NXP

KILOWATTHOURS
06 00189
102947-128
CL 20 120-480V 4W FM9S Kt

KILOWATTHOURS
02 00623
7000123 - 001
CL 200 240V 2W 60Hz

KILOWATTHOURS
05 00556
7000123 - 001
CL 200 120-480V 3W FM2S Kt 7.2

Smart Energy

Energy Efficient.
Connected. Secure.

freescale™

Table of Contents

Your Essential Source for Energy Applications

The goal of a worldwide rollout of smart grids and smart meters is to provide energy efficiency throughout the entire networked infrastructure.

Freescale provides secure end-to-end solutions that support the entire smart grid, including all points along the system—from transmission, distribution and substations to energy delivery in and around the home.

Metrology
- Electricity meters
- Gas and water flow meters
- Heat meters

Communication
- Home area network (HAN)
- Neighborhood area network (NAN)

Home energy management systems
Smart appliances
Plug-in hybrid electric vehicles (PHEV)
Renewable energy
Data aggregators/concentrators
Grid routers
Grid power management and protection (relay, breaker, monitor)
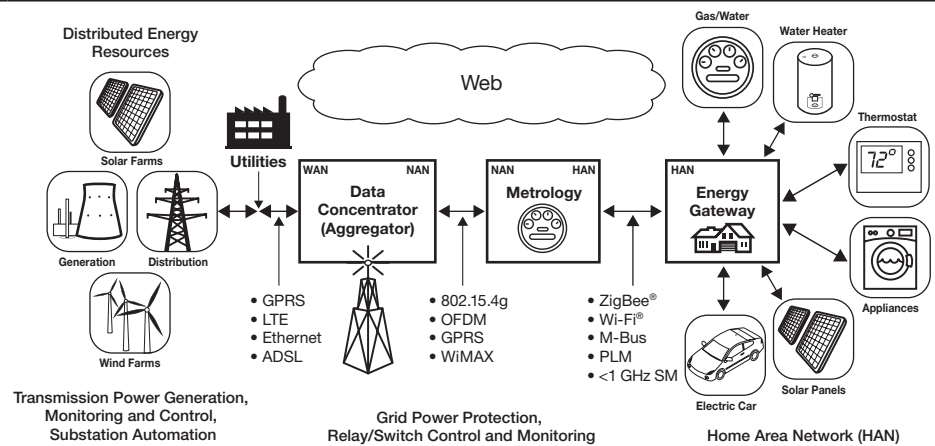**Substation Automation**

Freescale and Smart Energy

Governments worldwide are mandating improved energy efficiency, requiring an investment in the new smart grid and smart energy management structure. The goal is to create a smart grid that will change the way power is deployed for sustainable energy around the world. This document will address the design challenges within the smart grid.

- Lower system cost: Required to reduce time to market, R&D investment and BOM costs while adding features for smart grid requirements

- Low (system) power: Must have efficient metering code to enable energy calculations at low processing speeds for meters supported by capacitive supplies

- Data preservation during fail or brownout events: Low-power, real-time clock with the ability to switch to battery supply, on-chip clock compensation, calendaring or an internal clock if the external crystal fails

- Meter tampering: Requires the ability to time-stamp even if supply is disconnected due to tampering

- Increased meter complexity for smart metering communication, which requires more GPIOs and serial communication modules (I²C, SCI and SPI)

- Aggregate information from individual meters and communicate usage to utility sub via power line communication in order to regulate energy usage

Freescale Smart Grid and Metering Solutions: Overview

Distributed Energy Resources

Solar Farms

Generation   Distribution

Wind Farms

Transmission Power Generation, Monitoring and Control, Substation Automation

Utilities

Web

Data Concentrator (Aggregator)   WAN   NAN

- GPRS
- LTE
- Ethernet
- ADSL

- 802.15.4g
- OFDM
- GPRS
- WiMAX

Metrology   NAN   HAN

Grid Power Protection, Relay/Switch Control and Monitoring

- ZigBee®
- Wi-Fi®
- M-Bus
- PLM
- <1 GHz SM

Energy Gateway   HAN

Gas/Water   Water Heater   Thermostat   Appliances   Solar Panels   Electric Car

Home Area Network (HAN)

Power Generation, Transmission Monitoring and Control, Substation Automation

- QorIQ communications platform
- MPC8xxx
- i.MX applications processors
- Kinetis MCUs

Utility/NAN

- Data concentrators/aggregators
  - P10xx
  - MPC8308
  - i.MX applications processors
- Interfaces to NAN
  - 802.15.4g radio
  - WiMAX
  - Power line comms
- Interfaces to utility
  - WiMAX
  - GPRS
- DLM/COSEM library

Metrology

- Smart single-two-three phase metering
  - Kinetis KM Family
- Metering applications processor
  - Kinetis MK30, MK60, MK21
- Low-end metering
  - Kinetis KM Family

Flow Metering

- Water, gas and heat
  - Kinetis L Family

HAN

- Smart energy gateway
  - MPC8308
  - i.MX28
- Processors
  - ZigBee®
  - Wi-Fi®
  - GPRS
  - M-Bus (Wired and Wireless)
  - HomePlug Green PHY™
- Appliance technology
  - 8–32-bit MCUs and DSPs
  - Touch sensors

Metrology

Freescale offers energy-efficient 8- and 32-bit microcontroller (MCU) solutions to implement smart utility metering systems for electricity, gas, water and heat meters. Smart meter products, such as the Kinetis MKM3x, have on-chip, high-accuracy 24-bit sigma-delta ADC as well as a range of support functions to provide security including WELMEC support and accuracy for the meter with minimal external components.

For designs where a platform approach is followed, Kinetis MK21/MK30/MK60 are used as applications processors.

Extremely low-power products, such as the Kinetis L2x, are ideal for flow meter applications because they consume very little power, ensuring extremely long (over 15 years) battery life.

Available Metering Reference Designs

Three-Phase		3-ph electricity Meter, MCF51EM256	2/3-ph electricity Meter, MK30	2/3-ph electricity Meter, KM3x					
Single-Phase	Cost-Effective Meter 9RS08KA8	Cost-Effective Meter 9S08LA8	Cost-Effective Meter 9S08LL/LG32	China State-Grid Spec. Meter MZ Family	Single-Phase Meter MCF51EM256 Integrated AFE	Cost-Effective Meter 9S08LH64 Integrated AFE	Secure, Prepaid Electricity Meter, MK30	Single-Phase Electricity Meter, MK30	Single-Phase Electricity Meter, KM3x

Freescale Microcontrollers for Metering Applications

Applications	Products	Key Features
Electricity Meter: Single-Phase, Two-Phase, Three-Phase	• Kinetis MKM3x/1x	• ARM® Cortex®-M0+ core upto 50 MHz • 24-bit sigma-delta ADC, internal 1.2 V reference voltage 10-15 ppm/C 6-ch 12-bit SAR for auxiliary measurement, 2x analog comparator • LCD controller • Low power, security features
Metering Applications Processor	• Kinetis MK21, MK30, MK60	• ARM Cortex-M4 core up to 120 MHz, FPU (MK21), up to 1 M byte program flash, up to 128 k bytes RAM, security features
Anti-Tamper User Interface Air Flow, Liquid Level	• Accelerometers: MMA845xQ, • Proximity sensors: MPR121, MPR03x • Pressure sensors: MP3V5004, MPX12 • Power management: MC34704	• Low power consumption, competitive price positioning • Low power consumption, cost-effective, reduced mechanical dimensions
Power Management IC	• Power management unit IC: MC13892, MC33730	• Regulated voltages for Kinetis microcontrollers, MCU monitoring and fail-safe support

Electricity Meters

An electricity meter, or energy meter as it is sometimes called, is a device that measures the amount of electrical energy which is consumed by a residence, business or an electrically powered device.

There are many different types of electricity meters, such as electro-mechanical, standalone meters with pre-payment capabilities, smart meters with automatic meter reading (AMR) connectivity, which allows utility companies to read meters remotely, and advanced smart meters which have a bi-directional connectivity feature that allows customers to receive tariff information from the utility companies.

Electricity meters also differ in voltage and current ranges, as well as measuring single-phase, two-phase and three-phase electricity.

Freescale provides a solution for the various types of electricity meters, from the very low-end meter to an advanced smart electricity meter with two-way communication capabilities.

Low-End Electronic Single-Phase Electricity Meter

Low-end electronic meters rely on microcontrollers to measure, process, log, display and protect measurement data. Often these meters use a standalone analog front end to condition and measure the power supplied on the electric line. Once the measurement is taken, the MCU stores the reading and updates the segment LCD display.

Low-End Electronic Type
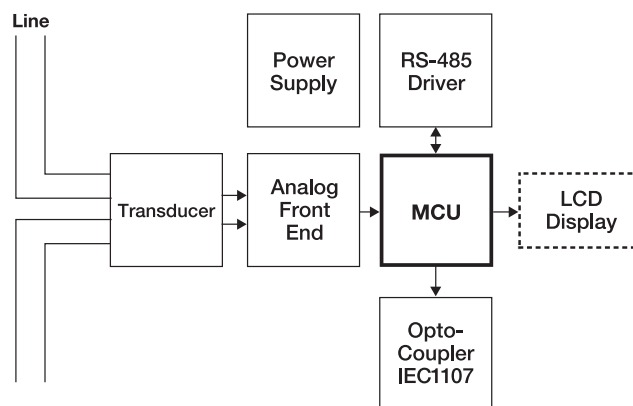
Freescale Technology   Optional

8- and 32-bit Microcontrollers

Products

Kinetis KM1x/3x: 32-bit microcontroller with ARM Cortex-M0+

RS08KA: 8-bit microcontroller family

RS08LA: RS08 cost-effective MCUs with LCD driver

S08LG: S08LG32 and S08LG16 8-bit LCD microcontrollers

S08LL: S08 ultra-low-power segment LCD microcontroller

S08QE: Flexis 8-bit HCS08 microcontrollers

Solution Advantages
- The KM3x has an integrated 24-bit sigma-delta ADC and LCD controller.
- The RS08KA is an integrated ADC, cost-effective MCU.
- The RS08LA is a cost-effective MCU with LCD drivers.
- The S08LG is an integrated 8-bit MCU with LCD control for up to 296 segments.
- The S08LL is our ultra-low-power MCU with LCD control for extended battery life applications.
- The S08QE is a highly integrated, pin-compatible 8-bit and 32-bit device duo.

Mid-Level Electronic Prepaid Electricity Meter

Mid-level prepaid electronic meters rely on microcontrollers to measure, process, log, display and protect system data. When the measurement is taken, the MCU stores the reading, checks and updates the customer's current balance and displays the information on the segment LCD display. Prepaid meters also have a special payment module which allows a customer to purchase additional power.

Solution Advantages

- The Kinetis KM3x MCU based on the ARM Cortex®-M0+ core with 4 integrated 24-bit sigma-delta ADC, plus programmable gain amplifier, security features, LCD controller, integrate power management, Active and Reactive energy accuracy IEC50470-3 Class C, 0.2%, ANSI C12.20, and Class 0.2

- K30 MCU based on the ARM Cortex-M4 core with integrated 2xADC, plus programmable gain amplifier, LCD controller and touch-sensing capabilities to implement keypad functionality

- KW20 Kinetis 2.4 GHz 802.15.4 RF and ARM Cortex-M4 MCU with up to 512 KB flash, 64 KB RAM

Mid-Level Electronic Prepaid Type
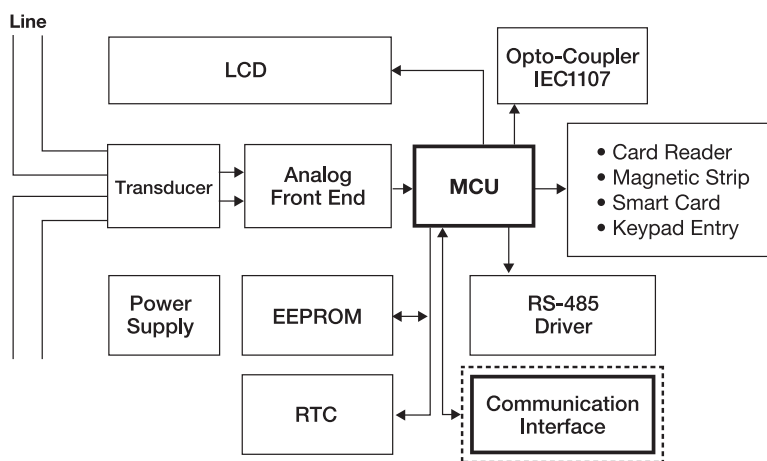
8- and 32-bit Microcontrollers

Products

KM3x: Kinetis ARM Cortex-M0+ core based 32-bit microcontroller for metering and measurement applications

MK30: Kinetis microcontroller based on the ARM Cortex-M4 32-bit core

S08GW: S08 ultra-low-power microcontroller

RF Low Power

Products

KW01: Kinetis sub-1 GHz radio and ARM Cortex®-M0+ MCU with 128 KB flash, 16 KB RAM

