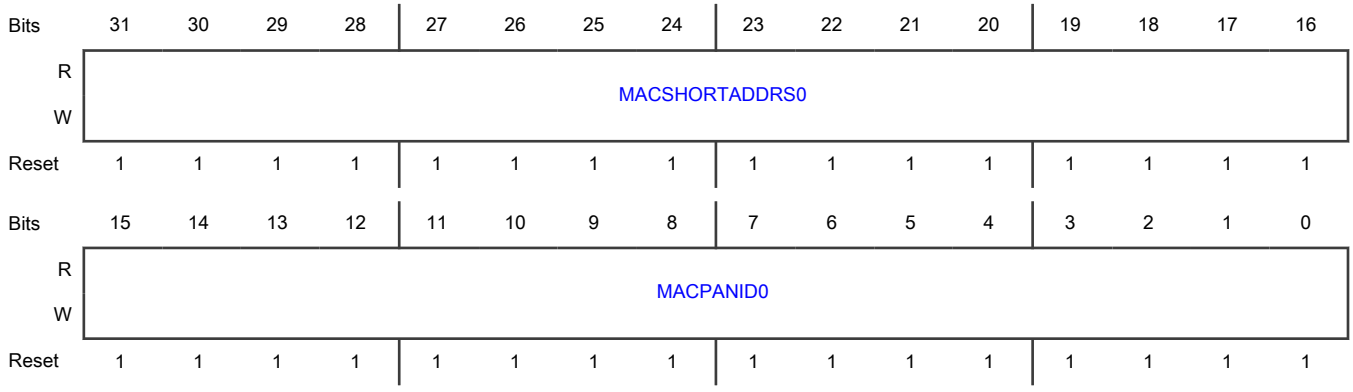
Offset

Register	Offset
MACSHORTADDRS0	B8h

Function

MAC SHORT ADDRESS for PAN0

Diagram



Fields

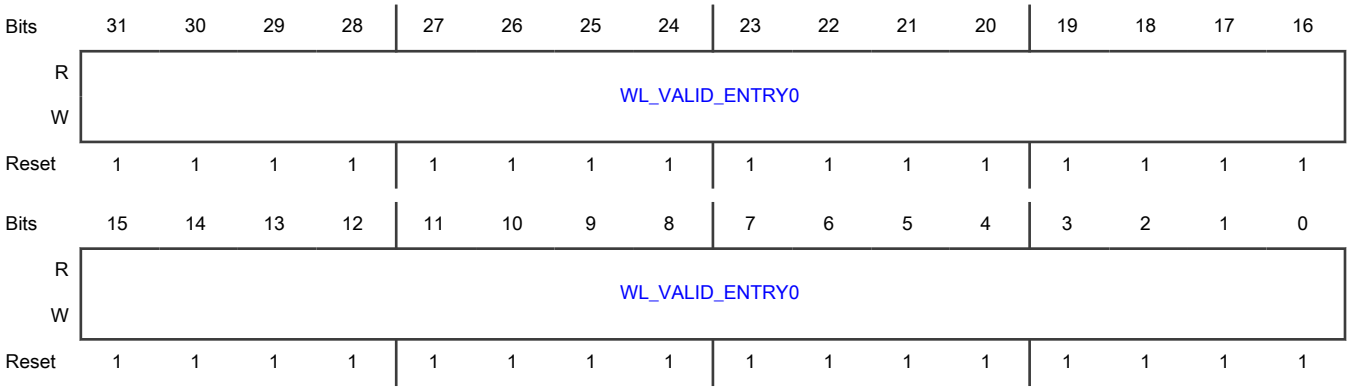
Field	Function
31-16 MACSHORTADDRS0	MAC SHORT ADDRESS FOR PAN0 MAC Short Address for PAN0, for 16-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.
15-0 MACPANID0	MAC PAN ID for PAN0 MAC PAN ID for PAN0. The packet processor compares the incoming packet's Destination PAN ID against the contents of this register to determine if the packet is addressed to this device; or if the incoming packet is a Beacon frame, the packet processor compares the incoming packet Source PAN ID against this register. Also, if PANCORDNTR0=1, and the incoming packet has no Destination Address field, and if the incoming packet is a Data or MAC Command frame, the packet processor compares the incoming packet Source PAN ID against this register.

52.4.4.4.2.4.2.57 VALID ENTRY OF WHITE LIST 0 (WL_VALID_ENTRY0)

Offset

Register	Offset
WL_VALID_ENTRY0	B8h

Diagram



Fields

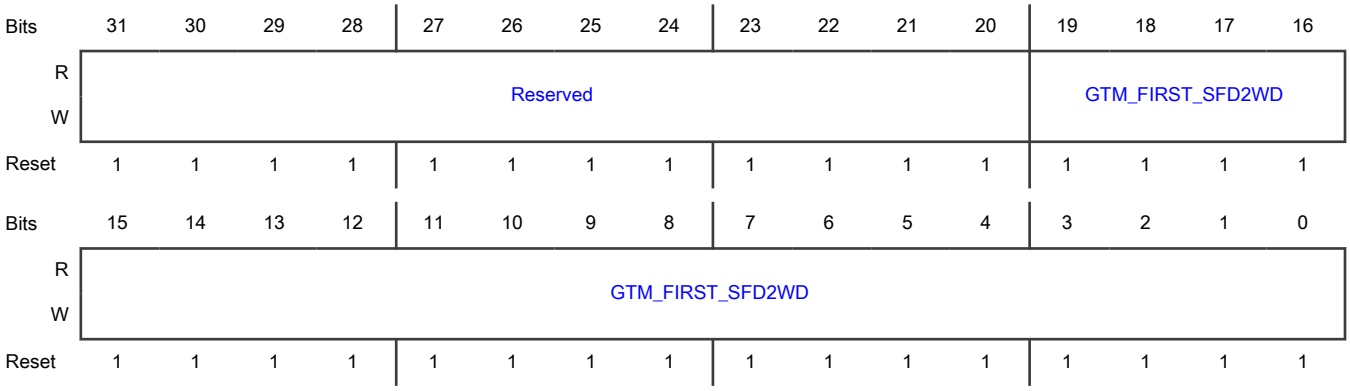
Field	Function
31-0 WL_VALID_ENTRY0	Here bits [31:0] corresponds to validity of 32th to 1st entry in white list 0 respectively. Value "1" means the entry is valid, "0" means invalid.

52.4.4.4.2.4.2.58 GTM MODE TIME OF FIRST SFD FOUND TO FORCE RX WARM-DOWN (GTM_FIRST_SFD2WD)

Offset

Register	Offset
GTM_FIRST_SFD2WD	BCh

Diagram



Fields

Field	Function
31-20 —	Reserved
19-0 GTM_FIRST_SFD2WD	GTM MODE TIME OF FIRST SFD FOUND TO FORCE RX WARMDOWN Used in GTM mode, in microseconds unit; Indicates the time between the "force Rx warm-down" and "first SFD found". It is possibly the longest packet duration plus some margin.

52.4.4.4.2.4.2.59 MAC LONG ADDRESS 0 LSB (MACLONGADDRS0_LSB)

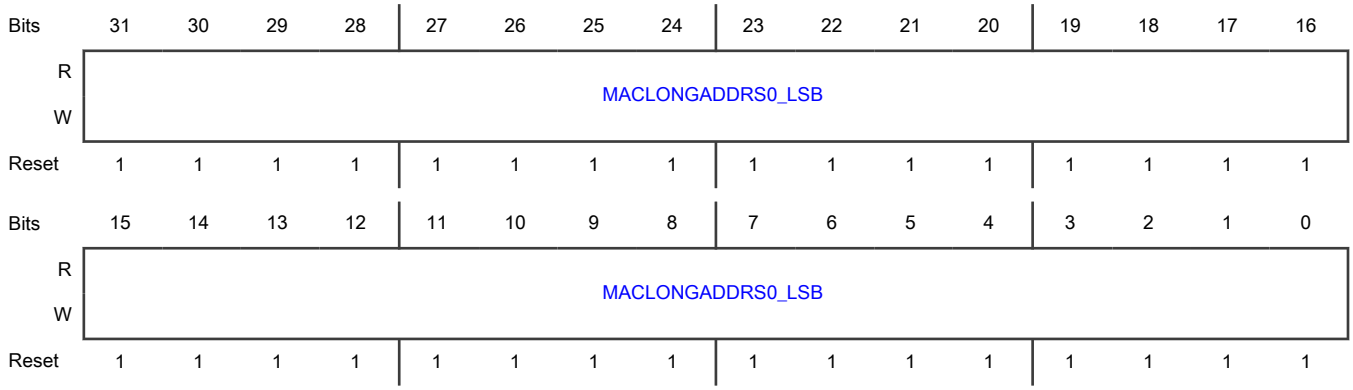
Offset

Register	Offset
MACLONGADDRS0_LSB	BCh

Function

MAC LONG ADDRESS for PAN0 LSB

Diagram



Fields

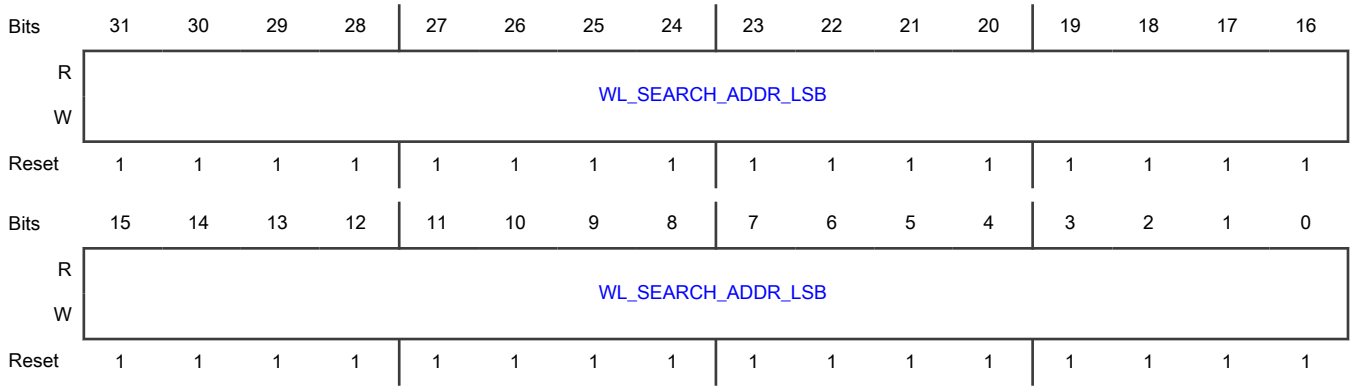
Field	Function
31-0 MACLONGADDRS0_LSB	MAC LONG ADDRESS for PAN0 LSB MAC Long Address for PAN0, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.

52.4.4.4.2.4.2.60 WL_SEARCH_ADDR[31:0] (WL_SEARCH_ADDR_LSB)

Offset

Register	Offset
WL_SEARCH_ADDR_LSB	BCh

Diagram



Fields

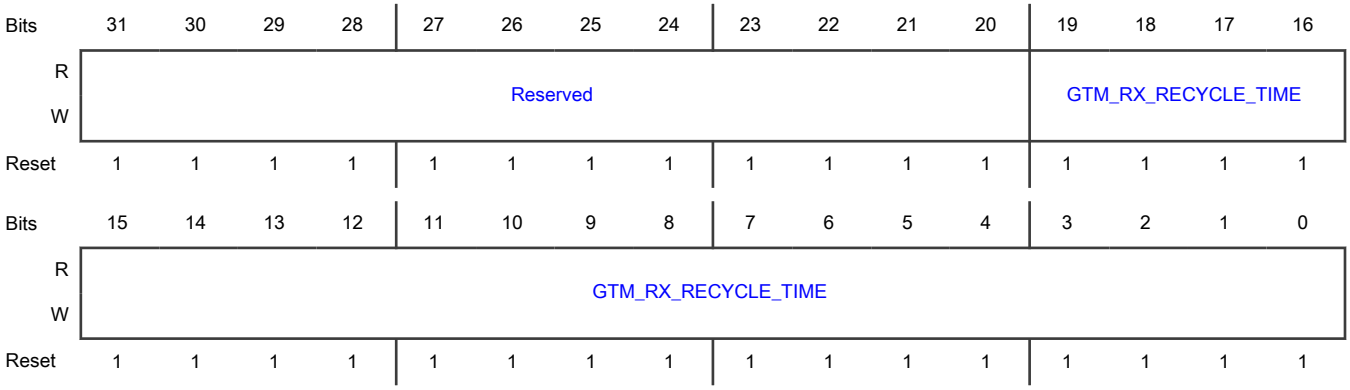
Field	Function
31-0 WL_SEARCH_ADDR_LSB	Lower 32 bit of 48-bit address to be searched in white list.

52.4.4.4.2.4.2.61 GTM MODE RX RECYCLE TIME (GTM_RX_RECYCLE_TIME)

Offset

Register	Offset
GTM_RX_RECYCLE_TIME	C0h

Diagram



Fields

Field	Function
31-20 —	Reserved
19-0 GTM_RX_RECYCLE_TIME	GTM MODE RX RECYCLE TIME Used in GTM mode, in microseconds unit; For TX, it means the delay between "first TX warmup" and "GTM_IN_TX is asserted"; For RX, it means the time between "force Rx warm-down" and "next Rx warmup".

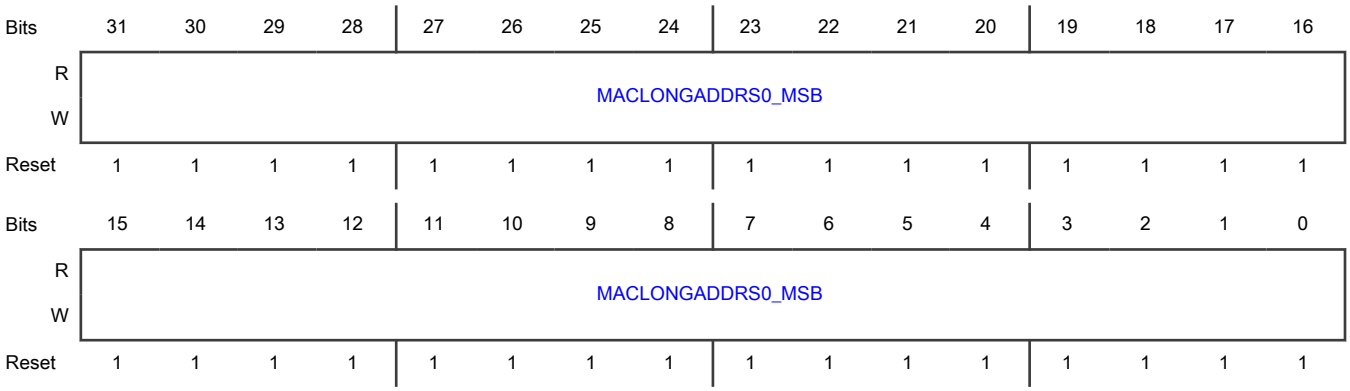
52.4.4.4.2.4.2.62 MAC LONG ADDRESS 0 MSB (MACLONGADDRS0_MSB)

Offset

Register	Offset
MACLONGADDRS0_MSB	C0h

Function
MAC LONG ADDRESS for PAN0 MSB

Diagram



Fields

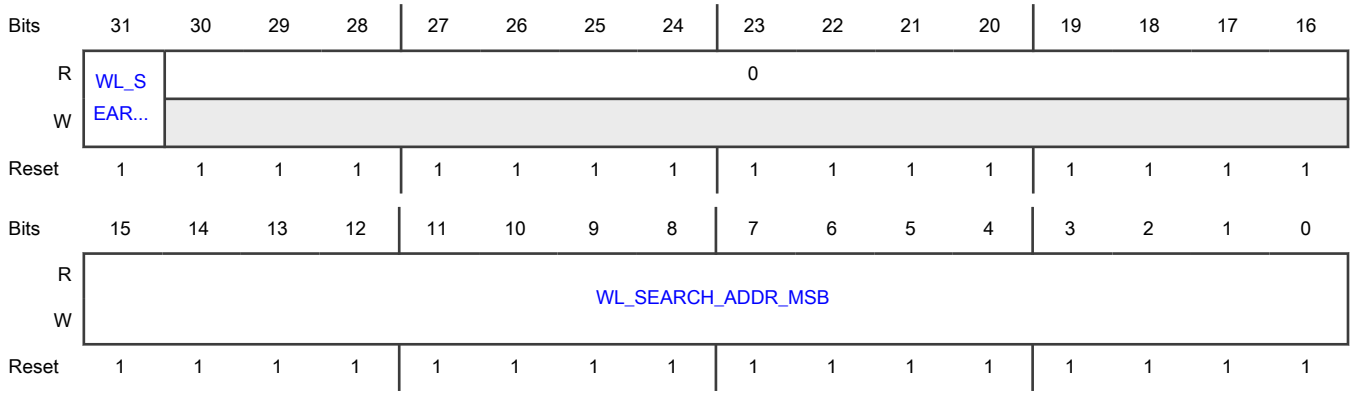
Field	Function
31-0 MACLONGADDRS0_MSB	MAC LONG ADDRESS for PAN0 MSB MAC Long Address for PAN0, for 64-bit destination addressing mode. The packet processor compares the incoming packet's Destination Address against the contents of this register to determine if the packet is addressed to this device.

52.4.4.4.2.4.2.63 WL_SEARCH_ADDR[47:32] (WL_SEARCH_ADDR_MSB)

Offset

Register	Offset
WL_SEARCH_ADDR_MSB	C0h

Diagram



Fields

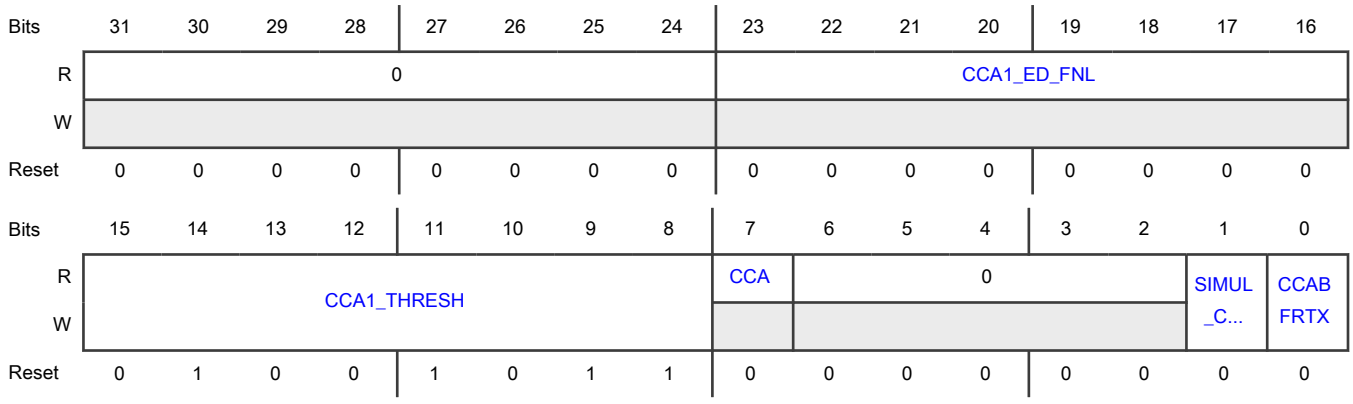
Field	Function
31 WL_SEARCH_ADDR_TYPE	0b - The address type is public. 1b - The address type is random.
30-16 —	Reserved
15-0 WL_SEARCH_ADDR_MSB	Higher 16 bit of 48-bit address to be searched in white list.

52.4.4.4.2.4.2.64 CCA AND LQI CONTROL (CCA_LQI_CTRL)

Offset

Register	Offset
CCA_LQI_CTRL	C4h

Diagram



Fields

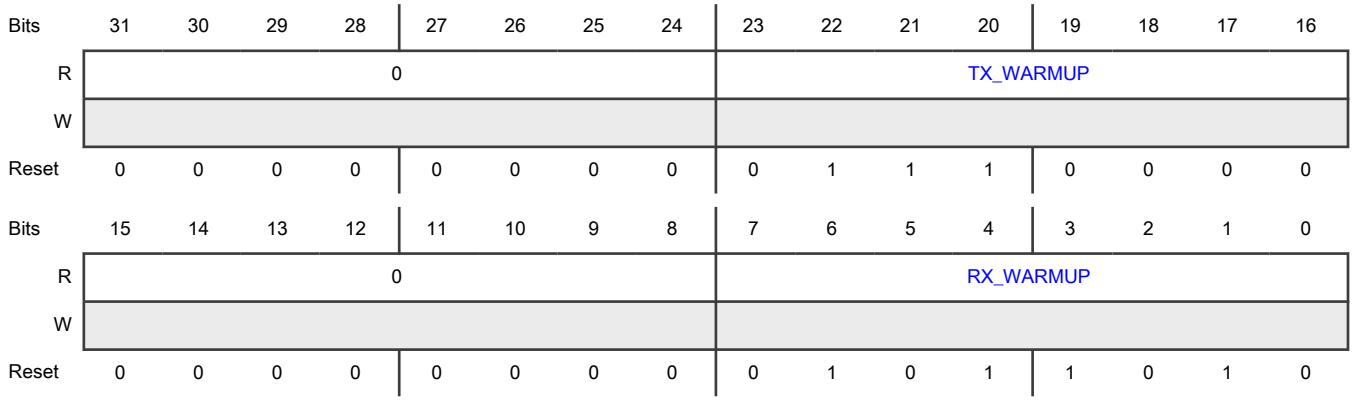
Field	Function
31-24 —	Reserved
23-16 CCA1_ED_FNL	Final Result for CCA Mode 1 and Energy Detect Output register to show final averaged RSSI value or compensated value of the same at the end of a CCA Mode1 or Energy Detect computation.
15-8 CCA1_THRESH	CCA Mode 1 Threshold Programmable energy threshold register for CCA mode 1.
7 CCA	CCA Status Channel IDLE/BUSY indicator. This indicator is valid at CCA_IRQ and also at SEQ_END_IRQ. This flag is cleared at next receiver warm up. 0b - IDLE 1b - BUSY
6-2 —	Reserved
1 SIMUL_CCA_RX	Simultaneous CCA and Receive Enable During autosequences of type Sequence T or Sequence TR with CCA before TX, this bit allows a packet to be received if preamble and SFD are detected during the CCA measurement window. 0b - Packets can't be received during CCA measurement 1b - Packet reception is enabled during CCA measurement if preamble and SFD are detected
0 CCABFRTX	CCA Before TX Applies only to Sequences T and TR, ignored during all other sequences. 0b - no CCA required, transmit operation begins immediately. 1b - at least one CCA measurement is required prior to the transmit operation (see also SLOTTED).

52.4.4.4.2.4.2.65 TX/RX WARMUP TIME (WARMUP_TIME)

Offset

Register	Offset
WARMUP_TIME	C8h

Diagram



Fields

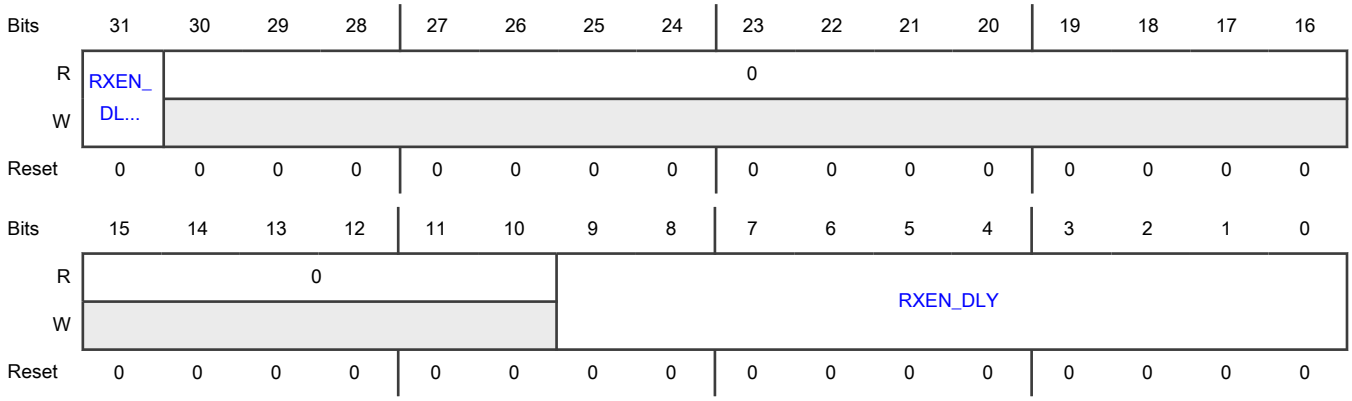
Field	Function
31-24 —	Reserved
23-16 TX_WARMUP	Transmit Warmup Time TX warmup time, in microseconds, provided to Link Layer software, so that warmup time can be accounted for when scheduling over-the-air transactions.
15-8 —	Reserved
7-0 RX_WARMUP	Receive Warmup Time RX warmup time, in microseconds, provided to Link Layer software, so that warmup time can be accounted for when scheduling over-the-air transactions.

52.4.4.4.2.4.2.66 RX_EN Delay Time (RXEN_DLY)

Offset

Register	Offset
RXEN_DLY	CCh

Diagram



Fields

Field	Function
31 RXEN_DLY_OVERRIDE	RX_EN delay to de-assert time override enable. 0b - For Bluetooth LE case, RX_EN signal will delay to de-assert according to the length of TERM2 or CTE(when BLE_V5P1_CTE_EN is enabled) field parsed by hardware 1b - For all receive case, RX_EN signal will delay to de-assert according to register RXEN_DLY[9:0].
30-10 —	Reserved
9-0 RXEN_DLY	When RXEN_DLY is not zero, the RX_EN signal will delay (RXEN_DLY +1) microseconds to de-assert after packet is received. The delay time range is from 2~1024 microseconds.

52.4.4.4.2.4.2.67 SAM CONTROL (SAM_CTRL)

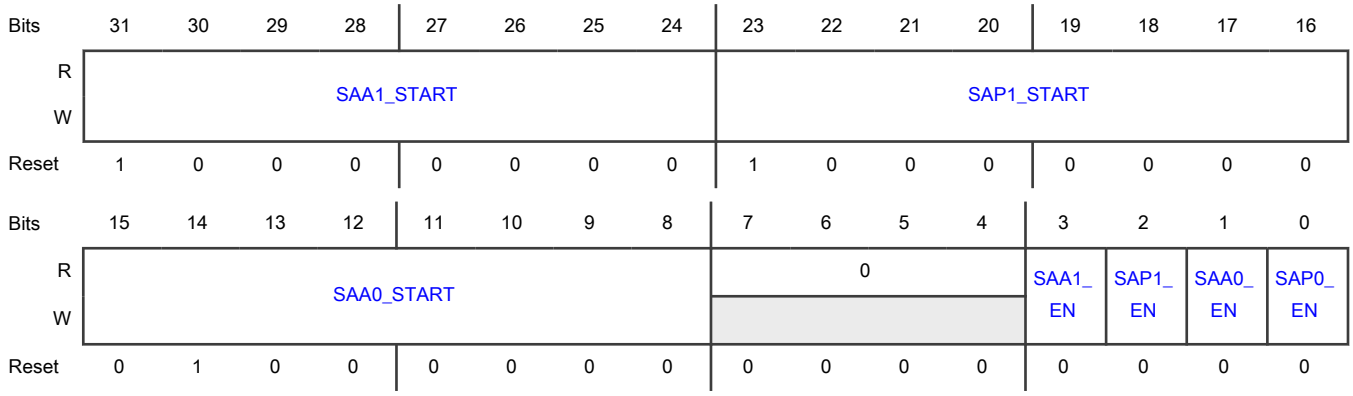
Offset

Register	Offset
SAM_CTRL	D4h

Function

Source Address Management Control Register

Diagram



Fields

Field	Function
31-24 SAA1_START	First Index of SAA1 partition
23-16 SAP1_START	First Index of SAP1 partition
15-8 SAA0_START	First Index of SAA0 partition
7-4 —	Reserved
3 SAA1_EN	Enables SAA1 Partition of the SAM Table 0b - Disables SAA1 Partition 1b - Enables SAA1 Partition
2 SAP1_EN	Enables SAP1 Partition of the SAM Table 0b - Disables SAP1 Partition 1b - Enables SAP1 Partition
1 SAA0_EN	Enables SAA0 Partition of the SAM Table 0b - Disables SAA0 Partition 1b - Enables SAA0 Partition
0 SAP0_EN	Enables SAP0 Partition of the SAM Table 0b - Disables SAP0 Partition 1b - Enables SAP0 Partition

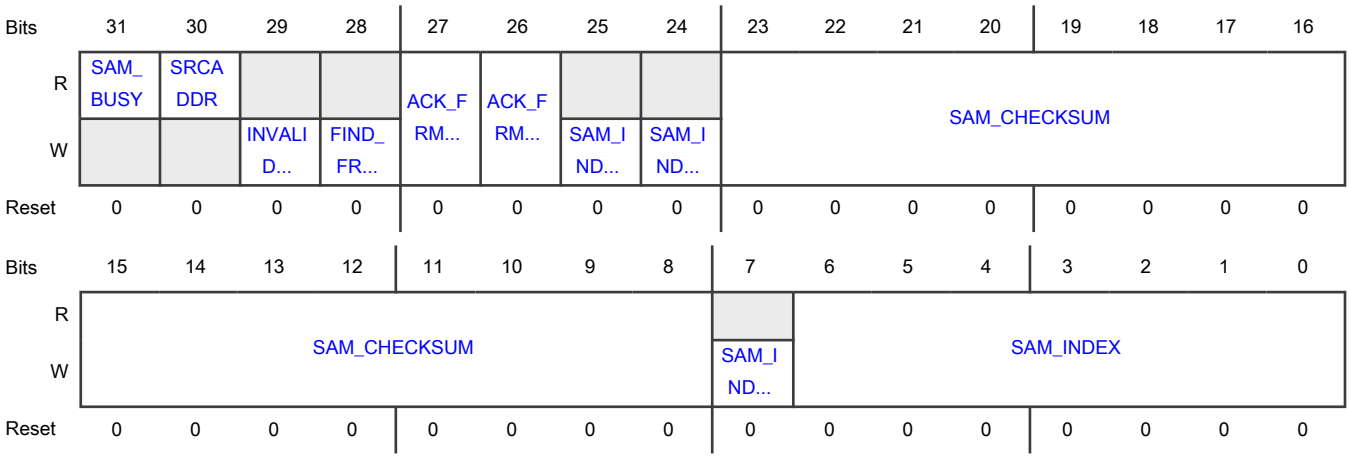
52.4.4.4.2.4.2.68 SOURCE ADDRESS MANAGEMENT TABLE (SAM_TABLE)

Offset

Register	Offset
SAM_TABLE	D8h

Function
Source Address Management Table

Diagram



Fields

Field	Function
31 SAM_BUSY	SAM Table Update Status Bit Hardware is in the process of updating the Source Address table, either in response to a poll indication from the packet processor, or due to software setting FIND_FREE_IDX=1. In the latter case, software should poll SAM_BUSY until low before accessing the "First Free Index" registers. Read-only bit.
30 SRCADDR	Source Address Match Status If Source Address Management is engaged, meaning at least one of the following bits is set: SAP0_EN SAA0_EN SAP1_EN SAA1_EN Then SRCADDR will be set to 1 if the packet just received is a poll request (PI=1), *and* at least one of the following conditions is met: SAP0_EN and SAP0_ADDR_PRESENT SAA0_EN and SAA0_ADDR_ABSENT SAP1_EN and SAP1_ADDR_PRESENT

Table continues on the next page...

Table continued from the previous page...

Field	Function
	SAA1_EN and SAA1_ADDR_ABSENT If SRCADDR=1, this indicates to SW that the Packet Processor has determined that an auto-TxACK frame must be transmitted with the FramePending subfield of the FrameControlField set to 1. HW will assemble and transmit this Ack packet. If the above conditions are not met, SRCADDR will be cleared to 0.
29 INVALIDATE_ALL	Invalidate Entire SAM Table Writing a 1 to this bit clears all 128 Valid bits. Invalidates the entire table. Write-only bit. Writing 0 to this bit has no effect. Readback value is indeterminate.
28 FIND_FREE_IDX	Find First Free Index After modifying Valid bits (enabling or invalidating), write this bit to 1 to force hardware to update the "First Free Index" registers to account for the changed Valid bits. This hardware update process takes 4us. Software can poll SAM_BUSY to determine when the table update is complete. Write-only bit. Writing 0 to this bit has no effect. Readback value is indeterminate.
27 ACK_FRM_PND_CTRL	Manual Control for AutoTxAck FramePending field 0b - the FramePending field of the Frame Control Field of the next automatic TX acknowledge packet is determined by hardware 1b - the FramePending field of the Frame Control Field of the next automatic TX acknowledge packet tracks ACK_FRM_PEND
26 ACK_FRM_PND	State of AutoTxAck FramePending field when SAM Acceleration is Disabled Software can take manual control of the FramePending field of the Frame Control Field of the next automatic TX acknowledge packet, by setting ACK_FRM_PND_CTRL=1; in that case FramePending will track the state of this bit. The FramePending field also tracks this bit if Source Address Management is completely disabled, i.e., SAP0_EN=SAA0_EN=SAP1_EN=SAA1_EN=0 Otherwise, the FramePending field is determined by Source Address Management (SAM) hardware.
25 SAM_INDEX_EN	Enable the SAM table index selected by SAM_INDEX
24 SAM_INDEX_INV	Invalidate the SAM table index selected by SAM_INDEX
23-8 SAM_CHECKSUM	Software-computed source address checksum, to be installed into a table index Software-computed source address checksum, to be installed into a table index. The value on SAM_CHECKSUM[15:0] can be installed into the table with a single, atomic 32-bit write; in that case, the write data would contain the desired SAM_INDEX[6:0] and SAM_CHECKSUM[15:0], and SAM_INDEX_WR=1.

Table continues on the next page...

Table continued from the previous page...

Field	Function
	If SAM_INDEX_WR=0, then the SAM_INDEX[6:0] register is written, but the checksum is *not* written to the table. The readback value of SAM_CHECKSUM[15:0] is the contents of the SAM Table at the location pointed to by SAM_INDEX[6:0]. To readback from a specific table index, software should first write the desired index to SAM_INDEX[6:0], and then read back the checksum from the table on SAM_CHECKSUM[15:0].
7 SAM_INDEX_WR	Enables SAM Table Contents to be updated For 32-bit writes, SAM_INDEX_WR must be set to indicate that the table entry specified by SAM_INDEX[6:0] is to be written; if SAM_INDEX_WR=0, the table entry is not written, but the SAM_INDEX[6:0] register is updated. For 8-bit writes, this bit is ignored.
6-0 SAM_INDEX	Contains the SAM table index to be enabled or invalidated Contains the table index to be enabled or invalidated. Software must ensure that the index is within the range of the desired partition.

52.4.4.4.2.4.2.69 SOURCE ADDRESS MANAGEMENT MATCH (SAM_MATCH)

Offset

Register	Offset
SAM_MATCH	DCh

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	SAA1_AD...	SAA1_MATCH							SAP1_AD...	SAP1_MATCH						
W																
Reset	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	SAA0_AD...	SAA0_MATCH							SAP0_AD...	SAP0_MATCH						
W																
Reset	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1

Fields

Field	Function
31	A Checksum Match is Absent in the SAP1 Partition of the SAM Table

Table continues on the next page...

Table continued from the previous page...

Field	Function
SAA1_ADDR_ABSENT	
30-24 SAA1_MATCH	Index in the SAA1 Partition of the SAM Table corresponding to the first checksum match
23 SAP1_ADDR_PRESENT	A Checksum Match is Present in the SAP1 Partition of the SAM Table
22-16 SAP1_MATCH	Index in the SAP1 Partition of the SAM Table corresponding to the first checksum match
15 SAA0_ADDR_ABSENT	A Checksum Match is Absent in the SAA0 Partition of the SAM Table
14-8 SAA0_MATCH	Index in the SAA0 Partition of the SAM Table corresponding to the first checksum match
7 SAP0_ADDR_PRESENT	A Checksum Match is Present in the SAP0 Partition of the SAM Table
6-0 SAP0_MATCH	Index in the SAP0 Partition of the SAM Table corresponding to the first checksum match

52.4.4.4.2.4.2.70 SAM FREE INDEX (SAM_FREE_IDX)

Offset

Register	Offset
SAM_FREE_IDX	E0h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	SAA1_1ST_FREE_IDX								SAP1_1ST_FREE_IDX							
W																
Reset	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	SAA0_1ST_FREE_IDX								SAP0_1ST_FREE_IDX							
W																
Reset	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Fields

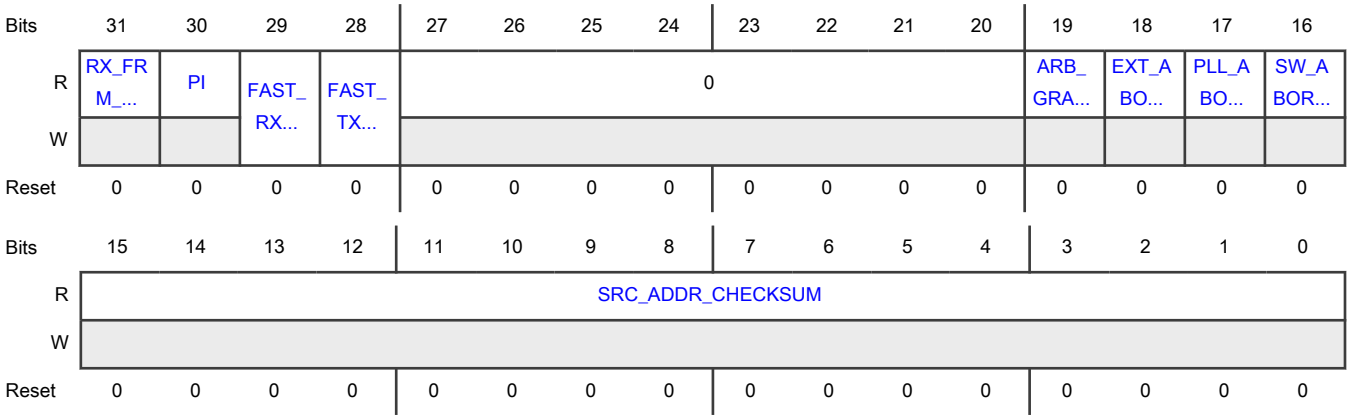
Field	Function
31-24 SAA1_1ST_FREE_IDX	First non-enabled (invalid) index in the SAA1 partition
23-16 SAP1_1ST_FREE_IDX	First non-enabled (invalid) index in the SAP1 partition
15-8 SAA0_1ST_FREE_IDX	First non-enabled (invalid) index in the SAA0 partition
7-0 SAP0_1ST_FREE_IDX	First non-enabled (invalid) index in the SAP0 partition

52.4.4.4.2.4.2.71 MISCELLANEOUS(1) (MISC1)

Offset

Register	Offset
MISC1	E4h

Diagram



Fields

Field	Function
31 RX_FRM_PEND	RX Frame Pending Status of the frame pending bit of the frame control field for the most-recently received packet. Read-only.
30 PI	Poll Indication 0b - the received packet was not a data request 1b - the received packet was a data request, regardless of whether a Source Address table match occurred, or whether Source Address Management is enabled or not
29 FAST_RX_WU_OVRD	FAST_RX_WU override 0b - If TSM enables Fast Warmup Capability, LL will request it when RX in TR 1b - If TSM enables Fast Warmup Capability, LL will request it at every RX. User should insure channel is not changed since last sequence.
28 FAST_TX_WU_OVRD	FAST_TX_WU override 0b - If TSM enables Fast Warmup Capability, LL will request it when TX in RT or (CCA+TX) 1b - If TSM enables Fast Warmup Capability, LL will request it at every TX. User should insure channel is not changed since last sequence.
27-20 —	Reserved
19 ARB_GRANT_DEASSERTION_ABORTED	Autosequence has terminated due to an arb_grant de-assertion event when asserted, indicates that the autosequence has terminated due to an arb_grant de-assertion event. This bit is valid at the SEQ_END_IRQ interrupt. Hardware will maintain this bit asserted until the next autosequence commences. Read-only bit.
18	Autosequence has terminated due to a Wake-On-Radio command

Table continues on the next page...