MC12311: sub-1 GHz, UHF RF transceiver + HCS08 8-bit MCU SiP for smart metering and home automation

KW20: Kinetis 2.4 GHz 802.15.4 RF and ARM Cortex-M4 MCU with up to 512 KB flash, 64 KB RAM

Electronic Single-Phase Electricity Meter (Integrated Electronic Type)

Integrated electronic meters reduce the number of ICs used in the system by using highly integrated MCU solutions. These MCUs often measure the power, process the measurement data, directly drive the segment LCD display and handle communication for the AMI network.
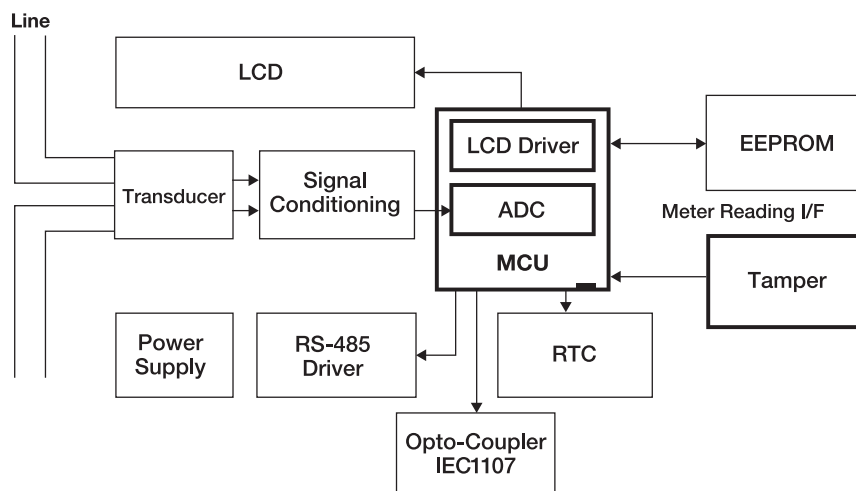
Pictured: Secure, prepaid 1-ph electricity meter with MK30 and Inside Secure's Vault™ IC

Solution Advantages

- Kinetis KM3x MCU based on the ARM Cortex-M0+ core with 4 integrated 24-bit sigma-delta ADC, plus programmable gain amplifier, security features, LCD controller, Active and Reactive energy accuracy IEC50470-3 Class C, 0.2%, ANSI C12.20, Class 0.2

- The MK30 MCU based on the ARM Cortex-M4 core with integrated 2xADC, plus programmable gain amplifier and LCD controller to help implement accurate metering functionality for active and reactive energy, satisfying IEC50470-3 class B, 1%. This device can also support PLC and wireless communication.

- The MMA8491Q is a low-voltage, three-axis tilt sensor in a 3 x 3 QFN package.

- The MMA766x is a low-profile capacitive accelerometer with signal conditioning, a low-pass filter, temperature compensation, self-test, 0g detect, pulse detect for quick motion detection and requires no external devices.

Integrated Electronic Type

☐ Freescale Technology ⬚ Optional

8- and 32-bit Microcontrollers

Products

KM3x: Kinetis ARM Cortex-M0+ core based 32-bit microcontroller for metering and measurement applications

MK30: Kinetis microcontroller based on the ARM Cortex-M4 core with MQX™ RTOS

RF Low Power

Products

KW01: Kinetis sub-1 GHz radio and ARM Cortex-M0+ MCU with 128 KB flash, 16 KB RAM

MC12311: sub-1 GHz UHF RF tranceiver + HCS08 8-bit MCU SiP for smart metering and home automation

KW20: Kinetis 2.4 GHz 802.15.4 RF and ARM Cortex-M4 MCU with up to 512 KB flash 64 KB RAM

Acceleration Sensors for Tamper Detection

Products

MMA7660FC: Three-axis digital output accelerometer

MMA8453Q: Three-axis, 12-bit digital accelerometer

Electronic Three-Phase Electricity Meter

Three-phase electricity meters are used in residential and commercial metering applications. Smart polyphase electricity meters form a key part of implementing the smart grid. These meters measure energy (active, reactive and apparent), have flash upgrade, connectivity and security features, which include tamper detection.
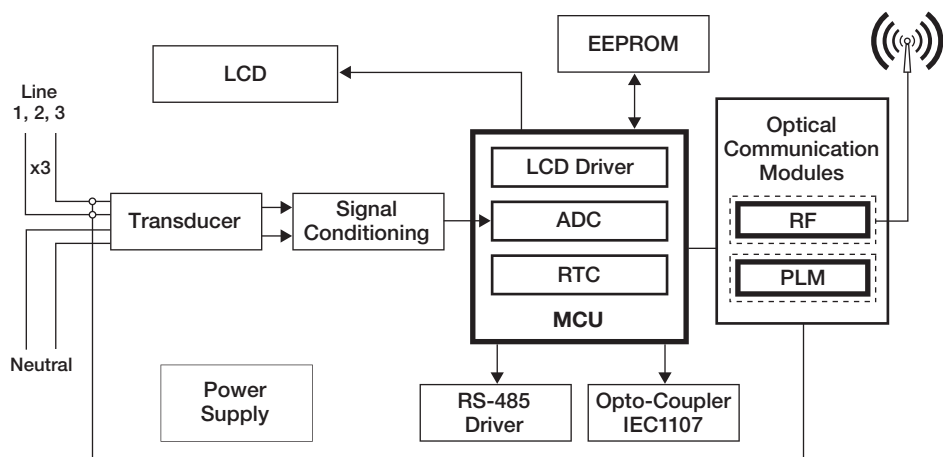
Solution Advantages

- Kinetis KM3.x MCU based on the ARM Cortex-M0+ core with 4 integrated 24-bit sigmadelta ADC, plus programmable gain amplifier, security features, LCD controller, ADC, plus programmable gain amplifier, security features, LCD controller, Active and Reactive energy accuracy IEC50470-3 Class C, 0.2%, ANSI C12.20 and Class 0.2

- 5(100) A, four quadrant measurement, 85–264 V, 50/60 Hz, active and reactive energy accuracy IEC50470-3 Class C, 0.2%

- Integrated ADC, tamper detection, iRTC

- Comprehensive polyphase meter reference design contains all of the necessary hardware and software to make the development of production smart meters quick and easy

Pictured: Secure, pre-post paid MK30 reference design with Vault IC

Polyphase Electricity Meter Diagram

☐ Freescale Technology   ⬚ Optional

32-bit Microcontrollers

Products
KM3x: Kinetis ARM Cortex-M0+ core based 32-bit microcontroller for metering and measurement applications
MK30: Kinetis microcontroller based on the ARM Cortex-M4 core with MQX RTOS

RF Low Power

Products
KW01: Kinetis sub-1 GHz radio and ARM Cortex-M0+ MCU with 128 KB flash, 16 KB RAM
MC12311: sub-1 GHz UHF RF tranceiver + HCS08 8-bit MCU SiP for smart metering and home automation
KW20: Kinetis 2.4 GHz 802.15.4 RF and ARM Cortex-M4 MCU with up to 512 KB flash 64 KB RAM

Acceleration Sensors for Tamper Detection

Products
MMA7660FC: Three-axis digital output accelerometer
MMA8453Q: Three-axis, 12-bit digital accelerometer

Flow Meters: Gas and Water Meters

Gas flow meters are devices designed to measure the volume of natural gas or water at a specific time or over a prolonged period. The measurement is then displayed via low-power segment LCDs often driven by segment LCD drivers on a MCU.

Advanced gas flow meters incorporate RF communication interfaces for connecting one-way or two-way RF meter reading systems.

The latest trend in metering is to use advanced accelerometers to detect small degrees of movement and record in the event of tampering.
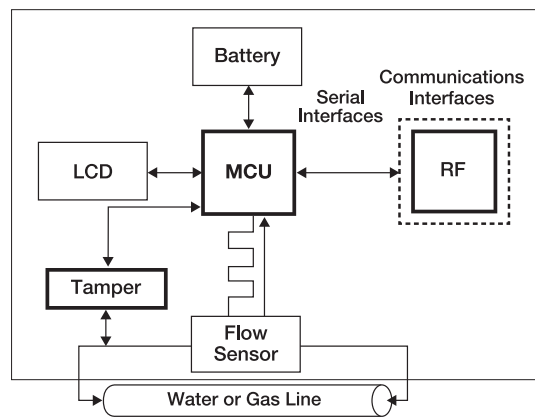
Important Design Parameters

- Cost of the devices in the system
- Reliability of the devices in the system due to harsh outdoor environments
- Battery life of the system >10 years
- Security to guard against tampering
- Communication interface requirements
- Ability to expand and update the system in the field

Solution Advantages

- System MCU is responsible for processing the data from the flow sensor, tamper sensor and communication interface. Once the MCU processes the information, it outputs the corresponding data to the segment LCD display and communication interface.
- Kinetis L2x and 3x Families are ideal products for designing flow meter applications.

Flow Meter Block Diagram

☐ Freescale Technology   ⬚ Optional

8-bit and 32-bit Microcontrollers

Products

S08LL: S08 ultra-low-power segment LCD microcontroller for extended battery life applications

S08GW: S08 ultra-low-power MCU with 2xADC, pulse counter and LCD controller for extended battery life applications

MK30: Kinetis family of low-power ARM Cortex-M4 MCUs

KL2x and KL3x: Kinetis family of low-power ARM Cortex-M0+ MCUs

RF Low Power

Products

KW01: Kinetis sub-1 GHz radio and ARM Cortex-M0+ MCU with 128 KB flash, 16 KB RAM

MC12311: sub-1 GHz UHF RF tranceiver + HCS08 8-bit MCU SiP for smart metering and home automation

KW20: Kinetis 2.4 GHz 802.15.4 RF and ARM Cortex-M4 MCU with up to 512 KB flash 64 KB RAM

Acceleration

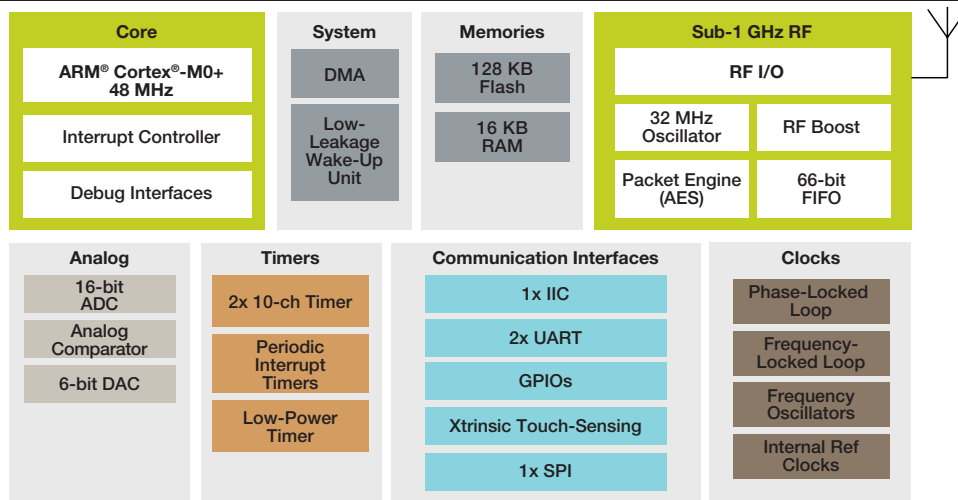| Products	Key Features
MMA7660FC: Three-axis digital output accelerometer	• Accelerometer for tamper detection
MMA8453Q: Three-axis, 12-bit digital accelerometer	• Accelerometer for tamper detection

- Multiple, flexible low-power modes, including new compute clocking option which reduces dynamic power by placing peripherals in an asynchronous stop mode. LPSCI, SPI, I^{2}C, ADC, DAC, LP timer and DMA support low-power mode operation without waking up the core.

- The MMA7455x accelerometer features digital output (I^{2}C) with very low power and a low profile capacitive micro-machined accelerometer with a low-pass filter and compensation for 0g offset and gain errors. It is used for sensor data changes, product orientation and gesture detection through an interrupt pin (INT) and sports an extremely small 3 mm x 3 mm x 0.9 mm DFN package.

- The MMA766x accelerometer is a low-profile capacitive accelerometer with signal conditioning, a low-pass filter, temperature compensation, self-test, pulse detect for quick motion detection that is configurable to detect 0g, and requires no external devices. The standby mode makes it ideal for hand-held battery-powered electronics.

- If motion is detected, the MCU triggers a meter tamper flag and sends a tamper message to the utility company via the communication interface or LCD display.

- The PLL-tuned UHF transceivers have a context switching feature without using an MCU, programmable fractional phase-locked loop (PLL), a received signal strength indicator circuit and a periodic wake-up timer. Additionally, there are 304, 315, 426, 434, 868 and 915 MHz ISM bands, OOK and FSK (software selectable) and data rates up to 20 kb/s.

- RF communications range from sub-1 GHz to 2.4 GHz 802.15.4 and ZigBee.

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MC1322x Block Diagram

Core	System	Memories	Sub-1 GHz RF
ARM® Cortex®-M0+ 48 MHz	DMA	128 KB Flash	RF I/O
Interrupt Controller	Low-Leakage Wake-Up Unit	16 KB RAM	32 MHz Oscillator / RF Boost
Debug Interfaces			Packet Engine (AES) / 66-bit FIFO

Analog	Timers	Communication Interfaces	Clocks
16-bit ADC	2x 10-ch Timer	1x IIC	Phase-Locked Loop
Analog Comparator	Periodic Interrupt Timers	2x UART	Frequency-Locked Loop
6-bit DAC	Low-Power Timer	GPIOs	Frequency Oscillators
		Xtrinsic Touch-Sensing	Internal Ref Clocks
		1x SPI	

Transceivers

Products

MC33696: PLL-tuned UHF transceiver

UHF Receivers

Products

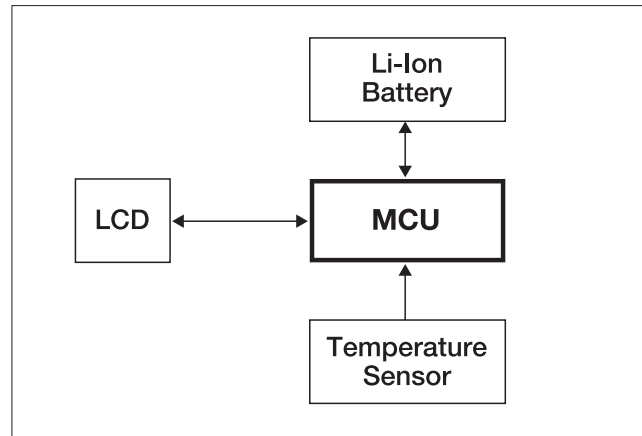MC33596: PLL-tuned UHF receiver

Heat Meters

Basic electronic heat allocation meters are designed to measure the temperature at the domestic heat panel for estimating heat energy usage (typically in instances where more than two households are using the same central heater). The challenge for these devices is that they must run 10 to 20 years on one set of batteries.

Solution Advantages
- Low power consumption
- Competitive price positioning

Basic Heat Meter

```
              ┌──────────────┐
              │   Li-Ion     │
              │   Battery    │
              └──────────────┘
                     ↕
┌──────────┐   ┌──────────────┐
│   LCD    │←→ │     MCU      │
└──────────┘   └──────────────┘
                     ↑
              ┌──────────────┐
              │ Temperature  │
              │   Sensor     │
              └──────────────┘
```

☐ Freescale Technology   ⸬ Optional

8-bit Microcontrollers

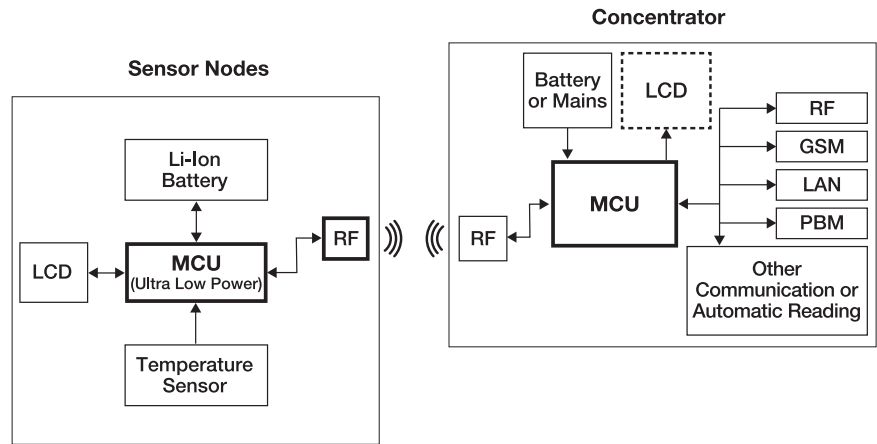| Products	Key Features
S08LL: S08 ultra-low-power segment LCD microcontroller	• Ultra-low-power MCU with LCD control for extended battery life applications
S08QB: Ultra-low-power 8-bit microcontroller family	• Cost-effective integrated 5 V MCU
S08QE: Flexis 8-bit HCS08 microcontrollers	• Highly integrated, pin-compatible 8-bit and 32-bit device duo

Heat Meter: Advanced

Advanced electronic heat allocation meters employ RF technologies to measure the temperature and transmit data from sensor nodes to the main concentrator. These devices are typically used in instances where more than two households with multiple rooms use the same central heater. The challenge for these devices is that they have to run 10 to 20 years on one set of batteries.

Electronic heat allocation meters sense and record the temperature of the radiator surface and the room air. The temperature difference is the amount of heat consumption. The meter starts as soon as there is a temperature difference of at least 4.5°C between the radiator sensor and the room air sensor. No measuring takes place below a temperature reading of 23°C on the radiator.

Solution Advantages

- Concentrator offers secure encryption, IP, high performance, real-time operating system (RTOS) support
- Leader in ZigBee technology
- ZigBee stack designed in-house
- Fully integrated, flexible solution
- Low power consumption
- Competitive price positioning
- Proven robustness in field

Advanced Heat Meter

8-bit and 32-bit Microcontrollers

Products

S08LL: S08 ultra-low-power segment LCD microcontroller for extended battery life applications

S08GW: S08 ultra-low-power MCU with 2xADC, pulse counter and LCD controller for extended battery life applications

MK30: Kinetis family of low-power ARM Cortex-M4 MCUs

KL2x and KL3x: Kinetis family of low-power ARM Cortex-M0+ MCUs

RF Low Power

Products

KW01: Kinetis sub-1 GHz radio and ARM Cortex-M0+ MCU with 128 KB flash, 16 KB RAM

MC12311: sub-1 GHz UHF RF tranceiver + HCS08 8-bit MCU SiP for smart metering and home automation

KW20: Kinetis 2.4 GHz 802.15.4 RF and ARM Cortex-M4 MCU with up to 512 KB flash 64 KB RAM

Transceivers

Products	Key Features
MC33696: PLL-tuned UHF transceiver	• RF for sensor node: Context switching feature without using MCU, prog fractional PLL, RSSI, periodic wake-up timer. 304, 315, 426, 434, 868 and 915 MHz ISM bands. OOK and FSK (software selectable). Data rate up to 20 kb/s

Home Energy Management Systems

Communications-enabled smart meters have many applications for optimizing overall energy management within the home and for utility companies wanting to manage the load of their grid and prevent power demand peaks.

The energy management system is the interface between the utility-controlled smart grid and energy-consuming in-house objects. It is also the interface to the consumer. If a consumer can see how their energy usage affects their costs and carbon footprint, they can change their behavior. The energy management system provides this information via a user interface than can be part of an in-house object or be viewed on a smart mobile device.

Functions for Home Energy Management

- Collect real-time energy consumption from smart meter and power consumption data from various in-house objects
- Generate a dashboard to provide feedback about power usage
- Provide menus to control appliances
- Provide a ubiquitous link to a broadband connection

Freescale energy management solutions enable rapid development with comprehensive reference designs embedded with the latest technology, including i.MX ARM processors and MPC8308 PowerQUICC II Pro processors. These are ideal for a broad range of connectivity options that offer flexibility and cost-effectiveness. The i.MX and MPC8308 processors support many different

Home Energy Management Systems Diagram
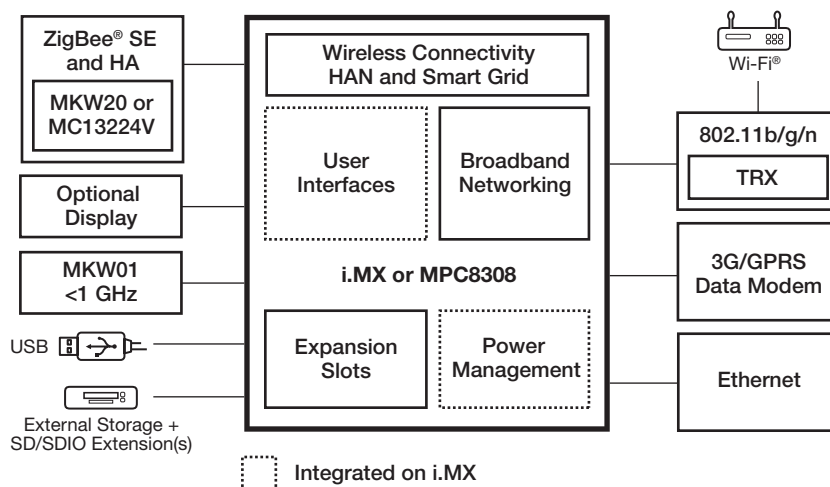
serial communications protocols, including SPI for ZigBee, single and dual Ethernet options, SDIO and PCIe for Wi-Fi. These smart energy management systems are supported by wireless chipsets and drivers from Atheros as well as DLMS stacks offering complete solutions.

Home energy management within HAN is an emerging market which has multiple options for implementation. Freescale provides reference platforms to meet different needs and provide options for these solutions. The i.MX-based reference design is optimally suited for standalone home energy management systems or integration into smart in-house objects. The MPC8308 reference platform supports an optimized blend of capabilities, including energy monitoring and management, home automation control, home security and surveillance, as well as VoIP and HD video

streaming, and is designed to be combined with in-home routers/gateways.

MKW20 is an ARM Cortex-M4-based high-performance RF and MCU chip supporting ZigBee 2.0 with a BeeStack smart energy or home automation profiles, providing an easy-to-implement, cost-effective mesh network that brings a common solution to appliances, meters and smart plugs. MKW01 supports <1 GHz frequencies.

Bridging the smart grid with the HAN, Freescale's energy management systems offer new energy gateway possibilities including in-home energy management.
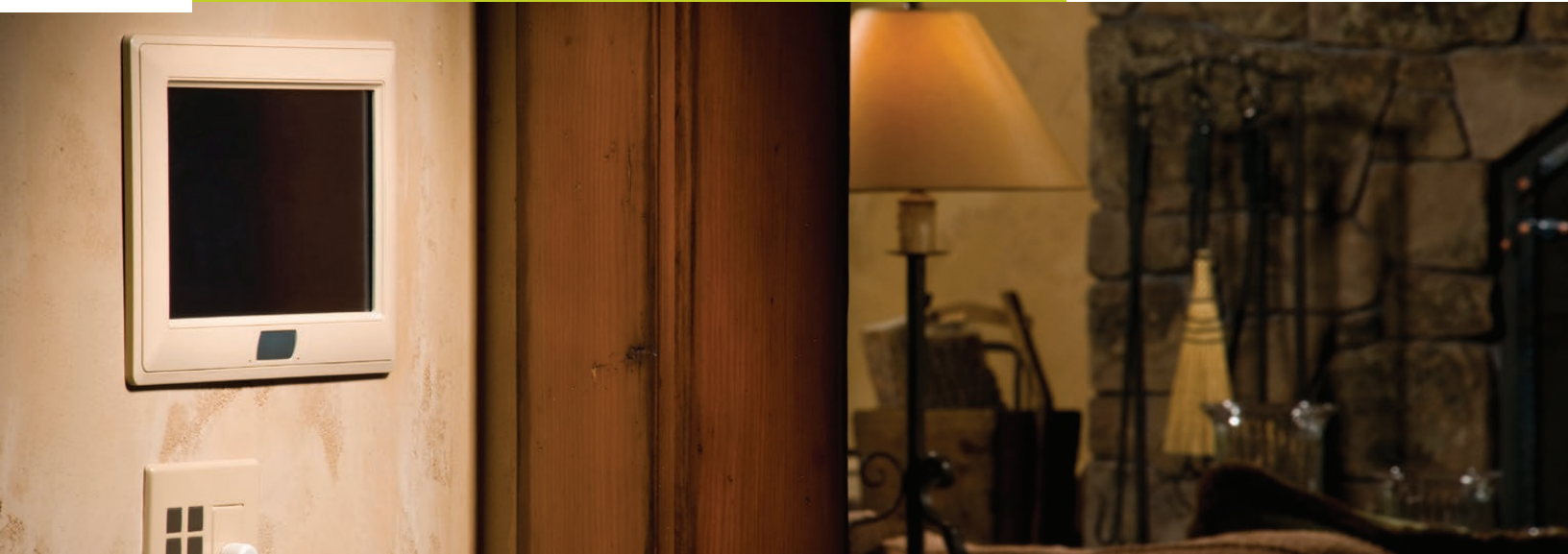
Home Area Networking

ZigBee Smart Energy is becoming the default standard for the HAN in several regions. As companies are building and deploying meters, programmable thermostats, in-home displays and appliances, ZigBee enables communication with the grid to provide automated demand-side management. Freescale provides ZigBee solutions based on MKW20 with Smart Energy profile 2.0 and Home Automation Profile for communications in and around the home.
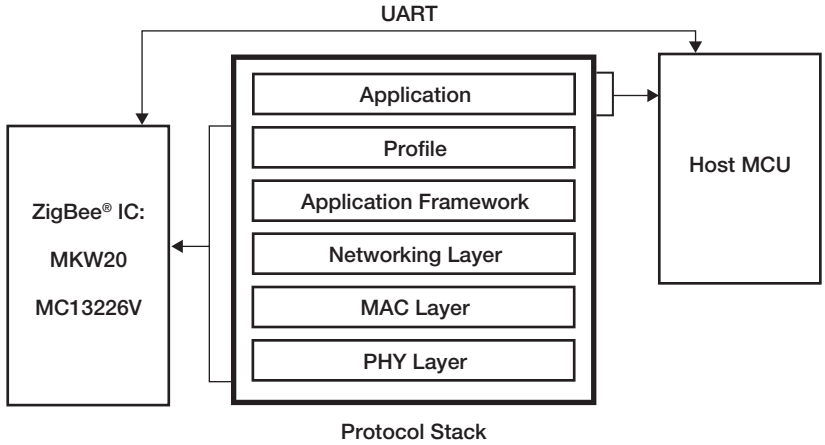
WirelessMBus and 802.15.4g protocols are supported by MKW01, ARM Cortex-M0+ core + <1 GHz transceiver.