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Field	Function
EXT_ABORTED	when asserted, indicates that the autosequence has terminated due to an external event, such as a Wake-On-Radio stop command. This bit is valid at the SEQ_END_IRQ interrupt. Hardware will maintain this bit asserted until the next autosequence commences. Read-only bit.
17 PLL_ABORTED	Autosequence has terminated due to an PLL unlock event. When asserted, indicates that the autosequence has terminated due to an PLL unlock event. This bit is valid at the SEQ_END_IRQ interrupt. Hardware will maintain this bit asserted until the next autosequence commences. Read-only bit.
16 SW_ABORTED	Autosequence has terminated due to a Software abort. When asserted, indicates that the autosequence has terminated due to an Software abort. Software can abort any programmed autosequence by writing Sequence I to XCVSEQ. This bit is valid at the SEQ_END_IRQ interrupt. Hardware will maintain this bit asserted until the next autosequence commences. Read-only bit.
15-0 SRC_ADDR_CHECKSUM	Hardware-computed received source address checksum The checksum is computed on-the-fly by hardware as the source address octets are received

52.4.4.4.2.4.2.72 SEQUENCE STATUS (SEQ_STS)

Offset

Register	Offset
SEQ_STS	E8h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				SEQ_T_STATUS				0							CCA_STA...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	CCA_STA...	TR_STAR...	TR_STAR...	RX_IN_W...	RX_IN_P...	RX_IN_S...	RX_IN_W...	RX_STOP...	RX_STOP...	RX_STAR...	RX_STAR...	TX_IN_W...	TX_IN_P...	TX_IN_W...	TX_STAR...	TX_STAR...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-29 —	Reserved
28-24 SEQ_T_STATUS	Status of the just-completed or ongoing Sequence T or Sequence TR Status of the just-completed (or ongoing) Sequence T or Sequence TR autosequence. This register is valid at all times during, and after, the Sequence T or Sequence TR. Not valid for other types of autosequences. This is a read-only register. The bits of this register map to status, according to the following table: [0] 1st CCA complete (CCABFRTX=1) [1] 2nd CCA complete (SLOTTED=1) [2] Tx operation complete [3] Rx Recycle occurred (Sequence TR only) [4] Rx operation complete (Sequence TR only)
23-17 —	Reserved
16 CCA_START_T2_PEND	CCA T2 Start Pending Status CCA Sequence will start @ next T2 Match
15 CCA_START_T1_PEND	CCA T1 Start Pending Status CCA Sequence will start @ next T1 Match
14 TR_START_T2_PEND	TR T2 Start Pending Status TR Sequence will start @ next T2 Match
13 TR_START_T1_PEND	TR T1 Start Pending Status TR Sequence will start @ next T1 Match
12 RX_IN_WARMDN	RX Warm-down Status RX Sequence in TSM Warm-down
11 RX_IN_PROGRESS	RX in Progress Status RX Packet Reception Currently Underway
10	RX Search Status RX Sequence in Network Address Search

Table continues on the next page...

Table continued from the previous page...

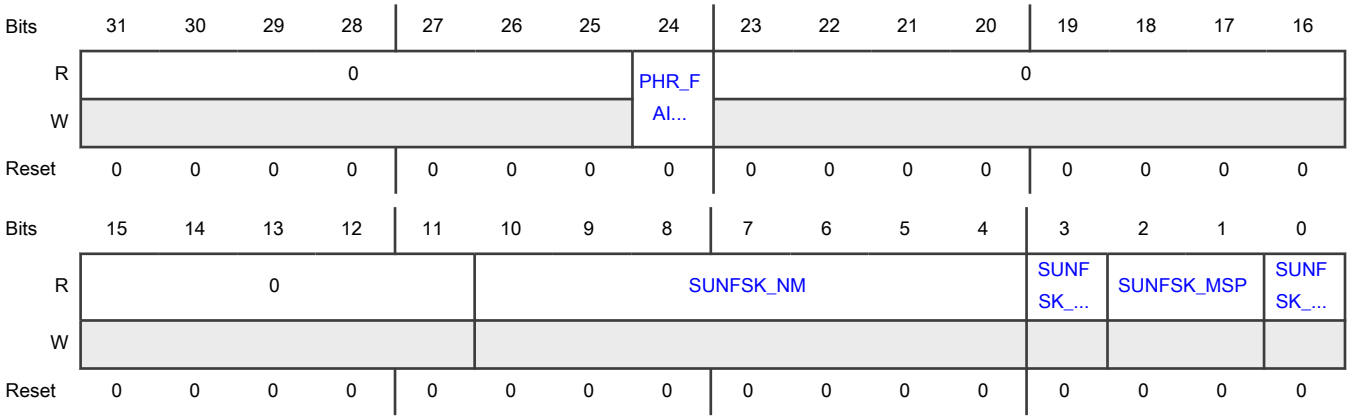
Field	Function
RX_IN_SEARCH	
9 RX_IN_WARMUP	RX Warmup Status RX Sequence in TSM Warmup
8 RX_STOP_T2_PEND	RX T2 Start Pending Status RX Sequence will stop @ next T2 Match
7 RX_STOP_T1_PEND	RX T1 Stop Pending Status RX Sequence will stop @ next T1 Match
6 RX_START_T2_PEND	RX T2 Start Pending Status RX Sequence will start @ next T2 Match
5 RX_START_T1_PEND	RX T1 Start Pending Status RX Sequence will start @ next T1 Match
4 TX_IN_WARMDN	TX Warm-down Status TX Sequence in TSM Warm-down
3 TX_IN_PROGRESS	TX in Progress Status TX Packet Transmission Currently Underway
2 TX_IN_WARMUP	TX Warmup Status TX Sequence in TSM Warmup
1 TX_START_T2_PEND	TX T2 Start Pending Status TX Sequence will start @ next T2 Match
0 TX_START_T1_PEND	TX T1 Start Pending Status TX Sequence will start @ next T1 Match

52.4.4.4.2.4.2.73 PHR MISCELLANEOUS (PHR_MISC)

Offset

Register	Offset
PHR_MISC	ECh

Diagram



Fields

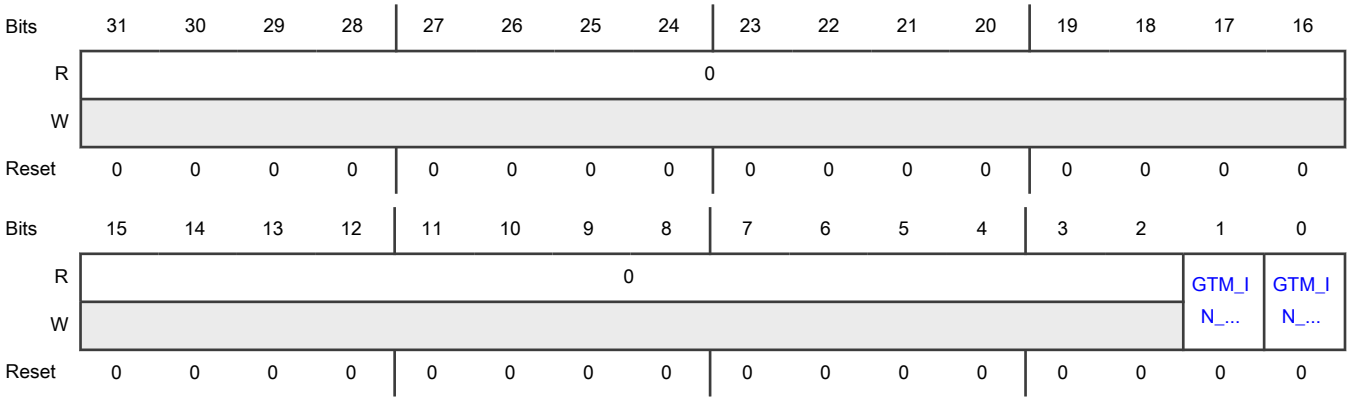
Field	Function
31-25 —	Reserved
24 PHR_FAIL_IGNORE	Ignore PHR Fail If set, assert RX_IRQ even for a received packet which fails PHR verification.
23-11 —	Reserved
10-4 SUNFSK_NM	New Mode Bit SUN FSK Mode Switch PHR New Mode Bit
3 SUNFSK_FEC	New Mode FEC Bit SUN FSK Mode Switch PHR New Mode FEC Bit
2-1 SUNFSK_MSP	Mode Switch Parameter Bit SUN FSK Mode Switch PHR Mode Switch Parameter Bit
0 SUNFSK_MS	Mode Switch Bit SUN FSK Mode Switch PHR Mode Switch Bit

52.4.4.4.2.4.2.74 GTM CONTROL (GTM_CTRL)

Offset

Register	Offset
GTM_CTRL	F0h

Diagram



Fields

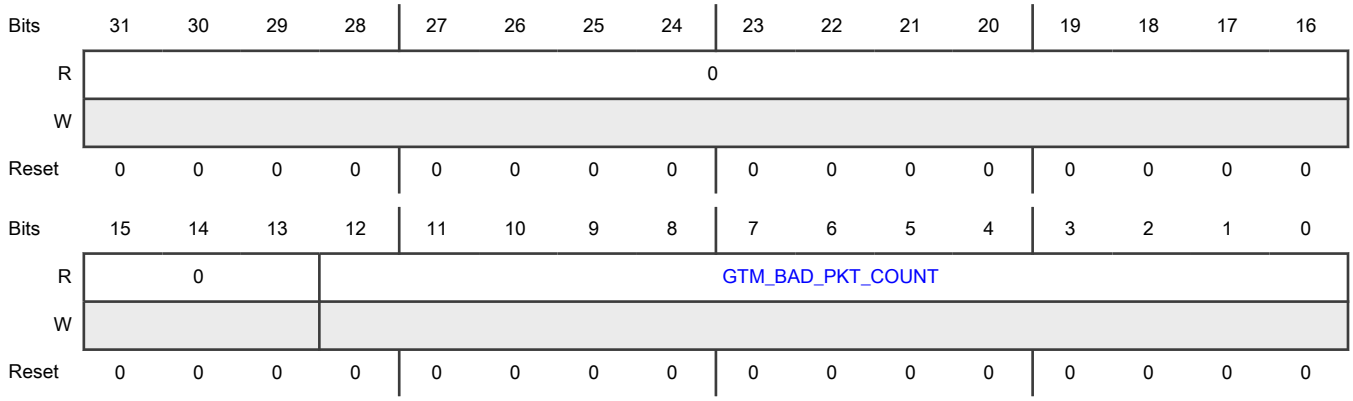
Field	Function
31-2 —	Reserved
1 GTM_IN_TX	Enable GTM Transmit Mode 0b - GTM transmit mode is not enabled. 1b - GTM transmit mode is enabled.
0 GTM_IN_RX	Enable GTM Receive Mode 0b - GTM receive mode is not enabled. 1b - GTM receive mode is enabled.

52.4.4.4.2.4.2.75 GTM BAD PACKET COUNTER (GTM_BAD_CNT)

Offset

Register	Offset
GTM_BAD_CNT	F4h

Diagram



Fields

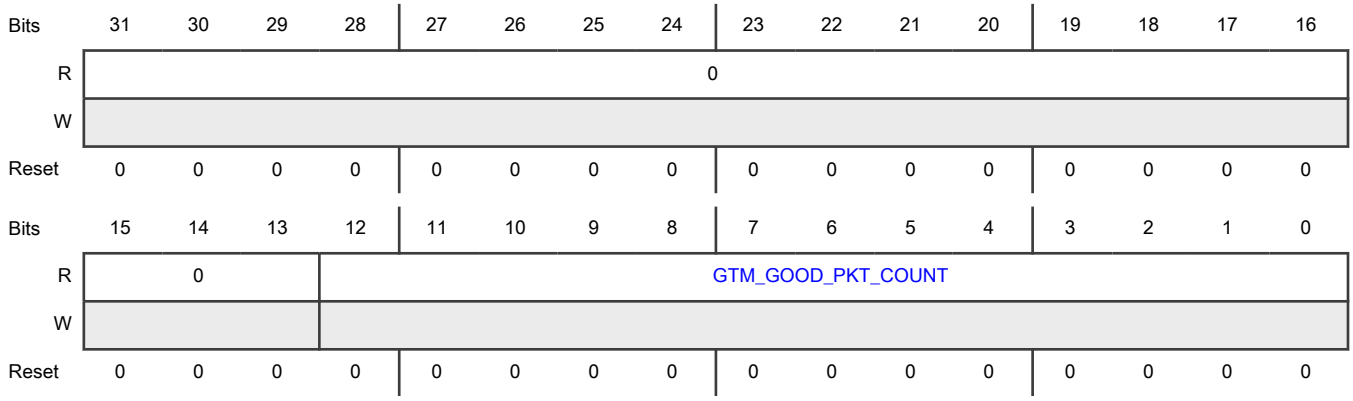
Field	Function
31-13 —	Reserved
12-0 GTM_BAD_PKT_COUNT	GTM Bad Packet Counter The Packet is counted as "Bad" for CRC fail or header(H0/Length/H1) fail or there is no AA matched. This register is reset to zero when bit GTM_IN_RX is written to 1.

52.4.4.4.2.4.2.76 GTM GOOD PACKET COUNTER (GTM_GOOD_CNT)

Offset

Register	Offset
GTM_GOOD_CNT	F8h

Diagram



Fields

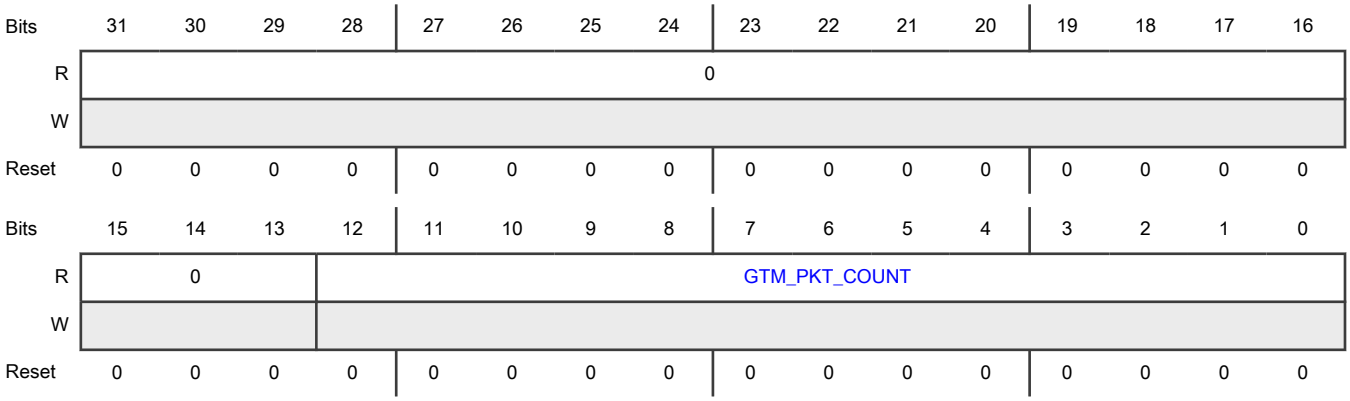
Field	Function
31-13 —	Reserved
12-0 GTM_GOOD_PKT_COUNT	GTM Good Packet Counter The Packet is counted as "Good" when there is no CRC fail or header(H0/Length/H1) fail. This register is reset to zero when bit GTM_IN_RX is written to 1.

52.4.4.4.2.4.2.77 GTM PACKET COUNTER (GTM_PKT_CNT)

Offset

Register	Offset
GTM_PKT_CNT	FCh

Diagram



Fields

Field	Function
31-13 —	Reserved
12-0 GTM_PKT_COUNT	GTM Packet Counter For Tx process, it counts for the number of packet sent; for Rx, it is same as (GTM_GOOD_PKT_COUNT + GTM_BAD_PKT_COUNT). This register is reset to zero when bit GTM_IN_RX or GTM_IN_TX is written to 1.

52.4.4.4.2.4.2.78 COEXISTENCE CONTROL (COEX_CTRL)

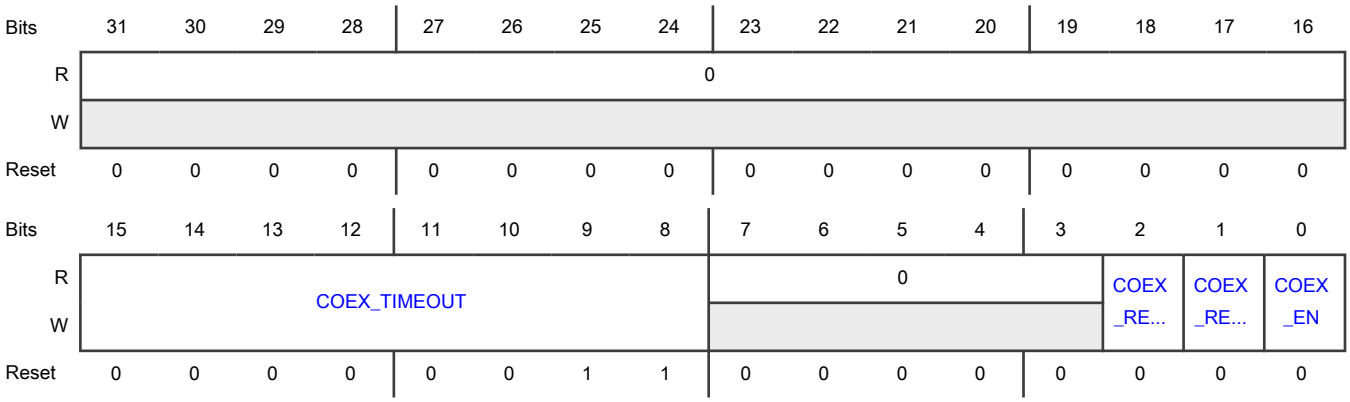
Offset

Register	Offset
COEX_CTRL	100h

Function

Coexistence Control Registers.

Diagram



Fields

Field	Function
31-16 —	Reserved
15-8 COEX_TIMEOUT	Coexistence timeout value After arb_request asserts, arb_grant should assert before the timeout value. Otherwise the sequence is abort and COEX_TIMEOUT_IRQ bit is set. The step of the timeout value is 32us.
7-3 —	Reserved
2 COEX_REQ_ON_PD	Coexistence Request on Preamble detected 0b - arb_request is delayed until Access Address is detected during R sequence. 1b - arb_request is delayed until preamble is detected during R sequence.
1 COEX_REQ_DELAY_EN	Coexistence Request Delay Enable 0b - arb_request is not delayed during R sequence. 1b - arb_request is delayed until preamble or Access Address is detected during R sequence.
0 COEX_EN	Coexistence Enable 0b - Coexistence function is disabled. 1b - Coexistence function is enabled.

52.4.4.4.2.4.2.79 COEXISTENCE PRIORITY (COEX_PRIORITY)

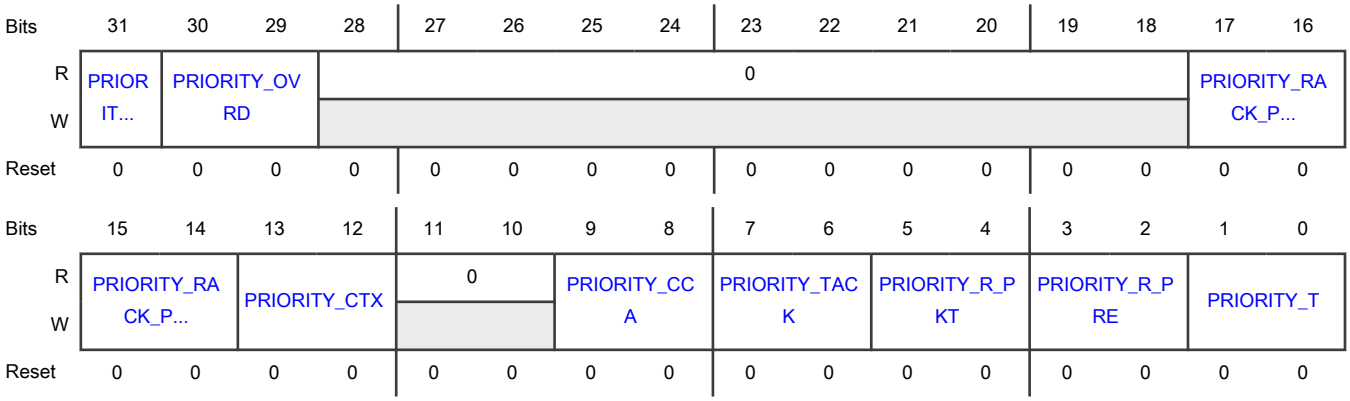
Offset

Register	Offset
COEX_PRIORITY	104h

Function

Programmable 2-bit priority for each RX or TX state.

Diagram



Fields

Field	Function
31 PRIORITY_OVRD_EN	PRIORITY_OVRD_EN Enable/Disable overriding PRIORITY value. 0b - Disable overriding PRIORITY value. 1b - Enable overriding PRIORITY value.
30-29 PRIORITY_OVRD	PRIORITY_OVRD When PRIORITY_OVRD_EN is set to 1, PRIORITY_OVRD is used to override PRIORITY value.
28-18 —	Reserved
17-16 PRIORITY_RACK_PKT	PRIORITY_RACK_PKT PRIORITY value during receiving ACK packet.
15-14	PRIORITY_RACK_PRE PRIORITY value during searching preamble of ACK packet.

Table continues on the next page...

Table continued from the previous page...

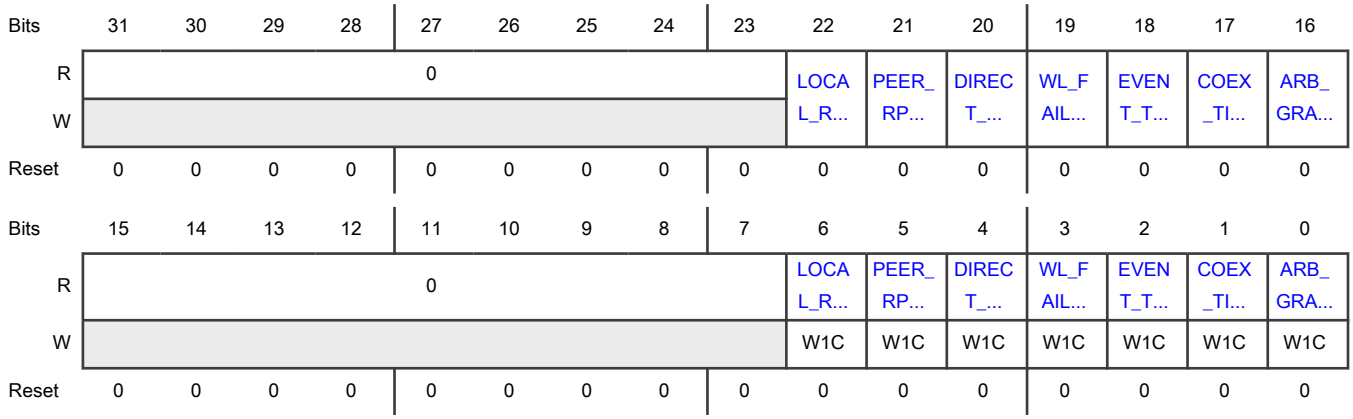
Field	Function
PRIORITY_RACK_PRE	
13-12 PRIORITY_CTX	PRIORITY_CT PRIORITY value for CCA before TX Packet.
11-10 —	Reserved
9-8 PRIORITY_CCA	PRIORITY_CCA PRIORITY value for CCA.
7-6 PRIORITY_TACK	PRIORITY_TACK PRIORITY value for TX ACK Packet.
5-4 PRIORITY_R_PKT	PRIORITY_R_PKT PRIORITY value for RX Packet.
3-2 PRIORITY_R_PRE	PRIORITY_R_PRE PRIORITY value of searching Preamble for RX Packet.
1-0 PRIORITY_T	PRIORITY_T PRIORITY value for TX Packet.

52.4.4.4.2.4.2.80 IRQ CONTROL 2 (IRQ_CTRL2)

Offset

Register	Offset
IRQ_CTRL2	108h

Diagram



Fields

Field	Function
31-23 —	Reserved
22 LOCAL_RPA_FAIL_IRQ_EN	0b - LOCAL_RPA_FAIL Interrupt is not enabled. 1b - LOCAL_RPA_FAIL Interrupt is enabled.
21 PEER_RPA_FAIL_IRQ_EN	0b - PEER_RPA_FAIL Interrupt is not enabled. 1b - PEER_RPA_FAIL Interrupt is enabled.
20 DIRECT_ID_FAIL_IRQ_EN	0b - DIRECT_ID_FAIL Interrupt is not enabled. 1b - DIRECT_ID_FAIL Interrupt is enabled.
19 WL_FAIL_IRQ_EN	0b - WL_FAIL Interrupt is not enabled. 1b - WL_FAIL Interrupt is enabled.
18 EVENT_TIMER_OVER_FLOW_IRQ_EN	Event Timer Overflow Interrupt enable bit 0b - Interrupt generation is disabled, but an EVENT_TIMER_OVER_FLOW_IRQ flag can be set 1b - allows interrupt when Event Timer overflow
17 COEX_TIMEOUT_IRQ_EN	Coexistence Timeout Interrupt enable bit 0b - Interrupt generation is disabled, but a COEX_TIMEOUT_IRQ flag can be set 1b - allows interrupt when coexistence timeout
16	arb_grant Deassertion Interrupt enable

Table continues on the next page...

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Field	Function
ARB_GRANT_DEASSERTION_IRQ_EN	0b - An arb_grant deassertion event will set the ARB_GRANT_DEASSERTION_IRQ status bit, but no interrupt is not generated 1b - allows arb_grant deassertion event to generate an interrupt
15-7 —	Reserved
6 LOCAL_RPA_FAIL_IRQ	Local RPA Check Fail Interrupt Interrupt flag to show that local address is not in LRPA list and can not be resolved. This is write '1' to clear bit.
5 PEER_RPA_FAIL_IRQ	Peer RPA Check Fail Interrupt Interrupt flag to show that peer address is not in PRPA list and can not be resolved. This is write '1' to clear bit.
4 DIRECT_ID_FAIL_IRQ	Direct Case Check Fail Interrupt Interrupt flag to show that peer address and address type do not match the DIRECT_PEER_ADDRESS and DIRECT_PEER_ADDRESS_TYPE register. This is write '1' to clear bit.
3 WL_FAIL_IRQ	White List Check Fail Interrupt Interrupt flag to show that identity address resolved(RPA is enabled) or peer address received(RPA is not enabled) and its address type are not in the white list. This is write '1' to clear bit.
2 EVENT_TIMER_OVER_FLOW_IRQ	Event Timer Overflow Interrupt Indicates Event Timer overflow occurs. This is write '1' to clear bit.
1 COEX_TIMEOUT_IRQ	Coexistence Timeout Interrupt Indicates coexistence timeout occurs. This is write '1' to clear bit.
0 ARB_GRANT_DEASSERTION_IRQ	arb_grant Deassertion IRQ arb_grant(!RF_NOT_ALLOWED) Deassertion Interrupt Status bit. A '1' indicates an arb_grant deassertion event has occurred. This is write a '1' to clear bit. 0b - An arb_grant Deassertion Interrupt has not occurred 1b - An arb_grant Deassertion Interrupt has occurred

52.4.4.4.2.4.3 Manual DSM

When the GENERIC_FSK Link Layer anticipates long periods of inactivity, the Link Layer controller can be put into a Deep Sleep Mode (DSM), where all of its clocks are turned off. In addition, the GENERIC_FSK Link Layer can be configured to optionally turn off the RF Oscillator, if it is not otherwise needed by the SoC. Deep Sleep Mode results in dramatic power savings. The procedure described below, is called Manual DSM.

To make Manual DSM possible, the transceiver incorporates a low-frequency, high-precision Deep Sleep Timer, TIMER. This timer is clocked by a crystal-referenced 32.768KHz oscillator. The timer is 24-bit wide, yielding a 8.5 minute rollover (the maximum length of a deep sleep period).

The hardware to implement DSM within the SoC, is partitioned across several modules, and several power domains. This is to allow the maximum achievable power savings, by retaining full voltage for only those modules which need to be active in DSM, and placing the remaining modules in "state retention" mode. The diagram below depicts the partitioning of DSM hardware across the various modules, including the GENERIC_FSK Link Layer Controller.

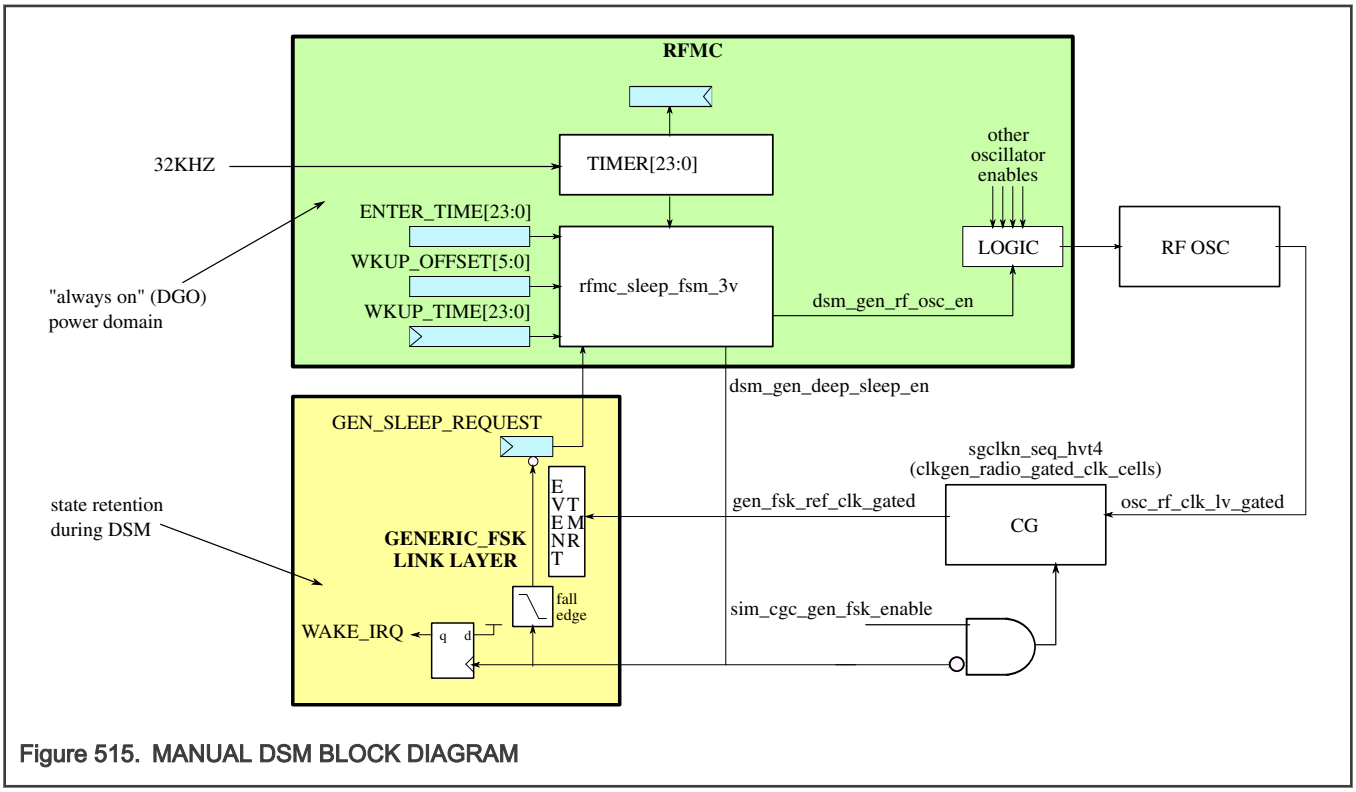

Figure 515. MANUAL DSM BLOCK DIAGRAM

The concept behind Manual DSM, as it is implemented for GENERIC_FSK, is to allow the GENERIC_FSK timebase to be maintained for a period of time, while the RF Oscillator is turned off and much of the SoC is placed in state-retention. During DSM, the timebase management is temporarily transferred from the GENERIC_FSK EVENT_TMR to the low-power TIMER, and after DSM exit, timebase management is transferred back to the EVENT_TMR, under software control. During DSM, the EVENT_TMR is frozen. The total time spent in DSM is known to software, so that upon exiting DSM, the EVENT_TMR can be updated to correct for the precise amount of time it was frozen.

DSM entry and exit, and RF Oscillator re-start during Manual DSM, are governed by 5 registers, as described in the table below.

Field	R/W	Description
ENTER_TIME[23:0]	rw	If GEN_SLEEP_REQUEST=1, enter DSM & freeze EVENT_TMR when ENTER_TIME matches TIMER. **NOTE** This register resides in RFMC Address Space
WKUP_OFFSET[5:0]	rw	Determines the power and RF oscillator re-start times relative to WKUP_TIME

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Field	R/W	Description
		NOTE This register resides in RFMC Address Space
WKUP_TIME[23:0]	rw	Exit Deep Sleep Mode, and resume EVENT_TMR, when WKUP_TIME matches TIMER **NOTE** This register resides in RFMC Address Space
GEN_SLEEP_REQUEST	w	Enable a match on ENTER_TIME[23:0] to TIMER[23:0], to enter Deep Sleep Mode, by writing a 1 to this bit. Cancel a pending sleep request by writing a 0 to it, if already set, at least 2 32.768KHz clock cycles prior to ENTER_TIME[23:0]
TIMER[23:0]	r	Current State of the 32KHz Sleep Timer **NOTE** This register resides in RFMC Address Space

Procedure

The procedure to schedule a Manual DSM cycle (entry/exit) as well as to program the desired RF Oscillator re-start time, and the calculation to restore the GENERIC_FSK EVENT_TMR after a DSM cycle, is described below.

1. Software determines the future time at which it would like to enter DSM, by reading the TIMER, computing the number of 32KHz clock cycles remaining until the desired DSM start-time, and writing this value into ENTER_TIME register. The value programmed into ENTER_TIME should be no fewer than 4 clocks greater (in the future) than the current time as read from TIMER.
2. Software determines the future time at which it would like to exit DSM, by computing the number of 32KHz clock cycles remaining until the desired DSM exit-time, and writing this value into WKUP_TIME register.
3. Software writes a 1 to DSM_CTRL[GEN_SLEEP_REQUEST]. This bit resides in GENERIC_FSK address space. Writing this bit to 1 enables a DSM cycle to commence using the values programmed into ENTER_TIME and WKUP_TIME.
4. MCU can go into a low power state (e.g., STOP, VLPS, or VLLSx)
5. When TIMER = ENTER_TIME, the EVENT_TMR will be clock-gated so that it will remain frozen at its current count. The RF Oscillator will be turned off (unless overridden due to a non-Generic-related SoC requirement)
6. All hardware not in the low-voltage domain will be placed into state-retention, or other low-power state.
7. When TIMER = WKUP_TIME, clocking of the GENERIC_FSK Link Layer Controller will resume and the EVENT_TMR will be ungated (allowed to resume counting).
8. Software computes the time that the SoC was in DSM (and hence the time the EVENT_TMR was frozen), in microseconds, with the equation:

   (WKUP_TIME - ENTER_TIME) / 32768 * 1000000
9. Software increments the GENERIC_FSK EVENT_TMR by this amount, by writing this value to EVENT_TMR[23:0] register with EVENT_TMR_ADD=1.

10. On the next 1MHz clock edge, the EVENT_TMR has been restored to where it would have been, had no DSM occurred, with 1.0-microsecond accuracy.

Note that the 1.0-microsecond accuracy quoted above, assumes an ideal 32.768KHz source. Any ppm error in the 32.768KHz source will degrade the microsecond accuracy proportionally to the magnitude of the error.

Once GEN_SLEEP_REQUEST has been set to 1 to request Manual DSM, the request can be cancelled by writing a 0 to the bit. The cancellation must be performed at least 2 32.768KHz before the ENTER_TIME[23:0] match to TIMER[23:0] to avoid a race condition to enter DSM.

The following timing diagram depicts an GENERIC_FSK-driven DSM entry/exit cycle.