Freescale also offers BeeKit development tools which provide a new approach to wireless application development through graphical user interface (GUI) and valid network configuration. Codebases deliver libraries, templates and applications to export directly to IDE for development and debugging.
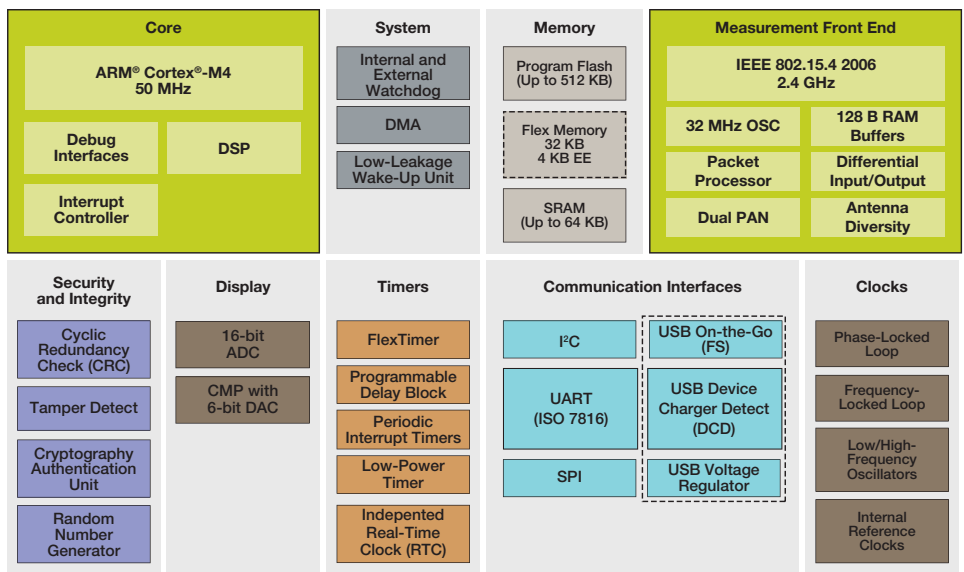
Wireless Communications Applications

- MKW20 (ARM Cortex-M4 and 2.4 GHz Transceiver)
- MKW01 (ARM Cortex-M0+ and <1 GHz Transceiver)
- MC1321x
- MC12311 (sub-1 GHz SiP device)
- MC1322x (ZigBee technology)
- MC33696 (ISM band)
- Power management unit IC: MC13892, MC33730

Home Area Networking Reference Diagram

UART

| Application |
| Profile |
| Application Framework |
| Networking Layer |
| MAC Layer |
| PHY Layer |

ZigBee® IC:

MKW20

MC13226V

Host MCU

Protocol Stack

MKW20 Block Diagram

Core	System	Memory	Measurement Front End		
ARM® Cortex®-M4 50 MHz	Internal and External Watchdog	Program Flash (Up to 512 KB)	IEEE 802.15.4 2006 2.4 GHz		
Debug Interfaces / DSP	DMA	Flex Memory 32 KB 4 KB EE	32 MHz OSC	128 B RAM Buffers	
Interrupt Controller	Low-Leakage Wake-Up Unit	SRAM (Up to 64 KB)	Packet Processor	Differential Input/Output	
			Dual PAN	Antenna Diversity	

| Security and Integrity	Display	Timers	Communication Interfaces		Clocks
Cyclic Redundancy Check (CRC)	16-bit ADC	FlexTimer	I²C	USB On-the-Go (FS)	Phase-Locked Loop
Tamper Detect	CMP with 6-bit DAC	Programmable Delay Block	UART (ISO 7816)	USB Device Charger Detect (DCD)	Frequency-Locked Loop
Cryptography Authentication Unit		Periodic Interrupt Timers	SPI	USB Voltage Regulator	Low/High-Frequency Oscillators
Random Number Generator		Low-Power Timer			Internal Reference Clocks
		Indepedent Real-Time Clock (RTC)			

Optional

Smart Appliances

Realizing long-term savings in a typical home via the smart grid means that technology, legislation and mindset must come together to drive a permanent change in the way consumers perceive energy consumption. Most of our high energy use today comes from heating/cooling, cooking, lighting, washing and drying. These home appliances are now becoming smarter, using advances in technology to improve the energy efficiency of the product.

Appliances such as washing machines (drum and pump), refrigerators (compressors) and room air-conditioners (compressors and fans) are now adopting advanced three-phase motors, which offer greater control and reduce the overall electricity consumption. Freescale provides digital signal controllers, 8- and 32-bit MCUs that have an intelligent peripheral set optimised to deliver precise control for all types of motors used in smart appliances.

Home appliances are beginning to include connectivity functionality that allows them to automatically take advantage of the benefits that smart metering and variable tariffs bring. The utility companies are able to better manage the energy demand and perform load balancing more efficiently, while consumers benefit from potential savings by using smart appliances when energy prices are at their lowest. This is driving human-machine interface (HMI) improvements to make available the relevant information that consumers need to make informed decisions. Freescale has a range of solutions for the HMI control panel, from MC9S08 8-bit MCUs, to higher end i.MX application processors.

Washing Machine Block Diagram
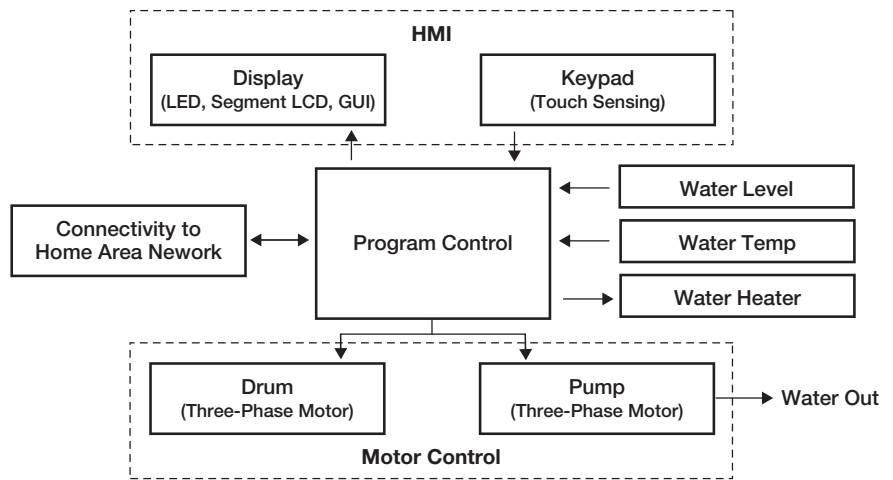
8-bit Microcontrollers

Products	Key Features
MC9S08 8-bit MCUs	• Flash, ADC, timer, touch-sensing interface
Kinetis 32-bit ARM Cortex-M4 and M0+ MCUs	• Flash, touch-sensing interface, segment LCD, graphic LCD
MC56F8xxx digital signal controllers	• Fast ADC, high-resolution PWM, math capability
i.MX application processors	• SVGA, VGA LCD support, superior LCD controller IP, flexible communication support
MKW20, MC12311 and MKW01 RF IC family	• Flash, RAM, RF transceiver

The featured microcontrollers also support U-SNAP implementation standards, which was developed for appliances and meters to allow a general-purpose interface to be added to an appliance. It can later be used for connectivity with an energy gateway, smart meter or Wi-Fi router. U-SNAP is an SPI and standard interface that can accept a small module with the connectivity option of choice. Freescale supports communication technologies and protocols such as ZigBee, providing all the building blocks used in a complete ZigBee-compliant platform solutions, including the RF transceiver, MAC and ZigBee software, microcontrollers and sensors.
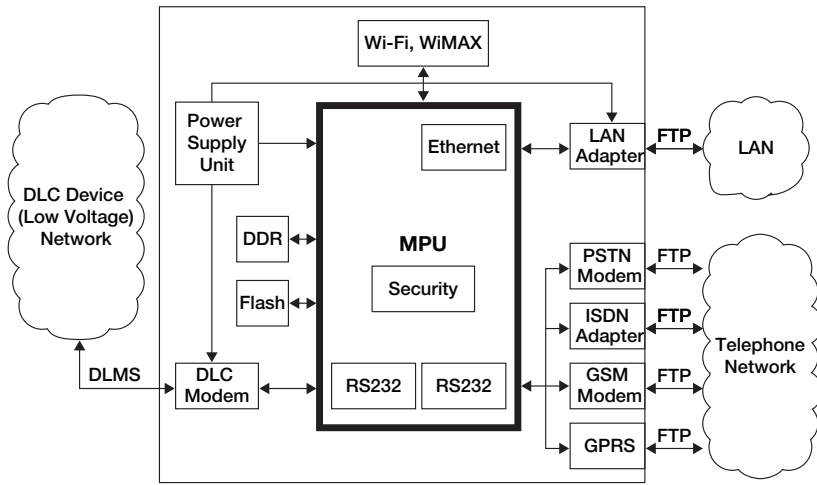
Grid-End Applications

The utility company manages the measurement, billing and loading throughout the entire grid. Therefore, it must manage a large quantity of data, including critical time constraints and a very large number of nodes. IP protocols, via Ethernet (powerline communications) or other high-speed communication, are often used. The link from the substation to the smart meter in the buildings and homes can be impractical, making it necessary to deploy a range of options according to local need.

The applications required for this task can be broken down into the following groups: data aggregator/concentrator, grid routers, substation automation, grid power management and protection.

Freescale and partner solutions today support IEC61850 substation automation communication protocols based on i.MX, Power Architecture® and QorIQ products.

Data Concentrator Functional Block Diagram

☐ Freescale technology

Freescale Products Grid-End Applications

| Function	Protocol	Physical	Source
Powerline to home (EU)	• ERDF G3 • PRIME • IEC61334-5	• OFDM PLC • OFDM PLC • S-FSK PLC	• Third-party development partnership • Third-party development partnership • Demo of P-LAN from Freescale
Powerline (USA)	• HomePlug AV/GP	• MII	• Third-party development partnership
Radio to home (USA)	• 802.15.4g	• 900 MHz RF	• Active Freescale standards participation
Utility link	• 3 G wireless • WiMAX	• Ethernet MII • Ethernet MII/SDIO	• Freescale TCP/IP stack with third-party hardware solutions
IP	• IETF RFC 2460 (IPv6) • IETF RFC 791 (IPv6)		• BSP
Time synchronization	• IEEE® 1588	• Ethernet	• IXXAT (Freescale partner)
Meter and revenue	• IEC62056 DLMS (EU) • ANSI C12.xx (USA)		• Third-party development partnership • Available on MPC8308 gateway reference design

Data Aggregators/Concentrators

The data concentrator is an important component in automatic meter reading (AMR). It creates the necessary network infrastructure by linking several utility meters (e.g. electricity, gas, water, heat) to the central utility server where it captures and reports vital data. The data concentrator also synchronizes the time and date data of utility meters to the central utility server. It ensures the secure data transfer of user authentication and encryption information. Communication to utility meters requires an RF or wired (power line modem) connection, enabling data transfers to the central utility server via Ethernet, GSM, GPRS, POTS or UHF/VHF networks.

Freescale offers a data concentrator reference design based on the MPC8308, supporting the DLMS/COSEM client/server stack. The P1025, a QorIQ device built on Power Architecture technology, offers a dual-core solution to allow applications and communications to coexist. It provides a platform for a fully featured operation system and hypervisor support for a high-end data concentrator or aggregator application.

Data Aggregators/Concentrators
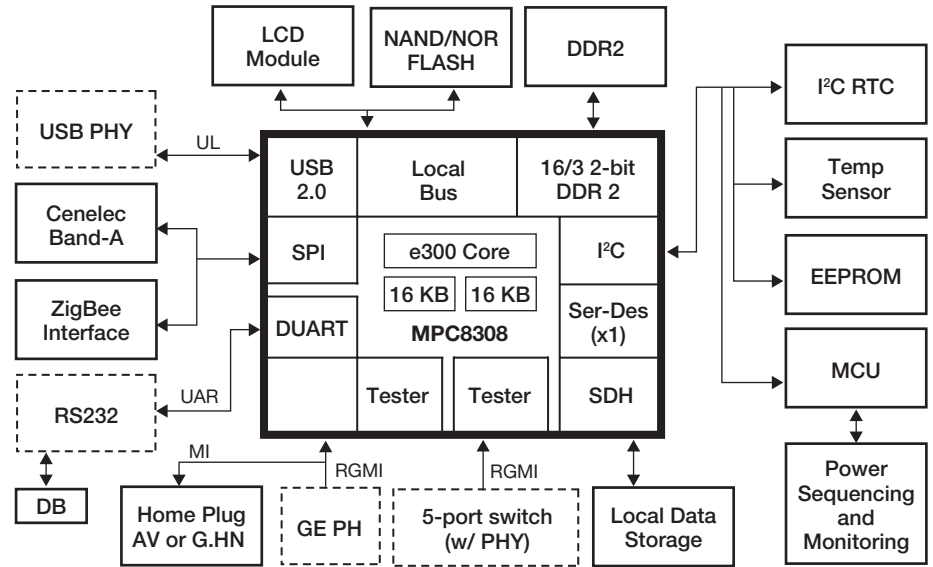
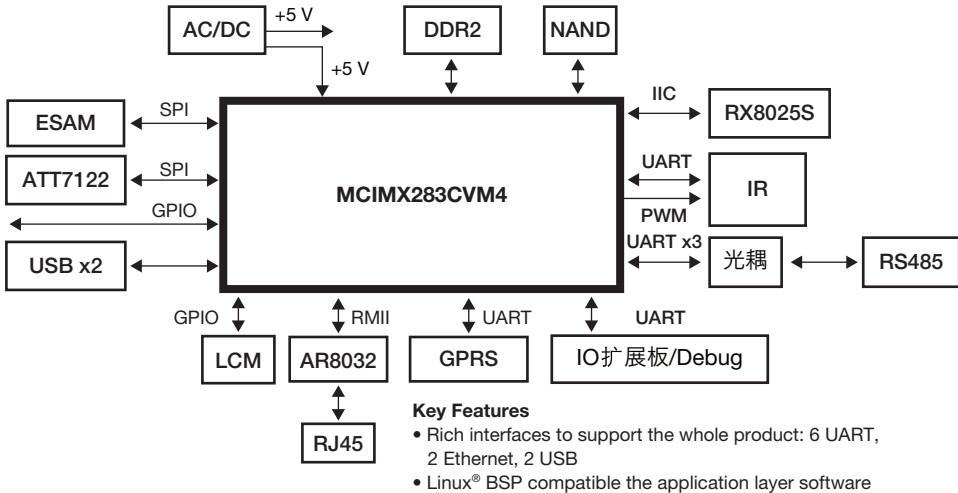### Data Aggregators/Concentrators
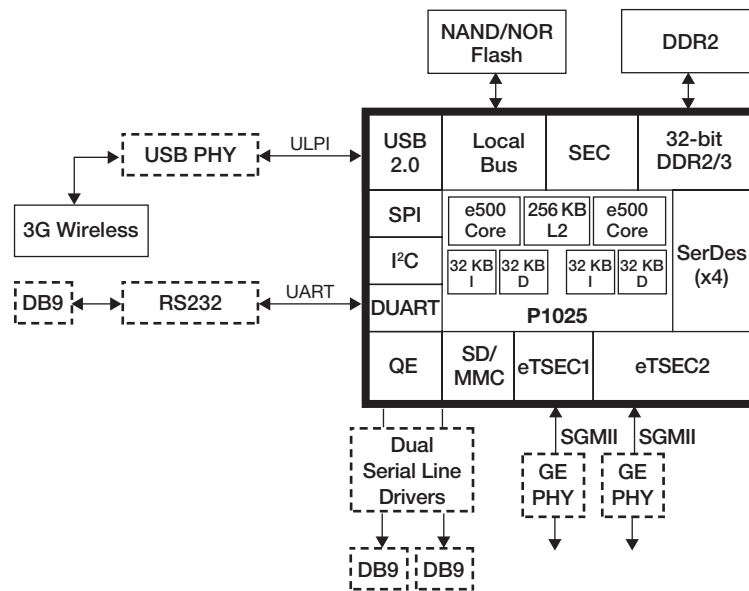
China State Grid Type I Concentrator Solution

The i.MX28 has been successful in addressing the requirements set out by China State Grid for Type I concentrator.

China State Grid Type II Concentrator Solution

Freescale's MK60 has been successful in addressing the requirements set out by China State Grid for Type II Concentrator.
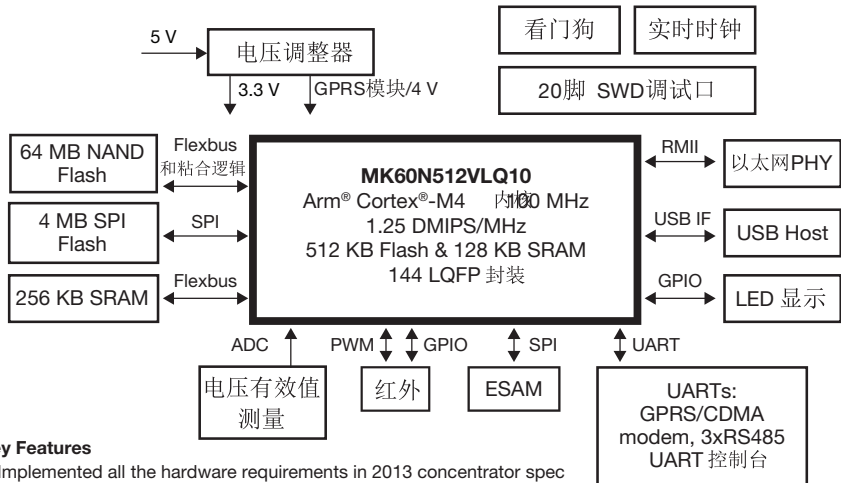
China State Grid Type I Concentrator Solution

Key Features
- Rich interfaces to support the whole product: 6 UART, 2 Ethernet, 2 USB
- Linux® BSP compatible the application layer software

China State Grid Type 1 Concentrator Solution

Offers	Key Features	Value
Hardware	454 MHz ARM926EJ-STM core	Compatible with current Type I concentrator architecture and application software
	Power management unit	Powers the device and drive external components, supports Li-ion batteries and direct connection to 5 V supplies
	Dual IEEE® 1588 10/100 Ethernet	RMII support and L2 switch (1 port in i.MX283 & 2 port in i.MX287)
	NAND support	SLC/MLC and eMMC 4.4 (managed NAND)
	Dual High-Speed USB with PHY	Supports DEVICE and HOST model in concentrator simultaneously
	12-bit ADC channels	RTC and backup battery monitor and detection
	Temperature sensor	Thermal protection
	6 UART, 4 SPI	Enough ports for 2013 Type I concentrator spec
	LCD controller	High display resolutions up to 800x480 supported
	SDIO	Supports SPI, MMC, SDIO, Triflash
	External memory interface (EMI)	Supports DDR2-400 (1.8 V), LP-DDR1-400 (1.8 V) and LV-DDR2-400 (1.5 V)
	Low power consumption Wait-for-interrupt standby mode system power (SRAM retain)=8 mA Power-down (RTC-only) power=12 uA	Supports State Grid Type I concentrator power consumption requirement
Software	Linux® BSP	Compatible with current Type I concentrator application software

China State Grid Type II Concentrator Solution

Key Features
- Implemented all the hardware requirements in 2013 concentrator spec
- MQX OS support all the communication protocols and hardware drivers

Grid Routers

Router Function

Interface between the smart meter and the utility network is performed using a grid router (sometimes referred to as a concentrator). The number of homes serviced by a grid router varies from a few (small cluster of buildings supported by a small substation) to several hundred (in the case of a city with high concentrations of buildings and housing). The role of the router is the same: to provide a link from the utility company to all local smart meters. In very complex networks, a hierarchy of concentrators may be required to collect all data and provide links to what is sometimes called the "back-hall" network where the utility services reside.

Connectivity

Data rates vary according to the local configuration and type of connectivity. At the heart of the router lies a powerful 32-bit processor, usually running a real-time operating system and providing high-level services, such as communications stacks, prioritization of messages, store and forwarding, network routing and discovery. Depending upon the local needs, a range of options are possible for local communication that include short range wireless (around 900 MHz), power line communications (low frequency carriers typically below 500 kHz) for local communications and options from longer range communications such as Ethernet (TCP/IP), ISDN, WiMAX or GPRS.

Grid Routers
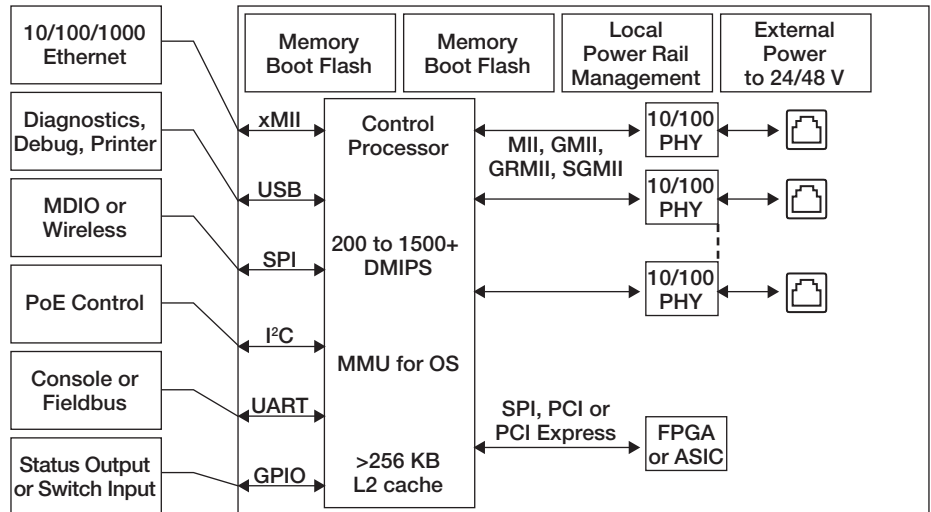
Security

With so many forms of communication, security of these communications and that of the grid is paramount. Public key cryptography, such as RSA 1024/2048, has very high protection from external attacks and is commonly used to protect these otherwise vulnerable links in the network. The PowerQUICC and QorIQ families support an expansive range of security protocols and functions for both private and public key cryptography to ensure these links are protected from external attacks. For low data rate communication, AES and DES are commonly used. Since these are private key cryptography functions, extra care is needed to ensure system integrity. QorIQ MPUs provide secure on-board storage of the keys to provide enhanced security for local

communication and many of the platforms provide trust architecture and secure boot for added security.

Freescale offers a wide range of networking controllers that provide the communications, performance and security required to provide this critical link in the smart grid.

Key Features

- High performance (100 up to 38,000 MIPs)

- Built-in security functions supporting public and private key cryptography

- Wide range of communication ports, including Gigabit Ethernet and fast serial ports, plus USB 2.0 for local on-board interfacing

- PCI Express® for FPGA interfacing

Grid Power Management and Protection (Relay, Breaker, Monitor)

Electricity substations are under increasing pressure to provide functionality to actively manage the local grid. As the load steadily increases, new forms of local energy generation are being added to grid architectures that never foresaw such a complex combination of generation and loads. When communication with smart meters is added to the mix, power management becomes even more complex. Deployment of new high-performance power controller systems is now common across all regions as utility companies attempt to stay one step ahead of technical challenges.

Power relay controllers must manage surges and loading on the grid locally. With an increasing range in the types of loads and generators on the local grid, this task is becoming more complex. There is also the possibility of a domino effect if a section of the grid trips without re-routing power further down the line. Real-time control is essential to maintain the grid integrity. This is accomplished using the IEEE 1588 protocol, which is supported on many PowerQUICC and all QorIQ families. An important function of these new power management systems is the display and handling of local information. Graphic LCD displays are becoming more desirable to the user as they allow for easier data control and management of local grid performance.

Power Breaker Controller Block Diagram
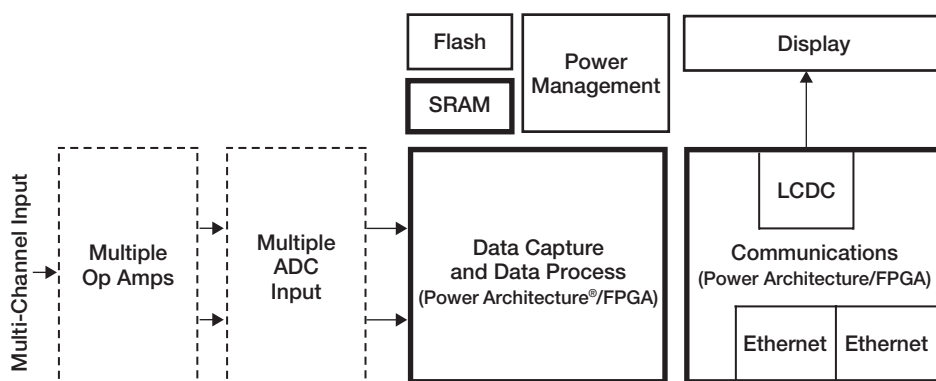
Low power operation is also an important consideration for microprocessor (MPU) choice. Fan-less operation greatly improves overall system reliability as these units may be installed in remote substations and have a long maintenance cycle. Power Architecture products are highly efficient and many are designed for fan-less operation.