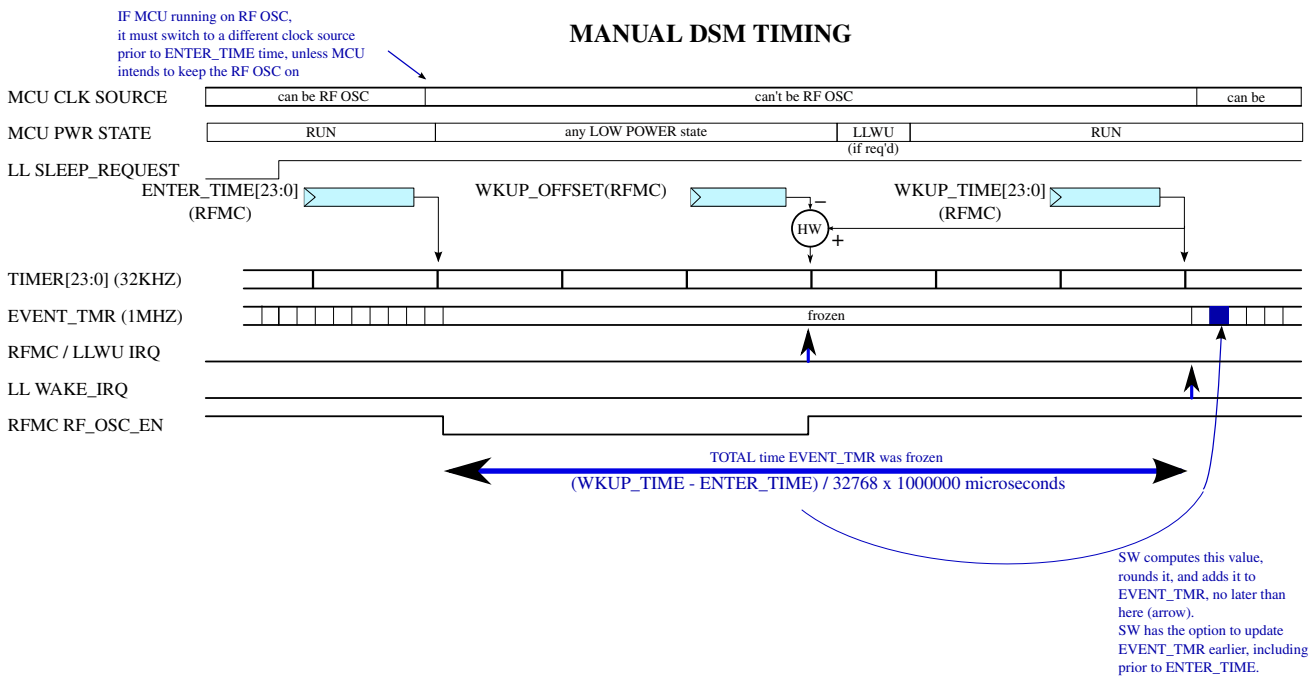

Figure 516. GENERIC_FSK DEEP SLEEP TIMING

DSM Early Exit

Circumstances may arise where the Manual DSM cycle may occasionally need to be cut short, due to circumstances beyond the control of the radio. When this happens, the SoC, starting with the MCU, is awakened out of its low power state, long before the RFMC TIMER reaches WKUP_TIME. Therefore, software handling the event which triggered the wakeup, will determine if the radio needs to be awakened as well. If this is the case, software will advance the WKUP_TIME setting to a point in the near future, but no fewer than 4 32KHz clock cycles beyond the current time ascertained by reading TIMER. So, to execute a Manual DSM Early Exit, software shall read TIMER, add +4 to the value, and write the sum to the RFMC WKUP_TIME register. Software shall then wait for the GENERIC_FSK WAKE_IRQ interrupt, which will assert once the full radio wakeup from the low power state has completed. Software should then take whatever steps are necessary to configure the radio to respond to the conditions which triggered the early exit. Servicing of a DSM early exit interrupt is beyond the scope of this document.

52.4.4.4.2.4.4 Wake-On-Radio

The GENERIC_FSK Link Layer can take advantage of the automated sequence- and DSM-scheduling provided by Wake-On-Radio. Wake-On-Radio is one of two DSM control schemes that can be selected for GENERIC_FSK, as an alternative to Manual DSM. See Chapter *Wake-On-Radio*.

Several changes to the GENERIC_FSK Link Layer Controller have been made to support Wake-On-Radio.

Interrupt WAKE_IRQ has been made dual-purpose. If Wake-On-Radio is disabled, i.e., WOR_CTRL[WOR_EN]=0, or Wake-On-Radio not assigned to GENERIC_FSK, WAKE_IRQ performs its legacy function for Manual DSM. (See Section Manual

DSM). If Wake-On-Radio is enabled, i.e., WOR_EN=1, and assigned to GENERIC_FSK, this interrupt becomes WOR_IRQ, and has new functionality specific to Wake-On-Radio. See Chapter *Wake-On-Radio*, Section *Interrupt Management*, for more details on the meaning, and handling of WOR_IRQ. The Interruptssection of this chapter describes the dual-purpose nature of WAKE_IRQ / WOR_IRQ.

In addition to WOR_IRQ, numerous interface changes have been made to support Wake-On-Radio. The changes allow, for example, WOR to manage GENERIC_FSK's RF interrupts, inhibit timestamp updates, etc. The added port signals are listed in the table below, along with a description or each:

WAKE-ON-RADIO INTERFACE SIGNAL	DIRECTION	DESCRIPTION
wor_event_tmr_add[23:0]	WOR -> GENERIC_FSK	The Event Timer "Addback" value computed by WOR to compensate for the amount of time Event Timer was frozen during DSM
wor_addback	WOR -> GENERIC_FSK	A 1µs-long pulse commanding the GENERIC_FSK Event Timer to auto-increment by the the amount appearing on wor_event_tmr_add[23:0]
wor_force_wake_irq	WOR -> GENERIC_FSK	Force WOR_IRQ to assert, due to an occurrence of one of the 3 WOR_IRQ interrupt triggers
wor_block_wake_irq	WOR -> GENERIC_FSK	Inhibit the legacy WAKE_IRQ assertion when WOR_EN=1 (this interrupt becomes WOR_IRQ)
tx_start_ext	WOR -> GENERIC_FSK	A 1µs-long pulse to the GENERIC_FSK command decoder to initiate a WOR-driven TX sequence
rx_start_ext	WOR -> GENERIC_FSK	A 1µs-long pulse to the GENERIC_FSK command decoder to initiate a WOR-driven RX sequence
seq_stop_ext	WOR -> GENERIC_FSK	A 1µs-long pulse to the GENERIC_FSK command decoder to stop (abort) a WOR-driven RX sequence
wor_allow_irq	WOR -> GENERIC_FSK	Inhibits RF interrupts, so that interrupt assertions can be managed based on WOR descriptor settings. Controlled dynamically by the WOR state machine.
timestamp_inhibit	WOR -> GENERIC_FSK	In Wake-On-Radio, the legacy GENERIC_FSK TIMESTAMP register becomes WOR TIMESTAMP0 (timestamp for SLOT0). This signal blocks this register from updating on SLOTS 1-3
wake_irq_trig	WOR <- GENERIC_FSK	WOR uses this signal to cancel GEN_SLEEP_REQUEST and transition

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WAKE-ON-RADIO INTERFACE SIGNAL	DIRECTION	DESCRIPTION
		from IN_DSM -> COMP_ADDBACK state
event_tmr[23:0]	WOR <- GENERIC_FSK	GENERIC_FSK Event Timer, used by WOR for timestamp capture
event_tmr_plus_1[23:0]	WOR <- GENERIC_FSK	GENERIC_FSK Event Timer + 1, used by WOR to schedule RF operation starts and stops
tx_irq_trig	WOR <- GENERIC_FSK	TXIRQ trigger, indicates the completion of a packet transmission, used by WOR to transition out of WAKE_SEQ_END state
rx_irq_trig	WOR <- GENERIC_FSK	RXIRQ trigger, indicates the completion of a good packet reception, used by WOR to transition out of WAKE_SEQ_END state
rx_status_for_wor[2:0]	WOR <- GENERIC_FSK	Internal RX status signals used by WOR to formulate TIMESTAMPx_STS[2:0]. **NOTE** See Section Timestamp Status for Wake-On-Radio following this table
timestamp_clk_en	WOR <- CGM <- GENERIC_FSK	Timestamp clock gate enable, the resultant clock is used by WOR to update the TIMESTAMP1,2, and 3 registers

Timestamp Status for Wake-On-Radio

The GENERIC_FSK Link Layer has 5 methods for filtering and screening packets as they are being received:

- H0 filtering
- H1 filtering
- LENGTH_MAX filtering
- PHR filtering(PAN or FAN mode)
- MAC rule filtering(PAN or FAN mode)

In Normal operation, when one or more of the filtering rules are violated, an RX recycle will occur immediately after the header, and the cause of the filtering violation (status bit) will not be preserved. In addition, the final CRC status can't be known at the point of recycle. In Wake-On-Radio operation, The TIMESTAMPx_STS[1] bit reflects CRC status, and TIMESTAMPx_STS[2] bit reflects Packet Filter status. For an RX recycle at the end of the packet header, the GENERIC_FSK Link Layer won't be able to provide the necessary signalling to Wake-On-Radio in order to properly set those 2 bits of each TIMESTAMPx_STS register, so these bits should be considered invalid. To render them valid, set the GENERIC_FSK PACKET_CFG[REC_BAD_PKT]=1, which will

force reception of the entire packet, including CRC, before recycling. Set RX_FRAME_FILTER[FILTER_FAIL_IGNORE] to ignore MAC rule filtering fail and set PHR_MISC[PHR_FAIL_IGNORE] to ignore PHR filtering rule fail. This will allow the Wake-On-Radio TIMESTAMPx_STS[2:1] bits to yield valid information.

52.4.4.4.2.4.5 Multi-protocol Arbitration

The GENERIC_FSK Link Layer controller may be included in an SoC that includes similar controllers for other protocols (e.g., Bluetooth Low Energy). GENERIC_FSK may be required to operate simultaneously with other protocols on the SoC, and there are scenarios where both protocol engines require access to the RF channel at the same time.

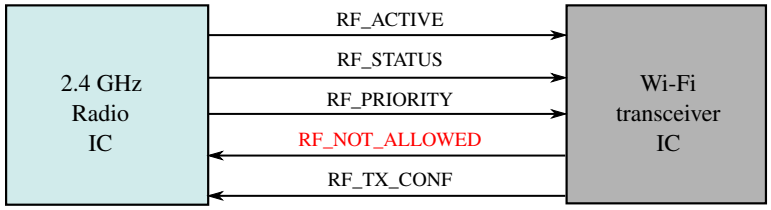
To assist in software arbitration between GENERIC_FSK and other protocols, the read-only status but XCVR_BUSY has been included in the XCVR_STS register. When this bit is set, this indicates that the RF channel is currently in use (TSM is busy), by one of the Radio's four link layer controllers. When this bit it clear, the RF channel is available to GENERIC_FSK (TSM is idle).

52.4.4.4.2.4.6 Wifi Coexistence

Provisions have been made to allow for the 2.4GHz transceiver to coexist in the same space as a WiFi transceiver IC, which shares the same frequency band. The coexistence scheme designates the WiFi transceiver as the master, and the 2.4GHz transceiver as the slave. The objective of the coexistence strategy is to prevent both the WiFi and 2.4GHz transceivers transmitting simultaneously; a configuration option exists to also prevent the 2.4GHz transceiver from receiving when the WiFi transceiver owns the RF channel.

The 2.4GHz Radio IC support the coexistence interface signals as shown in the figure below, though in a typical application only a subset of these are used.

The WiFi IC generates a signal, RF_NOT_ALLOWED. If this signal is asserted, then 2.4GHz radio does not perform any communication. When this signal is de-asserted, then 2.4GHz radio is free to perform communications.



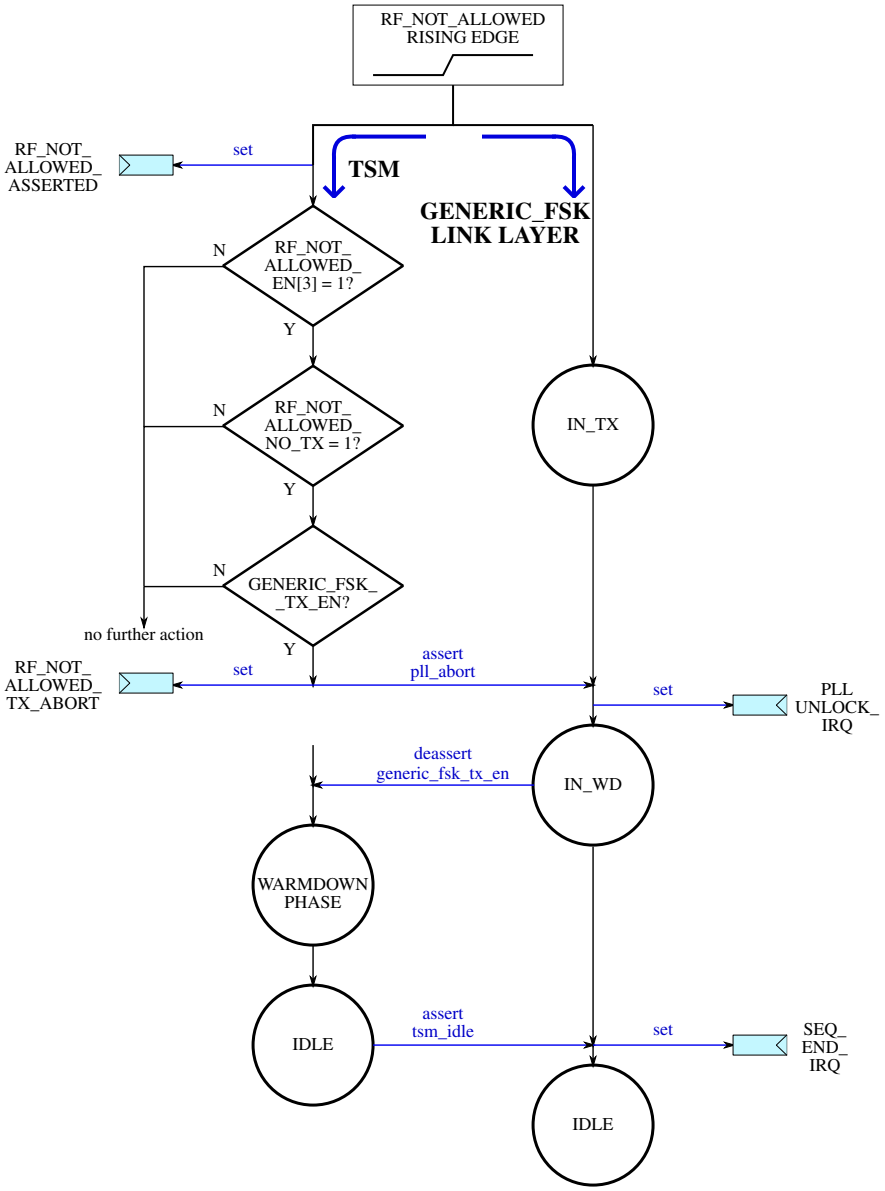
When RF_NOT_ALLOWED aborting is enabled, the GENERIC_FSK Link Layer hardware must respond to RF_NOT_ALLOWED assertions, by aborting any TX or RX sequence which is currently underway, and Link Layer software must not initiate any new sequences until RF_NOT_ALLOWED has been deasserted. The hardware response must be handled autonomously by the Link Layer, with no MCU intervention required. This is because the RF_NOT_ALLOWED assertions can occur during a Wake-On-Radio timeslot which has been designated as "no-MCU-wakeup" in the slot's descriptor. In this scenario, the aborting of the sequence occurs without any assistance from, or notification of, the MCU.

In the multi-protocol 2.4GHz radio, RF_NOT_ALLOWED aborting can be individually enabled/disabled for each protocol engine. For GENERIC_FSK, RF_NOT_ALLOWED_EN[3] is the associated enable control bit. This bit resides in the COEX_CTRL register in XCVR address space. When this bit is 0, transitions on RF_NOT_ALLOWED are ignored by the GENERIC_FSK Link Layer hardware; when this bit is 1, the GENERIC_FSK Link Layer hardware will monitor RF_NOT_ALLOWED at all times, and abort any active sequence which is underway when an assertion on the pin occurs. The complete hardware response to RF_NOT_ALLOWED assertions is described below.

Additional control over RF_NOT_ALLOWED aborting is provided by the RF_NOT_ALLOWED_NO_TX and RF_NOT_ALLOWED_NO_RX control bits. If RF_NOT_ALLOWED_NO_TX=1, then an RF_NOT_ALLOWED abort will occur only if a GENERIC_FSK TX sequence is underway (generic_fsk_tx_en=1). GENERIC_FSK TX sequences will not be aborted if RF_NOT_ALLOWED_NO_TX=0. If RF_NOT_ALLOWED_NO_RX=1, then an RF_NOT_ALLOWED abort will occur only if GENERIC_FSK RX sequence is underway (generic_fsk_rx_en=1). GENERIC_FSK RX sequences will not be aborted if RF_NOT_ALLOWED_NO_RX=0. The RF_NOT_ALLOWED_NO_TX and RF_NOT_ALLOWED_NO_RX control bits reside in the COEX_CTRL register.

For the purposes of triggering a hardware abort, the *pll_abort* input to the GENERIC_FSK Link Layer hardware is used. This is because the hardware response to the RF_NOT_ALLOWED assertion is identical to that of a PLL unlock event. This also means that, when RF_NOT_ALLOWED aborting is enabled for GENERIC_FSK the PLL_UNLOCK_IRQ interrupt status bit, will be dual purpose: it will not only indicate a PLL unlock condition, but also a RF_NOT_ALLOWED abort. PLL aborting and RF_NOT_ALLOWED aborting are enabled separately, with the COEX_CTRL register maintaining the control bits required for the latter. The status bits for RF_NOT_ALLOWED aborting are also available in COEX_CTRL, so that software will be able to distinguish the source of the PLL_UNLOCK_IRQ, in case both PLL and RF_NOT_ALLOWED aborting are enabled.

The sequence of events which results in a hardware abort of an GENERIC_FSK TX operation triggered by an assertion on RF_NOT_ALLOWED, is a collaboration between the TSM (Transceiver Sequence Manager) and the GENERIC_FSK Link Layer hardware, as shown in the following diagram.



Upon assertion on RF_NOT_ALLOWED, the TSM sets the RF_NOT_ALLOWED_ASSERTED status bit in COEX_CTRL, then checks that the conditions for a hardware abort are all met:

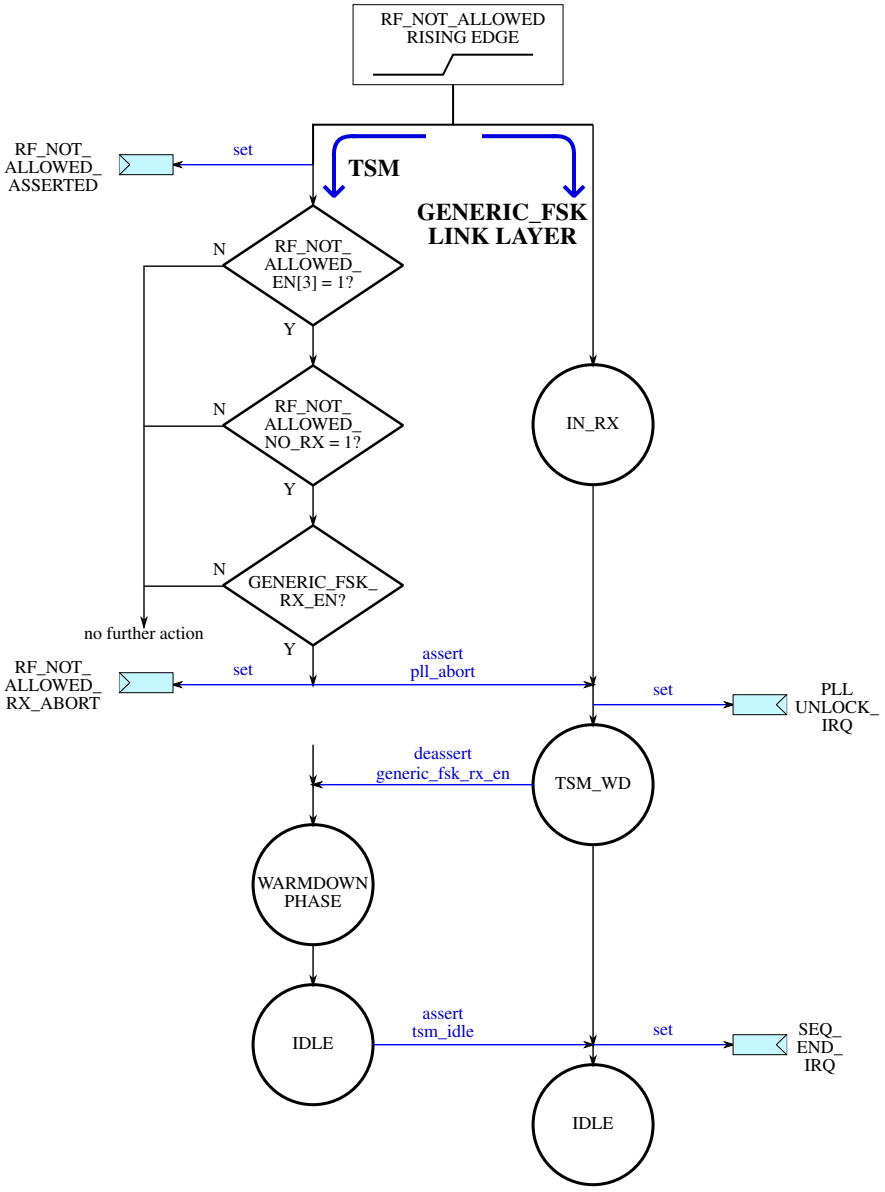
- RF_NOT_ALLOWED_EN[3] = 1, which enables GENERIC_FSK to respond to RF_NOT_ALLOWED events
- RF_NOT_ALLOWED_NO_TX = 1, which enables TX operations to be aborted

- generic_fsk_tx_en = 1, TX request to TSM from GENERIC_FSK, indicating TX operation in progress

If all conditions are not met, no further action is taken. Otherwise, the TSM sets COEX_CTRL[RF_NOT_ALLOWED_TX_ABORT], and also asserts *pll_unlock* to the GENERIC_FSK Link Layer hardware. GENERIC_FSK responds by asserting IRQ_CTRL[PLL_UNLOCK_IRQ] in GENERIC_FSK address space. GENERIC_FSK enters IN_WD state, which deasserts generic_fsk_tx_en to the TSM. This initiates the TSM TX warmdown. GENERIC_FSK holds in IN_WD to wait for TSM to return to idle. Once this occurs, GENERIC_FSK asserts IRQ_CTRL[SEQ_END_IRQ] and returns to its IDLE state. Three status bits are now set to indicate to software that the source of the abort was an RF_NOT_ALLOWED assertion:

- IRQ_CTRL[PLL_UNLOCK_IRQ]
- COEX_CTRL[RF_NOT_ALLOWED_ASSERTED]
- COEX_CTRL[RF_NOT_ALLOWED_TX_ABORT]

The sequence of events which results in a hardware abort of an GENERIC_FSK RX sequence triggered by an assertion on RF_NOT_ALLOWED, is shown in the following diagram.



Upon assertion on RF_NOT_ALLOWED, the TSM sets the RF_NOT_ALLOWED_ASSERTED status bit in COEX_CTRL, then checks that the conditions for a hardware abort are all met:

- RF_NOT_ALLOWED_EN[3] = 1, which enables GENERIC_FSK to respond to RF_NOT_ALLOWED events
- RF_NOT_ALLOWED_NO_RX = 1, which enables RX operations to be aborted
- generic_fsk_rx_en = 1, RX request to TSM from GENERIC_FSK, indicating RX operation in progress

If all conditions are not met, no further action is taken. Otherwise, the TSM sets COEX_CTRL[RF_NOT_ALLOWED_RX_ABORT], and also asserts *pll_unlock* to the GENERIC_FSK Link Layer hardware. GENERIC_FSK responds by asserting IRQ_CTRL[PLL_UNLOCK_IRQ] in GENERIC_FSK address space. GENERIC_FSK enters IN_WD state, which deasserts generic_fsk_rx_en to the TSM. This initiates the TSM TX warmdown. GENERIC_FSK holds in IN_WD to wait for TSM to return to idle. Once this occurs, GENERIC_FSK asserts IRQ_CTRL[SEQ_END_IRQ] and returns to its IDLE state. Three status bits are now set to indicate to software that the source of the abort was an RF_NOT_ALLOWED assertion:

- IRQSTS1[PLL_UNLOCK_IRQ]
- COEX_CTRL[RF_NOT_ALLOWED_ASSERTED]
- COEX_CTRL[RF_NOT_ALLOWED_RX_ABORT]

Some additional statuses related to RF_NOT_ALLOWED are also available in RSM_INT_STATUS register of the Transceiver as described in the following table:

Field	R/W	Description
XCVR_IRQ_RF_DENY_RISE	RW	The bit is set at the assertion of rf_not_allowed coexistence signal. This interrupt line is valid for all standards(Zigbee/BLE/CS/generic_FSK LL). Write 1 to clear the bit. This interrupt line is only routed to NBU processor.
XCVR_IRQ_RF_DENY_FALL	RW	The bit is set at the deassertion of rf_not_allowed coexistence signal. This interrupt line is valid for all standardss (Zigbee/BLE/CS/generic_FSK LL). Write 1 to clear the bit. This interrupt line is only routed to NBU processor
XCVR_IRQ_RF_DENY_BTA	RW	The bit is set at the rising edge of rf_active signal while rf_not_allowed coexistence signal is already set. This interrupt is valid for all standards (Zigbee/BLE/CS/generic_FSK LL). Write 1 to clear the bit. This interrupt line is only routed to NBU processor.

Please refer to RADIO_MISC.COEX_CTRL register to get all description details for each field.

52.4.4.5 Clocking

The radio uses the following clock sources:

- Radio XO: A 32MHz or 26MHz crystal is normally connected to the radio's XTAL and EXTAL pins, but a 32MHz or 26MHz clock input to EXTAL is also supported.
- Radio FRO192M: This 192MHz clock source is used to derive the clocks for the radio CM3, the radio flash and buses related to the NBU and radio flash.
- SOC 32.768kHz. This clock, from the SOC's CCM32K module, is used by the radio's "always on" logic and by the radio's SFA32K module.

The figure below shows the clock distribution, with focus on the NBU clocks. For the FRO clock outputs, the default output frequency to the NBU and PD_RF AHB, etc. is 32MHz, and the default output frequency for the flash APB and RF_CMC clock is 16MHz (with a maximum supported frequency of 24MHz).

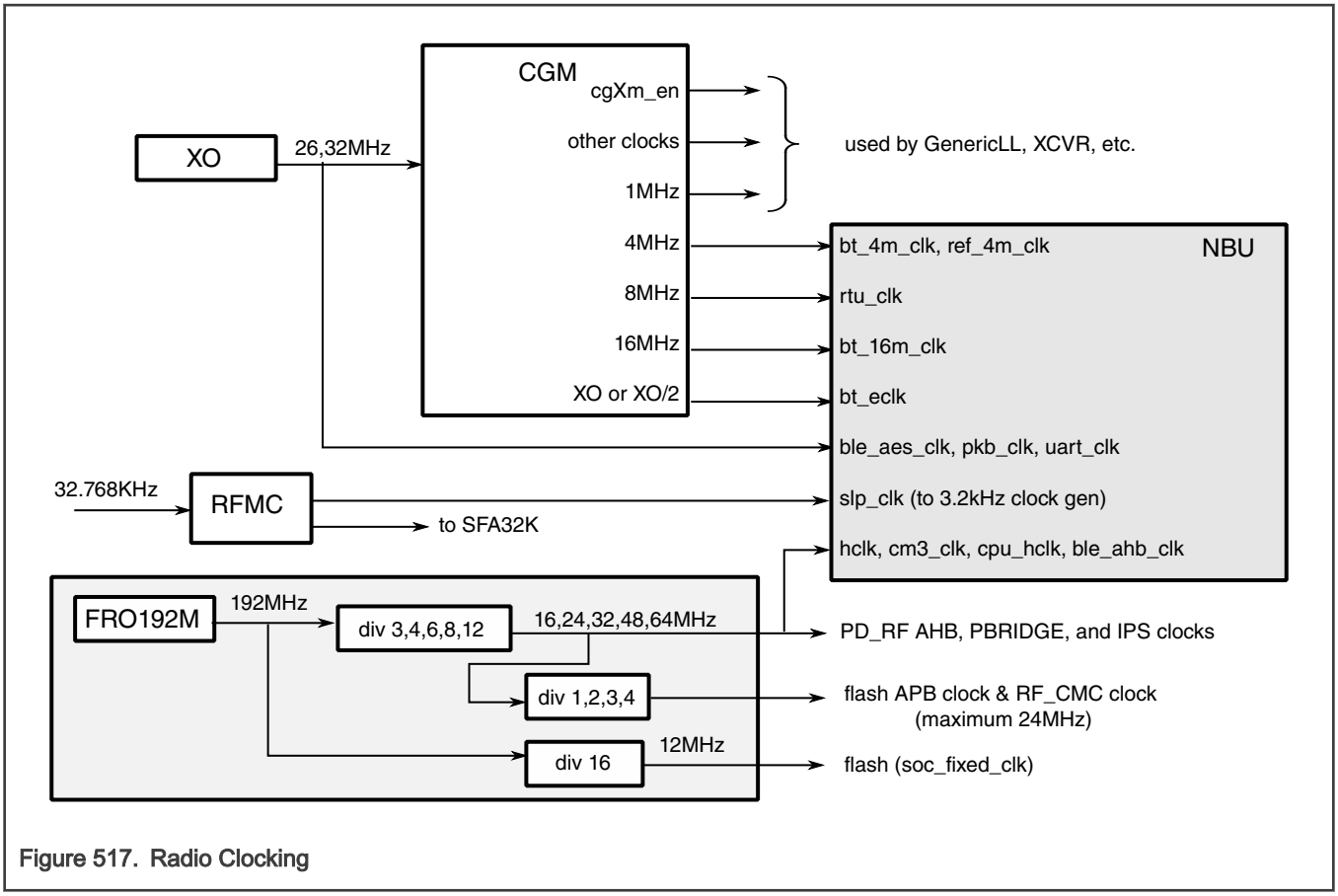


Figure 517. Radio Clocking

Inside the NBU, there is a module (bt_lpoClk_gen) which generates a 3.2KHz clock: in low power modes, this clock is derived from slp_clk (32.768KHz), while when not in low power mode the clock is derived from bt_4m_clk (4MHz).

The NBU's clock inputs are further described in the table below.

Table 563. NBU Clocks

NBU clock input	Source	Used in NBU by	Clock enabled by
cm3_hclk	FRO divider	CM3	RF_CLK_CTRL[CM3_HCLK_EN] & !cpu_sleeping & nbu_cm3_clock_en_mask[1]
cpu_hclk		flash/IMEM/ DMEM/buses	RF_CLK_CTRL[NBU_AHB_CLK_EN] & ((bt_clk_req & RF_CLK_CTRL[BT_CLK_REQ_EN]) || (!man_deep_sleep_enable & RF_CLK_CTRL[MAN_DS_EN]) || (!wor_deep_sleep_enable & RF_CLK_CTRL[WOR_DS_EN]) || ! cpu_cp15_sleep) & nbu_ahb_clock_en_mask[1]
hclk		AHB subsystem clock, SMU2, CIU2	
ble_ahb_clk		BTU	RF_CLK_CTRL[BLE_AHB_CLK_EN] & bt_clk_req
bt_eclk	XO or XO/2[2]	BTU	RF_CLK_CTRL[BT_ECLK_EN] & bt_clk_req & btll[3]
bt_16m_clk	XO divider (16MHz)	BTU	RF_CLK_CTRL[BT_16M_CLK_EN] & bt_clk_req & btll[3]
rtu_clk	XO divider (8MHz)	RTU	RF_CLK_CTRL[RTU_CLK_EN] & bt_clk_req & btll[3]

Table continues on the next page...

Table 563. NBU Clocks (continued)

NBU clock input	Source	Used in NBU by	Clock enabled by
bt_4m_clk	XO divider (4MHz)	BTU	RF_CLK_CTRL[BT_4M_CLK_EN] & bt_clk_req & btll[3]
ref_4m_clk		lpoClk_gen	RF_CLK_CTRL[BT_REF_4M_CLK_EN] & btll[3]
ble_aes_clk	XO	AES	RF_CLK_CTRL[BLE_AES_CLK_REQ] & ble_aes_clk_req & btll[3]
nbu_pkb_clk		Private Key Bus	RF_CLK_CTRL[NBU_PKB_CLK_EN]
uart_clk		UART	RF_CLK_CTRL[UART_CLK_EN] & btll[3]
slp_clk	32.768kHz	lpoClk_gen	RFMC: RF2p4GHz_CTRL register: BLE_LP_EN | CLK_OVR[3]

1. from RF_CMC
2. selected by RF_CLK_CTRL[BT_ECLK_DIV]. Should be >=16MHz, so for XO=26MHz select XO while for XO=32MHz XO/2 can be selected
3. btll = btll_en & (LL_CTRL[ACTIVE_LL]==Bluetooth LE) | RF_CLK_CTRL[BTLL_CLK_EN_OVRD], where btll_en is an IFR bit

The other radio peripherals outside of the NBU use only clocks derived from the XO. The following table describes the 802.15.4 LL, Generic LL, and WOR clocks

Table 564. Link Layer and WOR Clocks

Module	Clock	Clock enabled by
802.15.4 LL	zigbee_tsm	(tsm_clk_en | zig_force_clk_on) & zbll[1]
802.15.4 LL	zigbee	!dsm_zig_deep_sleep_enable & zbll[1]
Generic LL	generic_tmr (1MHz)	generic_tmrload & !dsm_gen_deep_sleep_en & genll[2]
Generic LL	generic_500k (500kHz)	!dsm_gen_deep_sleep_en & genll[2]
Generic LL	generic_1m (1MHz or XO when requested for tmrload)	!dsm_gen_deep_sleep_en & genll[2]
WOR	clk_wor	wor_en
WOR	clk_wor_1m (1MHz)	(wor_en | wor_clk_xtend)
WOR	clk_wor_comp (1MHz or XO when requested for computing)	(wor_en | wor_clk_xtend)
WOR	clk_wor_timestamp	(wor_en | wor_clk_xtend) & wor_timstamp_clk_en
WOR	clk_wor_ww_1m (1MHz)	(wor_en | wor_clk_xtend) & ! wor_deep_sleep_enable

1. zbll = zbll_en & (LL_CTRL[ACTIVE_LL]==ZIGBEE) | RF_CLK_CTRL[ZBLL_CLK_EN_OVRD], where zbll_en is an IFR bit
2. genll = genll_en & (LL_CTRL[ACTIVE_LL]==GENERIC) | RF_CLK_CTRL[GENLL_CLK_EN_OVRD], where genll_en is an IFR bit

52.4.4.6 Reset

The Radio IP has few main reset input nets, detailed in the following table:

Table 565. Radio IP Reset Nets

Reset	Description
ipg_async_reset_32khz_b_1p8v	Async HW reset for NBU AON logic, synced to 32khz clk
ipg_async_por_lv	Power-On Reset, not Synced
ipg_async_por_b_cmc	from RF_CMC, synced to FRO clk
ipg_async_reset_b	from RF_CMC, synced to FRO clk
ipg_async_cpu_reset_b	from RF_CMC, synced to FRO clk

Those input reset signals are connected to the Reset Control Module, that generates the internal resets for all the logic modules.

52.4.4.7 Radio interrupts and Wake-up request

The Radio can generate some asynchronous interrupts and one asynchronous MCU wakeup signal.

The interrupt configurations are illustrated in the diagram below and detailed in the following sections.

52.4.4.7.1 Interrupts and Wake-up request Diagram

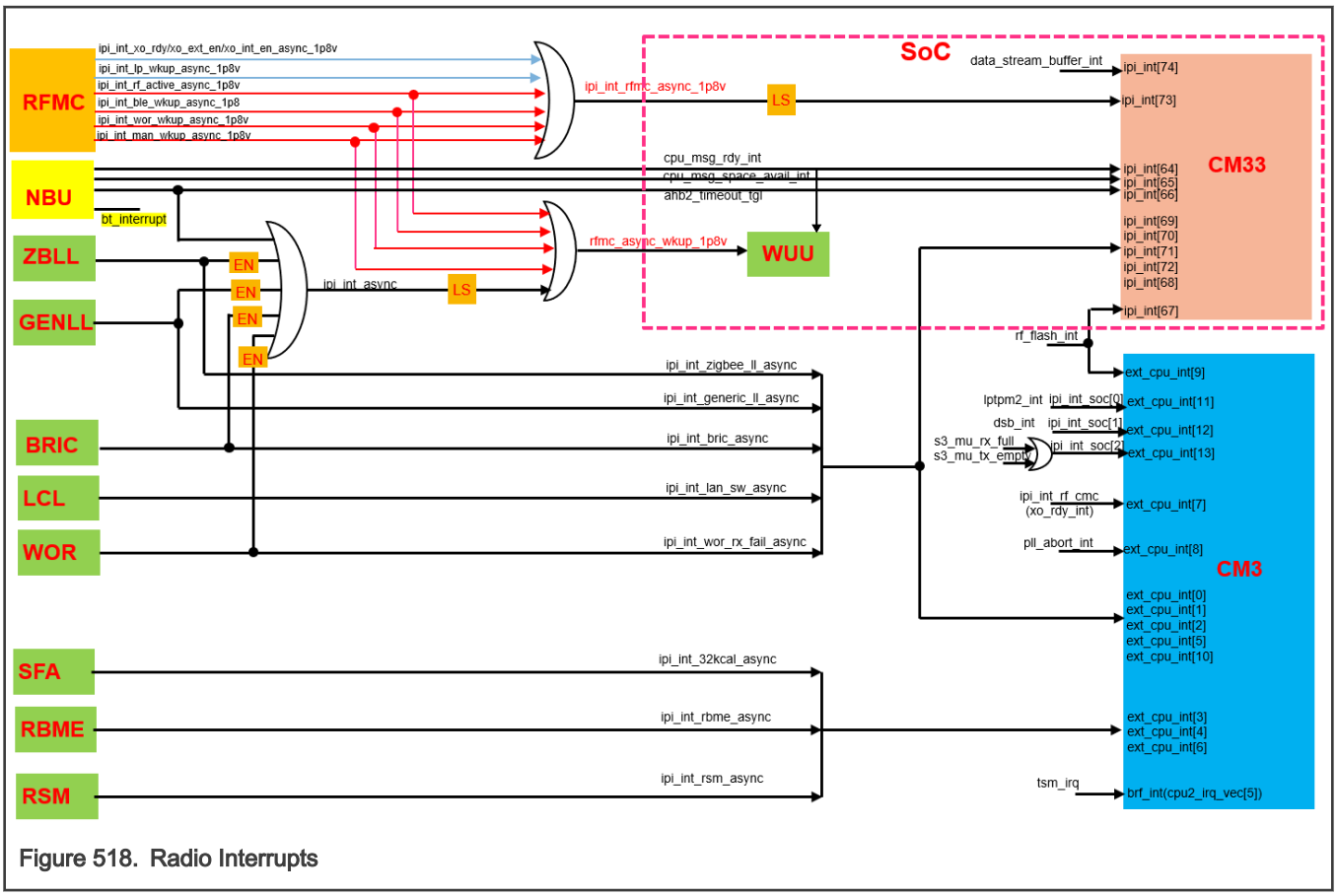


Figure 518. Radio Interrupts

52.4.4.7.2 Interrupt sources and connections

The radio interrupt sources and connections are summarized in the table below.