A move towards cost-effective functional integration brings the focus toward multicore MPUs. The QorIQ provides an entire family with up to eight cores. Today, dual-core processing is adequate with products like the P1020, providing a complete range of fast serial communications and dual-core performance at a low cost. Adding power meter functions in the power breaker provides more information

on grid performance and loading. MPUs run supervisory, control and data acquisition (SCADA) for substations control and must have fast response times for the management of transient events (such as surges).
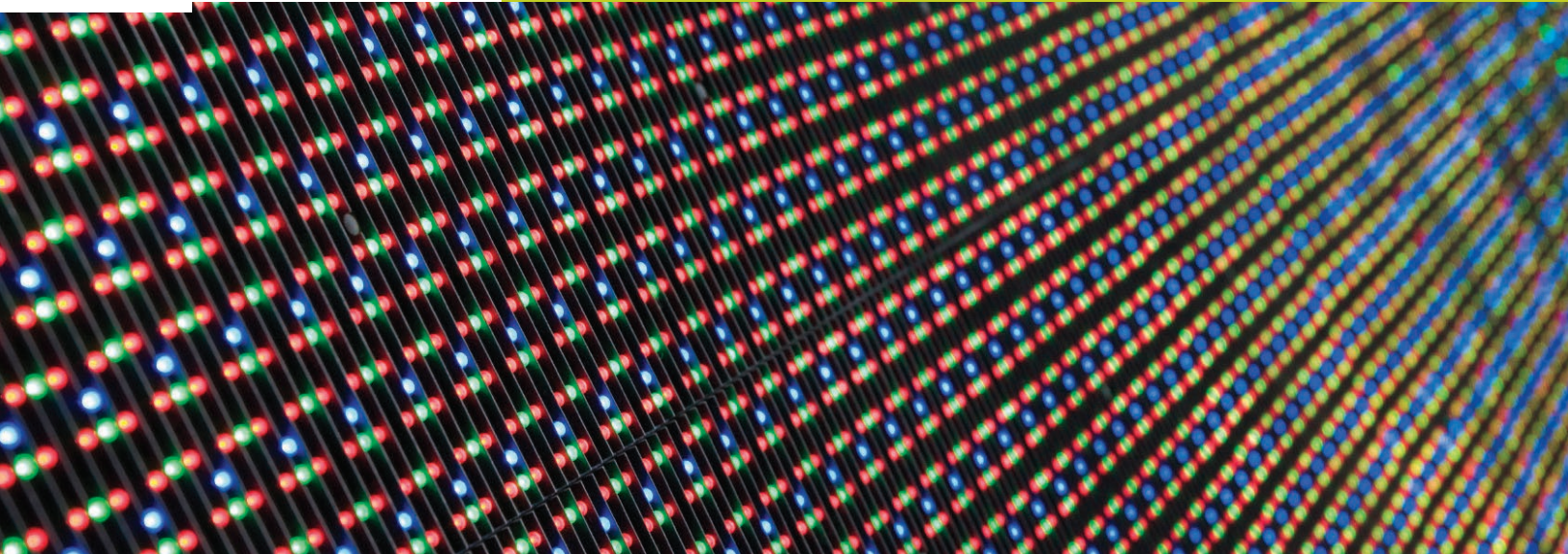
Digital Power Conversion and Storage

A critical component of the smart energy story is the necessity to increase the efficiency of the electronic systems and consumer devices operating in the world today. Every electronic device must be powered from an energy source. In most cases, this requires energy to be converted into a form useable by the device—a power supply. While power supplies have become increasingly more efficient, there is an industry trend to increase the digital component to the design.

Digital power conversion is a power system that is controlled by digital circuits, in much the same way as would be with analog circuits, to monitor, supervise, communicate and control system stability. A fully digitally controlled power system includes both digital control and digital power management. Control loops provide the mechanism by which to regulate the output of the power supply, usually through pulse width modulation of a power switch. Power management techniques provide the ability to monitor temperature, provide overcurrent protection and supply sequencing.

Freescale digital signal controllers (DSCs) are the right solution for digital power conversion applications as they provide both the control loop and power management functionality on one platform. By providing outstanding digital signal processing capabilities, high-speed pulse-width modulation (PWM) and extremely

Switched-Mode Power Supply
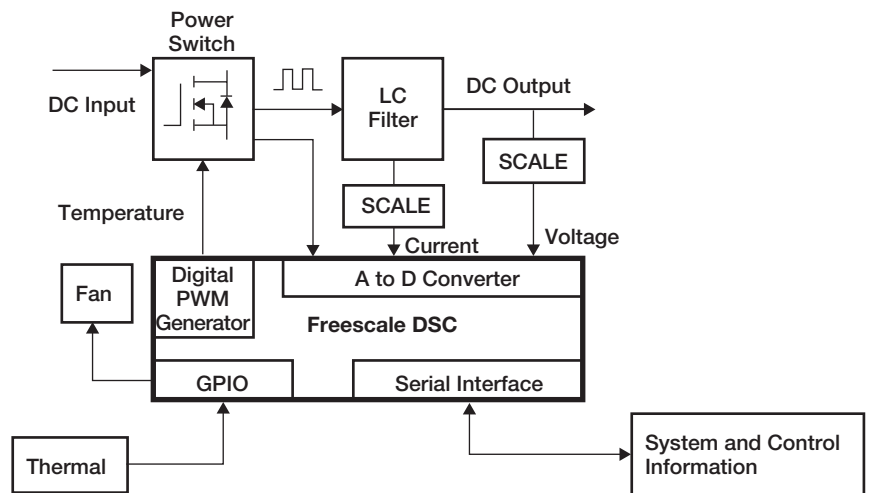
accurate ADCs, Freescale DSCs maximize system performance and reliability.

Freescale DSCs are excellent solutions for such applications as uninterruptable power supplies, telecom power supplies, server power supplies, power adapters, solar inverters, induction cooktops and wireless charging solutions. Digital power conversion provides direct and indirect benefits, many with far-reaching consequences. Digital power supplies are more efficient over a wider range of loads. This increase in efficiency reduces system cost and complexity. The reduction in discreet components not only reduces cost but also reduces environmental impact at the end-of-life cycle of the product by reducing waste. Increased system efficiency lowers system energy loss which is converted into heat. This translates into smaller heat sinks

and fans. Higher system efficiency reduces operational costs of the end product and its applications. For example, server farms with high efficiency digital power supplies require less cooling and lower operational costs. By providing more efficient power supply solutions, Freescale contributes to a smarter and more efficient energy supply use.
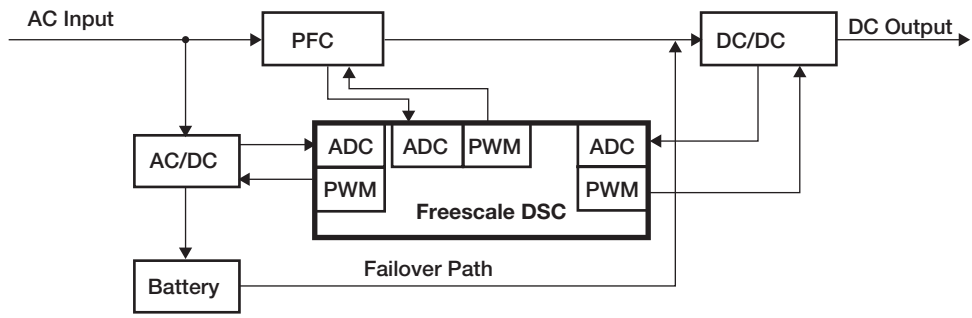
Switched-Mode Power Supplies

The growth motivator in the switched-mode power supply market has been largely driven by cost and efficiency metrics. As gains have begun to peak on pure analog systems, designers search for new methods to improve these performance drivers.

Freescale DSCs provide solutions for maximizing efficiency and reducing system cost through bill-of-materials reduction. The Freescale solution addresses system disadvantages, such as component aging and operational variability due to changing load conditions by compensating for these changes dynamically and efficiently. As the figure to the left indicates, the Freescale DSC integrates into the system and provides all system-level control and management of the switched-mode power supply.

Uninterruptable Power Supply

AC Input → PFC → DC/DC → DC Output; AC/DC, ADC, ADC, PWM, ADC, PWM, PWM, Freescale DSC, Battery, Failover Path

Uninterruptable Power Supply

Uninterruptable power supplies provide continuous energy to a load, even when the primary source of energy is interrupted or temporarily not available. Uninterruptable power supply systems include a battery backup subsystem which remains charged via the primary input. If the primary input fails, the battery subsystem provides a near instantaneous failover mechanism to maintain power to the load. Typically, uninterruptable power supply systems are designed to provide backup power for short periods of time, long enough to enable an auxiliary power source to be brought online. A Freescale DSC implemented in an uninterruptable power supply system provides digital control and power management for the entire power supply. As the figure above shows, all three converter stages are controlled by the Freescale DSC.
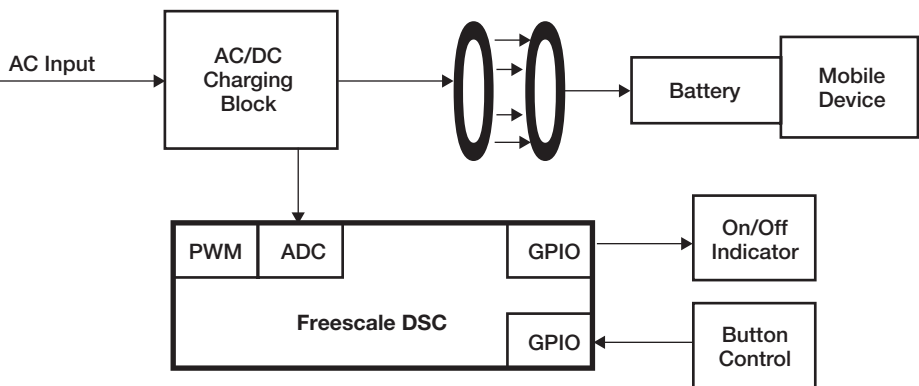
Wireless Charging

Wireless charging, or inductive charging, is the process of transferring energy from a power source to a load via magnetic energy. In such systems, a power supply is connected to an inductive coil called the transmitter. The device to be charged also has an inductive coil attached and is referred to as the receiver. When the transmitter and receiver are placed within close proximity, the power supply's energy is transferred between the coils and delivered to the load. At close distances, inductive charging is extremely efficient and very competitive with wired solutions.

There are several benefits to adopting inductive charging platforms. From a consumer perspective, wireless charging provides consumers more flexibility and ease of use. Users are no longer tethered or restricted to when and how they charge their devices. Charging pads can charge several devices at once. Consumers no longer need to be concerned with the compatibility of their device with the charger as industry standards are developed and adopted. From a manufacturer's perspective, migrating to wireless charging platforms immediately reduces costs and increases top-line growth potential. Potential applications range from hand-held consumer devices to electric vehicle recharge stations.

Wireless Charging

Freescale Products for Digital Power Conversion

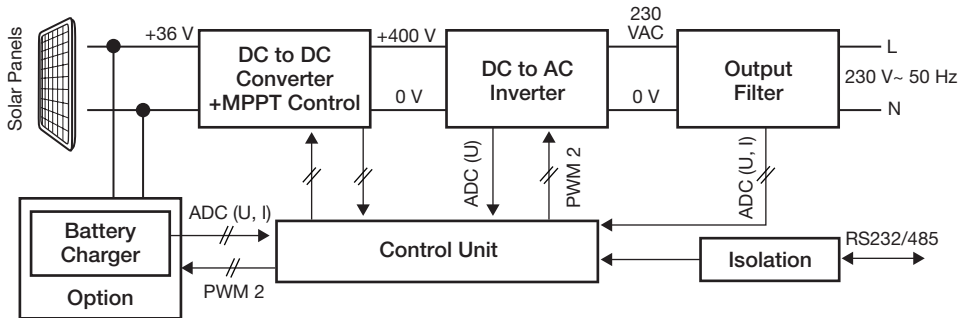| Products	Applications
MC56F801x MC56F8002/006 MC56F802x	Power supplies, uninterruptable power supply
MC56F824x/5x	Wireless chargers, power supplies, inverters
MC56F84xx	Switched-mode power supplies

Renewable Energy

Renewable energy will play a very important part in the smart grid over the coming years. As countries become more conscious of reducing their carbon footprint, harnessing solar energy and wind energy moves to the forefront. Freescale solutions provide our customers with the ability to design efficient and sustainable energy solutions.
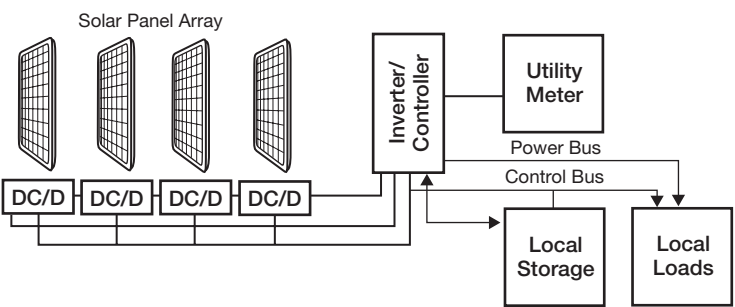
Solar Inverters

Solar inverters convert direct current (DC) produced by a solar module to alternating current (AC) for use by appliances or for feeding into the electrical power grid. They also serve to protect against power surges and for monitoring and logging performance data to maximize yield efficiency for the complete photovoltaic systems. Inverters may be designed with or without transformers and for a range of difference voltages and topologies depending on the application.

The Freescale DSC family of processors offers a cost-effective, single-chip solution for low-end single- or three-phase inverters. A reference design is available which demonstrates how to manage the three steps of power conversion and harness 400 W peak power from a solar panel for consumer use. DSC controllers combine MCU and DSP functionality on a single chip with high-performance PWM and ADC modules, coupled with SCI and GPIO support. For the higher end or grid-tied three-phase inverters, the PXS family of processors is an excellent fit. The PXS family is based on a dual-core architecture which has been specifically designed for safety-critical applications.

400 VA, 230 V 50 Hz Solar Panel Inverter Block Diagram

Photovoltaic System Block Diagram
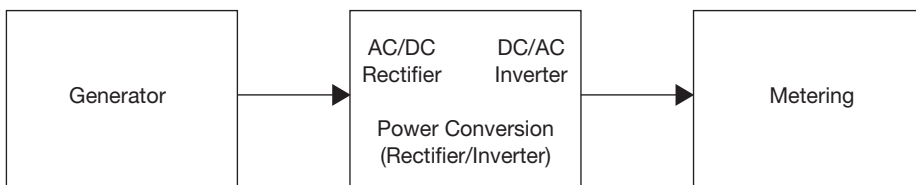

Freescale Products for Solar Applications

Products	Applications
56F80xx, 56F82xx	Micro inverters, low-end single-phase inverters
PXS20, PXS30	High-end single- and three-phase inverters
56F80xx, 56F82xx, S08	Battery chargers
S08, Kinetis ARM Cortex®-M4	Communications processor
MCF51EM, Kinetis ARM Cortex®-M4	Smart metering
i.MX, Kinetis ARM Cortex®-M4	Solar monitor and logging unit

The PXS family offers over 600 DMIPS of performance, floating-point unit and SIMD DSP capabilities, high-performance PWM and ADC modules as well as extensive communications support.

Wind Turbines

Freescale's portfolio of cores built on Power Architecture technology is well tuned for the demands of some of the world's largest wind turbines. The MPC85xx family is well suited to the high computational load required to manage a megawatt wind turbine. These large-scale wind turbines must react to changing environmental and energy loading conditions and maintain a stable output for the grid.

Wind Turbine Block Diagram

Freescale Products for Wind Turbine Applications

Products	Applications
• MPC55xx/56xx • QorIQ	Generator control
• MC56F801x • MC56F81x • MC56F825x • MC56F83xx • PPC5634	Power conversion
• MCF51EM	Metering
• MPC55xx/56xx • QorIQ	Main power control
• 9S08MP16 • MC56F8006 • MC56F8013	Yaw motor and yaw drive control
• MC1320x	Wireless communications
• MCF5225x • MCF51CN • S08DZ • 56F825x	Communications Ethernet/CAN
• i.MX • S08LL • TSS libraries • Flexis JM	Control panel and data logging
• Vibration • Pressure • Temperature	Sensor analysis

Wind Power Generation Solutions
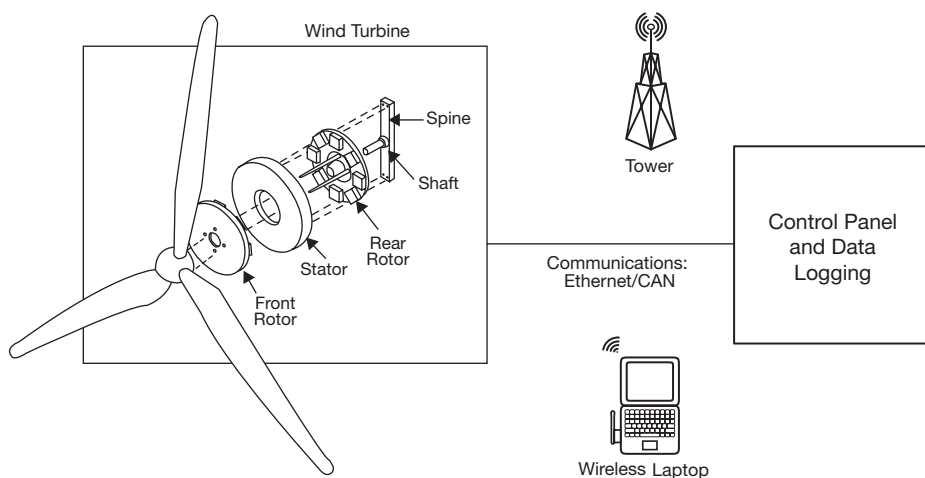
## Plug-in Hybrid Electric Vehicles (PHEV)

The PHEV contains rechargeable batteries which are charged via an external power source. PHEVs possess features of both a conventional hybrid electric and all-electric vehicles. Both have an electric motor and an internal combustion engine (ICE), as well as a plug that connects to the electrical grid. This market is growing worldwide, as China, the United States and many European countries have established goals to facilitate the introduction of PHEVs through stimulus grants and emissions mandates.

Freescale Solutions for PHEVs: Inside the Car

A hybrid vehicle combines an ICE and a battery-powered electric motor (E-motor) to power the drivetrain, which improves fuel economy and reduces harmful emissions. In addition to the internal combustion engine control unit, other modules are required to control the electric traction motor, recharge the battery and mange the energy used to run the auxiliaries, such as the start/stop system and fuel and water pumps.

Freescale and partner solutions today support ISO 15118 and DIN70121 standards for Grid to Vehicle communication. These stacks are implemented on i.MX processors.

Plug-in Hybrid Electric Vehicles
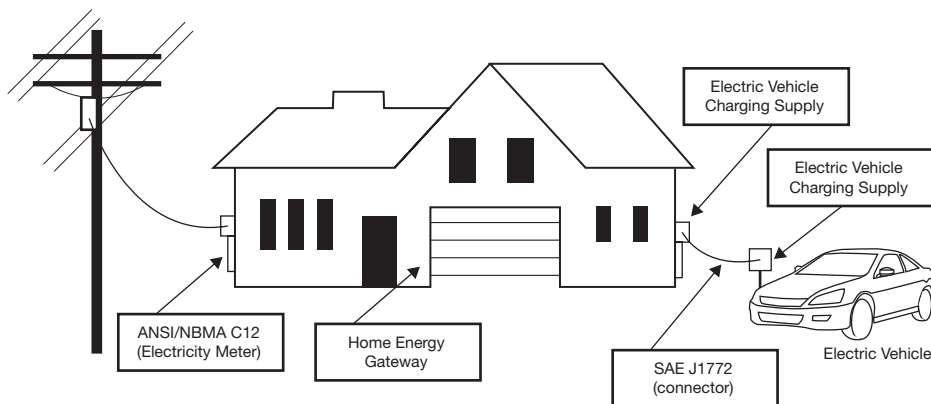
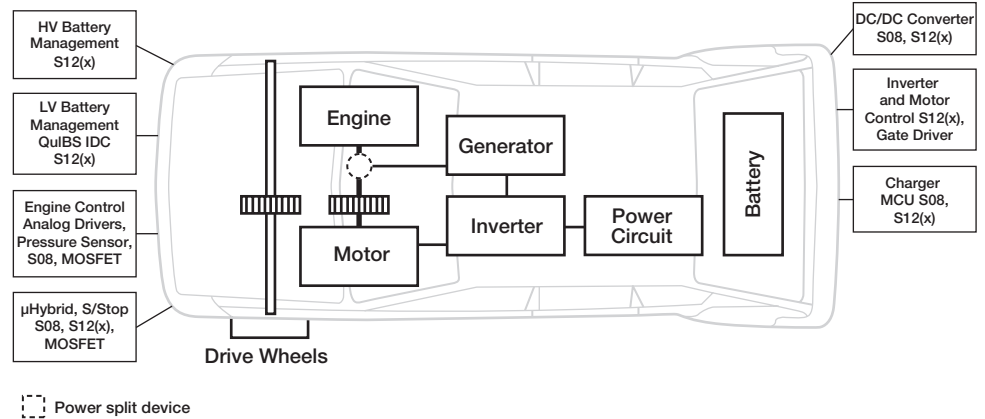

Freescale Solutions for PHEV: Outside the Car

Products	Key Features
Kinetis KM3x Electricity Metering Microcontroller	• Electricity meter or point-of-load meter
i.MX2xx family, MPC8308	• Home energy gateway
MKW20 ZigBee (Smart Energy profile and Home Automation profile)	• Home area networking
MC56F82xx, MCF84xx	• HEV solutions for charging stations

Freescale's MCU portfolio includes a number of electric motor control solutions with an available low-level software library. The charger can be addressed with a 16-bit MCU S12 which provides the resource to control the voltage from the grid to the converter. The CAN network allows the diagnostics and interaction of the charger to communicate with all electronic modules embedded in the car.

We are continually developing new products with dedicated peripheral sets for the electric architectures used in hybrid vehicles. For example, our intelligent distributed control (IDC) device integrates the industry-leading 16-bit S12 MCU with analog, mixed-signal and networking physical interfaces to provide a reliable and cost-effective system-in-package (SiP) solution for battery monitoring.

PHEV Reference Diagram

HV Battery Management S12(x)

LV Battery Management QuIBS IDC S12(x)

Engine Control Analog Drivers, Pressure Sensor, S08, MOSFET

μHybrid, S/Stop S08, S12(x), MOSFET

Engine

Generator

Motor

Inverter

Power Circuit

Battery

Drive Wheels

DC/DC Converter S08, S12(x)

Inverter and Motor Control S12(x), Gate Driver

Charger MCU S08, S12(x)

Power split device

Freescale Products for Hybrid Drive Train

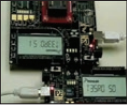| Product Family	Products	Key Features
32-bit MCU	• MPC55xx • MPC56xx • MPC564xA • MPC564xL	High-performance MCU family with scalable e200 cores built on Power Architecture technology, up to to 6 MB flash embedded
16-bit MCU	• S12XE • S12XS • S12P	Wide portfolio offering of compatible and scalable products with a range of feature set and packaging options
Analog and mixed-signal integrated circuits	• MC33730 • MC33904 • MC33905	Power supply and system basis chip
	• MC33811 • MC33972 • MC33975	Signal conditioning
	• MC33937	Three-phase pre-drivers
	• MC33899 • MC33926 • MC33931 • MC33932	H-bridge drivers
	• MC33661 • MC33902	CAN/LIN transceivers
	• MM912F634	IDC, low battery management
Enablement tools	• Evaluation board, calibration solution, software library, AUTOSAR	

Freescale Reference Designs

Electricity Meters

Reference Design	Features	Image
<$10 single-phase electricity meter using 9RS08KA8	• Rated voltage: 220 V, maximum operating voltage range: 80%–120% • Current range I: 5(30) A, frequency range: 50 Hz± 5%, accuracy level: 1.0 • Rated temperature: 23°C, maximum operating temperature range: –25° C to +55° C power consumption: ≤1 VA • Basic, measurement and active power accumulating functions • Output: main control board outputs pulses for active power measurement • Power pulses are square waves with 80 ms period and ±20% tolerance. Voltage drop of pulses' amplitude is <10% of rated value (high level >0.9 VD), low level of output pulses is <0.9 V • Communication: infrared communication port with 1200 bps baud rate, RS485 communication with 1200 bps baud rate, communication protocol complies with DL/T645 • Display: maintains display when powered off • Electromagnetic compatibility: electronic static discharge: 8 kV, high frequency electromagnetic field: 10 V/m, electrical fast transient: operating state 2 kV, non-operating state 4 kV, voltage surge: 4 kV	
<$10 single-phase electricity meter using 9S08LA8	• Cost-effective single-phase power meter based on 9RS08LA8 8-bit MCU with on-chip LCD driver • Single-phase active power measurement with forward, reverse and aggregated energy accumulation • Implemented with DL/T-645 2007 AMR specification via RS485 and infrared (for market in China)	
Single-phase multi-rate meter with external AFE using 9S08LG32	• Cost-effective single-phase multi-tariff power meter based on 9S08LG32 with on-chip LCD driver • External analog front end (AFE) • External real-time clock (RTC) • Single-phase active power measurement: forward, reverse and aggregated energy accumulation • Multi-tariff control with stand-alone RTC • Flexible MCU clock configuration • Implemented with DL/T-645 2007 AMR specification via RS485 and infrared (for market in China)	
Single-phase power meter turnkey solution using MZ60	• Cost-effective single-phase power meter based on Freescale's 9S08MZ60 8-bit MCU • Based on China SGCC specification • External LCD driver • AFE • Supports +ve/-ve active energy and tariff 4 • Flexible MCU clock configuration	
Single-phase electricity meter using MC9S08LH64	• Single-phase cost-optimized design • Voltage: 230 V ± 10%, current: 5(60) A • Active power measurement: URMS, IRMS • IEC50470-3 Class B accuracy • EMC proven design: EN61000-4-4, EN61000-4-2 • LED and open collector pulse outputs • EN 62056-21 infrared interface hardware • Optically isolated RS232 interface • The 110 segment LCD consumes 1.8 mA when all segments are on • Tampering: open cover detection • Excellent standby current of 1.4 µA • Dual array flash with EEPROM emulation, no external EEPROM needed • 16-bit SAR AD converter, RTC	
Single-phase meter using MCF51EM256 (Integrated AFE)	• Voltage and current capability: 85–264 V, 5(100) A • Measures: U_{RMS}, I_{RMS}, active, reactive, apparent power (energy), cos j, RTC • IEC50470-3 Class B (1%) accuracy • Tamper (open cover) detection via tamper button, three-axis I²C accelerometer • User interface: energy output interface (two LEDs), LED and open collector pulse outputs • EN 62056-21 infrared interface, RS232 opto-isolated serial interface, SPI header for t2.4 GHz RF interface (1320x), user buttons and LCD • Other features: MQX™ based for advanced markets, FFT algorithm for precision reactive measurement	