Table 566. Radio Interrupts

Interrupt Source	to NBU/CM3 NVIC	to SOC
sources inside the NBU used exclusively by CM3	connected inside the NBU	
NBU IMU interrupt to SOC Core (cpu_msg_rdy_int)		radio output to SOC Core NVIC
NBU IMU interrupt to SOC Core (cpu_msg_space_avail_int)		radio output to SOC Core NVIC
NBU timeout (ahb2_timeout_tgl)		radio output to SOC Core NVIC *or* SOC RESET
Transceiver: TSM	connected inside radio to brf_int	
15.4 LL	connected inside radio to ext_cpu_int[0]	radio output to SOC Core NVIC
Generic LL	connected inside radio to ext_cpu_int[1]	radio output to SOC Core NVIC
BRIC	connected inside radio to ext_cpu_int[2]	radio output to SOC Core NVIC
SFA32K	connected inside radio to ext_cpu_int[3]	
Transceiver: RBME	connected inside radio to ext_cpu_int[4]	
Transceiver: LCL_CTRL (lant_sw)	connected inside radio to ext_cpu_int[5]	radio output to SOC Core NVIC
Transceiver: Ranging Sequence Manager	connected inside radio to ext_cpu_int[6]	
RFMC		radio output to SOC Core NVIC
RF_CMC (XO ready)	connected inside radio to ext_cpu_int[7]	
Transceiver: PLL abort	connected inside radio to ext_cpu_int[8]	
Radio Flash FMU	radio input from PD_RF domain to ext_cpu_int[9]	PD_RF domain output to SOC Core NVIC
WOR (RX failure)	connected inside radio to ext_cpu_int[10]	radio output to SOC Core NVIC
TPM2 (in PD_RF domain)	radio input from PD_RF domain to ext_cpu_int[11]	
Data Stream Buffer (in SOC domain)	radio input from SOC domain to ext_cpu_int[12]	
EdgeLock Secure Enclave (in SOC domain) rx_full || tx_empty	radio input from SOC domain to ext_cpu_int[13]	
RFMC WUU_MxIF (OR of radio interrupts assigned to SOC Core)		radio output to SOC Core WWU

52.4.4.8 Packet ram to ips transfer

With this DMA It is possible to transfer data from RX or TX packet RAM to registers of ZLL, GENFSK, XCVR . The register PACKET_RAM_TO_IPS makes possible manipulate this feature. The data transfer is non-blocking, while it is being performed others read or write access to other registers can be performed normally. .

This module is connected with TX RAM, RX RAM, XCVR, RF Control, zigbee and generic link layers. Once the system is started after the boot they can be initialized. Those configuration can be saved with a transfer from registers to RX or TX RAM, so later they can be recovered with a transfer from RAM to registers..

52.4.4.8.1 Data packet

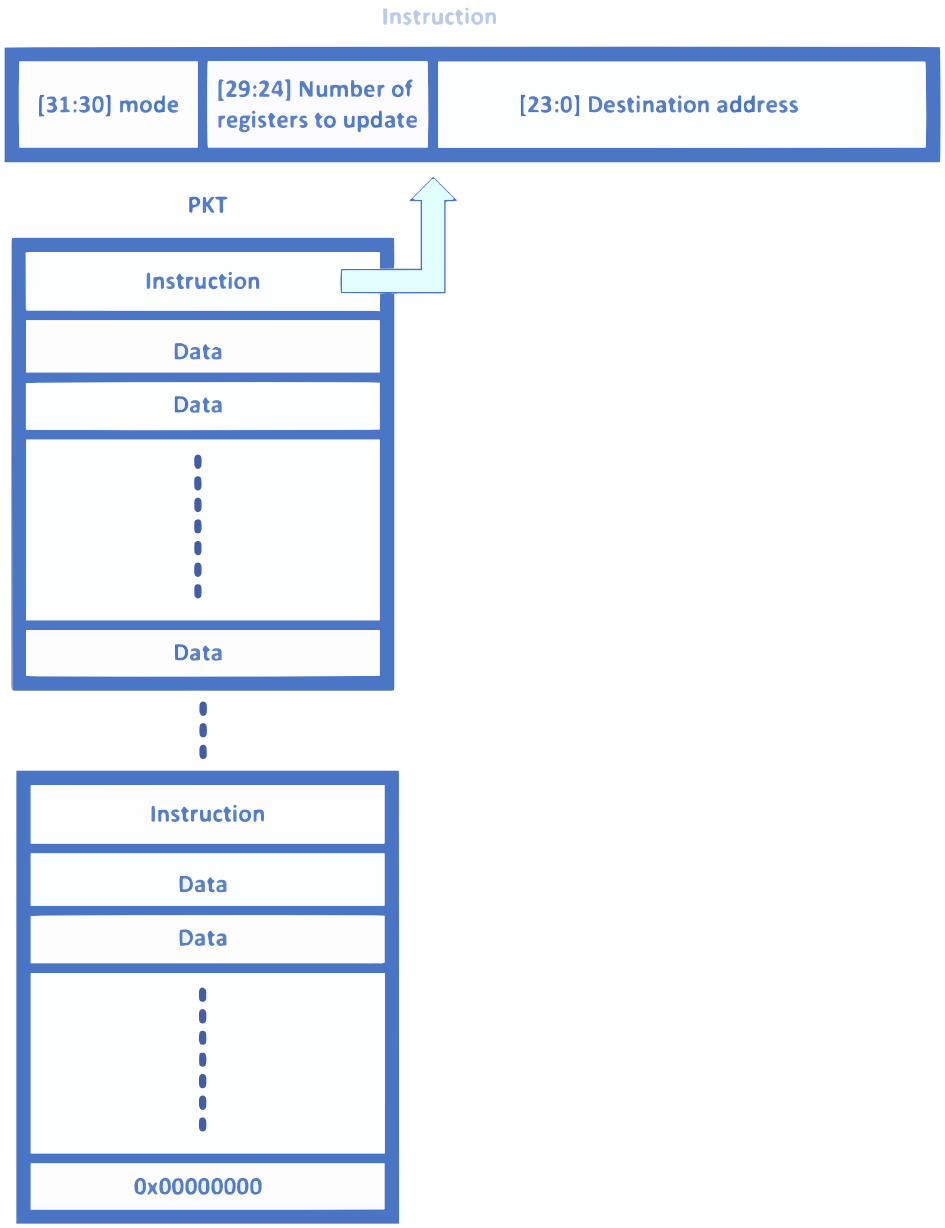


Figure 519. Packet structure

This data structure consists of a series of 32 bits words, it can be written on TX or RX RAM. The first word is the instruction. The following words are the data to be written to of from registers. The instruction bits [31:30] sets the mode, for single mode it should be 1 and for burst mode it should be 2,[29:24] specifies the number of registers to be written or read in burst mode, for single mode this field has no sense. [23:0] is the destination address for single mode or the first address for burst mode. Several data packet can be chained, the last word of the last packet must be set to 0x00000000 in order to indicate that it is the end of a series of chained packets.

The Packet RAM data structure has to be the same for both Read and Write transfers.

52.4.4.8.2 Transfer from packet RAM to registers

- Create the data structure on the TX or RX Packet RAM

- Source is RX PACKET : write 1 to PACKET_RAM_TO_IPS_CTRL[PR2IPS_RAM_SEL]
- Source is TX PACKET: write 0 to PACKET_RAM_TO_IPS_CTRL[PR2IPS_RAM_SEL]
- Program PACKET_RAM_TO_IPS_CTRL[PR2IPS_ADDR_SRC] with the source address of instructions in Packet RAM
- Write 0 to PACKET_RAM_TO_IPS_CTRL[PR2IPS_REGS2PKT]
- Write 1 to PACKET_RAM_TO_IPS_CTRL[PR2IPS_ENA] to turn the feature on.
- The data transfer starts.
- When the data transfer is over the field PACKET_RAM_TO_IPS_CTRL[PR2IPS_STATUS] is set to 1.

52.4.4.8.3 Transfer from registers to packet RAM

- Create the data structure on the TX or RX Packet RAM
- Destination is RX PACKET : write 1 to PACKET_RAM_TO_IPS_CTRL[PR2IPS_RAM_SEL]
- Destination is TX PACKET: write 0 to PACKET_RAM_TO_IPS_CTRL[PR2IPS_RAM_SEL]
- Program PACKET_RAM_TO_IPS_CTRL[PR2IPS_ADDR_SRC] with the source address of instructions in Packet RAM
- Write 1 to PACKET_RAM_TO_IPS_CTRL[PR2IPS_REGS2PKT]
- Write 1 to PACKET_RAM_TO_IPS_CTRL[PR2IPS_ENA] to turn the feature on.
- The data transfer starts.
- When the data transfer is over the field PACKET_RAM_TO_IPS_CTRL[PR2IPS_STATUS] is set to 1.

52.4.5 External signals

Some of the Digital Radio I/O signals are shown in the table below.

Signal	I/O	Description
ipg_async_reset_b	input	Async reset - from RF_CMC synced to FRO
ipg_async_reset_32khz_b_1p8v	input	Async Reset for NBU AO
ipg_async_por_lv	input	from RFMC, not synced
ipg_async_por_b_cmc	input	from RF_CMC, synced to FRO
iipg_async_cpu_reset_b	input	from RF_CMC, synced to FRO
btll_en	input	BTLE LL Enable - from CGC/IFR bit
zbll_en	input	Zigbee LL Enable - from CGC/IFR bit
genll_en	input	Generic LL Enable - from CGC/IFR bit
genll_remap0_dis	input	Generic LL Remap0 Disable - from CGC/IFR bit
genll_remap1_dis	input	Generic LL Remap1 Disable - from CGC/IFR bit
genll_remap2_dis	input	Generic LL Remap2 Disable - from CGC/IFR bit
ble_version	input	from SoC
radio_uid	input	from RFMC
cpu_msg_rdy_int	output	NBU IMU interrupt to CM33

Table continues on the next page...

Table continued from the previous page...

Signal	I/O	Description
cpu_msg_space_avail_int	output	NBU IMU interrupt to CM33
ahb2_timeout_tgl	output	NBU ahb timeout output
ipi_int*	output	different interrupts to SoC
ipi_int*	input	Interrupt sources from SoC (RF Flash, RF_CMC..)
h*_nbu_s	input/output	AHB Slave Interface, from CM33 AXBS
h*nbu_m	input/output	AHB Master Interface, to CM33 AXBS
h*_pd_rf_m	input/output	Interface to to PD_RF pbridge
h*rf_s	input/output	from CM33 AXBs Interface, to AHB gasket
dap_*	input/output	DAP Interface
cti_*	input/output	CTI Interface
*_uart_*	input/output	UART Interface
nbu_host_trigger_in	input	HOST Trigger to NBU
nbu_host_trigger_out	output	from NBU to HOST
nbu_host_trigger_oen	output	from NBU to HOST
pkb_*_bric	input/output	PKB Interface to BRIC
pkb_*_nbu	input/output	PKB Interface to NBU
rf_fro_divided_clk	input	RF FRO192 clock
rf_osc_clk	input	RF OSC clock
xtal_ready	input	RF OSC clock ready - lv
dft_pll_ref_clk	input	High precision reference clock for PLL test
data_stream	output	to SoC Async FIFO
data_stream_vld	output	to SoC Async FIFO
lant_sw	output	Localization Antenna Switch
lant_lut_gpio	output	array of gpio that are looked up at every doublet instant
fad_lant_lut_gpio	output	muxed output from fad and lant_lut_gpio
tof_timestamp_trig	output	"time-of-flight time-stamp
ipd_bric*	input/output	IPD BRIC Interface
ipg_clk_ble_32kHz_1p8v	input	Clock to NBU AO
ipg_clk_32kHz	input	Clock to SFA
rfmc_rf_not_allowed	input	External to the SoC request that TSM abort any Radio operation WiFi co-exist feature
rf_active	output	to RFMC

Table continues on the next page...

Table continued from the previous page...

Signal	I/O	Description
rf_priority	output	to RFMC
rf_status	output	to RFMC
rfmc_*	input/output	RFMC Interface
ipp_do_ant_a	output	Antenna Diversity
ipp_do_ant_b	output	Antenna Diversity
ipp_do_tx_switch	output	Antenna Diversity
ipp_do_rx_switch	output	Antenna Diversity
ipp_port_enable_tx_rx_switch	output	port enable for ant_a and ant_b
ipp_port_enable_ant_a_b	output	port enable for tx_switch and rx_switch
cpu_sleeping	output	to TPM2
ble_lp_wkup	input	from RFMC
rfmc*_lv	input	from RFMC with level shifter
*_dtest	output	DTEST data, to PADRING
h*_rom	input/output	AHB Master Interface to Flash
cpu_imem*	input/output	CPU IMEM Interface
cpu_dmem*	input/output	CPU DMEM Interface
smu_*	input/output	SMU memory interface
btu_*	input/output	BTU EBRAM interface
tx_ram_*	input/output	TX RAM Interface
rx_ram_*	input/output	RX RAM Interface
adc_code_i_act	input	data from ADC (Analog Hardblock Interface)
adc_code_q_act	input	data from ADC (Analog Hardblock Interface)
seq_*_dig	output	Digital control signals for the analog hardblock (dynamic)
reg_*_dig	output	Digital configuration signals for the analog hardblock (static)

52.4.6 Initialization

There is no particular sequence to initialize the Radio IP.

52.4.7 Application information

Radio context restore after Low Power exit

In order to optimize leakage current during Deep Sleep mode, the LIF transceiver as well as the RBME are not retained during Deep Sleep mode. This means, that LIF transceiver and RBME configurations are lost during at DeepSleep entry.

To avoid complete SW reconfiguration of those 2 modules at Radio wakeup, usage of the Radio DMA Lite Pkt RAM is recommended to restore the control register context.

SW needs to prepare inside the Pkt RAM, a list of control registers to be stored/restored at each DeepSleep entries. This list will remain stored inside the Pkt RAM which are retained during Deep Sleep and also Power Down (based on RF_CMC configuration). SW needs to ensure that Pkt RAM remain retained during DeepSleep.

The process of Store/Restore LIF/RBME context should be conducted as follow:

- Store process: Prior to DeepSleep entry, the DMA Lite shall be activated to store inside Pkt RAM, the cuurent control registers of the LIF and RBME registers. The end of DMA Lite transfer must gate the LP entry (SW controlled). For a complete storage of all LIF/RBME control registers, for XTAL @32MHz, store process duration is 15us.
- Restore process: This process will be triggered by the RFMC BLE Wakeup interrupt. This interrupt will be raised immediathely at Radio Low Power exit. Inside the RFMC BLE Wakeup interrupt service routine, restore process will be triggered by simply enabling the DMA Lite (RAM to registers). For a complete storage of all LIF/RBME control registers, for XTAL @32MHz, restore process duration is 30us. As Radio is woke up one BLE half slot prior to next BLE event, LIF and RBME will be safely reconfigured prior to RF transaction trigger.

52.4.8 Register Descriptions

52.4.8.1 Register Descriptions

Table 567. Radio Memory Space (excluding CM33 access to RFMC)

Radio CM33 Memory Space				Host CM33 access to radio via NBU	Host CM33 access to radio via PBRIDGE
Start Addr	End Addr	Size	Module/Description[1]	Start Addr	Start Addr
00000000	0007FFFF	512KB	Radio CM33 access to flash (main array)		
00080000	00087FFF	32KB	Radio CM33 access to flash (IFR0)		
00088000	00089FFF	8KB	Radio CM33 access to flash (IFR1)		
0008A000	000FFFFF	472KB	Radio CM33 access to flash (Reserved)		
00100000	001007FF	2KB	Radio CM33 access to IMEM		
00140000	00167FFF	160KB (Max)	Radio CM33 access to DMEM		
00180000	9FFFFFFF	~2.5GB	Reserved		
20140000	20167FFF	160KB (Max)	Radio CM33 access to DMEM (shadow) by AHB S-bus		
A0000000	A007FFFF	512KB	SOC access to flash (main array)	48800000	
A0080000	A0087FFF	32KB	SOC access to flash (IFR0)	48880000	
A0088000	A0089FFF	8KB	SOC access to flash (IFR1)	48888000	
A008A000	A00FFFFF	472KB	SOC access to flash (Reserved)	4888A000	
A0100000	A013FFFF	256KB	Reserved (was SOC access to IMEM)		
A0140000	A017FFFF	256KB	Reserved (was SOC access to DMEM)		
A0180000	A01FFFFF	512KB	Reserved		
A0200000	A7FFFFFF	126MB	Reserved		
A8000000	A80007FF	2KB	Reserved	48940000	

Table continues on the next page...

Table 567. Radio Memory Space (excluding CM33 access to RFMC) (continued)

Radio CM33 Memory Space				Host CM33 access to radio via NBU	Host CM33 access to radio via PBRIDGE
Start Addr	End Addr	Size	Module/Description[1]	Start Addr	Start Addr
A8000800	A8000FFF	2KB	AHB2 arbiter config	48940800	
A8001000	A80030FF	8.25KB	Reserved	48941000	
A8003100	A80031FF	256B	BT UART	48943100	
A8003200	A8003FFF	3.5KB	Reserved (returns OKAY response)	48943200	
A8004000	A8004FFF	4KB	BT UART PFU	48944000	
A8005000	A8007FFF	12KB	Reserved	48945000	
A8008000	A80093FF	5KB	CIU2	48948000	
A8009400	A80097FF	1KB	BT_RTU1	48949400	
A8009800	A803FFFF	218KB	Reserved (returns OKAY response)	48949800	
A9000000	A900FFFF	64KB	BTU		
A9010000	A901FFFF	64KB	Reserved		
A9020000	A902FFFF	64KB	Bluetooth LE		
A9030000	A903FFFF	64KB	Reserved		
A9100000	A913FFFF	256KB	Access to Radio PBRIDGE (outside NBU), see detailed entries below		00180000
A9100000	A9100FFF	4KB	>Reserved		48A00000
A9101000	A9101FFF	4KB	>802.15.4 LL		48A01000
A9102000	A9102FFF	4KB	>Generic LL		48A02000
A9103000	A9103FFF	4KB	>Generic LL REMAP0		48A03000
A9104000	A9104FFF	4KB	>Generic LL REMAP0		48A04000
A9105000	A9105FFF	4KB	>Generic LL REMAP0		48A05000
A9106000	A91060FF	256B	>Radio Control MISC		48A06000
A9106100	A91061FF	256B	>WOR		48A06100
A9106200	A91062FF	256B	>RBME		48A06200
A9106300	A91066FF	256B	>SFA		48A06300
A9106700	A91067FF	256B	>BRIC (KEY)		48A06700
A9106800	A9106FFF	2KB	>BRIC (LTC)		48A06800
A9107000	A91071FF	512B	>XCVR/RX_DIG		48A07000
A9107200	A91072FF	256B	>XCVR/TX_DIG		48A07200
A9107300	A91073FF	256B	>XCVR/PLL		48A07300

Table continues on the next page...

Table 567. Radio Memory Space (excluding CM33 access to RFMC) (continued)

Radio CM33 Memory Space				Host CM33 access to radio via NBU	Host CM33 access to radio via PBRIDGE
Start Addr	End Addr	Size	Module/Description[1]	Start Addr	Start Addr
A9107400	A91074FF	256B	>XCVR/ Reserved		48A07400
A9107500	A91075FF	256B	>XCVR/802.15.4 PHY		48A07500
A9107600	A91077FF	512B	>XCVR/GEN4 PHY		48A07600
A9107800	A9107BFF	1KB	>XCVR/TSM		48A07800
A9107C00	A9107CFF	256B	>XCVR/XCVR_ANA		48A07C00
A9107D00	A9107DFF	256B	>XCVR/XCVR_MISC		48A07D00
A9107E00	A9107FFF	512B	>XCVR/ Reserved		48A07E00
A9108000	A9108FFF	4KB	>TX Packet RAM		48A08000
A9109000	A91097FF	2KB	>RX Packet RAM		48A09000
A9109800	A910FFFF	26KB	>Reserved		48A09800
A9110000	A913FFFF	192KB	>Reserved		
A9140000	A917FFFF	256KB	Access to PD_RF PBRIDGE (outside NBU), see detailed entries below	48980000	
A9140000	A9140FFF	4KB	>Radio FRO192M	48980000	
A9141000	A9141FFF	4KB	>Radio Flash FMU	48981000	
A9142000	A9142FFF	4KB	>Radio Flash FMC	48982000	
A9143000	A9143FFF	4KB	>RF_CMC	48983000	
A9144000	A9144FFF	4KB	>TPM2	48984000	
A9145000	A9145FFF	4KB	>Radio Flash test	48985000	
A9146000	A9146FFF	4KB	>LPTIMER	48986000	
A9147000	A917FFFF	228KB	>Reserved	48987000	
A9180000	A91FFFFF	512KB	Access to SOC XBAR (outside NBU)		
A9200000	AFFFFFFF	110MB	Reserved		
A8040000	A8FFFFFF	15.75MB	Reserved		
B0000000	B0027FFF	160KB (Max)	SMU2	489C0000	001C0000
B0028000	B003FFFF	96KB	Reserved (returns OKAY response)	489E8000	001E8000
B0040000	FFFFFFFF	~1.31GB	Reserved		

1. Access to "Reserved" regions return ERROR response except as noted.

Table 568. Radio NVIC

IRQ Line	Source
0	BLE_INT0_IRQn
1	BLE_INT1_IRQn
2	BLE_INT2_IRQn
3	BTU_FIQ_IRQn
4	BTU_INT_IRQn
5	BRF_INT_IRQn
6	CTI_IRQ0_IRQn
7	T1_INT_IRQn
8	T2_INT_IRQn
9	T3_INT_IRQn
10	T4_INT_IRQn
11	WDG2_INT_IRQn
12	SI_INT_IRQn
13	CTI_IRQ1_IRQn
14	CPU2_MSG_RDY_INT_IRQn
15	CPU2_MSG_SPC_AVAIL_INT_IRQn
16	ZIGBEE_INT_IRQn
17	CIU2_INT_IRQn
18	CPU2_ERR_INT_IRQn
19	GENLL_INT_IRQn
20	BRIC_INT_IRQn
21	SFA32K_INT_IRQn
22	RBME_INT_IRQn
23	LCL_INT_IRQn
24	RSM_INT_IRQn
25	XO_RDY_INT_IRQn
26	PLL_ABORT_INT_IRQn
27	FMU_INT_IRQn
28	WOR_INT_IRQn
29	TPM2_INT_IRQn
30	DSB_IRQn
31	SECSUBSYS_IRQn

Table continues on the next page...

Table 568. Radio NVIC (continued)

IRQ Line	Source
32	LPTMR2_IRQn

52.4.8.2 RADIO_MISC register descriptions

52.4.8.2.1 RADIO_MISC memory map

RADIO.RADIO_CTRL base address: 48A0_6000h

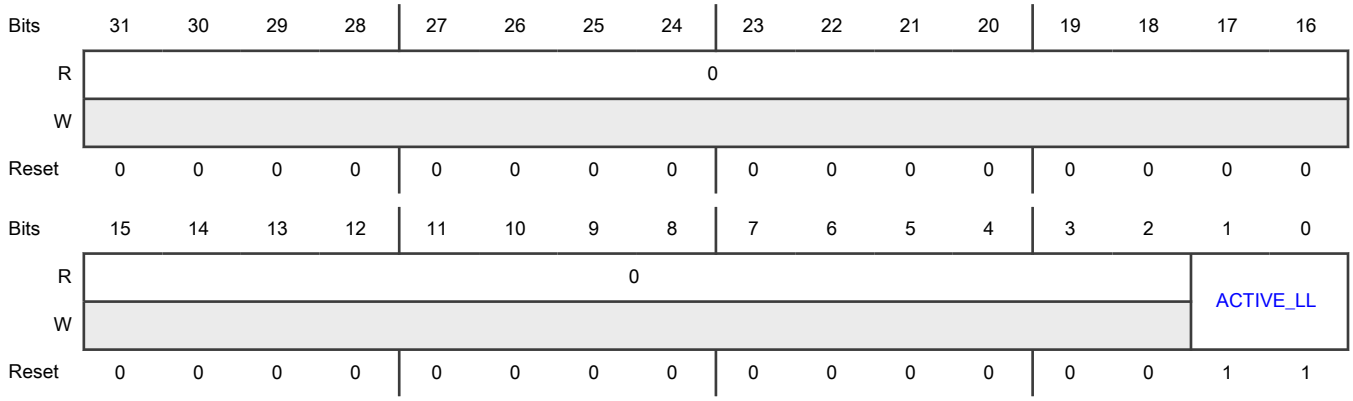
Offset	Register	Width (In bits)	Access	Reset value
4h	LL Control Register (LL_CTRL)	32	RW	0000_0003h
8h	Radio Control Register (RF_CTRL)	32	RW	0000_0000h
Ch	Radio Clock Control Register (RF_CLK_CTRL)	32	RW	801F_FF00h
10h	COEXISTENCE CONTROL (COEX_CTRL)	32	RW	0000_0000h
14h	Radio Control Register (UID_MSB)	32	R	0000_0000h
18h	Radio Control Register (UID_LSB)	32	R	0000_0000h
1Ch	PACKET RAM Control Register (PACKET_RAM_CTRL)	32	RW	0000_0000h
20h	BLE PHY Interface Control Register (BLE_PHY_CTRL)	32	RW	0F0F_1222h
24h	DTEST Control register (DTEST_CTRL)	32	RW	0000_0000h
30h	DTEST PIN Control 2 register (DTEST_PIN_CTRL2)	32	RW	0B0A_0908h
3Ch	Packet RAM to IPS transfer control and status (PACKET_RAM_TO_IPS_CTRL)	32	RW	0000_0000h

52.4.8.2.2 LL Control Register (LL_CTRL)

Offset

Register	Offset
LL_CTRL	4h

Diagram



Fields

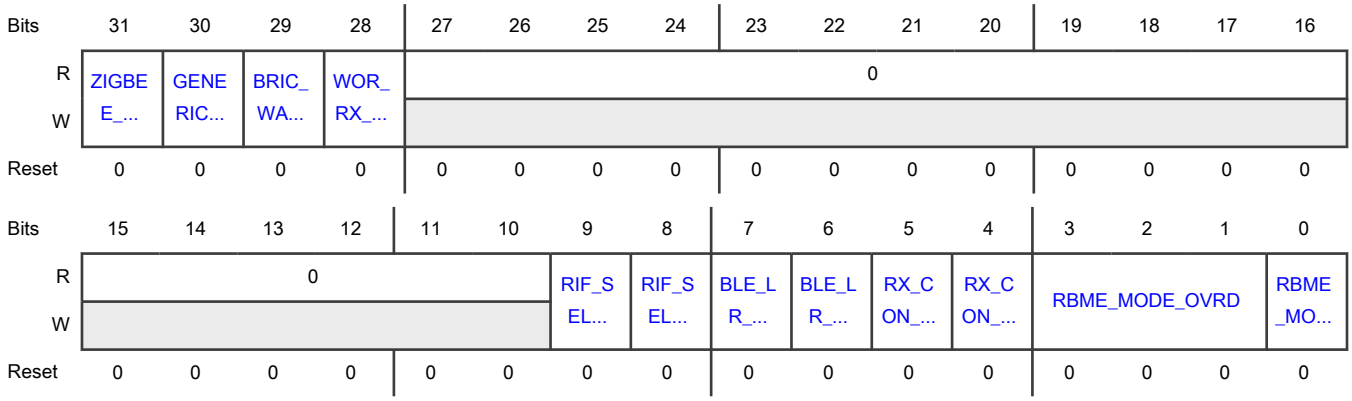
Field	Function
31-2 —	Reserved
1-0 ACTIVE_LL	link layer control register Controls access to shared resources: Packet RAM, DSM, WOR, DEMOD_SEL, LL Channel index to PLL. 00b - Bluetooth LE LL is selected 01b - ZIGBEE LL is selected 10b - GENERIC LL is selected 11b - Disabled (default)

52.4.8.2.3 Radio Control Register (RF_CTRL)

Offset

Register	Offset
RF_CTRL	8h

Diagram



Fields

Field	Function
31 ZIGBEE_WAKEUP_EN	Zigbee LL Wakeup Enable 0b - The Zigbee LL interrupt doesn't assert rfmc_wakeup. 1b - The Zigbee LL interrupt asserts rfmc_wakeup.
30 GENERIC_WAKEUP_EN	Generic LL Wakeup Enable 0b - The Generic LL interrupt doesn't assert rfmc_wakeup. 1b - The Genecir LL interrupt asserts rfmc_wakeup.
29 BRIC_WAKEUP_EN	BRIC Wakeup Enable 0b - The BRIC interrupt doesn't assert rfmc_wakeup. 1b - The BRIC interrupt asserts rfmc_wakeup.
28 WOR_RX_FAIL_WAKEUP_EN	WOR RX Fail Wakeup Enable 0b - The wor_rx_fail interrupt doesn't assert rfmc_wakeup. 1b - The wor_rx_fail interrupt asserts rfmc_wakeup.
27-10 —	Reserved
9 RIF_SEL_2MBPS_OVRD	rif_sel_2mbps Override Override rif_sel_2mbps
8 RIF_SEL_2MBPS_OVRD_EN	rif_sel_2mbps Override Enable 0b - rif_sel_2mbps Override Disable 1b - rif_sel_2mbps Override Enable
7	ble_lr_en Override

Table continues on the next page...

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Field	Function
BLE_LR_EN_OVRD	Typically, the value of ble_lr_en(longrange mode enable) is controlled by GEN-LL or NBU, however, which can be override by BLE_LR_EN_OVRD and BLE_LR_EN_OVRD_EN field.
6 BLE_LR_EN_OVRD_EN	ble_lr_en Override Enable 0b - ble_lr_en Override Disable 1b - ble_lr_en Override Enable
5 RX_CON_EN_OVRD	rx_con_en Override Typically, the value of rx_con_en(uncoded and coded concurrent acquisition enable) is controlled by GEN-LL or NBU, however, which can be override by RX_CON_EN_OVRD and RX_CON_EN_OVRD_EN field.
4 RX_CON_EN_OVRD_EN	rx_con_en Override Enable 0b - rx_con_en Override Disable 1b - rx_con_en Override Enable
3-1 RBME_MODE_OVRD	RBME Mode Override Typically, the value of rbme_mode is controlled by GEN-LL or NBU, however, which can be override by RBME_MODE_OVRD and RBME_MODE_OVRD_EN field.
0 RBME_MODE_OVRD_EN	RBME Mode Override Enable 0b - RBME Mode Override Disable 1b - RBME Mode Override Enable

52.4.8.2.4 Radio Clock Control Register (RF_CLK_CTRL)

Offset

Register	Offset
RF_CLK_CTRL	Ch

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	BT_CLK_...	WOR_DS_...	MAN_DS_...	0								UART_CL...	BLE_AES...	BT_ECLK...	BT_XCVR...	BT_XCVR...
W																
Reset	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	BT_REF_...	BT_4M_C...	RTU_CLK...	BT_16M_...	NBU_PKB...	BLE_AHB...	CM3_HCL...	NBU_HCL...	0			BT_ECLK...	BTU_EBR...	BTLL_CL...	GENL_C...	ZBLL_CL...
W																
Reset	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0

Fields

Field	Function
31 BT_CLK_REQ_EN	BT_CLK_REQ control enable 0b - Disable the control of bt_clk_req for nbu_hclk. 1b - Enable the control of bt_clk_req for nbu_hclk.
30 WOR_DS_EN	WOR deep sleep control enable 0b - Disable the control of rfmc_wor_deep_sleep_enable for nbu_hclk. 1b - Enable the control of rfmc_wor_deep_sleep_enable for nbu_hclk.
29 MAN_DS_EN	Manual deep sleep control enable 0b - Disable the control of rfmc_man_deep_sleep_enable for nbu_hclk. 1b - Enable the control of rfmc_man_deep_sleep_enable for nbu_hclk.
28-21 —	Reserved
20 UART_CLK_EN	UART Clock Enable 0b - uart_clk is disabled. 1b - uart_clk is enabled.
19 BLE_AES_CLK_EN	BLE_AES_CLK Enable 0b - bt_aes_clk is disabled. 1b - bt_aes_clk is enabled.
18 BT_ECLK_EN	BT_ECLK Enable 0b - bt_eclk is disabled. 1b - bt_eclk is enabled.
17 BT_XCVR_32M_CLK_EN	BT XCVR 32M Clock Enable 0b - bt_xcvr_32m_clk is disabled. 1b - bt_xcvr_32m_clk is enabled.
16 BT_XCVR_4M_CLK_EN	BT XCVR 4M Clock Enable 0b - bt_xcvr_4m_clk is disabled. 1b - bt_xcvr_4m_clk is enabled.
15 BT_REF_4M_CLK_EN	BT REF 4M Clock Enable 0b - bt_ref_4m_clk is disabled. 1b - bt_ref_4m_clk is enabled.
14 BT_4M_CLK_EN	BT 4M Clock Enable 0b - bt_4m_clk is disabled. 1b - bt_4m_clk is enabled.

Table continues on the next page...

Table continued from the previous page...

Field	Function
13 RTU_CLK_EN	RTU Clock Enable 0b - rtu_clk is disabled. 1b - rtu_clk is enabled.
12 BT_16M_CLK_EN	BT 16M Clock Enable 0b - bt_16m_clk is disabled. 1b - bt_16m_clk is enabled.
11 NBU_PKB_CLK_EN	NBU PKB Clock Enable 0b - nbu_pkb_clk is disabled. 1b - nbu_pkb_clk is enabled.
10 BLE_AHB_CLK_EN	BLE_AHB CLOCK Enable 0b - ble_ahb_clk is disabled. 1b - ble_ahb_clk is enabled.
9 CM3_HCLK_EN	CM3 HCLK Enable 0b - cm3_hclk is disabled. 1b - cm3_hclk is enabled.
8 NBU_HCLK_EN	NBU HCLK Enable 0b - nbu hclk/cpu_hclk are disabled. 1b - nbu hclk/cpu_hclk are enabled.
7-5 —	Reserved
4 BT_ECLK_DIV	BE_ECLK Divider Enable bt_eclk divider. 0b - ref_clk is not divided as bt_eclk. 1b - ref_clk is divided by 2 as bt_eclk.
3 BTU_EBRAM_CLK_ON_OVRD	BTU EBRAM Clock Enable Override 0b - btu_ebram_clk is not forced on. 1b - btu_ebram_clk is forced on.
2 BTLL_CLK_EN_OVRD	BTLL Clock Enable Override 0b - BTLL clock force on is disabled. 1b - BTLL clock force on is enabled.
1	GENLL Clock Enable Override

Table continues on the next page...

Table continued from the previous page...

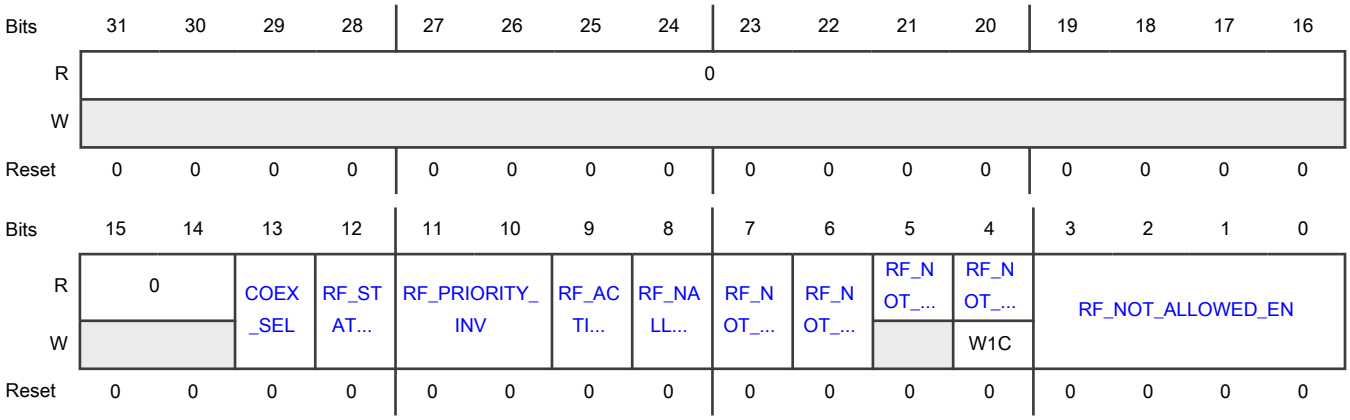
Field	Function
GENLL_CLK_EN_OVRD	0b - GENLL clock force on is disabled. 1b - GENLL clock force on is enabled.
0 ZBLL_CLK_EN_OVRD	ZBLL Clock Enable Override 0b - ZBLL clock force on is disabled. 1b - ZBLL clock force on is enabled.

52.4.8.2.5 COEXISTENCE CONTROL (COEX_CTRL)

Offset

Register	Offset
COEX_CTRL	10h

Diagram



Fields

Field	Function
31-14 —	Reserved
13 COEX_SEL	COEX_SEL 0b - Select coexistence signals from LL. 1b - Select coexistence signals from TSM.
12	RF_STATUS Invert

Table continues on the next page...

Table continued from the previous page...

Field	Function
RF_STATUS_INV	The normal behavior for the RF_STATUS signal is active high. This bit can optionally invert this signal. Refer also to "Radio Coexistence/FEM/LANT Mux diagram" figure. 0b - rf_status is not inverted. 1b - rf_status is inverted.
11-10 RF_PRIORITY_INV	RF_PRIORITY Invert The normal behavior for the RF_PRIORITY signals is active high. This bitfield can optionally invert these signals. Refer also to "Radio Coexistence/FEM/LANT Mux diagram" figure. 0xb - rf_priority[1] is not inverted. 1xb - rf_priority[1] is inverted. x0b - rf_priority[0] is not inverted. x1b - rf_priority[0] is inverted.
9 RF_ACTIVE_INV	RF_ACTIVE Invert The normal behavior for the RF_ACTIVE signal is active high. This bit can optionally invert this signal. Refer also to "Radio Coexistence/FEM/LANT Mux diagram" figure. 0b - rf_active is not inverted. 1b - rf_active is inverted.
8 RF_NALLOWED_INV	RF_NALLOWED Invert The normal behavior for the RF_NALLOWED signal is active high. This bit can optionally invert this signal. Refer also to "Radio Coexistence/FEM/LANT Mux diagram" figure. 0b - rf_nallowed is not inverted. 1b - rf_nallowed is inverted.
7 RF_NOT_ALLOWED_OVRD_EN	RF_NOT_ALLOWED Override Enable 0b - RF_NALLOWED Override Disable 1b - RF_NALLOWED Override Enable
6 RF_NOT_ALLOWED_OVRD	RF_NOT_ALLOWED Override Override rf_not_allowed
5 RF_NOT_ALLOWED	RF_NOT_ALLOWED Reflects the instantaneous state of the RF_NOT_ALLOWED pin, synchronized into the RF OSC clock domain.
4	RF_NOT_ALLOWED_ASSERTED 0b - Assertion on RF_NOT_ALLOWED has not occurred 1b - Assertion on RF_NOT_ALLOWED has occurred since the last time this bit was cleared

Table continues on the next page...

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Field	Function
RF_NOT_ALLOWED_ASSERTED	
3-0 RF_NOT_ALLOWED_EN	RF_NOT_ALLOWED PER-LINK-LAYER ENABLE The coexistence input RF_NOT_ALLOWED can be enabled to selectively abort TX or RX sequences, with individual enables for each supported protocol, according to the following table: **xxx1** : RF_NOT_ALLOWED assertions are enabled to abort Bluetooth LE TX and RX sequences **xxx0** : RF_NOT_ALLOWED assertions are not enabled to abort Bluetooth LE TX and RX sequences **xx1x** : RF_NOT_ALLOWED assertions are enabled to abort ANT TX and RX sequences, also used in context of RSM Channel Sounding localization sequence **xx0x** : RF_NOT_ALLOWED assertions are not enabled to abort ANT TX and RX sequences , also used in context of RSM Channel Sounding localization sequence **x1xx** : RF_NOT_ALLOWED assertions are enabled to abort Zigbee TX and RX sequences **x0xx** : RF_NOT_ALLOWED assertions are not enabled to abort Zigbee TX and RX sequences **1xxx** : RF_NOT_ALLOWED assertions are enabled to abort GENERIC_FSK TX and RX sequences **0xxx** : RF_NOT_ALLOWED assertions are not enabled to abort GENERIC_FSK TX and RX sequences

52.4.8.2.6 Radio Control Register (UID_MSB)

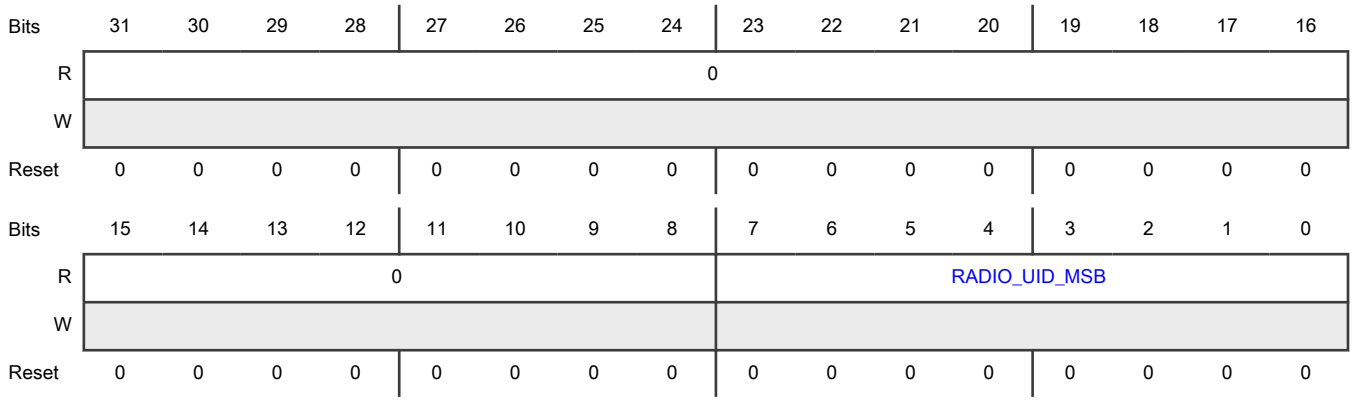
Offset

Register	Offset
UID_MSB	14h

Function

The UID_MSB and UID_LSB registers provide read-only access to the 40bit Radio Unique ID which is stored in Flash IFR. This can be used in part to define MAC address(es) needed by radio protocols.

Diagram



Fields

Field	Function
31-8 —	Reserved
7-0 RADIO_UID_MSB	The most signficant 8bits of the 40bit Radio UID.

52.4.8.2.7 Radio Control Register (UID_LSB)

Offset

Register	Offset
UID_LSB	18h

Function

The UID_MSB and UID_LSB registers provide read-only access to the 40bit Radio Unique ID which is stored in Flash IFR. This can be used in part to define MAC address(es) needed by radio protocols.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	RADIO_UID_LSB															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	RADIO_UID_LSB															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 RADIO_UID_LSB	The least signficant 32bits of the 40bit Radio UID.

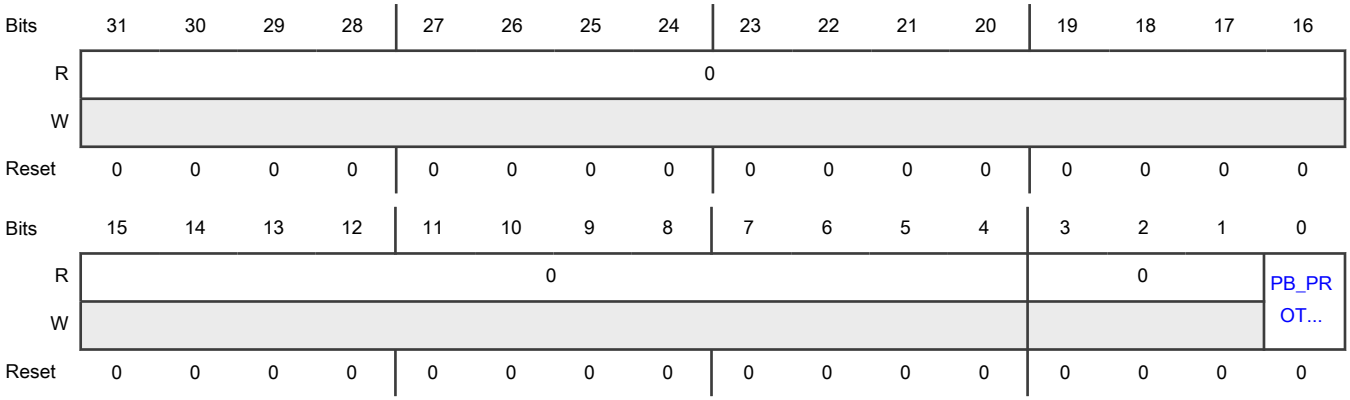
52.4.8.2.8 PACKET RAM Control Register (PACKET_RAM_CTRL)

Offset

Register	Offset
PACKET_RAM_CTRL	1Ch

Function
Packet RAM Control Register

Diagram



Fields

Field	Function
31-4 —	Reserved
3-1 —	Reserved
0 PB_PROTECT	PB_PROTECT The bit inhibits receive-packet overwriting of the RX section of the Packet Buffer contents, but doesn't inhibit TX content loading of the TX section of the Packet Buffer. 0b - Incoming receive data can overwrite the existing contents of the RX section of the Packet Buffer. 1b - Incoming receive data is been blocked from overwriting the existing contents of the RX section of the Packet Buffer.

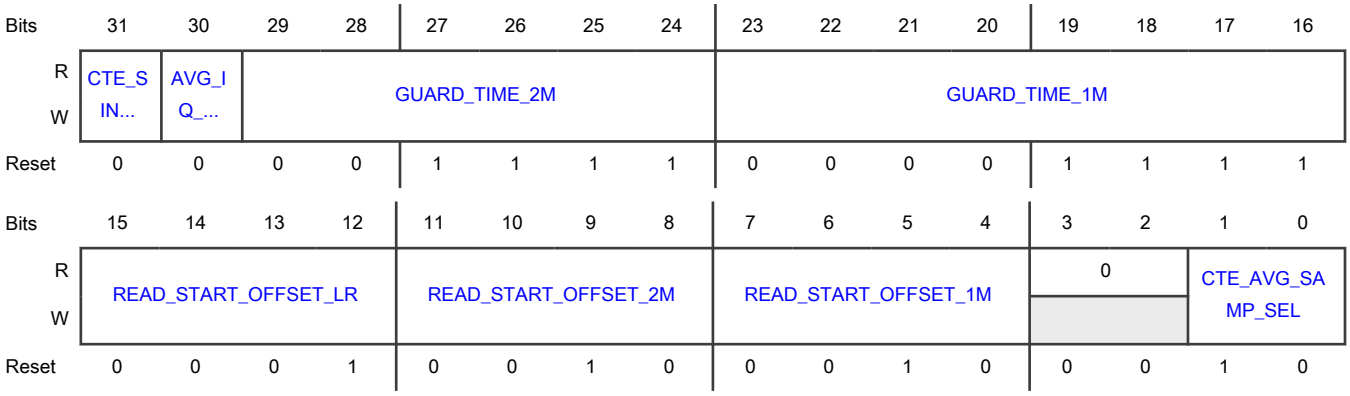
52.4.8.2.9 BLE PHY Interface Control Register (BLE_PHY_CTRL)

Offset

Register	Offset
BLE_PHY_CTRL	20h

Function
BLE PHY Interface Control Register

Diagram



Fields

Field	Function
31 CTE_SINGLE_BUF	Config for using single buffer for Rx data and CTE samples
30 AVG_IQ_DISABLE	Disable IQ sample averaging
29-24 GUARD_TIME_2M	Guard time offset for 2M
23-16 GUARD_TIME_1M	Guard time offset for 1M
15-12 READ_START_OFFSET_LR	Start sending Rx data to NBU after a programmable number of symbols are received from PHY - LR

Table continues on the next page...

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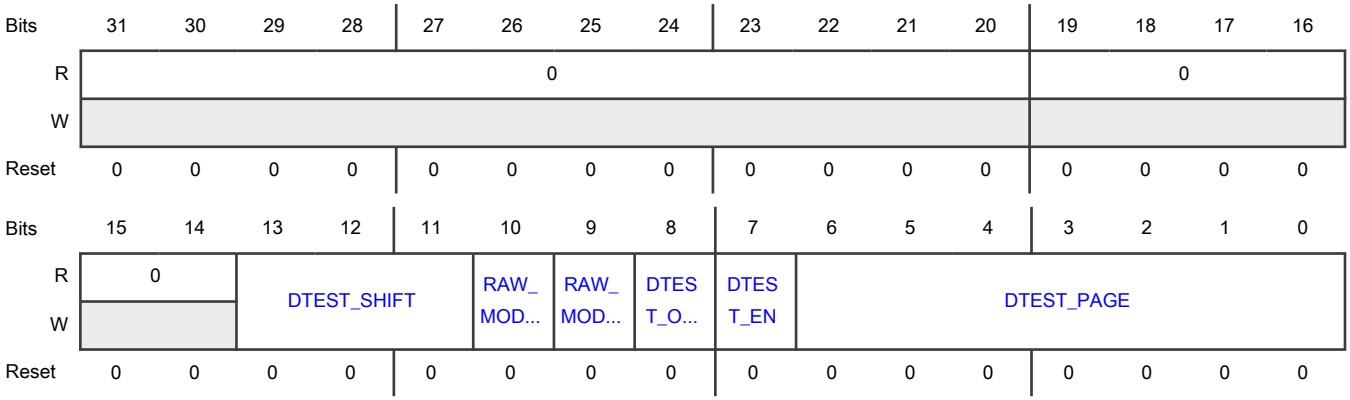
Field	Function
11-8 READ_START_OFFSET_2M	Start sending Rx data to NBU after a programmable number of symbols are received from PHY - 2M
7-4 READ_START_OFFSET_1M	Start sending Rx data to NBU after a programmable number of symbols are received from PHY - 1M
3-2 —	Reserved
1-0 CTE_AVG_SAMP_SEL	Sampling select

52.4.8.2.10 DTEST Control register (DTEST_CTRL)

Offset

Register	Offset
DTEST_CTRL	24h

Diagram



Fields

Field	Function
31-20 —	Reserved

Table continues on the next page...

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Field	Function
19-16 —	Reserved
15-14 —	Reserved
13-11 DTEST_SHIFT	DTEST shift control 1.Shift control for rx_dig_iq 0bx00: rx_dig_iq[11:0] 0bx01: {rx_dig_iq[11],rx_dig_iq[11:1]} 0bx10: {rx_dig_iq[11],rx_dig_iq[11],rx_dig_iq[11:2]} 0bx11: Reserved - same as x00 2.Shift control for pll_ripple_counter 0b000: pll_ripple_counter[18:5] 0b001: pll_ripple_counter[17:4] 0b010: pll_ripple_counter[16:3] 0b011: pll_ripple_counter[15:2] 0b100: pll_ripple_counter[14:1] 0b101: pll_ripple_counter[13:0] 0b110: Reserved - same as 0b000 0b111: Reserved - same as 0b000
10 RAW_MODE_Q	Select rx_dig_q as DTEST RX_IQ page
9 RAW_MODE_I	Select rx_dig_i as DTEST RX_IQ page
8 DTEST_OUT_REG_EN	Enable/Disable register dtest signal 0b - output dtest signal directly 1b - output dtest signal after registered
7 DTEST_EN	DTEST_EN control 0b - disable dtest feature 1b - enable dtest feature
6-0 DTEST_PAGE	DTEST PAGE Number Refer to the detailed dtest page definition table

52.4.8.2.11 DTEST PIN Control 2 register (DTEST_PIN_CTRL2)

Offset

Register	Offset
DTEST_PIN_CTRL2	30h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	DTEST_PIN11_OVRD_SEL				DTEST_PIN11_MUX_SEL				DTEST_PIN10_OVRD_SEL				DTEST_PIN10_MUX_SEL			
Reset	0	0	0	0	1	0	1	1	0	0	0	0	1	0	1	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	DTEST_PIN9_OVRD_SEL				DTEST_PIN9_MUX_SEL				DTEST_PIN8_OVRD_SEL				DTEST_PIN8_MUX_SEL			
Reset	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0

Fields

Field	Function
31-28 DTEST_PIN11_OVRD_SEL	DTEST_PIN11_OVRD_SEL Select the override signal for DTEST PIN11 0000b - override is disabled 0001b - aa_sfd_matched 0010b - rx_pd_fnd 0011b - agc_gain_change 0100b - tsm_combined_tx_en 0101b - tsm_combined_rx_en 0110b - crc_fail 0111b - decode_data_out 1000b - tx_data_out 1001b - nbu_testbus[14] 1010b - nbu_testbus[15] 1011b-1111b - reserved
27-24 DTEST_PIN11_MUX_SEL	DTEST_PIN11_MUX_SEL Select DTEST PIN11 signal from the signal on DTEST PIN[13:0].

Table continues on the next page...

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Field	Function
23-20 DTEST_PIN10_OVRD_SEL	DTEST_PIN10_OVRD_SEL Select the override signal for DTEST PIN10 0000b - override is disabled 0001b - aa_sfd_matched 0010b - rx_pd_fnd 0011b - agc_gain_change 0100b - tsm_combined_tx_en 0101b - tsm_combined_rx_en 0110b - crc_fail 0111b - decode_data_out 1000b - tx_data_out 1001b - nbu_testbus[14] 1010b - nbu_testbus[15] 1011b-1111b - reserved
19-16 DTEST_PIN10_MUX_SEL	DTEST_PIN10_MUX_SEL Select DTEST PIN10 signal from the signal on DTEST PIN[13:0].
15-12 DTEST_PIN9_OVRD_SEL	DTEST_PIN9_OVRD_SEL Select the override signal for DTEST PIN9 0000b - override is disabled 0001b - aa_sfd_matched 0010b - rx_pd_fnd 0011b - agc_gain_change 0100b - tsm_combined_tx_en 0101b - tsm_combined_rx_en 0110b - crc_fail 0111b - decode_data_out 1000b - tx_data_out 1001b - nbu_testbus[14] 1010b - nbu_testbus[15] 1011b-1111b - reserved
11-8	DTEST_PIN9_MUX_SEL Select DTEST PIN9 signal from the signal on DTEST PIN[13:0].

Table continues on the next page...

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Field	Function
DTEST_PIN9_MUX_SEL	
7-4 DTEST_PIN8_OVRD_SEL	DTEST_PIN8_OVRD_SEL Select the override signal for DTEST PIN8 0000b - override is disabled 0001b - aa_sfd_matched 0010b - rx_pd_fnd 0011b - agc_gain_change 0100b - tsm_combined_tx_en 0101b - tsm_combined_rx_en 0110b - crc_fail 0111b - decode_data_out 1000b - tx_data_out 1001b - nbu_testbus[14] 1010b - nbu_testbus[15] 1011b-1111b - reserved
3-0 DTEST_PIN8_MUX_SEL	DTEST_PIN8_MUX_SEL Select DTEST PIN8 signal from the signal on DTEST PIN[13:0].

52.4.8.2.12 Packet RAM to IPS transfer control and status (PACKET_RAM_TO_IPS_CTRL)

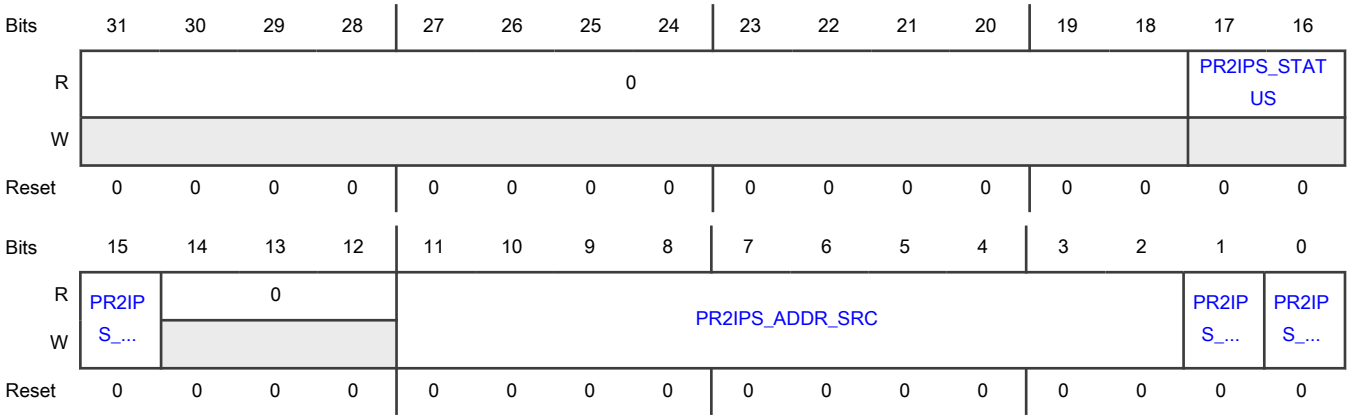
Offset

Register	Offset
PACKET_RAM_TO_IPS_CTRL	3Ch

Function

Programming of internal registers can be prepared in Packet RAM and transferred by burst to relevant IPs with a single request here.

Diagram



Fields

Field	Function
31-18 —	Reserved
17-16 PR2IPS_STATUS	PR2IPS_STATUS Status[0]: 0 means transfer not done yet or feature not enabled, 1 means feature enabled and transfer completed Status[1]: 1 means error in specified destination addresses, which is out of supported range
15 PR2IPS_REGS2PKT	Radio IP registers to packet RAM Registers of Radio IP are loaded with content pre-stored in packet RAM descriptors, in default mode. If this bit is set, current values of registers from Radio IP are transfered to packet RAM descriptors. In both cases, a valid descriptor is required. 0b - Transfer from packet RAM to Radio IP registers 1b - Transfer from Radio IP registers to packet RAM
14-12 —	Reserved
11-2 PR2IPS_ADDR_SRC	PR2IPS_ADDR_SRC Source address of instructions in packet RAM. Instruction is a collection of 32b words: [31:30] mode. 0 is end of instructions. 1 is single transfer. 2 is burst transfer [29:24] number of registers to update in case of burst. NO meaning in case of single transfer, although it should be set to 1 in that case [23:0] destination address for a single transfer, or first destination address for a burst Next words are data to be written during the burst
1 PR2IPS_RAM_SEL	PR2IPS_RAM_SEL A 1 selects RX_RAM, a 0 selects TX_RAM.
0 PR2IPS_ENA	PR2IPS_ENA Enables features. This will start automatically transfer from packet RAM to registers.

Chapter 53
Data Stream Buffer (DSB)

53.1 Overview

DSB captures streaming data from the radio and transfers the data to system memory with minimal intervention from a host processor. The hardware microarchitecture includes:

- An internal FIFO for temporary storage of the data stream
- A small Direct Memory Access (DMA) controller that performs:
  - Destination address calculations
  - Data movement operations

53.1.1 Block diagram

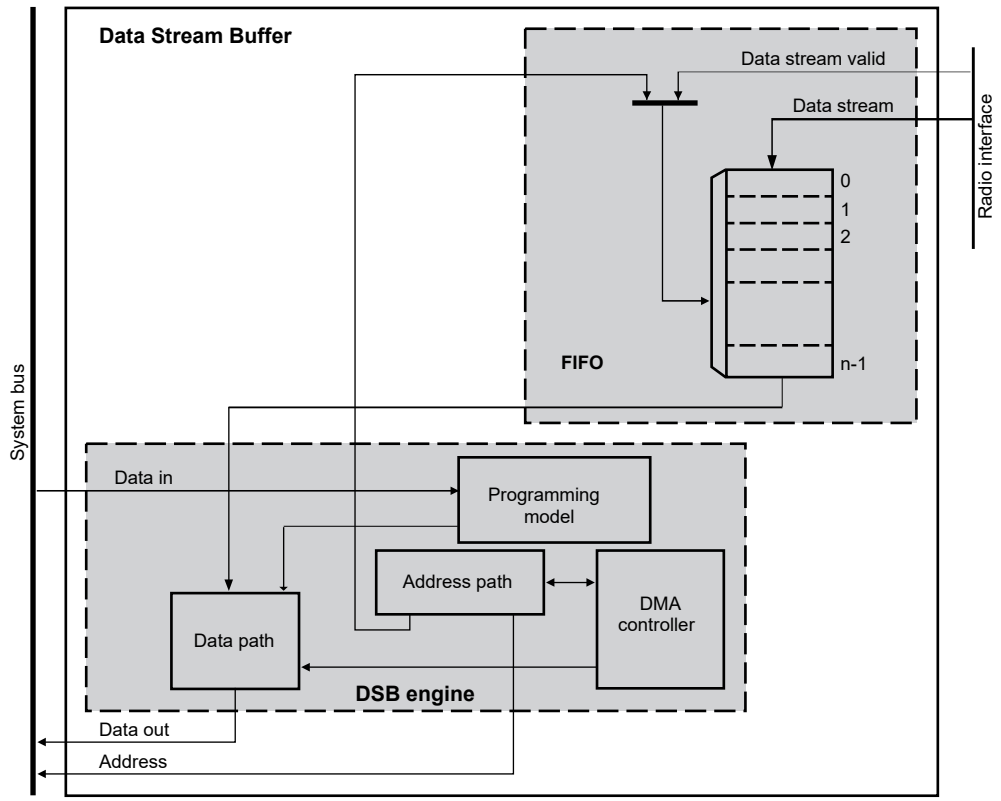


Figure 520. DSB block diagram

53.1.2 Features

- FIFO for collecting data stream with read accessibility
- Watermark throttle control for initiating DMA transfer of FIFO data
- Interrupt notification on watermark threadhold

53.2 Functional description

53.2.1 FIFO

The FIFO submodule captures valid data from the the data stream. Each FIFO element is 32-bit wide.

53.2.2 DSB engine

DSB engine contains the programming model and internal register bus (IPS) interface for DSB. It also controls the DMA function and the FIFO pointers.

53.2.3 DSB operation

When CSR[DSB_EN] is enabled, the DSB takes in data from the radio interface and captures it in a FIFO and WMC[CNT] is incremented. DSB continues to capture valid stream data until the FIFO is full, which occurs when WMC[CNT] equals WMC[SIZE]. The contents of the FIFO can be read directly by reading the RDATA register. When reading RDATA register, the DSB provides the next element in the FIFO and pops the element off the FIFO stack.

The contents of the FIFO can also be moved to a target, such as an SRAM, by using the DSM DMA function. To use the DMA function, the following steps are needed to configure the DSB DMA function:

1. Enable the DSB DMA by setting CSR[DMA_EN]
2. Set the watermark value in WMC[WMRK]
3. Set the desired DMA transfer count by setting XCR[TCNT]
4. Provide the destination address for the DMA transfer by setting DADDR[DADDR]

As the DSM collects stream info into the FIFO, FIFO COUNT (WMC[CNT]) is checked against the watermark (WMC[WMRK]). Once the watermark value has been reached, as indicated when WMC[CNT] = WMC[WMRK], the DMA operation is initiated. The DSB begins to transfer the contents of the FIFO by issuing a series of transfers on the system bus AHB interface, one tranfer per FIFO element. After each transfer is complete, the FIFO element is popped off the FIFO stack and the WMC[CNT] is deprecated.

53.2.4 Clocking

DSB has two clocks:

- Functional clock (hclk) for functional domain
- Programming model clock (ipg_clk) for IPS programming model domain

DSB requires both functional and programming model clocks to be synchronous with 1:1 clock ratio. Clock synchronization must be handled outside of DSB.

For detailed information about the clock sources, see the chip-specific Clocking chapter.

53.2.5 Reset

DSB has one reset input for the whole block. For detailed information about the reset sources, see the chip-specific Reset chapter.

DSB also provides a software reset option. Software can initiate a reset by writing 1 to CSR[SFTRST]. A software reset will revert the DSB programming model fields to the default state. Software reset will also clear the DSB functional datapath, including the FIFO and kill any DMA operation in progress.

53.2.6 Interrupts

DSB provides one interrupt notification out. DSB interrupt can be configured to trigger on two event types:

- Data Ready Event

  To enable interrupt notification when data is ready, set CSR[INT_EN]:

- Data Ready interrupt is triggered when the FIFO watermark has been reached, as indicated when WMC[CNT] = WMC[WMRK].
- Data ready event is captured in INT[DRDY].
- DMA tranfer complete, as indicated when XCR[TCNT] = XCR[CCNT], is captured in INT[DONE].

When servicing this interrupt, use W1C action to clear INT[DONE].

- Error Events

  To enable interrupt notification on error events, set CSR[ERR_EN]:

  - Destination Error Event: system AHB bus error on DMA transfer to destination, as indicated by INT[DBE]. When servicing this interrupt, use W1C action to clear INT[DBE].
  - FIFO Overflow Event: data stream capture has exceeded the capacity of the FIFO, as indiated by INT[OVRF]. When servicing this interrupt, use W1C action to clear INT[OVRF].
  - FIFO Overrun Event: attempt to read empty FIFO, as indicated by INT[UNDR]. When servicing this interrupt, use W1C action to clear INT[UNDR].

53.2.7 DMA

For details on the DMA operation, see DSB operation.

The DMA function can be cancelled by driving the Stop request input. When this input is asserted, the current system bus transfer is completed and then DMA operation is cancelled.

Driving the Stop request input also clears the FIFO, but XCR[TCNT] and XCR[CCNT] are left intact.

53.3 External signals

This module has no external signals.

53.4 Initialization

This section discusses initialization of DSB and its programming considerations.

To use the internal DMA engine to transfer streaming radio data to system memory, initialize the transfer profile before enabling DSB. Follow the below procedure:

1. Initialize the DADDR with the destination buffer location in system memory.
2. Set the required total transfer count, XCR[TCNT], with the total packet length (in 32-bit words).
3. Set the watermark threshold value in WMC[WMRK].
4. Set the CSR[DMA_EN] bit.
5. Set the CSR[INT_EN] bit and CSR[ERR_EN] bit for interrupts on error or packet transfer completion.
6. Set the CSR[DSB_EN] bit when ready to receive the data stream.

For example:

1. DADDR = 0x80004000 (system memory location)
2. TCNT = 0x1000 (16 KB of data)
3. WMRK = 0x8 (1/2 of the 16 element depth)
4. DMA_EN = 1, INT_EN = 1, ERR_EN = 1
5. DSB_EN = 1

NOTE

Real-time deadline analysis should be performed to ensure that DSB has sufficient system resources to meet all deadlines with respect to transferring the radio data stream to system memory.

53.5 Memory map and register definition

The programming model of DSB is partitioned into four parts:

- The first part, Control/Status, defines a number of registers providing overall control functions.
- The second part corresponds to the interrupt status.
- The third part corresponds to the FIFO attributes.
- The fourth part corresponds to the FIFO read data.

DMA initialization

Before enabling the DMA logic, you must initialize the control fields of DMA with the appropriate transfer profile.

Reserved memory and bit fields

- Reading reserved bits in a register returns the value of zero.
- Writes to reserved bits in a register are ignored.
- Reading a reserved memory location returns undefined.
- Writes to a reserved memory location is ignored.

53.5.1 DSB register descriptions

53.5.1.1 DSB memory map

DSB0 base address: 4004_1000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Control (CSR)	32	RW	0000_0000h
4h	Interrupt Request Status (INT)	32	RW	0000_0000h
8h	Watermark Configuration (WMC)	32	RW	1000_0000h
Ch	FIFO Read Data (RDATA)	32	R	0000_0000h
10h	DMA Destination Address (DADDR)	32	RW	0000_0000h
14h	DMA Transfer Count (XCR)	32	RW	0000_0000h

53.5.1.2 Control (CSR)

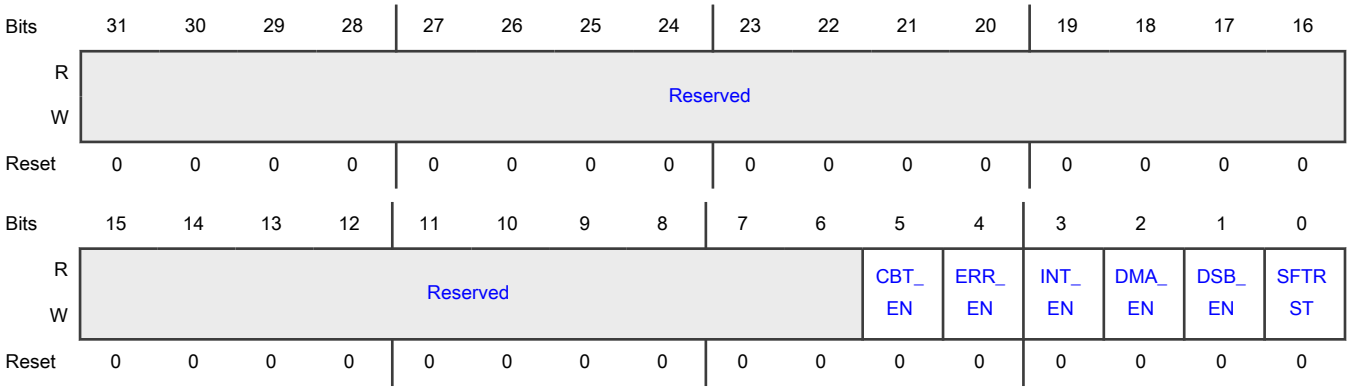
Offset

Register	Offset
CSR	0h

Function

Defines the basic operating configuration of DSB.

Diagram



Fields

Field	Function
31-6 —	Reserved
5 CBT_EN	Continuous Burst Transfer Enable Specifies whether continuous burst transfer mode is enabled. When enabled, continuous burst transfer streams data from the FIFO to the system bus until either the FIFO is empty or the transfer count, XCR[TCNT], has been achieved. The continous data transfer is executed as a single, undefined length burst transfer. When disabled, the burst transfer length is equal to the watermark value WMC[WMRK]. 0b - Disabled 1b - Enabled
4 ERR_EN	Error Interrupt Request Enable Specifies whether error interrupts requests on overflow, underrun, or bus error are enabled. 0b - Error interrupt requests disabled 1b - Error interrupt requests enabled
3 INT_EN	Interrupt Request Enable Specifies whether interrupts requests on "data ready" or "DMA done" are enabled. When the DMA is enabled (CSR[DMA_EN] = 1), this field enables interrupt requests when the packet transfer is complete (INT[DONE] = 1). Otherwise, this field enables interrupt requests when data is ready (INT[DRDY] = 1). 0b - Interrupt requests disabled 1b - Interrupt requests enabled
2	DMA Transfer Enable

Table continues on the next page...

Table continued from the previous page...

Field	Function
DMA_EN	0b - Disables 1b - Enables
1 DSB_EN	DSB Enable 0b - Disables 1b - Enables
0 SFTRST	Soft Reset 0b - No operation 1b - Resets DSB

53.5.1.3 Interrupt Request Status (INT)

Offset

Register	Offset
INT	4h

Function

Indicates the current state of the interrupt service request sources for DSB.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	Reserved															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	Reserved											DONE	DBE	UNDR	OVRF	DRDY
W												W1C	W1C	W1C	W1C	
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-5 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
4 DONE	DMA Packet Transfer Complete 0b - Packet transfer not done; CCNT less than TCNT 1b - Packet transfer is done; TCNT 32-bit words transferred
3 DBE	Destination Bus Error 0b - No destination bus error 1b - The last recorded error is bus error on a write
2 UNDR	Underrun Error 0b - No underrun error 1b - The last recorded error is an underrun on a read
1 OVRF	Overflow Error 0b - No overflow error 1b - The last recorded error is a buffer overflow
0 DRDY	Data Ready 0b - No data to read (watermark has not been reached) 1b - Data is ready to read (watermark has been reached)

53.5.1.4 Watermark Configuration (WMC)

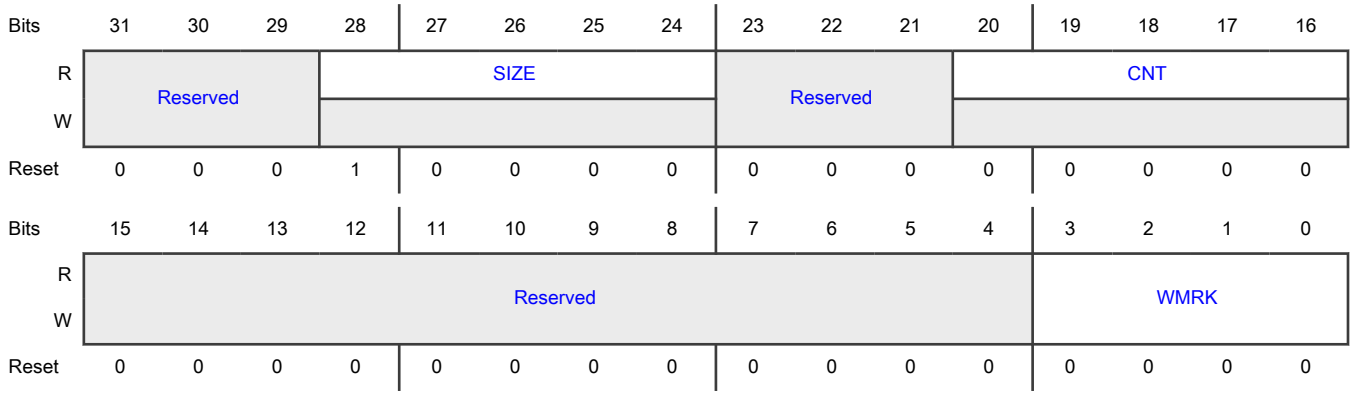
Offset

Register	Offset
WMC	8h

Function

Controls the DMA operations of DSB and indicates data is available via the INT[DRDY] bit. The WMC register shows the depth of the data stream FIFO and the number of elements written into the FIFO.

Diagram



Fields

Field	Function
31-29 —	Reserved
28-24 SIZE	FIFO size Indicates the number of elements the FIFO can hold.
23-21 —	Reserved
20-16 CNT	FIFO Count Indicates the number of elements currently in the FIFO.
15-4 —	Reserved
3-0 WMRK	Watermark DSB starts DMA transfers, if enabled, and sets DRDY when the number of elements in the FIFO is equal to or greater than the watermark value. 0000b - Disables 0001b - Enables

53.5.1.5 FIFO Read Data (RDATA)

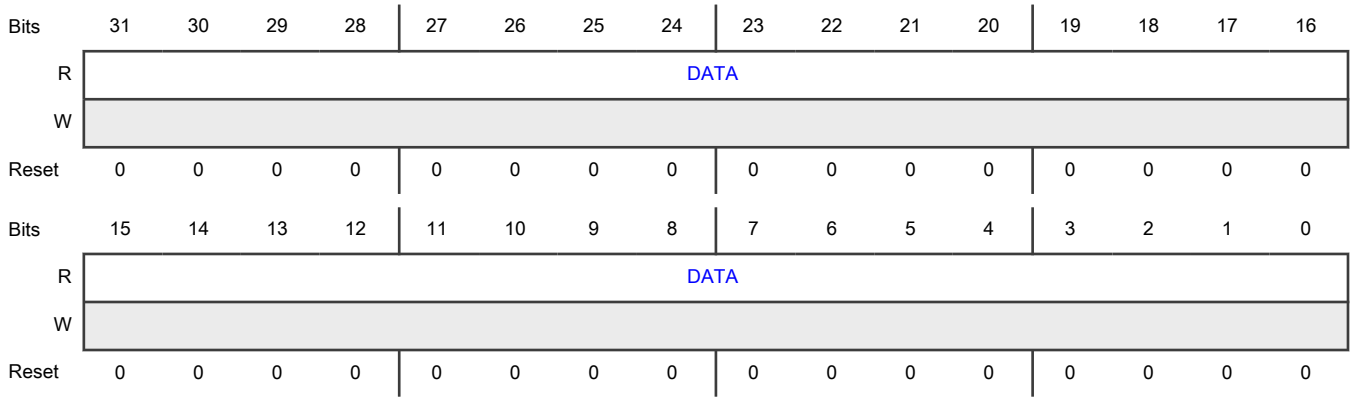
Offset

Register	Offset
RDATA	Ch

Function

Presents the next element in the FIFO. Reading the RDATA register pops the element off the FIFO stack.

Diagram



Fields

Field	Function
31-0 DATA	FIFO Data Reads data from FIFO. **NOTE** This field is not testable by an automated register test.

53.5.1.6 DMA Destination Address (DADDR)

Offset

Register	Offset
DADDR	10h

Function

The target address in system memory where the FIFO data is transferred to upon reaching the watermark value. The transfer profile to the destination address is undefined length INCR burst, 32-bits per beat. The number of beats is equal to the watermark value until TCNT is reached. This byte address register automatically increments by four after each transfer beat.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R W	DADDR															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	DADDR															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-0 DADDR	Destination Address Destination address for the DMA transfer. **NOTE** If illegal address is programmed into DADDR, the DMA transfer will still be executed, but likely will be blocked and return a system bus error on each transfer.

53.5.1.7 DMA Transfer Count (XCR)

Offset

Register	Offset
XCR	14h

Function

Indicates the required and actual number of 32-bit words that the internal DMA controller transfers.

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	CCNT															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	TCNT															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-16 CCNT	Current Transfer Count The current number of elements transferred to system memory.
15-0 TCNT	Total Transfer Count The required total number of elements to transfer to system memory. When the CCNT equals the TCNT: • DSB disables, • DMA operations stop, • any remaining data discards in the FIFO, • the CCNT resets to zero, • an optional DONE interrupt request generates.

Chapter 54
RF Core Mode Controller (RF_CMC)

54.1 Overview

The RF_CMC provides the sequencing of the overall radio power domain, including the CPU core instantiated inside the Radio, and associated logic through the different operating modes.

54.1.1 Block diagram

The following diagram gives a high-level overview of the RF_CMC.

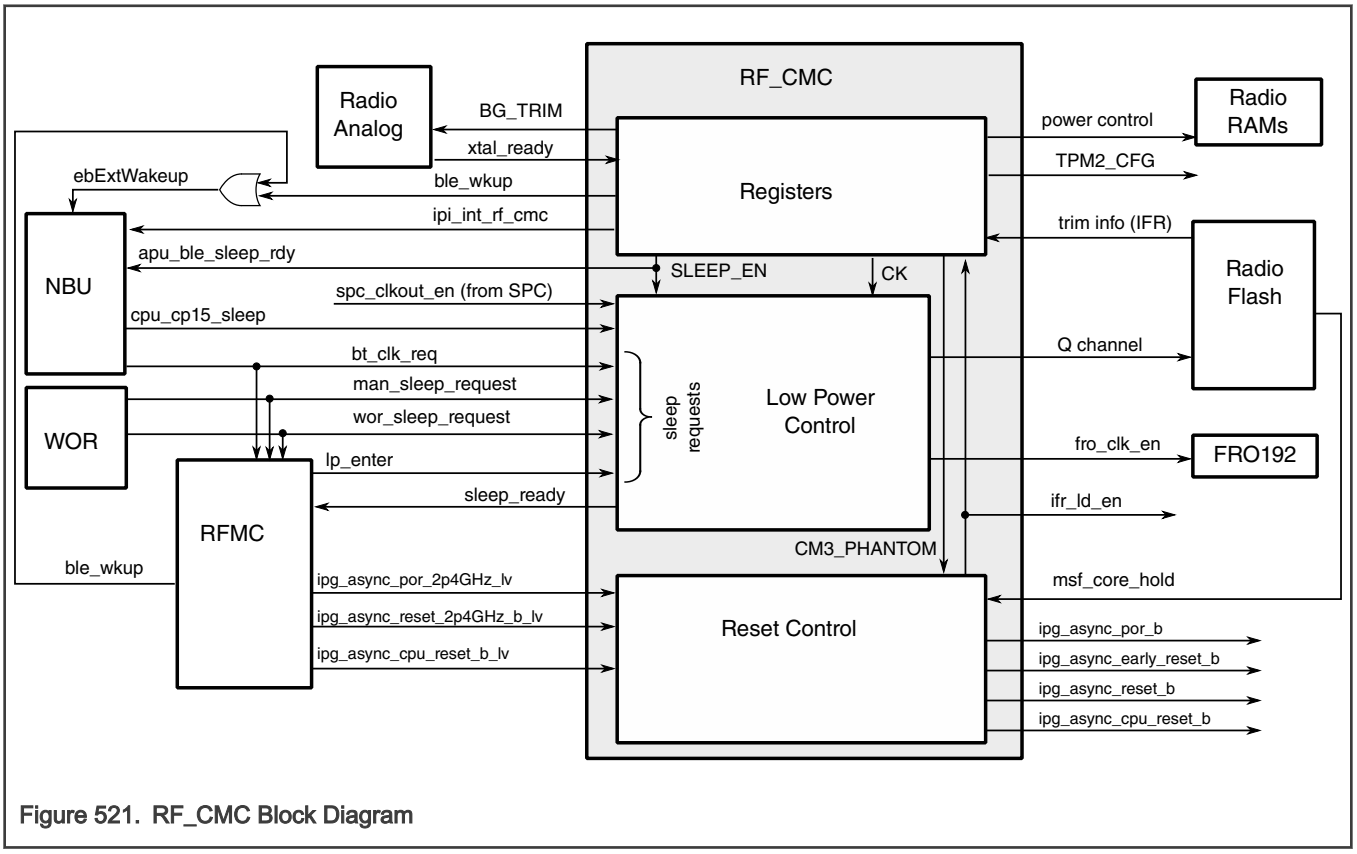


Figure 521. RF_CMC Block Diagram

54.1.2 Features

The Radio Core Mode Controller (RF_CMC) provides the following functions:

- Provides the enable to radio FRO module, which is sequenced off at low power entry, and on at low power exit
- Controls the low power sequencing for the radio flash via Q-channel interface.
- Conditions the low power entry requests from the NBU and WOR (for WOR and MAN) to wait until the NBU/CM33 is ready and the radio flash has entered low power
- On exit from Power Down or Deep Power Down low power modes, holds the radio LV in reset until the radio flash has finished its initialization.
- Creates XTAL ready interrupt for CM33
- Provides programmable control for TPM2 (clock control and input channel selection)
- Generates ifr_ld_en associated with the radio flash IFR outputs

- Implements SOC Core status registers
- Implements RAM related control registers (power controls)

The RF_CMC's logic uses the IPS/APB clock provided by the radio FRO module. It does not use the XTAL clock or the 32.768KHz clock.

54.2 Functional description

54.2.1 Reset Control

The Reset control module performs the following functions

- On exit from Power Down or Deep Power Down low power modes, holds the radio LV in reset until the radio flash has finished its initialization.
- Generates the flash ifr_ld_en used to capture the radio flash IFR outputs

54.2.2 Low Power Control

The Low Power control module performs the following functions

- Provides the enable to radio FRO module, which is sequenced off at low power entry, and on at low power exit using the spc_clkout_en signal. The FRO can also be gated off in the CK=01 configuration
- Controls the low power sequencing for the radio flash via Q-channel interface.
- Creates a sleep_rdy signal to the RFMC. This signal must be asserted before the RFMC will accept a request to enter low power mode.

The RF_CMC supports the following low power configurations, selected by the programmable CK bits.

- CK=00. This is the normal/default configuration. When NBU CPU executes WFI and SLEEP_EN=1 (or if NBU CPU reset is asserted), and a sleep request from RFMC (LP_ENTER) NBU, MAN or WOR is asserted, the flash is put in low power, then the sleep_rdy to RFMC asserts and the FRO will be disabled.
- CK=01. This configuration supports use cases where NBU, FRO and flash are not used. When NBU CPU reset is asserted, or NBU CPU executes WFI and SLEEP_EN=1, the flash will be placed in low power, then the FRO disabled, the sleep_rdy to RFMC will assert and the NBU CM33 and AHB clocks will be gated off. Note the following behavior in the configuration after the FRO is disabled:
  - Read/write access to RF_CMC's registers will not be possible
  - RF_CMC's sleep_rdy output will remain asserted, so low power requests from RFMC (LP_ENTER), MAN or WOR will be immediately accepted by RFMC
  - If will not be possible to reprogram the RAM_RM registers, but the RAM control logic will still respond correctly to voltage select changes
- CK=10. Configuration where NBU CPU is not used but FRO and flash can still be used. When NBU CPU reset is asserted, or NBU CPU executes WFI and SLEEP_EN=1, the clock to the NBU CPU will be gated. When RFMC (LP_ENTER), MAN or WOR request sleep, the flash is put in low power, then the sleep_rdy to RFMC asserts and the FRO will be disabled as in configuration 00.

54.2.3 Radio SMU/DMEM muxing

Based on Radio SW use case, SMU and DMEM are multiplexed at SOC level to enable various configurations of memory between SMU and DMEM.

The default configuration is 80kB for SMU and 80kB for DMEM. Overall, there are 4x8kB, 4x16kB and 2x32kB of SRAM which are allocated between SMU and DMEM. Each of this SRAM can be allocated either to SMU or DMEM.

RAM_MUX_CTRL[SMU_MEM_SEL] controls the allocation of those SRAM instances. Writing to RAM_MUX_CTRL[SMU_MEM_SEL] is protected by the RAM_MUX_CONTROL[UNLOCK] bitfiled, which needs to be set to

0x5 before any write operation. Application should ensure that there are no on-going processing beeing done on SMU or DMEM prior to change RAM_MUX_CTRL[SMU_MEM_SEL], that will be set typically during SW boot time.

Below are given the supported configurations, any other configuration is not supported:

Table 569. RF SMU/DMEM valid multiplexing options

SMU_MEM_SEL[9:0]	SMU space (kB)	DMEM space (kB)
0x3E0	80 kB	80 kB
0x3F0	64 kB	96
0x3F8	32	128
0x3FC	16	144
0c3FE	8	152
0x3FF	-	160
0x3C0	96	64
0x380	128	32
0x300	144	16
0x200	152	8
0x000	160	-

54.2.4 SPC high power request

In use cases where the Radio needs to transmit at a high power (i.e. +10dBm), there is a need to increase the DCDC output voltage. This request can be manage directly from the Radio power domain (whithout need to wakeup the main power domain), using the RF_CMC. In order to request High Power mode entry, Radio software provides the target DCDC output level by configuring SPC_HP_CTRL[SPC_HP_MODE][3:0]. This parameter is one-hot encoded; possible DCDC output values are: 1.35V, 1.8V and 2.5V, while when setting SPC_HP_MODE to 0x0, DCDC output will remain unchanged.

Once SPC_HP_MODE configured, Radio software will initiate a request by setting SPC_HP_CTRL[SPC_HP_REQ], and then wait for this request to be acknowledged by reading SPC_HP_STAT[SPC_HP_ACK]. Once acknowledged, the SPC has finalized the transition from ACTIVE_CFG to HP_CFG.

Resetting SPC_HP_CTRL[SPC_HP_REQ], will trigger SPC to transition back from HP_CFG to ACTIVE_CFG.

54.2.5 Clocking

This module has no clocking considerations.

54.2.6 Interrupts

This section describes all the interrupts (IRQs) that the RF_CMC module generates. Below interrupt sources can be generated individually from RF_CMC to Radio CPU core.

- after the XTAL ready output from XO analog asserts

54.3 External signals

There are no RF_CMC signals directly available at the chip boundary of the SoC externally.

54.4 Initialization

RF_CMC does not require any special initialization.

54.5 Application Information

To enable Radio Low Power entry, RADIO_LP[SLEEP_EN] should be asserted.

Prior to Low Power entry (DeepSleep or PowerDown), each invidual Radio RAM can be configured to be retained or not duing Radio Low Power mode via RAM_PWR[DS_EN].

Each individual Radio RAM can be shut down via RAM_PWR[[SD_EN].

54.6 Register descriptions

54.6.1 RF_CMC register descriptions

54.6.1.1 RF_CMC memory map

RF_CMC1 base address: 4898_3000h

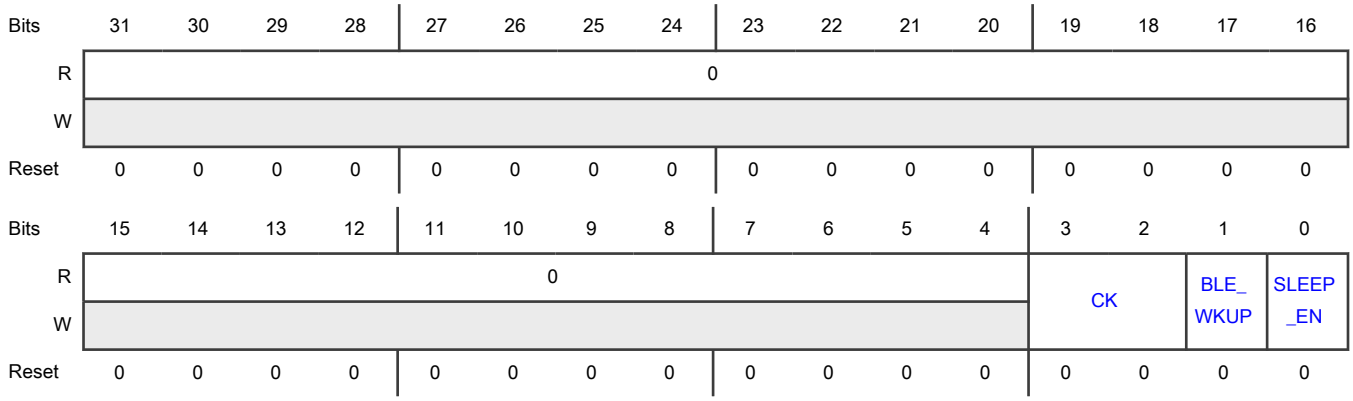
Offset	Register	Width (In bits)	Access	Reset value
0h	Radio Low Power Control Register (RADIO_LP)	32	RW	0000_0000h
4h	SOC Low Power Control and Status Register (SOC_LP)	32	RW	0000_0000h
8h	Interrupt Control Register (IRQ_CTRL)	32	RW	0000_0000h
Ch	TPM2 Configuration Register (TPM2_CFG)	32	RW	0000_0800h
10h	Radio Trim Register (RADIO_TRIM)	32	RW	0000_0073h
14h	RAM Power Control register (RAM_PWR)	32	RW	0000_0000h
18h	NBU RAM Block Mux Control (RAM_MUX_CTRL)	32	RW	0000_03E0h
20h	SPC High Power configuration (SPC_HP_CTRL)	32	RW	0000_0000h
24h	SPC High Power Acknowledge Status (SPC_HP_STAT)	32	R	0000_0000h

54.6.1.2 Radio Low Power Control Register (RADIO_LP)

Offset

Register	Offset
RADIO_LP	0h

Diagram



Fields

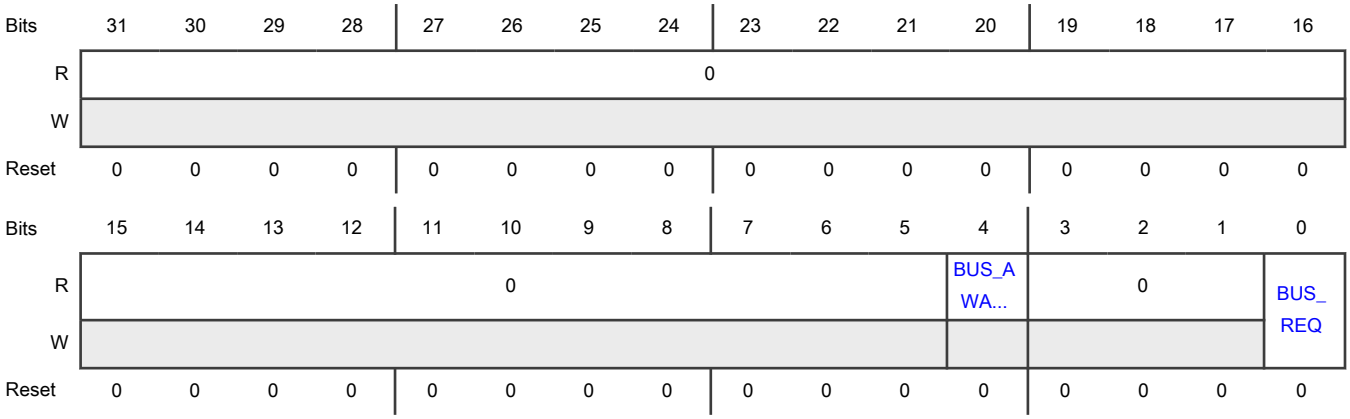
Field	Function
31-4 —	Reserved
3-2 CK	Clock Control These bits provide additional configuration for the RF_CMC 00b - Normal configuration. When NBU CPU executes WFI and SLEEP_EN=1 (or if NBU CPU reset is asserted), and a sleep request from RFMC (LP_ENTER) NBU, MAN or WOR is asserted, the flash is put in low power, the sleep_rdy to RFMC asserts and the FRO will be disabled. 01b - Configuration where NBU, FRO and flash are not used. When NBU CPU reset is asserted, or NBU CPU executes WFI and SLEEP_EN=1, the flash will be placed in low power, the FRO disabled, the sleep_rdy to RFMC will assert and the NBU CM3 and AHB clocks will be gated off. The RF_CMC and NBU CPU will be without a clock until the next reset, but low power requests (RFMC LP_ENTER, MAN or WOR) will by accepted by RFMC since RF_CMC's sleep_rdy output will remain asserted. 10b - Configuration where NBU CPU is not used but FRO and flash can still be used. When NBU CPU reset is asserted, or NBU CPU executes WFI and SLEEP_EN=1, the clock to the NBU CPU will be gated. When RFMC (LP_ENTER), MAN or WOR request sleep, the flash is put in low power, the sleep_rdy to RFMC asserts and the FRO will be disabled as in configuration 00.
1 BLE_WKUP	Bluetooth Wakeup Software control bit which can be used to force the NBU to assert its bt_clk_req output. Note that this bit is OR'ed with RFMC's BLE_WKUP bit; the output of that OR is connected to the NBU's ebExtWakeup input.
0 SLEEP_EN	Sleep Enable Software control bit which gates all sleep entry requests. Software should clear this bit if it is not ready to enter sleep, and set it when it is ready. This bit does not automatically clear on low power exit. This bit is also input to NBU as "apu_ble_slp_rdy".

54.6.1.3 SOC Low Power Control and Status Register (SOC_LP)

Offset

Register	Offset
SOC_LP	4h

Diagram



Fields

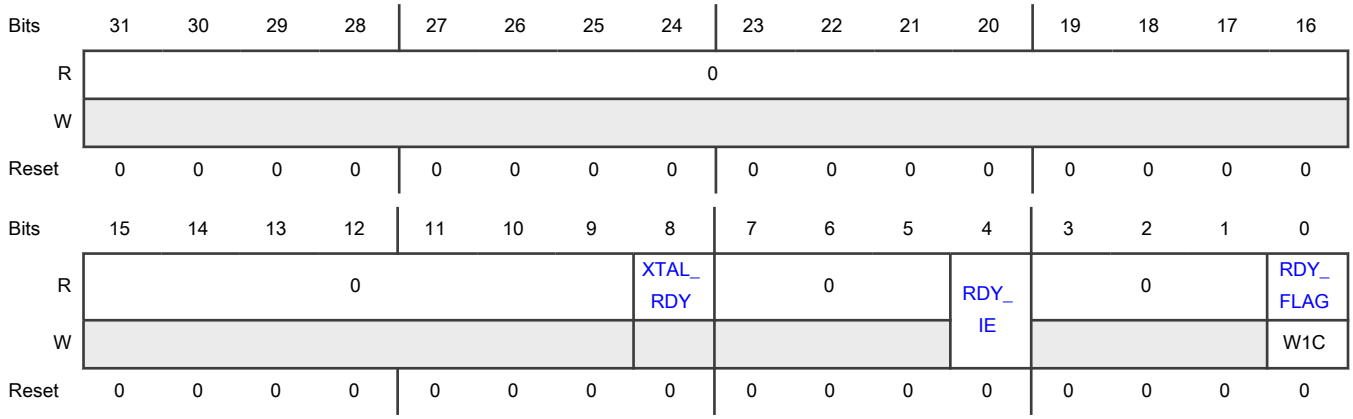
Field	Function
31-5 —	Reserved
4 BUS_AWAKE	Bus Awake This status bit indicates that the SOC bus is awake, and the CM3 software can perform a bus access.
3-1 —	Reserved
0 BUS_REQ	Bus Access Request This bit can be set by software to request the SOC to wake the logic so that the CM3 can perform a bus access to the SOC XBAR. This will be connected to SOC WUU_MxDR input.

54.6.1.4 Interrupt Control Register (IRQ_CTRL)

Offset

Register	Offset
IRQ_CTRL	8h

Diagram



Fields

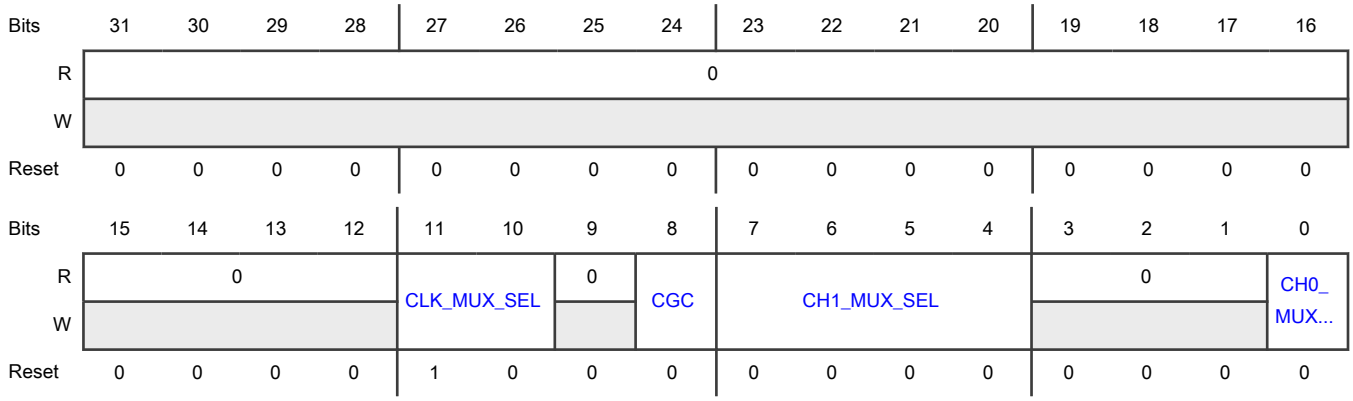
Field	Function
31-9 —	Reserved
8 XTAL_RDY	XTAL Ready Reflects the instantaneous value of the XTAL rady signal from the XO analog.
7-5 —	Reserved
4 RDY_IE	XTAL Ready Interrupt Enable If set, an interrupt is enabled when RDY_FLAG asserts.
3-1 —	Reserved
0 RDY_FLAG	XTAL Ready Flag Flash which sets after the XTAL ready output from XO analog asserts (write 1 to clear).

54.6.1.5 TPM2 Configuration Register (TPM2_CFG)

Offset

Register	Offset
TPM2_CFG	Ch

Diagram



Fields

Field	Function
31-12 —	Reserved
11-10 CLK_MUX_SEL	Clock Mux Select Selects which clock is input to TPM2 00b - No clock 01b - Core Clock 10b - Radio Oscillator 11b - 32kHz clock
9 —	Reserved
8 CGC	Clock Gate Control 0b - TPM2 clock disabled 1b - TPM2 clock enabled
7-4 CH1_MUX_SEL	Channel1 Input Mux Select Selects which signal is input to TPM2 Channel 1 0000b - TPM2_CH1 pin 1111b - Reserved
3-1 —	Reserved
0 CH0_MUX_SEL	Channel0 Input Mux Select Selects which signal is input to TPM2 Channel 0

Table continues on the next page...

Table continued from the previous page...

Field	Function
	0b - TPM2_CH0 pin 1b - tof_timestamp_trig signal from radio

54.6.1.6 Radio Trim Register (RADIO_TRIM)

Offset

Register	Offset
RADIO_TRIM	10h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0									CM3_PHANTOM			0	BG_TRIM		
W																
Reset	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1

Fields

Field	Function
31-7 —	Reserved
6-4 CM3_PHANTOM	CM3 Phantom This bitfield is used by boot ROM. **NOTE** This bitfield resets (to 3'b111) on a power-on-reset, but the value is overwritten after that by IFR load events.
3 —	Reserved
2-0	Bandgap Trim

Table continues on the next page...

Table continued from the previous page...

Field	Function
BG_TRIM	Controls the bandgap trim in the analog. **NOTE** This bitfield only resets (to 3'b011) on a power-on-reset, but the value is overwritten after that by IFR load events. Normally, this bitfield should not need to be changed by software except for debug or characterization purposes. 000b - 787mV 001b - 794mV 010b - 800mV 011b - 806mV 100b - 812mV 101b - 819mV 110b - 825mV 111b - 831mV

54.6.1.7 RAM Power Control register (RAM_PWR)

Offset

Register	Offset
RAM_PWR	14h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		DS_EN													
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		SD_EN													
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-30	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
—	
29-16 DS_EN	Deep Sleep Enable These bits are used to control whether the RAM blocks are retained or power-gated in Power Down andDeep Sleep low power modes. Setting a bit causes the associated RAM block to be powered on in Power Down orDeep Sleep low power modes. Mapping is as shown below Bit [16] TXRAM Bit [17] RXRAM Bit [18] NBU IRAM Bit [19] NBU RAM block 0, 8KB Bit [20] NBU RAM block 1, 8KB Bit [21] NBU RAM block 2, 16KB Bit [22] NBU RAM block 3, 32KB Bit [23] NBU RAM block 4, 16KB Bit [24] NBU RAM block 5, 8KB Bit [25] NBU RAM block 6, 8KB Bit [26] NBU RAM block 7, 16KB Bit [27] NBU RAM block 8, 32KB Bit [28] NBU RAM block 9, 16KB Bit [29] EBRAM
15-14 —	Reserved
13-0 SD_EN	Shut Down Enable These bits can be used to shut down radio RAM blocks. Setting a bit causes theassociated RAM block to be powered off. Mapping is as shown below Bit [0] TXRAM Bit [1] RXRAM Bit [2] NBU IRAM Bit [3] NBU RAM block 0, 8KB Bit [4] NBU RAM block 1, 8KB Bit [5] NBU RAM block 2, 16KB Bit [6] NBU RAM block 3, 32KB Bit [7] NBU RAM block 4, 16KB Bit [8] NBU RAM block 5, 8KB Bit [9] NBU RAM block 6, 8KB

Table continues on the next page...

Table continued from the previous page...

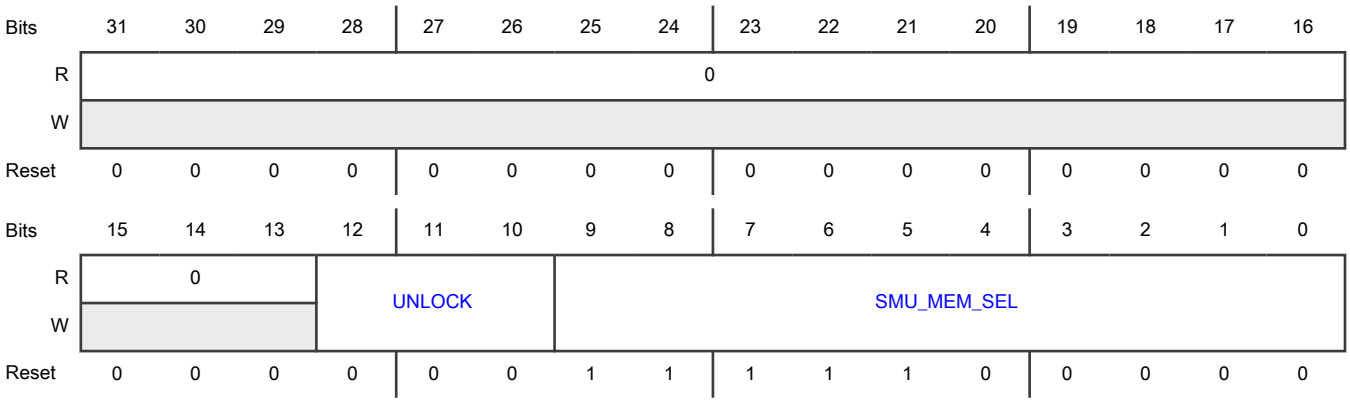
Field	Function
	Bit [10] NBU RAM block 7, 16KB Bit [11] NBU RAM block 8, 32KB Bit [12] NBU RAM block 9, 16KB Bit [13] EBRAM

54.6.1.8 NBU RAM Block Mux Control (RAM_MUX_CTRL)

Offset

Register	Offset
RAM_MUX_CTRL	18h

Diagram



Fields

Field	Function
31-13 —	Reserved
12-10 UNLOCK	Unlock 3'b101: Unlocked for write
9-0 SMU_MEM_SEL	Control whether the RAM blocks are attached to DMEM or SMU These bits are used to control whether the RAM blocks are attached to DMEM or SMU 0x3e0: SMU 80kB / DMEM 80kB 0x3f0: SMU 64kB / DMEM 96kB

Table continues on the next page...

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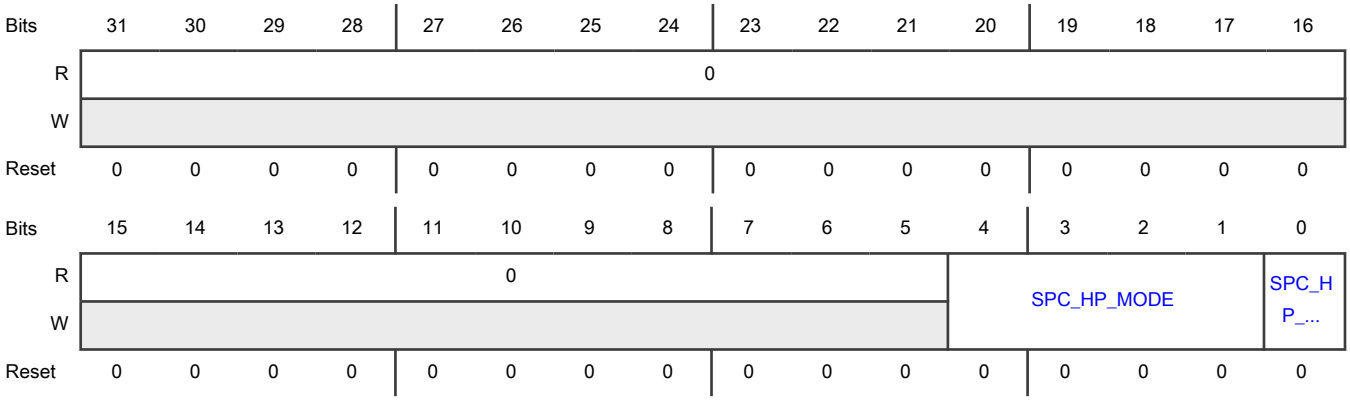
Field	Function
	0x3f8: SMU 32kB / DMEM 128kB 0x3fc: SMU 16kB / DMEM 144kB 0x3fe: SMU 8kB / DMEM 152kB 0x3ff: SMU 0kB / DMEM 160kB 0x3c0: SMU 96kB / DMEM 64kB 0x380: SMU 128kB / DMEM 32kB 0x300: SMU 144kB / DMEM 16kB 0x200: SMU 152kB / DMEM 8kB 0x000: SMU 160kB / DMEM 0kB All other values are undefined

54.6.1.9 SPC High Power configuration (SPC_HP_CTRL)

Offset

Register	Offset
SPC_HP_CTRL	20h

Diagram



Fields

Field	Function
31-5 —	Reserved
4-1	SPC High Power Mode Control

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Field	Function
SPC_HP_MODE	4'b0000: Use HP_CFG voltage settings from SPC 4'b0001: 1.35V 4'b0010: 1.50V 4'b0100: 1.80V 4'b1000: 2.50V Any other values are undefined
0 SPC_HP_REQ	SPC High Power Request 0b - No High Power Mode request to SPC 1b - High Power Mode request to SPC active

54.6.1.10 SPC High Power Acknowledge Status (SPC_HP_STAT)

Offset

Register	Offset
SPC_HP_STAT	24h

Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															SPC_HP_...
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fields

Field	Function
31-1 —	Reserved
0	SPC High Power Mode entry acknowledge status

Table continues on the next page...

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Field	Function
SPC_HP_ACK	0b - SPC High Power Mode request not acknowledged 1b - SPC High Power Mode request acknowledged

Chapter 55
Radio Flash Management Unit (RF_FMU1)

55.1 Overview

The flash module includes the following accessible memory regions:

- Program flash memory for vector space and code store
- Separate flash memory for parameter store

Flash memory is ideal for single-supply applications, permitting in-the-field erase and reprogramming operations without the need for any external high voltage power sources.

The flash module includes a command controller that executes commands to modify flash memory contents. An erased bit reads '1' and a programmed bit reads '0'. The programming operation is unidirectional; it can only move bits from the '1' state (erased) to the '0' state (programmed). Only the erase operation restores bits from '0' to '1'; bits cannot be programmed from a '0' to a '1'.

CAUTION

A flash memory location must be in the erased state before being programmed. Cumulative programming of bits (back-to-back program operations without an intervening erase) within a flash phrase or page is not allowed. Re-programming of existing 0s to 0 is not allowed as this overstresses the device.

The standard shipping condition for flash memory is erased. Data loss over time may occur due to degradation of the erased ('1') states and/or programmed ('0') states. Therefore, it is recommended that flash memory be re-erased immediately prior to factory programming to ensure that the full data retention capability is achieved.

55.1.1 Block diagram

The block diagram of the flash module is shown in the following figure.

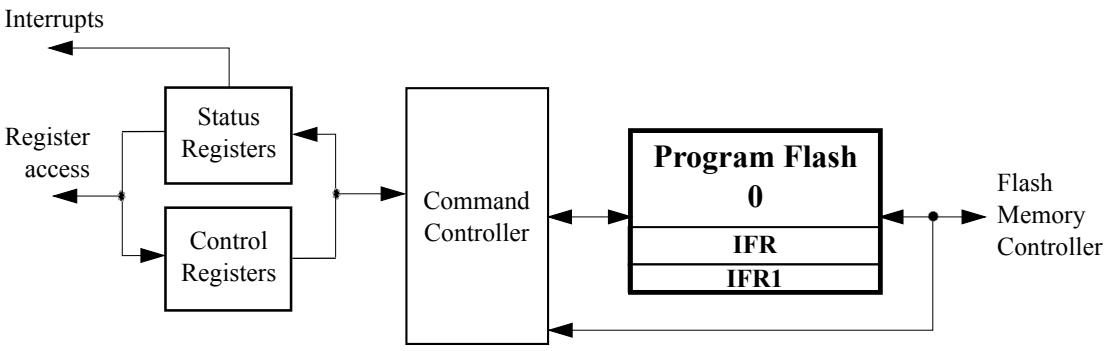

Figure 522. Flash block diagram

55.1.2 Features

The flash memory module provides the following features:

- Sector size of 8 Kbytes
- Single-bit error correction and double-bit error detection for each flash or IFR phrase
- Signature generation for flash contents
- Command-based flash program, erase, and verify operations

- Internal high-voltage supply generator for flash program and erase operations
- Optional interrupt generation upon flash command completion
- Optional interrupt generation upon double-bit error detection during flash reads from the FMC

NOTE

See the chip configuration details for the exact amount of flash memory available.

55.2 Functional description

The following sections describe functional details of the flash module.

55.2.1 Operations

Operations are typically used to modify flash memory contents. The next sections describe:

- Command write sequence used to set flash command parameters and launch execution
- Available flash commands
- Commands impacted by Block Checker and FMC access protection

55.2.1.1 Command write sequence

Flash commands are accomplished using a command write sequence illustrated in Figure 523. The command controller monitors the transaction protection level on writes during the command write sequence, performs various checks on the command (FCCOB) content, and continues with command execution if all requirements are fulfilled.

Before launching a command, the ACCERR, PVIOL, and CMDABT flags in the FSTAT register must be zero and the CCIF flag must be one to verify that any previous command has completed. The FAIL flag in the FSTAT register is cleared by the command controller when a command is launched unless the FAIL flag was set during initialization due to FMU parameters not being loaded from IFR1. If CCIF is clear, the previous command execution is still active, a new command write sequence cannot be started, and all writes to the FCCOB registers are ignored.

55.2.1.1.1 Load the FCCOB Registers

The user must load the FCCOB registers with all parameters required by the specific flash command. The contents of any FCCOB register not used by the specific flash command are ignored except for FCCOB1 (command options) where undefined bits should be cleared. The individual registers that make up the FCCOB data set can be written in any order. All writes to the FCCOB registers in a command write sequence must occur at the same transaction protection level. Any write to the FCCOB registers that violates this rule will be ignored.

Addresses loaded into FCCOB registers assume the flash and IFR spaces start at 0000_0000h.

55.2.1.1.2 Launch the Command by Clearing CCIF

Once all relevant command parameters have been loaded, the user launches the command by clearing the FSTAT[CCIF] bit by writing a '1' to it. The write to clear CCIF must occur at the same transaction protection level as the writes used to load the FCCOB registers. Any write to clear CCIF that violates this rule will be ignored. The CCIF flag remains clear until the flash command completes.

The FSTAT register contains a blocking mechanism which prevents a new flash command from launching (unable to clear CCIF) if the previous command resulted in the setting of an access error (ACCERR), protection violation (PVIOL), or active command abort flag (CMDABT). In error scenarios, two writes to FSTAT are required to initiate the next command: the first write to clear these flags, the second write to clear CCIF. The write to clear these flags can occur at any transaction protection level.

55.2.1.1.3 Command Execution and Error Reporting

Flash command processing contains the following steps:

1. The command controller performs a series of parameter checks, if applicable, which are unique to each command. If the parameter check fails, the FSTAT[ACCERR] flag is set. ACCERR reports invalid instruction codes or options, out of bounds or misaligned addresses, or missing FMU parameters. In the case FMU parameters were not loaded from IFR1 during initialization, the ACCERR flag sets and the FSTAT[FAIL] flag remains set. Command processing never proceeds to execution when the parameter check fails. Instead, command processing is terminated after setting the FSTAT[CCIF] flag. Note that for program and erase operations, PEWEN will not set if FMU parameters were not loaded and PERDY will not set if program or erase related writes to flash or IFR space violate command requirements.
2. If necessary, the command controller performs a protection check to see if the command is allowed to execute on the requested memory space. If the protection check fails, the FSTAT[PVIOL] flag is set. Command processing never proceeds to execution when the protection check fails. Instead, command processing is terminated after setting the FSTAT[CCIF] flag.
3. If the parameter and protection checks pass, the command proceeds to execution. Run-time errors, such as failure to verify, may occur during the execution phase and are reported in the FAIL flag. A flash command may have access errors, protection violations, and run-time errors, but the run-time errors are not seen until all access errors and protection violations have been corrected.
4. If FCTRL[ABTREQ] sets during command execution, the operation will abort with the FSTAT[CMDABT] flag set.
5. Command execution results, if applicable, are reported back to the user via the FCCOB registers.
6. The command controller sets FSTAT[CCIF] signifying that the command has completed.

CAUTION

If the FAIL flag is set along with ACCERR, FMU parameters were not loaded from IFR1 during initialization. In this case, it is recommended that the flash module be reinitialized. If the issue persists, flash commands will continue to set the ACCERR and FAIL flags.

The flow for a generic command write sequence is illustrated in the following figure.

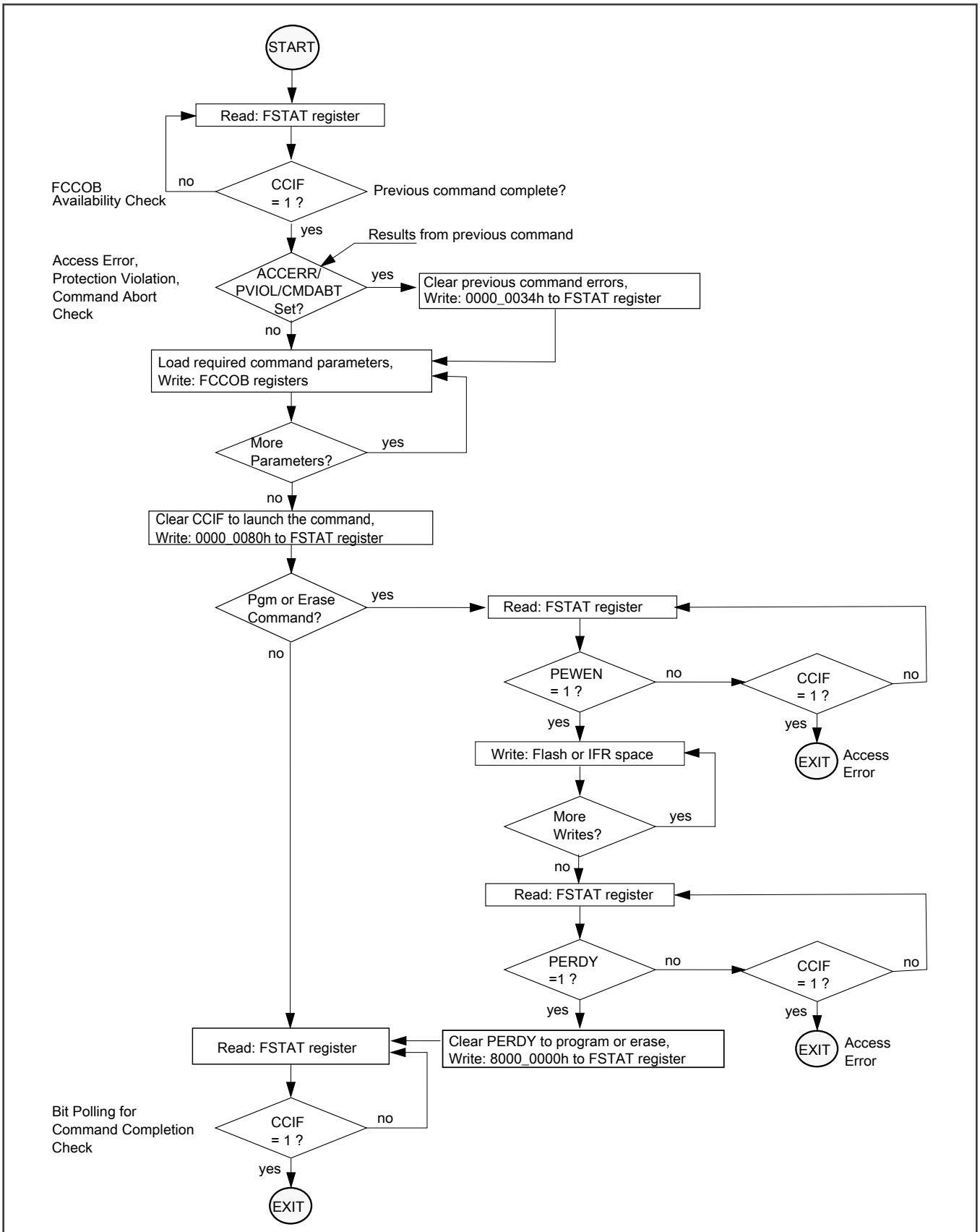

Figure 523. Generic Flash Command Write Sequence Flowchart

55.2.1.1.4 Aborting a Command Write Sequence or Command Operation

FSTAT[CMDP] sets at the start of a command write sequence, typically by writing to one of the FCCOB registers. With CMDP set, setting the FCTRL[ABTREQ] bit allows a user to abort a command write sequence and take control over a new command write sequence. The ABTREQ bit can only be set by a user with the same domain ID as indicated by FSTAT[CMDDID] and at the same or higher security/privilege protection level when compared to FSTAT[CMDPRT], the current owner of the command write sequence. While ABTREQ is set, CCIF cannot be cleared to launch a command.

If FSTAT[CCIF] is high when ABTREQ is set, the command write sequence will abort and ownership transferred to the user setting the ABTREQ bit. The FSTAT[CWSABT] flag will set and the CMDPRT field will be updated based on the write transaction that set the ABTREQ bit. The ABTREQ bit will then be cleared automatically.

If CCIF is low when ABTREQ is set, the command controller will abort execution of the current command operation, set FSTAT[CMDABT], and set CCIF. The CMDPRT field will be updated based on the write transaction that set the ABTREQ bit. The ABTREQ bit will then be cleared automatically. While CMDABT is set, CCIF cannot be cleared to launch a command. Aborting a program or erase operation may leave the flash or IFR space being modified in an indeterminate state.

NOTE

Aborting certain flash commands may take longer to abort than to execute. See the device data sheet for flash command timing specifications.

55.2.1.2 Flash commands

The following table summarizes the function of all flash commands. If any column is marked with an 'X', the flash command is relevant to that particular memory resource.

FCMD	Command	Program flash 0	IFR	Function
00h	Read 1s All (RD1ALL)	x	x	Verify that all flash and IFR space is erased
01h	Read 1s Block (RD1BLK)	x		Verify that a flash block is erased
02h	Read 1s Sector (RD1SCR)	x		Verify that a flash sector is erased
03h	Read 1s Page (RD1PG)	x		Verify that a flash page is erased
04h	Read 1s Phrase (RD1PHR)	x		Verify that a flash phrase is erased
05h	Read into MISR (RDMISR)	x		Generate MISR signature for range of flash pages
12h	Read 1s IFR Sector (RD1ISCR)		x	Verify that an IFR sector is erased
13h	Read 1s IFR Page (RD1IPG)		x	Verify that an IFR page is erased
14h	Read 1s IFR Phrase (RD1IPHR)		x	Verify that an IFR phrase is erased
15h	Read IFR into MISR (RDIMISR)		x	Generate MISR signature for range of IFR pages

Table continues on the next page...

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FCMD	Command	Program flash 0	IFR	Function
23h	Program Page (PGMPG)	x	x	Program data to a flash or IFR page
24h	Program Phrase (PGMPHR)	x	x	Program data to a flash or IFR phrase
40h	Erase All (ERSALL)	x	x	Erase all flash and IFR space if enabled
42h	Erase Sector (ERSSCR)	x	x	Erase a flash sector

55.2.1.3 Flash commands impacted by Block Checker and FMC access protection

The following flash commands are impacted by Block Checker and FMC access protection:

- Program Phrase (PGMPHR)
- Program Page (PGMPG)
- Erase Sector (ERSSCR)

During execution of these flash commands, a sequence of AHB writes to flash or IFR space are required with validity checked by the Block Checker or FMC. When writes are enabled by the FMU, violations detected by the FMC are reported as an access error in the FMU. The other violations are handled by the Block Checker or FMC.

Table 570. Flash Write Access Checks

Flash Write Violation Condition	Block Checker	FMC	FMU
Flash or IFR address out-of-range	X		
Flash or IFR write permission check fails	X		
Write to IFR1 space		X	
Write width not 32-bit		X	
Writes not enabled by FSTAT[PEWEN]		X	
First write in sequence not properly aligned per FSTAT[PEWEN]			X
Non-sequential write after first aligned write in sequence			X
Bus permissions for the AHB write do not match the bus permissions of the APB write that launched the flash command			X

55.2.2 Flash command descriptions

This section describes all flash commands that can be launched by a valid command write sequence. The flash module sets the FSTAT[ACCERR] bit and aborts the command execution if any of the following illegal conditions occur:

- There is an unrecognized command code in the FCCOB FCMD field.
- There is an error in an FCCOB field for the specific command. Refer to the error handling table provided for each command.

The ACCERR, PVIOL, and CMDABT flags in the FSTAT register should be cleared prior to starting a command write sequence. As described in Launch the Command by Clearing CCIF, a new command cannot be launched while these flags are set.

Do not attempt to read a flash block while a flash command is running (CCIF = 0) on that same block. The flash module may return a transfer error to the FMC resulting in a bus fault. The exception to this rule is during program operations where the flash block is still readable after the command is launched up until the time the FSTAT[PERDY] flag is cleared.

CAUTION

Flash data must be in the erased state before being programmed. Cumulative programming of bits (adding more zeros) is not allowed.

55.2.2.1 Read 1s All Command

The Read 1s All command checks if all flash and IFR space are in the erased state.

Table 571. Read 1s All Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	00h (RD1ALL)

Upon clearing CCIF to launch the Read 1s All command, the command controller:

- verifies that all flash and IFR space are in the erased state

If all flash and IFR space are not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s All operation completes.

Table 572. Read 1s All Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

55.2.2.2 Read 1s Block Command

The Read 1s Block command checks if a flash block is in the erased state.

Table 573. Read 1s Block Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	01h (RD1BLK)
2	Block address

Upon clearing CCIF to launch the Read 1s Block command, the command controller:

- verifies that the selected flash block is in the erased state

If the selected flash block is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s Block operation completes.

Table 574. Read 1s Block Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]

Table continues on the next page...

Table 574. Read 1s Block Command Error Handling (continued)

Error Condition	Error Bit
Address is not valid	FSTAT[ACCERR]
Address is not block aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

55.2.2.3 Read 1s Sector Command

The Read 1s Sector command checks if a flash sector is in the erased state.

Table 575. Read 1s Sector Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	02h (RD1SCR)
2	Sector address

Upon clearing CCIF to launch the Read 1s Sector command, the command controller:

- verifies that the selected flash sector is in the erased state

If the selected flash sector is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s Sector operation completes.

Table 576. Read 1s Sector Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Address is not sector aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

55.2.2.4 Read 1s Page Command

The Read 1s Page command checks if a flash page is in the erased state.

Table 577. Read 1s Page Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	03h (RD1PG)
2	Page address

Upon clearing CCIF to launch the Read 1s Page command, the command controller:

- verifies that the selected flash page is in the erased state

If the selected flash page is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s Page operation completes.

Table 578. Read 1s Page Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Address is not page aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

55.2.2.5 Read 1s Phrase Command

The Read 1s Phrase command checks if a flash phrase is in the erased state.

Table 579. Read 1s Phrase Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	04h (RD1PHR)
2	Phrase address

Upon clearing CCIF to launch the Read 1s Phrase command, the command controller:

- verifies that the selected flash phrase is in the erased state

If the selected flash phrase is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s Phrase operation completes.

Table 580. Read 1s Phrase Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Address is not phrase aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

55.2.2.6 Read into MISR command

The Read into MISR operation generates a signature based on the contents of the selected flash memory using an embedded MISR.

Table 581. Read into MISR Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	05h (RDMISR) [7:0]
2	Starting flash page address
3	Ending flash phrase address
4	Word 0 of MISR seed
5	Word 1 of MISR seed
6	Word 2 of MISR seed
7	Word 3 of MISR seed
Returned values	
4	Word 0 of MISR signature
5	Word 1 of MISR signature
6	Word 2 of MISR signature
7	Word 3 of MISR signature

Upon clearing CCIF to launch the Read into MISR command, the command controller:

1. initializes the MISR with the seed provided
2. processes flash data starting with the starting flash page address provided
3. continues until the ending flash phrase address has been processed (must be the last phrase in a page)
4. returns the resulting signature into the FCCOB register bank unless an uncorrectable ECC fault is detected

The CCIF flag sets after the Read into MISR operation completes. If the operation is aborted by setting FCTRL[ABTREQ], a signature will not be returned if the abort occurs prior to the operation writing the signature.

MISR polynomial is $X^{128} + X^{126} + X^{101} + X^{99} + 1$.

Table 582. Read into MISR Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Starting address is not flash page aligned	FSTAT[ACCERR]
Ending address is not flash phrase aligned	FSTAT[ACCERR]
Ending address is not the last phrase in a page	FSTAT[ACCERR]
Starting address is larger than the ending address	FSTAT[ACCERR]
Requested range crosses a flash block boundary	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Uncorrectable ECC error is detected	FSTAT[FAIL]

55.2.2.7 Read 1s IFR Sector Command

The Read 1s IFR Sector command checks if an IFR sector is in the erased state.

Table 583. Read 1s IFR Sector Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	12h (RD1ISCR)
2	IFR sector address

Upon clearing CCIF to launch the Read 1s IFR Sector command, the command controller:

- verifies that the selected IFR sector is in the erased state

If the selected IFR sector is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s IFR Sector operation completes.

Table 584. Read 1s IFR Sector Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Address is not IFR sector aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

55.2.2.8 Read 1s IFR Page Command

The Read 1s IFR Page command checks if an IFR page is in the erased state.

Table 585. Read 1s IFR Page Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	13h (RD1IPG)
2	IFR page address

Upon clearing CCIF to launch the Read 1s IFR Page command, the command controller:

- verifies that the selected IFR page is in the erased state

If the selected IFR page is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s IFR Page operation completes.

Table 586. Read 1s IFR Page Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Address is not IFR page aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]

Table continues on the next page...

Table 586. Read 1s IFR Page Command Error Handling (continued)

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

55.2.2.9 Read 1s IFR Phrase Command

The Read 1s IFR Phrase command checks if an IFR phrase is in the erased state.

Table 587. Read 1s IFR Phrase Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	14h (RD1IPHR)
2	IFR phrase address

Upon clearing CCIF to launch the Read 1s IFR Phrase command, the command controller:

- verifies that the selected IFR phrase is in the erased state

If the selected IFR phrase is not in the erased state, the FSTAT[FAIL] flag is set. The CCIF flag sets after the Read 1s IFR Phrase operation completes.

Table 588. Read 1s IFR Phrase Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Address is not IFR phrase aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

55.2.2.10 Read IFR into MISR command

The Read IFR into MISR operation generates a signature based on the contents of the selected IFR space using an embedded MISR.

Table 589. Read IFR into MISR Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	15h (RDIMISR) [7:0]
2	Starting IFR page address
3	Ending IFR phrase address
4	Word 0 of MISR seed
5	Word 1 of MISR seed
6	Word 2 of MISR seed

Table continues on the next page...

Table 589. Read IFR into MISR Command FCCOB Requirements (continued)

FCCOB Number	FCCOB Contents
7	Word 3 of MISR seed
Returned values	
4	Word 0 of MISR signature
5	Word 1 of MISR signature
6	Word 2 of MISR signature
7	Word 3 of MISR signature

Upon clearing CCIF to launch the Read IFR into MISR command, the command controller:

1. initializes the MISR with the seed provided
2. processes IFR data starting with the starting IFR page address provided
3. continues until the ending IFR phrase has been processed (must be the last phrase in a page)
4. returns the resulting signature into the FCCOB register bank unless an uncorrectable ECC fault is detected

The CCIF flag sets after the Read IFR into MISR operation completes. If the operation is aborted by setting FCTRL[ABTREQ], a signature will not be returned if the abort occurs prior to the operation writing the signature.

MISR polynomial is $X^{128} + X^{126} + X^{101} + X^{99} + 1$.

Table 590. Read IFR into MISR Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Address is not valid	FSTAT[ACCERR]
Starting address is not IFR page aligned	FSTAT[ACCERR]
Ending address is not IFR phrase aligned	FSTAT[ACCERR]
Ending address is not the last phrase in a page	FSTAT[ACCERR]
Starting address is larger than the ending address	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Uncorrectable ECC error is detected	FSTAT[FAIL]

55.2.2.11 Program Page command

The Program Page operation programs 32 words of data to a previously erased flash or IFR page.

CAUTION

The page must be in the erased state before being programmed. Cumulative programming of bits (back-to-back program operations without an intervening erase) within a page is not allowed.

Table 591. Program Page Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	23h (PGMPG) [7:0]

Upon clearing CCIF to launch the Program Page command, the command controller:

1. sets FSTAT[PEWEN] to enable writes to the flash and IFR space in the system memory map
2. waits for the user to write 32 consecutive words to the flash or IFR space with the first write being page aligned
3. clears FSTAT[PEWEN] field
4. sets FSTAT[PERDY]
5. waits for the user to clear FSTAT[PERDY]
6. programs the data into the targeted page written to in step 2
7. verifies bits to be programmed are programmed to the program verify level

The CCIF flag sets after the Program Page operation completes. The Program Page operation can be aborted by setting FCTRL[ABTREQ]. If the operation is aborted, the operation terminates with the FSTAT[CMDABT] flag set. Once CCIF is set, the Program Page command may be repeated (same addresses, same data) to complete the program operation without erasing the sector containing the targeted page. Invalid writes to flash or IFR space based on Block Checker or FMC access protection are trapped outside of the flash module.

Table 592. Program Page Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Protection level of the writes to flash or IFR space do not match the protection level of the command write sequence	FSTAT[ACCERR]
Initial address is not page aligned and subsequent addresses phrase aligned	FSTAT[ACCERR]
Number of writes to flash or IFR space is more than expected	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

55.2.2.11.1 Page programming

The standard process of programming one or more flash or IFR pages is as follows:

1. If required, launch the Erase Sector command to erase the flash or IFR sector to be programmed (repeat for additional sectors).
2. Launch the Program Page command to enable writes to the flash space.
3. After the command controller sets FSTAT[PEWEN], write 32 consecutive words to the flash space with the first word page aligned. The data written to the flash space is not readable until the program operation has successfully completed.
4. After the flash page has been written, the command controller will stall and set FSTAT[PERDY].
5. Clear PERDY allowing the command controller to resume and program the 32 words into the flash or IFR space written to in step 3.
6. Wait for CCIF to set indicating the program operation has completed.
7. To program additional flash or IFR pages in previously erased flash memory, repeat steps 2 through 6.

55.2.2.12 Program Phrase command

The Program Phrase operation programs 4 words of data to a previously erased flash or IFR phrase.

CAUTION

The phrase must be in the erased state before being programmed. Cumulative programming of bits (back-to-back program operations without an intervening erase) within a phrase is not allowed.

Table 593. Program Phrase Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	24h (PGMPHR) [7:0]

Upon clearing CCIF to launch the Program Phrase command, the command controller:

1. sets FSTAT[PEWEN] to enable writes to the flash and IFR space in the system memory map
2. waits for the user to write 4 consecutive words to the flash or IFR space with the first write being phrase aligned
3. clears FSTAT[PEWEN] field
4. sets FSTAT[PERDY]
5. waits for the user to clear FSTAT[PERDY]
6. programs the data into the targeted phrase written to in step 2.
7. verifies bits to be programmed are programmed to the program verify level

The CCIF flag sets after the Program Phrase operation completes. The Program Phrase operation can be aborted by setting FCTRL[ABTREQ]. If the operation is aborted, the operation terminates with the FSTAT[CMDABT] flag set. Once CCIF is set and the CMDABT flag is cleared, the Program Phrase command may be repeated (same addresses, same data) to complete the program operation without erasing the sector containing the targeted phrase. Invalid writes to flash or IFR space based on Block Checker or FMC access protection are trapped outside of the flash module.

Table 594. Program Phrase Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Protection level of the writes to flash or IFR space do not match the protection level of the command write sequence	FSTAT[ACCERR]
Address is not phrase aligned	FSTAT[ACCERR]
Number of writes to flash or IFR space is more than expected	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

55.2.2.12.1 Phrase programming

The standard process of programming one or more flash or IFR phrases is as follows:

1. If required, launch the Erase Sector command to erase the flash or IFR sector to be programmed (repeat for additional sectors).
2. Launch the Program Phrase command to enable writes to the flash and IFR space.
3. After the command controller sets FSTAT[PEWEN], write 4 consecutive words to the flash or IFR space with the first word phrase aligned. The data written to the flash or IFR space is not readable until the program operation has successfully completed.
4. After the flash or IFR phrase has been written, the command controller will stall the operation and set FSTAT[PERDY].

5. Clear PERDY allowing the command controller to resume and program the 4 words into the flash or IFR space written to in step 3.
6. Wait for CCIF to set indicating the program operation has completed.
7. To program additional flash or IFR phrases in previously erased flash memory, repeat steps 2 through 6.

55.2.2.13 Erase All command

The Erase All operation erases all flash and IFR space if enabled by the MCU.

Table 595. Erase All Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	40h (ERSALL) [7:0]

Upon clearing CCIF to launch the Erase All command, the command controller:

1. erases flash block 0 sector-by-sector
2. verifies flash block 0 is erased; if not, skips IFR space in block 0
3. erases IFR space in block 0 sector-by-sector
4. verifies IFR space in block 0 is erased
5. clears FSTAT[CMDP] flag

The CCIF flag sets after the Erase All operation completes. If either the flash or IFR space is not in the erased state, FSTAT[FAIL] sets.

Table 596. Erase All Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Command is disabled by the MCU	FSTAT[PVIOL]
Operation is aborted	FSTAT[CMDABT]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

55.2.2.14 Erase Sector command

The Erase Sector operation erases the IFR sector to prepare the sector for programming.

Table 597. Erase Sector Command FCCOB Requirements

FCCOB Number	FCCOB Contents
0	42h (ERSSCR) [7:0]

Upon clearing CCIF to launch the Erase Sector command, the command controller:

1. sets FSTAT[PEWEN] to enable writes to the flash and IFR space in the system memory map
2. waits for the user to write 4 consecutive words to the flash or IFR space with the first write being phrase (or sector) aligned
3. clears FSTAT[PEWEN] field
4. sets FSTAT[PERDY]

5. waits for the user to clear FSTAT[PERDY]
6. erases the selected flash or IFR sector
7. verifies the selected flash or IFR sector is erased

If the selected flash or IFR sector is not in the erased state, FSTAT[FAIL] is set. The CCIF flag sets after the Erase Sector operation completes. The Erase Sector operation can be aborted by setting FCTRL[ABTREQ]. If the operation is aborted, the operation terminates with the FSTAT[CMDABT] flag set. Once CCIF is set, the Erase Sector command may be repeated to complete the erase operation. Invalid writes to flash or IFR space based on Block Checker or FMC access protection are trapped outside of the flash module.

Table 598. Erase Sector Command Error Handling

Error Condition	Error Bit
FMU parameters not loaded from IFR1 during initialization	FSTAT[ACCERR]
Protection level of the writes to flash or IFR space do not match the protection level of the command write sequence	FSTAT[ACCERR]
Address is not flash or IFR phrase aligned	FSTAT[ACCERR]
Operation is aborted	FSTAT[CMDABT]
IFR Sector is protected (see FCNFG register)	FSTAT[PVIOL]
FMU parameters not loaded from IFR1 during initialization	FSTAT[FAIL]
Verify fails	FSTAT[FAIL]

55.2.3 Mass Erase

If enabled by the MCU, MCU resources can be used to launch a mass erase operation without accessing the flash registers.

To know how to enable/disable mass erase for your device, refer the chip-specific section.

The status of the mass erase request is reflected in the FCNFG[ERSREQ] bit. When launched, the mass erase operation occurs regardless of the state of the CMDP, ACCERR, PVIOL, or CMDABT flags in the FSTAT register but requires FSTAT[CCIF] to be set and the MCU to enable mass erase. When mass erase is launched with CCIF set, the CMDP, CCIF, CWSABT, PVIOL, and CMDABT flags in the FSTAT register clear. The ACCERR and FAIL flags also clear unless the FMU parameters were not loaded from IFR1 during initialization in which case the mass erase operation terminates without performing any erase of flash memory.

Upon successful launch of the mass erase operation, the command controller (same steps as the Erase All command):

1. erases flash block 0 sector-by-sector
2. verifies flash block 0 is erased; if not, skips IFR space in block 0
3. erases IFR space in block 0 sector-by-sector
4. verifies IFR space in block 0 is erased

The CCIF flag sets and the ERSREQ bit clears once the operation completes and the FSTAT[FAIL] flag sets if any verify step fails during the mass erase operation. This method of erasing the flash memory cannot be aborted by setting FCTRL[ABTREQ].

55.2.4 Modes

55.2.4.1 Sleep mode

If the CPU enters sleep mode while a flash command is executing, the flash module can wake the CPU via the command complete interrupt (see Interrupts).

55.2.4.2 Non-Active Power mode

If a flash command is active (CCIF = 0) when the MCU requests a non-active power mode, the command execution completes before the MCU is allowed to enter the non-active power mode.

55.2.5 Clocking

This module has no clocking considerations.

55.2.6 Interrupts

The flash module can generate interrupt requests to the MCU upon the occurrence of various flash module events. These interrupt events and their associated status and control bits are shown in the following table.

Table 599. Flash Module Interrupt Sources

Flash Event	Readable Status Bit	Interrupt Enable Bit
Flash Command Complete	FSTAT[CCIF]	FCNFG[CCIE]
Flash ECC Fault Detected	FSTAT[DFDIF]	FCNFG[DFDIE]

NOTE

Vector addresses and their relative interrupt priority are determined at the MCU level.

55.3 External signals

The flash module contains no signals that connect off-chip.

55.4 Initialization

On each reset, the command controller initializes the following based on IFR1 content:

1. FCTRL[RWSC]
2. FMU Parameters (FMUPARM)

The FSTAT[CCIF] flag is cleared throughout the initialization flow. The flash module also holds off all access to flash registers and flash memory during initialization. Completion of the initialization flow is marked by setting FSTAT[CCIF]. If an uncorrectable ECC error is detected during initialization, the FSTAT[FAIL] flag sets. The FAIL flag also sets if FMU parameters are not loaded from IFR1 during initialization. In this case, attempts to launch a flash command terminate with the ACCERR and FAIL flags set. The recommendation is to refrain from launching flash commands if the FAIL flag sets after initialization.

If a reset occurs while any flash command is in progress, that command is immediately aborted. The state of the flash memory or IFR space being programmed or erased is not guaranteed. Command operations do not automatically resume after exiting reset.

55.5 Memory map and registers

This section describes the flash memory map for IFR/IFR1 space and registers. See the MCU system memory map for the location of all flash memory space and registers. Data read from unimplemented memory space in the flash module is undefined.

55.5.1 IFR description

Each flash block contains IFR space separate from the main flash memory. IFR space is memory mapped (see the MCU system memory map). IFR space is divided into IFR pages programmable using the Program Page command. IFR pages are further divided into IFR phrases programmable using the Program Phrase command. Once programmed, IFR phrases can be

reprogrammed after a successful erase using the Erase Sector command operation unless the IFR sector is protected by the FCNFG register.

Table 600. IFR map

Offset Byte Address	IFR Field Size (Bytes)
Block 0 IFR Sector 0	
0000h-1FFFh	8,192
Block 0 IFR Sector 1	
2000h-3FFFh	8,192
Block 0 IFR Sector 2	
4000h-5FFFh	8,192
Block 0 IFR Sector 3	
6000h-7FFFh	8,192

Each flash block also contains IFR1 space separate from the main flash memory. IFR1 space in program flash block 0 is memory mapped for read-only access (see the MCU system memory map). IFR1 space cannot be erased or programmed by the user.

Table 601. IFR1 map

Offset Byte Address	IFR1 Field Size (Bytes)
Block 0 IFR1 Sector	
0000h-15FFh	5,632
1600h-16FFh	256
1700h-1FFFh	2,304

55.5.2 Register descriptions

The flash module contains a set of memory-mapped control and status registers.

NOTE

While a command is running (FSTAT[CCIF]=0), register writes are allowed to FSTAT[PERDY,DFDIF,CWSABT], FCNFG, and FCTRL[ABTREQ,FDFD,RWSC].

55.5.2.1 Flash register descriptions

55.5.2.1.1 Flash memory map

RF_FMU base address: 4898_1000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Flash Status Register (FSTAT)	32	RW	See section
4h	Flash Configuration Register (FCNFG)	32	RW	See section
8h	Flash Control Register (FCTRL)	32	RW	See section

Table continues on the next page...

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Offset	Register	Width (In bits)	Access	Reset value
10h	Flash Common Command Object Registers (FCCOB0)	32	RW	0000_0000h
14h	Flash Common Command Object Registers (FCCOB1)	32	RW	0000_0000h
18h	Flash Common Command Object Registers (FCCOB2)	32	RW	0000_0000h
1Ch	Flash Common Command Object Registers (FCCOB3)	32	RW	0000_0000h
20h	Flash Common Command Object Registers (FCCOB4)	32	RW	0000_0000h
24h	Flash Common Command Object Registers (FCCOB5)	32	RW	0000_0000h
28h	Flash Common Command Object Registers (FCCOB6)	32	RW	0000_0000h
2Ch	Flash Common Command Object Registers (FCCOB7)	32	RW	0000_0000h

55.5.2.1.2 Flash Status Register (FSTAT)

Offset

Register	Offset
FSTAT	0h

Function

The FSTAT register reports the operational status of the flash module.

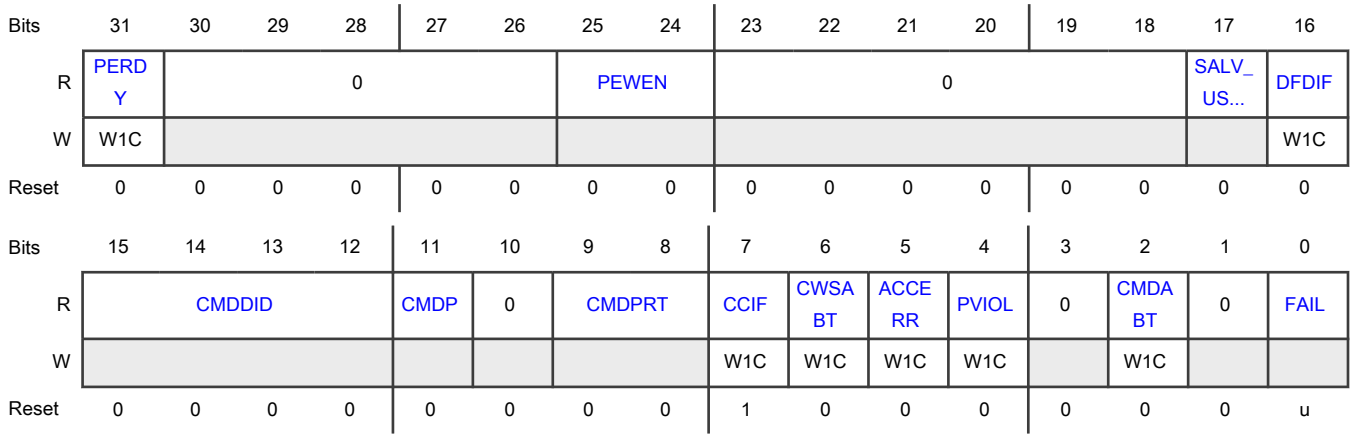
NOTE

When set, ACCERR, PVIOL, and CMDABT flags prevent the launch of any more commands until the flag is cleared (by writing a one to it).

CAUTION

When clearing the DFDIF flag, be careful not to use read-modify-write on the entire FSTAT register and inadvertently clear CCIF to launch a command.

Diagram



Fields

Field	Function
31 PERDY	Program-Erase Ready Control/Status Flag The PERDY flag is set by the command controller when a program or sector erase command operation has successfully completed the write phase. The command controller will stall the command operation until the user clears the PERDY flag by writing a 1 to PERDY. Failure to clear PERDY will leave the command controller stalled but the flash or IFR space targeted by the command operation will remain readable by the FMC. If FCTRL[ABTREQ] is set while the PERDY flag is set, the command controller will clear PERDY, abort the command operation, and set both CCIF and CMDABT. 0b - Program or sector erase command operation not stalled 1b - Program or sector erase command operation ready to execute
30-26 —	Reserved
25-24 PEWEN	Program-Erase Write Enable Control During program or sector erase command operations, writes are enabled to flash or IFR space in the system memory map. For phrase programming or sector erase, writes are enabled for 4 consecutive words (16 bytes) with address phrase aligned. For page programming, writes are enabled for 8 consecutive phrases (128 bytes) with address page aligned. For programming, data written to erased flash or IFR space for program commands is not available until the program operation has successfully completed. PEWEN will not assert if FMU parameters were not loaded from IFR1 during initialization. 00b - Writes are not enabled 01b - Writes are enabled for one flash or IFR phrase (phrase programming, sector erase) 10b - Writes are enabled for one flash or IFR page (page programming) 11b - Reserved
23-18 —	Reserved

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Field	Function
17 SALV_USED	Salvage Used for Erase operation This flag indicates salvage was used during the last Erase Sector, Erase All, or Mass Erase operation and is valid at the end of the operation. Salvage involves using ECC to pass erase verify allowing single-bit faults per phrase verified. This flag remains valid until any flash command or Mass Erase operation launches at which time the flag clears. Use of salvage does not guarantee that the erase operation succeeds but only that salvage was used on at least one phrase. 0b - Salvage not used during last operation 1b - Salvage used during the last erase operation
16 DFDIF	Double Bit Fault Detect Interrupt Flag The DFDIF flag indicates an uncorrectable ECC fault was detected during a valid flash read access from the FMC. The DFDIF flag is cleared by writing a 1 to DFDIF. Writing a 0 to DFDIF has no effect. 0b - Double bit fault not detected during a valid flash read access 1b - Double bit fault detected (or FCTRL[FDFD] is set) during a valid flash read access
15-12 CMDDID	Command domain ID While the CMDP flag is set, the CMDDID bits reflect the domain ID of the write transaction controlling a command write sequence or aborting a command operation. Writes to load an FCCOB register, clear CCIF, or clear PERDY must have the same domain ID as the write transaction that started the command write sequence. The CMDDID bits persist after the CMDP flag clears until the CMDP flag sets again at the start of a new command write sequence. Writes to clear the CWSABT, ACCERR, PVIOL, or CMDABT flags are not influenced by the state of the CMDDID bits.
11 CMDP	Command protection status flag The CMDP flag sets when a command write sequence starts with a write to load an existing FCCOB register or clear CCIF while ACCERR, PVIOL, and CMDABT are clear. Clearing the CWSABT, ACCERR, PVIOL, or CMDABT flags as part of a command write sequence will not set the CMDP flag. While the CMDP flag is set, the protection level of any subsequent write transaction to load an FCCOB register, clear CCIF, or clear PERDY must match the CMDPRT bits and the domain ID must match the CMDDID bits. The CMDP flag remains set until cleared when CCIF is set after a command operation or Power Down recovery completes unless the CMDABT flag is set. The CMDP flag is cleared even if the operation ends with ACCERR or PVIOL set. When the CMDP flag is cleared, the CMDPRT and CMDDID bits remain unchanged. The CMDP flag is also cleared by a mass erase request with CCIF set. 0b - Command protection level and domain ID are stale 1b - Command protection level (CMDPRT) and domain ID (CMDDID) are set
10 —	Reserved
9-8 CMDPRT	Command protection level

Table continues on the next page...

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Field	Function
	While the CMDP flag is set, the CMDPRT bits reflect the secure/privilege protection level of the write transaction controlling a command write sequence or aborting a command operation. Writes to load an existing FCCOB register, clear CCIF, or clear PERDY must occur with the same protection level as indicated by the CMDPRT bits. Writes to clear the CWSABT, ACCERR, PVIOL, or CMDABT flags are not influenced by the state of the CMDPRT bits. If FCTRL[ABTREQ] is set while CCIF is high or low, the CMDPRT bits will change to reflect the security/ privilege protection level of the write transaction that set the ABTREQ bit. 00b - Secure, normal access 01b - Secure, privileged access 10b - Nonsecure, normal access 11b - Nonsecure, privileged access
7 CCIF	Command Complete Interrupt Flag The CCIF flag indicates that a flash command has completed. The CCIF flag is cleared by writing a 1 to CCIF to launch a flash command. The CCIF flag stays low until the command completes. The CCIF flag is cleared by a mass erase request with CCIF set. The CCIF flag is also cleared upon entry into Deep Sleep, Power Down, and Deep Power Down modes and stays low until the end of recovery from these non-active power modes. The CCIF flag is reset to 0 but is set to 1 at the end of flash initialization. 0b - Flash command, initialization, or power mode recovery in progress 1b - Flash command, initialization, or power mode recovery has completed
6 CWSABT	Command Write Sequence Abort Flag The CWSABT flag indicates whether a request to abort a command write sequence prior to command launch has been granted. If FCTRL[ABTREQ] is set while CCIF is high, the CWSABT flag will get set. Once CWSABT is set, ABTREQ will get cleared. While the CWSABT flag is set, ABTREQ cannot be set. The CWSABT flag is cleared by writing a 1 to CWSABT while CCIF is set or clear and ABTREQ is clear. Writing a 0 to the CWSABT flag has no effect. The CWSABT flag is cleared by a mass erase request with CCIF set. 0b - Command write sequence not aborted 1b - Command write sequence aborted
5 ACCERR	Command Access Error Flag The ACCERR flag indicates an illegal attempt was made to launch a flash command due to a violation of the command write sequence or by providing invalid command parameters. The ACCERR flag also sets during command execution if FMU parameters were not loaded from IFR1 during initialization. While the ACCERR flag is set, the CCIF flag cannot be cleared to launch a command. The ACCERR flag is cleared by writing a 1 to ACCERR while CCIF is set. Writing a 0 to the ACCERR flag has no effect. The ACCERR flag is cleared by a mass erase request with CCIF set but is not cleared during Power Down recovery.

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Field	Function
	0b - No access error detected 1b - Access error detected
4 PVIOL	Command Protection Violation Flag The PVIOL flag indicates an attempt was made to modify a protected area of flash memory during a command operation. While the PVIOL flag is set, the CCIF flag cannot be cleared to launch a command. The PVIOL flag is cleared by writing a 1 to PVIOL while CCIF is set. Writing a 0 to the PVIOL flag has no effect. The PVIOL flag is cleared by a mass erase request with CCIF set but is not cleared during Power Down recovery. 0b - No protection violation detected 1b - Protection violation detected
3 —	Reserved
2 CMDABT	Command Abort Flag The CMDABT flag indicates FCTRL[ABTREQ] was set during a command operation while CCIF was clear. This event will result in the termination of the operation unless it occurs during the exit routine of the operation. Once CMDABT is set, ABTREQ will get cleared. While the CMDABT flag is set, ABTREQ cannot be set and the CCIF flag cannot be cleared to launch a command. The CMDABT flag is cleared by writing a 1 to CMDABT while CCIF is set and ABTREQ is clear. Writing a 0 to the CMDABT flag has no effect. The CMDABT flag is cleared by a mass erase request with CCIF set. 0b - No command abort detected 1b - Command abort detected
1 —	Reserved
0 FAIL	Command Fail Flag The FAIL flag is set if an error is detected during execution of a flash command, mass erase operation, or flash initialization. If the FAIL flag sets along with ACCERR after launching a flash command or mass erase operation, FMU parameters were not loaded from IFR1 during initialization and a clean POR where FMU parameters are successfully loaded is required to clear the FAIL flag. As a status flag, this bit cannot (and need not) be cleared by the user like some of the other flags in this register. The value of the FAIL flag for "command-N" is valid only at the end of the "command-N" execution when CCIF=1 and before the next command has been launched. At some point during the execution of "command-N+1," the FAIL flag is cleared unless FMU parameters were not loaded from IFR1 during initialization. The FAIL flag is cleared by a mass erase request with CCIF set unless FMU parameters were not loaded from IFR1 during initialization. The FAIL flag is not cleared during Power Down recovery.

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Field	Function
	0b - Error not detected 1b - Error detected

55.5.2.1.3 Flash Configuration Register (FCNFG)

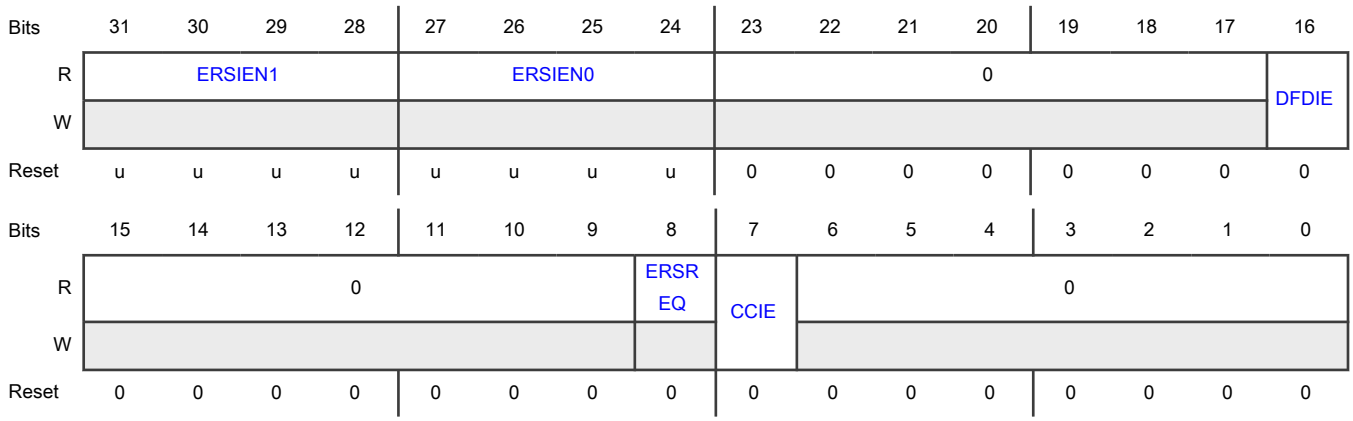
Offset

Register	Offset
FCNFG	4h

Function

This register provides information on the current functional state of the flash module.

Diagram



Fields

Field	Function
31-28 ERSIEN1	Erase IFR Sector Enable - Block 1 (for dual block configs) This field controls the ability to erase the IFR sectors in block 1 using the ERSSCR command. These bits are loaded from sideband signals during initialization and at launch of ERSSCR command. Note: These bits have no effect on single block configurations. Note: The ERSALL command and MCU mass erase request do not adhere to these restrictions. X equals 0, 1, 2, or 3. Any and all bits in the field are independently configured. 0000b - Block 1 IFR Sector X is protected from erase by ERSSCR command 0001b - Block 1 IFR Sector X is not protected from erase by ERSSCR command
27-24	Erase IFR Sector Enable - Block 0

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Field	Function
ERSIEN0	This field controls the ability to erase the IFR sectors in block 0 using the ERSSCR command. These bits are loaded from sideband signals during initialization and at launch of ERSSCR command. Note: The ERSALL command and MCU mass erase request do not adhere to these restrictions. X equals 0, 1, 2, or 3. Any and all bits in the field are independently configured. 0000b - Block 0 IFR Sector X is protected from erase by ERSSCR command 0001b - Block 0 IFR Sector X is not protected from erase by ERSSCR command
23-17 —	Reserved
16 DFDIE	Double Bit Fault Detect Interrupt Enable The DFDIE bit controls interrupt generation when an uncorrectable ECC fault is detected during a valid flash read access from the platform flash controller. 0b - Double bit fault detect interrupt disabled 1b - Double bit fault detect interrupt enabled. An interrupt request is generated whenever the FSTAT[DFDIF] flag is set.
15-9 —	Reserved
8 ERSREQ	Mass Erase Request This bit indicates whether a sideband request has been received by the command controller to execute the Mass Erase operation. ERSREQ is not directly writable but sets when a Mass Erase request is received by the flash module while CCIF is set. ERSREQ is cleared by the command controller when the operation completes. 0b - No request or request complete 1b - Request to run the Mass Erase operation
7 CCIE	Command Complete Interrupt Enable The CCIE bit controls interrupt generation when a flash command completes. 0b - Command complete interrupt disabled 1b - Command complete interrupt enabled. An interrupt request is generated whenever the FSTAT[CCIF] flag is set.
6-0 —	Reserved

55.5.2.1.4 Flash Control Register (FCTRL)

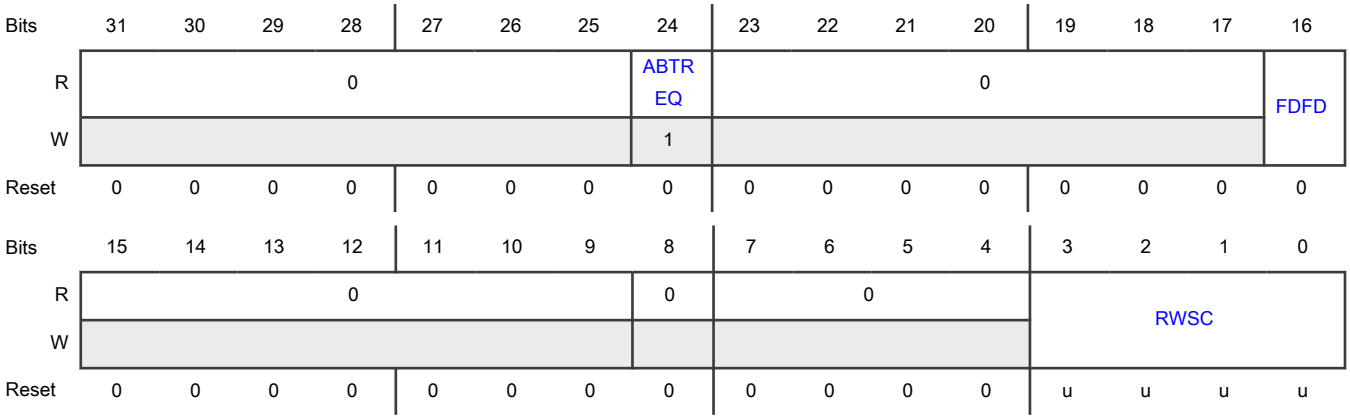
Offset

Register	Offset
FCTRL	8h

Function

The flash control register controls activity associated with flash memory reads and command operations.

Diagram



Fields

Field	Function
31-25 —	Reserved
24 ABTREQ	Abort Request With FSTAT[CMDP] set, setting the ABTREQ bit allows a user to abort a command write sequence or command operation. The ABTREQ bit can only be set by a user with the same domain ID as indicated by FSTAT[CMDDID] and the same or higher security/privilege protection level than is indicated by FSTAT[CMDPRT]. While ABTREQ is set, CCIF cannot be cleared to launch a command. If FSTAT[CCIF] is high when ABTREQ is set, the command write sequence will abort and ownership transferred to the user setting the ABTREQ bit. The FSTAT[CWSABT] flag will set and the CMDPRT field will be updated based on the write transaction that sets the ABTREQ bit. The ABTREQ bit will then be cleared automatically. If FSTAT[CCIF] is low when ABTREQ is set, the command operation will abort and ownership transferred to the user setting the ABTREQ bit. The FSTAT[CMDABT] flag will set and the CMDPRT field will be updated based on the write transaction that sets the ABTREQ bit. The ABTREQ bit will then be cleared automatically. While CWSABT or CMDABT are high, writes to ABTREQ will be ignored. 0b - No request to abort a command write sequence

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Field	Function
	1b - Request to abort a command write sequence
23-17 —	Reserved
16 FDFD	Force Double Bit Fault Detect The FDFD bit enables the user to emulate the setting of the FSTAT[DFDIF] flag to check the associated interrupt routine. The FDFD bit is cleared by writing a 0 to FDFD. 0b - FSTAT[DFDIF] sets only if a double bit fault is detected during a valid flash read access from the platform flash controller 1b - FSTAT[DFDIF] sets during any valid flash read access from the platform flash controller. An interrupt request is generated if the DFDIE bit is set.
15-9 —	Reserved
8 —	Reserved
7-4 —	Reserved
3-0 RWSC	Read Wait-State Control These bits control the number of wait-states added to account for the ratio of system clock period to flash access time during full speed power mode. Ratios greater than one require non-zero settings for the RWSC field for proper flash accesses. The required settings are documented in the device data sheet. 0h - no additional wait-states are added (single cycle access) 1h - 1 additional wait-state is added 2h - 2 additional wait-states are added ... Fh - 15 additional wait-states are added These bits are loaded from IFR1 during initialization. **NOTE** The default FCTRL[RWSC] is set to a value appropriate for the chip's max operating frequency. Refer to the chip-specific section for the default value.

55.5.2.1.5 Flash Common Command Object Registers (FCCOB0 - FCCOB7)

Offset

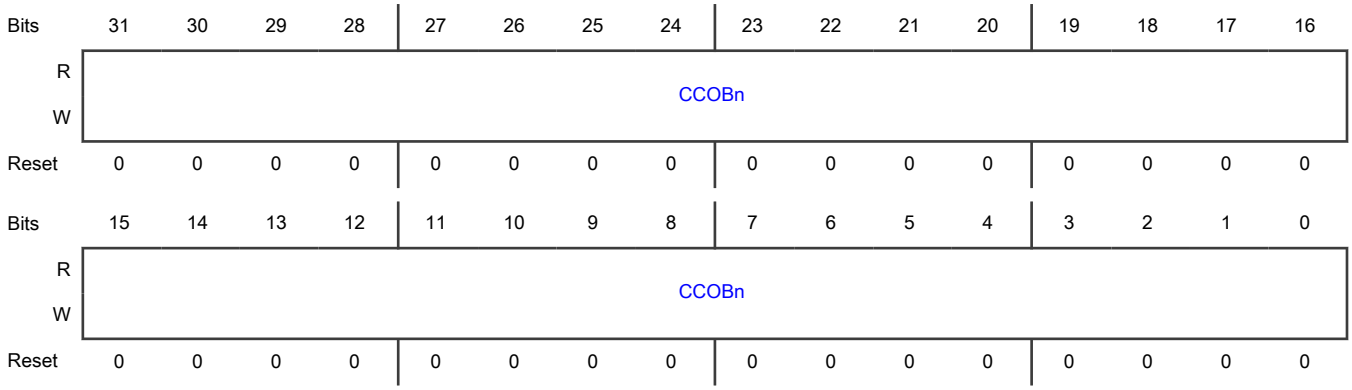
For a = 0 to 7:

Register	Offset
FCCOBa	10h + (a × 4h)

Function

The FCCOB register group provides fields for command codes and parameters. The individual words within the set append a 0-7 hex identifier to the FCCOB register name: FCCOB0, FCCOB1, ..., FCCOB7.

Diagram



Fields

Field	Function
31-0 CCOBn	CCOBn The FCCOB register group provides a command code and relevant parameters to the command controller. The individual registers that compose the FCCOB data set can be written in any order, but you must provide all needed values, which vary from command to command. First, set up all required FCCOB fields and then initiate the command execution by writing a 1 to the FSTAT[CCIF] bit. This clears the CCIF bit, which locks all FCCOB parameter fields and they cannot be changed by the user until the command completes (CCIF returns to 1). No command buffering or queueing is provided; the next command can be loaded only after the current command completes. Some commands return information to the FCCOB registers. Any values returned to FCCOB are available for reading after the FSTAT[CCIF] flag returns to 1. The following table shows a generic flash command format. The first FCCOB register, FCCOB0, always contains the command code. This 8-bit value defines the command to be executed. The command code is followed by the parameters required for this specific flash command, typically an address and/or data values. **NOTE** The command parameter table is written in terms of FCCOB Number (which is equivalent to the word number). This number is a reference to the FCCOB register name and is not the register address.

FCCOB Number[1]	Typical Command Parameter Contents [31:0]
0	FCMD [7:0] (flash command code, bits [31:8] are not writable)

Field	Function	
	FCCOB Number[1]	Typical Command Parameter Contents [31:0]
	1	FCMDOPT [7:0] (flash command options, bits [31:8] are not writable)
	2	Flash address 1 (start)
	3	Flash address 2 (end)
	4	Data Word 0
	5	Data Word 1
	6	Data Word 2
	7	Data Word 3
	1. Refers to FCCOB register name, not register address	

55.6 Glossary

Block Checker — MCU IP that provides a mechanism to set access rights to the flash memory for read and write operations.

Command write sequence — A series of MCU writes to the Flash FCCOB register group and FSTAT[CCIF] that initiates and controls the execution of flash algorithms that are built into the flash module.

Endurance — The number of times that an aligned flash or IFR phrase can be erased and reprogrammed.

FCCOB (Flash Common Command Object Block) — A group of flash registers that are used to pass command, address, data, and any associated parameters to the command controller.

Flash block — A macro within the flash module which provides the nonvolatile memory storage with an aligned block address being the first address in the block.

Flash module — All flash blocks plus a flash management unit providing command control and an interface to MCU buses.

Flash page — 128 bytes of flash main memory with an aligned page having byte-address[6:0] = 00h; represents the largest portion of the flash memory that can be programmed in one operation.

Flash phrase — 16 bytes of flash main memory with an aligned phrase having byte-address[3:0] = 0000b; represents the smallest portion of the flash memory that can be programmed in one operation.

Flash sector — 8 Kbytes of flash main memory with an aligned sector having byte-address[12:0] = 0000h; represents the smallest portion of the flash memory that can be erased in one operation.

FLW — The Flash Logical Window module allows a specific logical address range to access a programmable physical address range in the flash memory with programmable FLW default settings stored in IFR space.

FMC — Flash Memory Controller module manages flash memory reads and writes.

IFR — Information flash region separate from the main flash memory array. Each flash block has 32 Kbytes of user IFR space. Sometimes referred to as IFR0.

IFR1 — Information flash region separate from the main memory array reserved for array trim, MCU trim, and test. Each flash array has 8 Kbytes of IFR1 space.

IFR page — 128 bytes of IFR or IFR1 space with an aligned IFR page having byte-address[6:0] = 00h; represents the largest portion of IFR space that can be programmed.

IFR phrase — 16 bytes of IFR or IFR1 space with an aligned IFR phrase having byte-address[3:0] = 0000b; represents the smallest portion of IFR space that can be programmed in one operation.

IFR sector — 8 Kbytes of IFR or IFR1 space with an aligned IFR sector having byte-address[12:0] = 0000h; represents the smallest portion IFR space that can be erased.

MISR — Multiple-input signature register used to generate a signature based on flash memory contents read.

MSF — Microcontroller Secure Flash.

NVM — Nonvolatile memory. The flash block is an NVM using NOR-type flash memory technology.

Program flash — Program flash memory provides nonvolatile storage for vectors and code store.

Retention — The length of time that data (erased or programmed) can be kept in the NVM without experiencing errors upon readout.

Security/Privilege protection levels — The Flash module supports 4 levels of security/privilege protection for flash commands:

1. Secure (Trusted) / Privileged
2. Secure (Trusted) / User
3. Non-secure (Non-Trusted) / Privileged
4. Non-secure (Non-Trusted) / User

Chapter 56
Radio Flash

56.1 Overview

The Radio Flash is the wrapper that contains 512 KB flash and FMC. It manages accesses performed by the bus masters of the system to the radio flash memory.

56.2 Memory Map and register definition

This section includes the Radio Flash module memory map and detailed descriptions of all registers.

56.2.1 RadioFlash register descriptions

56.2.1.1 RadioFlash memory map

RF_FMCCFG base address: 4898_2000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Radio Flash Memory Controller Configuration Register (RFMCCFG)	32	RW	0000_0000h

56.2.1.2 Radio Flash Memory Controller Configuration Register (RFMCCFG)

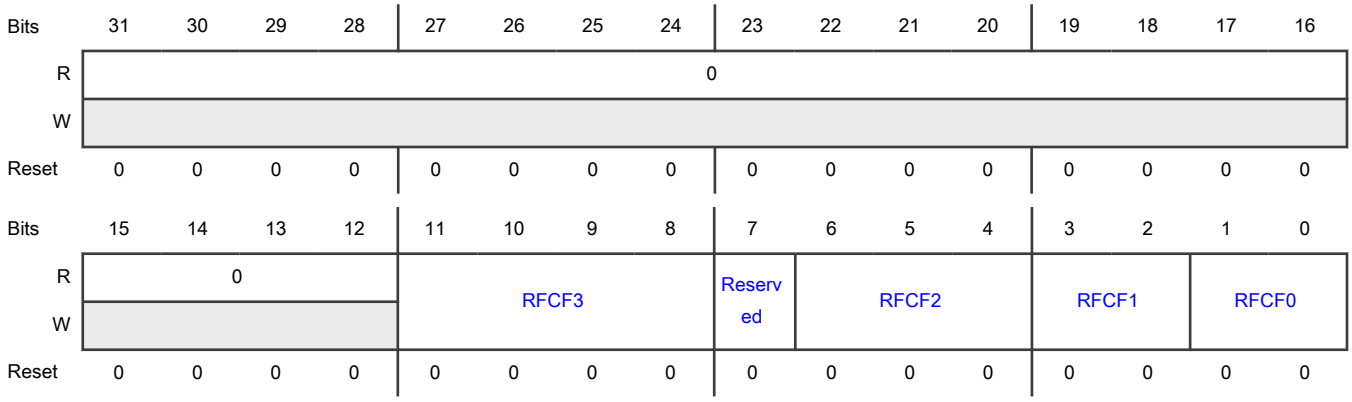
Offset

Register	Offset
RFMCCFG	0h

Function

The flash controller needs to be idle when writing to the RFMCCFG register associated with Flash memory. This means no read/erase/execute/etc operations from the Flash memory should be made while writing to the RFMCCFG register. Changing controller configuration while active can cause undesired results.

Diagram



Fields

<table>
<tr><th>Field</th><th>Function</th></tr>
<tr><td>31-12
—</td><td>Reserved</td></tr>
<tr><td>11-8
RFCF3</td><td>Radio Flash Control Field 3
CF3 = Control Field 3 - for flash cache
• CF3[3] - disable flash cache
• CF3[2] - disable instruction caching
• CF3[1] - disable flash data caching
• CF3[0] - clear flash cache</td></tr>
<tr><td>7
—</td><td>Reserved</td></tr>
<tr><td>6-4
RFCF2</td><td>Radio Flash Control Field 2
CF2[2] FSE - Flash Stall Enable
• 0b = Flash Stall is disabled on flash busy
• 1b = Flash Stall is enabled on flash busy
CF2[1] DFS - Disable Flash Speculate
CF2[0] DDP - Disable Data Prefetch
CF2[1:0] bits controls whether prefetches (or speculative accesses) are initiated in response to instruction fetches or data references, see section FMC speculative reads. Value 0 means enable and value 1 means disable.
<table>
<tr><th>CF2[1]
Flash Speculate</th><th>CF2[0]
Data Prefetch</th><th>Result</th></tr>
<tr><td>Disabled</td><td>Disabled</td><td rowspan="2">All speculation disabled and speculation buffer is cleared</td></tr>
<tr><td>Disabled</td><td>Enabled</td></tr>
<tr><td>Enabled</td><td>Disabled</td><td>Speculation for Instruction enabled and Speculation for Data disabled</td></tr>
<tr><td>Enabled</td><td>Enabled</td><td>Speculation for both Instruction and Data enabled</td></tr>
</table>
</td></tr>
<tr><td>3-2
RFCF1</td><td>Radio Flash Control Field 1
CF1 = Control Field 1 - for ECC control functions
CF1[1] DNCBED - Disable non-correctable bus errors on flash data fetches
• 0b = Enable bus error response for non-correctable error on data fetch from flash
• 1b = Disable bus error response for non-correctable error on data fetch from flash</td></tr>
</table>

Table continues on the next page...

Table continued from the previous page...

Field	Function
	CF1[0] DNCBEI - Disable non-correctable bus errors on flash instruction fetches • 0b = Enable bus error response for non-correctable error on instruction fetch from flash • 1b = Disable bus error response for non-correctable error on instruction fetch from flash
1-0 RFCF0	Radio Flash Control Field 0 CF0 = Control Field 0 CF0[1] - disable the use of flash, page buffer and speculation buffer CF0[0] - clear of flash cache and page buffer

Chapter 57
FRO Clock Generator (FRO192M)

57.1 Overview

The FRO192 module provides the system clocks for the Radio Mode Controller.

57.1.1 Block Diagram

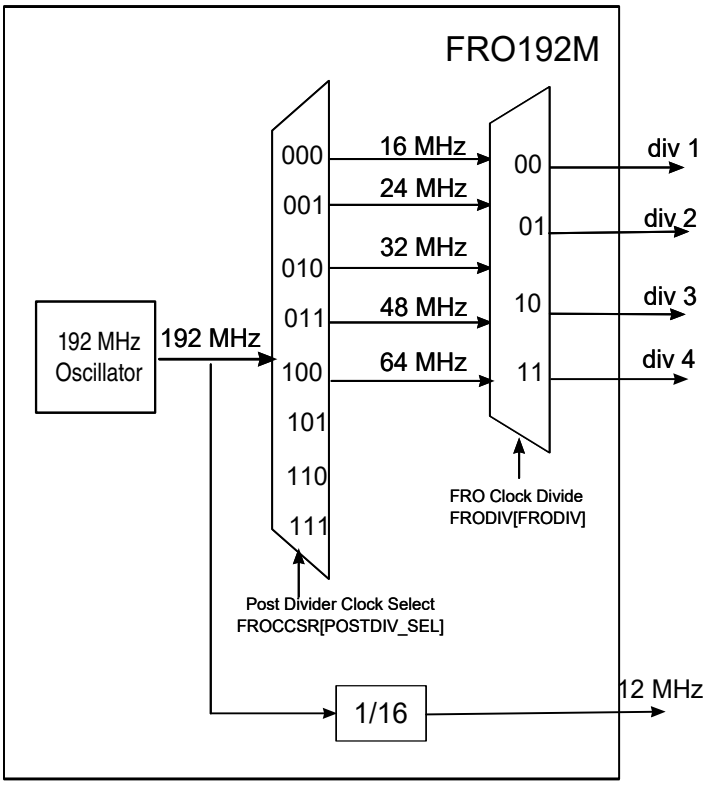


Figure 524. Clock Generator block diagram

57.1.2 Features

Key features of the FRO192 module are:

- Programmable post-divider for up to 5 different frequency ranges

57.2 Functional description

57.2.1 Modes of operation

The following table describes the modes available for FRO192.

Table 602. Operating modes

Mode	Entry	Exit	Description
Reset	POR Warm Reset Disabled	Reset Deassertion	FRO192 is reset.
Run	Enabled	POR Warm Reset Disabled	FRO192 is allowed to run and generate an output clock.
Disabled	Disabled	Run	FRO192 is held in a reset state and waiting to be enabled to switch over to Run mode.

57.2.2 Interrupts

FRO192 does not support any interrupts.

57.2.3 Clocks

FRO192 registers and logic are clocked by the slow bus clock.

The following table describes the clocks of FRO192.

Table 603. Clocks and their description

Clock	Type	Description
Slow Bus Clock	Input	FRO192 register read/write clock source.
FRO Bus Clock	Output	FRO192 Div Clock/FRODIV output divided system clock.
Fixed_clk	Output	FRO192 fixed 12 MHz output clock source.

57.3 External signals

This module has no external signals.

57.4 Initialization

By default, FRO192 is disabled and enabled by external block. It requires no initialization.

57.5 Memory Map/Register Definition

This section includes the memory map and register definition.

57.5.1 FRO192M register descriptions

- For any writeable registers, only 32-bit writes are allowed. 8-bit or 16-bit writes will result in transfer errors.

57.5.1.1 FRO192M memory map

FRO192M0 base address: 4898_0000h

Offset	Register	Width (In bits)	Access	Reset value
0h	FRO192 Clock Control Status Register (FROCCSR)	32	RW	0000_2001h
4h	FRO192 Divide Register (FRODIV)	32	RW	0000_0001h

57.5.1.2 FRO192 Clock Control Status Register (FROCCSR)

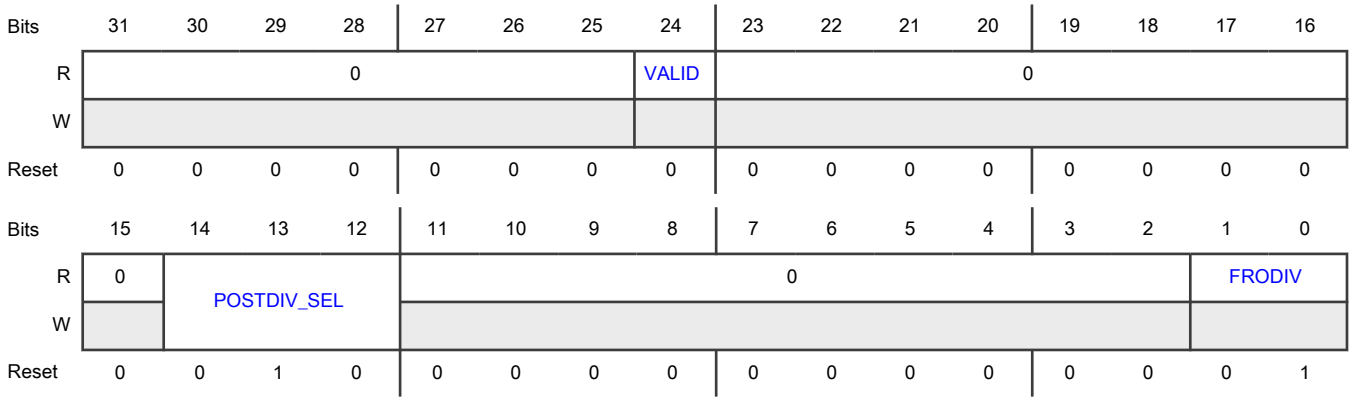
Offset

Register	Offset
FROCCSR	0h

Function

FRO192 control register is used to select the frequency range and post divider. It also shows the status of the FRO Clock.

Diagram



Fields

Field	Function
31-25 —	Reserved
24 VALID	Clock Valid Flag This flag indicates if the status of FRO192 clock is valid or invalid 0b - FRO192 is not enabled or clock is not valid. 1b - FRO192 is enabled and output clock is valid.
23-15 —	Reserved

Table continues on the next page...

Table continued from the previous page...

Field	Function
14-12 POSTDIV_SEL	Post Divider Clock Select This field selects the correct post divider to generate selected output frequenc clock. Output frequency options supported are 64 MHz, 48 MHz, 32 MHz, 24 MHz, and 16 MHz. Divide values can be changed while FRO192 is enabled 000b - FRO 16MHz Range selected. 001b - FRO 24MHz Range selected 010b - FRO 32MHz Range selected 011b - FRO 48MHz Range selected 100b - FRO 64MHz Range selected 101b - RESERVED. Not Supported 110b - RESERVED. Not Supported 111b - RESERVED. Not Supported
11-2 —	Reserved
1-0 FRODIV	FRO Clock Divide This field indicates the status of the FRODIV Divider. 00b - Divide by 1 01b - Divide by 2 10b - Divide by 3 11b - Divide by 4

57.5.1.3 FRO192 Divide Register (FRODIV)

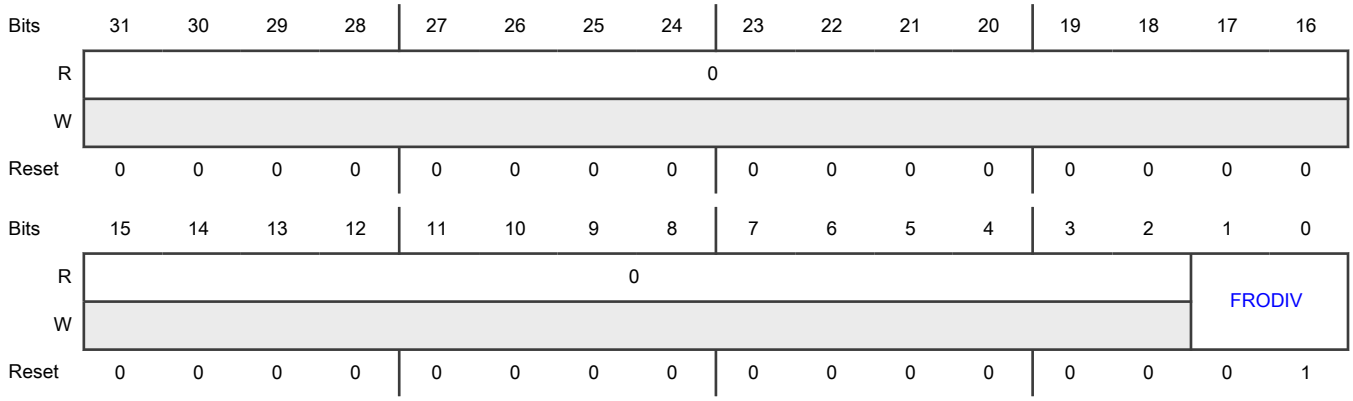
Offset

Register	Offset
FRODIV	4h

Function

This register divides the output of the POSTDIV_SEL to generate the a system clock source.

Diagram



Fields

Field	Function
31-2 —	Reserved
1-0 FRODIV	FRO Clock Divide This read/write field select the clock divider ratio for POSTDIV_SEL output clock. Used to generate the system clock source. 00b - Divide by 1 01b - Divide by 2 10b - Divide by 3 11b - Divide by 4

Appendix A
General changes

A.1 General changes

• Editorial changes — Each new release of this document includes editorial improvements such as: ◦ Spelling ◦ Grammar ◦ Punctuation ◦ Voice ◦ Tense ◦ Capitalization ◦ Formatting ◦ Presentation ◦ Navigation
• In the CMC chapter, the description of the RPC[LPFEN] bit has been updated by replacing the reference to a 1 MHz clock cycle with RTC 32.768 KHz. • In the CMC chapter, the description of the SRIE and LPACK registers has been updated by replacing the reference to a 32.768 KHz clock cycle with RTC 1 MHz. • The reference to FRO6M has been removed throughout the RM. • The reference to TSTMR has been removed throughout the RM.

Appendix B
Release Notes

B.1 About This Manual changes

This module chapter was added.

B.2 Introduction changes

• Changed text from "MCXW72x" to "MCX W72" in Functional overview. • Removed text "(P)" from Ordering information.

B.3 Core Overview changes

No substantial content changes.

B.4 LCE module changes

No substantial content changes.

B.5 Low Power Cache Controller (LPCAC)

B.5.1 Chip-specific LPCAC information changes

No substantial content changes.

B.5.2 LPCAC changes

No substantial content changes.

B.6 Peripheral Bridge2 (PBRIDGE2)

B.6.1 Chip-specific PBRIDGE2 information changes

No substantial content changes.

B.6.2 PBRIDGE2 module changes

No substantial content changes.

B.7 Crossbar Switch (AXBS)

B.7.1 Chip-specific AXBS information changes

No substantial content changes.

B.7.2 AXBS module changes

No substantial content changes.

B.8 Flash Memory Controller (FMC)

B.8.1 Chip-specific FMC information changes

No substantial content changes.

B.8.2 Flash Memory Controller (FMC-NPX) module changes

No substantial content changes.

B.9 System Performance Monitor (SYSPM)

B.9.1 Chip-specific SYSPM information changes

No substantial content changes.

B.9.2 SYSPM changes

- Updated Memory Map and register definition

B.10 Trusted Resource Domain Controller (TRDC)

B.10.1 Chip-specific TRDC information changes

No substantial content changes.

B.10.2 TRDC module changes

No substantial content changes.

B.11 Enhanced Direct Memory Access (eDMA)

B.11.1 Chip-specific eDMA information changes

No substantial content changes.

B.11.2 eDMA3 module changes

No substantial content changes.

B.12 Miscellaneous System Control Module (MSCM)

B.12.1 Chip-specific MSCM information changes

- Changed text from "MCXW72x" to "MCX W72" in SID[FAMID].

B.12.2 MSCM changes

No substantial content changes.

B.13 Miscellaneous Control Module (MCM)

B.13.1 Chip-specific MCM information changes

No substantial content changes.

B.13.2 MCM module changes

No substantial content changes.

B.14 Memory changes

No substantial content changes.

B.15 ROM Bootloader changes

- Removed sentence “Success of low power wakeup boot is designed to complete within 300 microseconds.” from Low power wakeup path topic.

B.16 Flash Memory Unit (FMU)

B.16.1 Chip-specific FMU information changes

- Added section FSTAT[PEWEN].

B.16.2 MSF1 changes

No substantial content changes.

B.17 System Register File (REGFILE)

B.17.1 Chip-specific REGFILE information changes

No substantial content changes.

B.17.2 REGFILE module changes

No substantial content changes.

B.18 Signalling changes

- Changed text from "MCXW72x" to "MCX W72" in Package pinout.
- Removed all references of "ALT11 - EZH_PIOxx" from Package pinout table.
- Removed all references of "ATXxx - RF_UART_CTS_b","ATXxx - RF_UART_RTS_b", "ATXxx - RF_UART_TX", and "ATXxx - RF_UART_RX" from Package pinout table.

B.19 Port Control (PORT)

B.19.1 Chip-specific PORT information changes

No substantial content changes.

B.19.2 PORT module changes

No substantial content changes.

B.20 General-purpose Input and Output (GPIO)

B.20.1 Chip-specific GPIO information changes

No substantial content changes.

B.20.2 GPIO module changes

No substantial content changes.

B.21 Debug changes

No substantial content changes.

B.22 Reset changes

No substantial content changes.

B.23 Clocking changes

- Removed TSTMR information from "Module/Peripheral clocking".

B.24 System Clock Generator (SCG)

B.24.1 Chip-specific SCG information changes

No substantial content changes.

B.24.2 SCG changes

- modified block diagram and hided FRO_6M in sections

B.25 Module Reset and Clock Control (MRCC)

B.25.1 Chip-specific MRCC information changes

No substantial content changes.

B.25.2 MRCC changes

No substantial content changes.

B.26 Signal Frequency Analyser (SFA)

B.26.1 Chip-specific SFA information changes

No substantial content changes.

B.26.2 Signal Frequency Analyser (SFA) module changes

No substantial content changes.

B.27 32 kHz Clock Control Module (CCM32K)

B.27.1 Chip-specific CCM32K information changes

No substantial content changes.

B.27.2 CCM32K changes

No substantial content changes.

B.28 Power changes

- Removed "Multi-rail supply configuration".

B.29 Core Mode Controller (CMC)

B.29.1 Chip-specific CMC information changes

No substantial content changes.

B.29.2 CMC module changes

- Updated bit-description of #unique_900/unique_900_Connect_42_FLASHCR.FLASHWAKE.
- Renamed SRAM Disable (SRAMDIS0).
- Renamed SRAM Retention (SRAMRET0)

- In Reset sequence, the Power-on reset and Warm reset sequences have been updated with a new step added at position 7.

B.30 System Power Control (SPC)

B.30.1 Chip-specific SPC information changes

No substantial content changes.

B.30.2 SPC module changes

• Updated the description of LP_CFG[LP_IREFEN].
• Updated the description of SC[ISO_CLR]. • Updated the Overview section.
• Updated bit 23 of ACTIVE_CFG.
• Updated value definition for ACTIVE_CFG, LP_CFG ,andHP_CFG.
• Updated Low-Power Request (LPREQ) pin and Low Power Wake-Up Delay(LPWKUP_DELAY)

B.31 Smart Power Switch (VBAT)

B.31.1 Chip-specific VBAT information changes

No substantial content changes.

B.31.2 VBAT module changes

No substantial content changes.

B.32 External Watchdog Monitor (EWM)

B.32.1 Chip-specific EWM information changes

No substantial content changes.

B.32.2 EWM module changes

- Updated the following sections: Overview, Using compare registers,Clocking, and Using the ewm_out_b signal.

B.33 Trigger Multiplexer (TRGMUX)

B.33.1 Chip-specific TRGMUX information changes

- Replaced Source Module "EZH_INT_CHANxx" with Reserved in TRGMUX0 inputs.

B.33.2 TRGMUX module changes

No substantial content changes.

B.34 Wakeup Unit (WUU)

B.34.1 Chip-specific WUU information changes

No substantial content changes.

B.34.2 WUU changes

- Updated the function description of Pin Mode Configuration (PMC)

B.35 Watchdog Timer (WDOG)

B.35.1 Chip-specific WDOG information changes

No substantial content changes.

B.35.2 WDOG module changes

- Some editorial updates.

B.36 Cyclic Redundancy Check (CRC)

B.36.1 Chip-specific CRC information changes

No substantial content changes.

B.36.2 CRC module changes

- Updated Modes of operation and Clocking

B.37 16-bit Analog-to-Digital Converter (ADC)

B.37.1 Chip-specific ADC information changes

No substantial content changes.

B.37.2 ADC module changes

No substantial content changes.

B.38 Low Power Comparator (LPCMP)

B.38.1 Chip-specific LPCMP information changes

No substantial content changes.

B.38.2 LPCMP module changes

No substantial content changes.

B.39 Voltage Reference (VREF)

B.39.1 Chip-specific VREF information changes

No substantial content changes.

B.39.2 VREF module changes

No substantial content changes.

B.40 Real Time Clock (RTC)

B.40.1 Chip-specific RTC information changes

No substantial content changes.

B.40.2 RTC module changes

No substantial content changes.

B.41 Low-Power Timer (LPTMR)

B.41.1 Chip-specific LPTMR information changes

No substantial content changes.

B.41.2 LPTMR module changes

No substantial content changes.

B.42 Low Power Periodic Interrupt Timer (LPIT)

B.42.1 Chip-specific LPIT information changes

No substantial content changes.

B.42.2 LPIT module changes

No substantial content changes.

B.43 Timer/PWM Module (TPM)

B.43.1 Chip-specific TPM information changes

No substantial content changes.

B.43.2 TPM module changes

- Updated Figure 140

B.44 Low Power Inter-Integrated Circuit (LPI2C)

B.44.1 Chip-specific LPI2C information changes

No substantial content changes.

B.44.2 LPI2C module changes

No substantial content changes.

B.45 Improved Inter-Integrated Circuit (I3C)

B.45.1 Chip-specific I3C information changes

No substantial content changes.

B.45.2 I3C module changes

- Updated Block diagram.
- Updated Controller requirements.

B.46 Low Power Serial Peripheral Interface (LPSPI)

B.46.1 Chip-specific LPSPI information changes

No substantial content changes.

B.46.2 LPSPI module changes

- Updated CFGR1[AUTOPCS].

B.47 Low Power Universal Asynchronous Receiver/Transmitter (LPUART)

B.47.1 Chip-specific LPUART information changes

No substantial content changes.

B.47.2 LPUART module changes

No substantial content changes.

B.48 CAN (FlexCAN)

B.48.1 Chip-specific CAN information changes

No substantial content changes.

B.48.2 FlexCAN module changes

No substantial content changes.

B.49 Flexible I/O (FlexIO)

B.49.1 Chip-specific FLEXIO information changes

No substantial content changes.

B.49.2 FLEXIO module changes

No substantial content changes.

B.50 Semaphores2 (SEMA42)

B.50.1 Chip-specific SEMA42 information changes

No substantial content changes.

B.50.2 SEMA42 module changes

No substantial content changes.

B.51 Messaging Unit (MU)

B.51.1 Chip-specific MU information changes

No substantial content changes.

B.51.2 MU module changes

No substantial content changes.

B.52 Radio Platform

B.52.1 Radio Platform changes

No substantial content changes.

B.52.2 RFMC module changes

No substantial content changes.

B.52.3 2.4GHz Radio

No substantial content changes.

B.52.3.4 Signal Frequency Analyser (SFA) module changes

No substantial content changes.

B.52.3.10 MOD module changes

No substantial content changes.

B.52.3.11 ZIGBEE Module Changes

No substantial content changes.

B.52.3.12 D_IP_GENERIC_FSK_SYN Module changes

No substantial content changes.

B.53 DSB module changes

No substantial content changes.

B.54 RF_CMC module changes

No substantial content changes.

B.55 FMU changes

No substantial content changes.

B.56 Radio Flash changes

No substantial content changes.

B.57 FRO192 module changes

No substantial content changes.

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Date of release: 11 December 2025
Document identifier: MCXW72RM