Freescale Reference Designs *(continued)*

Electricity Meters *(continued)*

Reference Design	Features	Image
Three-phase meter simulation using DEMOEM board	• Demo board simulates a three-phase metering application, including input waveforms • Three-phase meter is based on MCF51EM256 • 4 x 40 segment LCD driver, 16-bit ADC • Independent RTC • IR interface (SCI, TPM, PRACMP) • 9S08QE8 generates simulated input • Capacitive touchpad software	

Polyphase electricity meter based on MCF51EM256	• Complete solution for single-phase, three-phase 110 V and 230 V electricity meters for all global regions
	• Able to achieve beyond class 0.5 for active energy
	• Designed and tested against:
	  ○ IEC 62053-22 International Energy Metering Spec, class 0.5 (or better) for active energy
	  ○ IEC 62053-23 International Energy Metering Spec, class 2 for reactive energy
	  ○ IEC 62056-21 International Energy Metering Data Exchange Spec
	  ○ IEC 62053-22, IEC 62053-23, IEC 62052-11 Electro Static Discharge (ESD), tested per IEC 61000-4
	• Full documentation, including pre-compliance test data is available
	• Software source code is supplied as a CodeWarrior project for easy reuse or customization
	• Full working reference design is available for loan and evaluation	

Single-phase electricity meter based on MC9S08GW64	• Single-phase cost-optimized energy meter reference design • Based on MC9S08GW64 device having two 16-bit ADC hardware and dedicated RTC • Class 1 accuracy for 5–30 amp and 10–60 amp, meeting Indian standards • 10–60 amp, ZigBee® is also implemented on board • Running on capacitive power supply and shunt-based current measurement • Total current consumption: 4 V (meter), 4 ma (micro), running on 220 nF cap • Very low standby current • LCD display control	
Single-phase electricity meter based on the Kinetis MK30 MCU	A high-performance solution for power measurement in single-phase two-wire installations targeted towards residential metering. ZigBee connectivity through I²C. Firmware based on MQX RTOS. • 5 (60) amp current range, nominal current 5 amp, peak current 60 amp • 120/230 V AC, 50/60 Hz operational range • Active and reactive power (energy) measurement, IEC50470-3 class B, 1% • Shunt-resistor sensing circuit implementation, voltage sensing by an inexpensive resistor divider • 4 x 40 segment LCD, including charge pump (values shown on LCD: V, A, W, Var, VA, kWh, kVarh, cos, Hz, time, date) • Tamper detection • IEC1107 infrared hardware interface, optically isolated RS232 interface • 2.4 GHz RF interface through a 1322x-LPN daughter card • EMC-proven design (EN61000-4-2, EN610004-4)	

Secure Prepaid Electricity Meter Reference Design	Reference design showcasing secure, prepaid meter with ability to reload energy balance through NFC.
	• Features Inside Secure VaultIC 460 and Microread NFC chips
	  ○ 5–60 amp, 85–264 V, 47–63 Hz
	• Active and reactive energy accuracy: IEC50470-3 Class B, 1%
	• Cost-effective shunt-resistor-sensing circuit implementation
	• Effective implementation of low power modes, including use of the built-in real-time clock
	• Values displayed on the LCD: V, A, W, VAr, VA, kWh, kVArh, cos, Hz, time, date
	• OBIS identifier on the LCD
	• Tamper detection via two tamper buttons or magnetometer (event is stored in memory)
	• LED pulse outputs (kWh, kVArh)
	• IEC1107 infrared hardware interface
	• MQX-based for advanced markets
	• Advanced metering algorithm based on the fast Fourier transform (FFT)
	  ○ Security stack available	

Electricity Meters *(continued)*

Reference Design	Features	Image
One-Phase Electricity Power Meter (European) Based on MKM34	• 5–80 A current range (nominal current is 5 A, peak current is 80 A, 85–264 V, 50/60 Hz voltage range • Accuracy class: B or C (active energy EN50470-3) and 3% or 2% (reactive energy EN62053-23) • Line-frequency measurement (for precision zero-cross detection) • Cost-effective shunt-resistor sensing circuit implementation • Low-power modes, including the use of built-in RTC (Li-battery backup) • 4 x 22 segment LCD, including charge pump (values shown on LCD: V, A, W, Var, VA, kWh, kVarh, cos, Hz, time, date) • An upper and lower tamper meter cover monitoring with timestamp • IEC1107 infrared hardware interface and Isolated (4 kV) RS232 port for monitoring and SW upgrade • LED pulse outputs (kWh, kVarh) • EMC proven design (EN61000-4-2, EN610004-4) • RF connector supporting sub-GHz or 2.4 GHz 802.15.4 communications • Xtrinsic 3-axis low power tilt sensor for electronics tamper detection (optional) **Software provided** • Multiple advanced metering algorithms: filter-based, FFT method • MQX™ real-time operating system • Comprehensive peripheral library drivers	
Optimized One-Phase (India) Power Meter Based on MKM34	• Class 1, 5(30) capacitive power supply-based meter • 90–300 V operating range, 45–65 Hz & Backup battery • Shunt for phase current sensing • Active and reactive energy accuracy per IS13779 • Current transformer for neutral current sensing • Neutral missing current transformer for neutral missing tamper condition • 4 x 22 segment LCD, including charge pump (values shown on LCD: V, A, W, Var, VA, kWh, kVarh, cos, Hz, time, date) with auto scroll menu display • IS13779:1999 compatible • Built-in RTC, capable of detecting tamper in power-failure event **Software provided** • Multiple advanced metering algorithms: filter-based, FFT method • MQX™ real-time operating system • Comprehensive peripheral library drivers	
Two-Phase (U.S.) Power Meter Based on MKM34	• 200 A current range (CL200, TA 30 A); 85–264V, 50/60 Hz voltage range • Support two types of installation: Form 2S or Form 12S • Accuracy class: ANSI C12.20-2002 Class 0.5 • Line-frequency measurement (for precision zero-cross detection) • Current transformer-sensing circuit implementation for each phase • Low-power modes, including the use of built-in RTC (Li-battery backup) • 8 x 20 segment LCD, including charge pump • LED pulse outputs (kWh, kVARh) • Infrared optical port according to ANSI C12.18-2006 and isolated (4 kV) RS232 port for monitoring • EMC proven design (ANSI C62.41, IEC 61000-4-4) • RF connector supporting sub-GHz or 2.4 GHz 802.15.4 communications • Xtrinsic 3-axis low-power tilt sensor for electronics tamper detection (optional) • Xtrinsic 3-axis low-power magnetometer for electronic tamper detection (optional) **Software provided** • Multiple, advanced metering algorithms based on the fast Fourier transform • MQX™ real-time operating system • Comprehensive peripheral library drivers	

Freescale Reference Designs *(continued)*

Electricity Meters *(continued)*

Reference Design	Features	Image
MKM34Z5 Three-Phase Power Meter with Current Transformers	• 5(100) A current range, nominal current is 5 A, peak current is 100 A • Tested with range 0–240 A (320 A) • Four quadrant measurement • 85–264 V, 50/60 Hz voltage range • Active and reactive energy accuracy IEC50470-3 Class C, 0.2% • Line-frequency measurement (for precision zero-cross detection) • Current transformer-sensing circuit implementation • Cost-effective bill of materials (BOM) • Low-power modes effectively implemented, including the use of the built-in RTC • LCD display, 4 x 44 segments, including charge pump • Values shown on the LCD: V, A, W, Var, VA, kWh, kVarh, Hz • Magnetic field electronic tamper detection via ELECTRONIC TAMPER MAG3110 sensor and tamper buttons • Built-in user push-button • LEDs pulse outputs (kWh, kVARh) • IEC1107 infrared hardware interface or optically isolated RS232 interface • Comunication interface connector could be used for I^{2}C daughter card for connection to a ZigBee® network • Multiple, advanced filter-based metering algorithms	

Flowmeters

Reference Design	Features	Image
Flowmeter based on the MC9S08GW64	• Low-power STOP3 mode (500 uA), ultra-low-power STOP2 mode (300 uA) • Based on Hall Effect sensor • Position counter used to calculate the flow and run even when the MCU is in low power mode, MCU stays is low power mode for most of the time and position counter interrupt used to wake the MCU • Month-wise and accumulated flow stored in flash memory. User Interface available for displaying the flow on LCD • RF communications over 2.4 GHz low power ZigBee for smart flowmeter, compliant with Freescale ZigBee SMAC protocol stack • DLMS ported on the flowmeter for interfacing with smart meter, DLMS is over ZigBee (2.4 GHz) • UART Tx\Rx is available on board for communicating with flowmeter • Flowmeter cover opening tamper with time stamping	

Digital Power

Reference Design	Features	Image
LLC resonant converter	• LLC resonant half-bridge converter • Synchronous rectifier and buck converter are controlled by the MC56F8247 DSC on the secondary side • MC56F8013 on the primary side for PFC	
Solar panel inverter demo	• Uses MC56F8025 for inverter control • Battery charger and on/off grid options • MPPT algorithm is implemented to maximize output power	
Micro-inverter solar reference design	• The micro-inverter is based on the Freescale DSC MC56F8257 to perform the functions of control and measurement • MPPT algorithm is implemented to maximize output power • PLM communications, battery charger, on/off grid all optional features	No Image Available

Home Energy Management Systems

Reference Design	Features	Image
In-home energy display	• Low-power, cost-effective Kinetis K30 microcontroller provides the application platform and communications with remote sensors • ZigBee 2.4 GHz SE 2.0 can also support ZigBee Home Automation if needed • Sub-1 GHz ISM band RF to electricity meter and gas meter for Central Europe • Display: segment LCD to reduce power and cost • Expansion for additional wireless or wired (RS485) sensor nodes for enhanced energy management or building control • Option to include dot-matrix LCD or graphic LCD display via SPI link	
Home energy manager based on i.MX28	• ARM926™ i.MX28-based energy gateway reference design (1x Ethernet, 1x WLAN, 2x ZigBee, 1x ISM-RF, 1x RS232) • Compact form factor (3.29" x 2.98" in headless mode) • Very low BOM (<$40, including a 4-layer PCB) • Based on a powerful and low-power i.MX283 with intelligent integration (power management, connectivity, display, analog) for lowest possible solution • Scalable (features, performance, software) portfolio of ARM-based processors to future proof designs in an evolving HAN and home energy management market segment • Multiple connectivity options to smart meters and smart appliances, including M-Bus, Wi-Fi and ZigBee • Pre-validated communication stacks and example code • Freescale quality and reliability with industrial qualification, extended temperature range and long-term guarantee of supply (longevity program) • Development kit includes the fully tested home energy management unit, power supply, documentation and cabling and is available through Adeneo Embedded (**adeneo-embedded.com/heg**). Schematics, gerber files and software packages (Linux® and Windows® Embedded Compact 7 board support packages) available for free.	
Networked smart gateway based on MPC8308	• Complete mass production-ready design with integrated ZigBee Pro and 802.11n Wi-Fi modules • MPC8308 processor supports up to 400 MHz, delivering up to 800 DMIPS • Multi-application support for smart energy, home automation, home security/surveillance, streaming HD video and VoIP • Supports ZigBee Home Automation 1.0 and Smart Energy 1.0 profiles, as well as DLMS • Complete design files, including schematics and gerbers, as well as OpenWrt software stacks	

IPv6 Connectivity for Smart Cities

Reference Design	Features	Image
TWR-METRO-KIT	• Edge Routers/Data Concentrator based on QorIQ P1025 with 400 MHz to 667 MHz performance range, with advanced security, QUICC Engine for multiprotocol support and a rich set of interfaces • RF Transceiver based on MC12311: sub-1 GHz RF and 8-bit HCS08 MCU with 32KB flash, 2KB RAM Sub-GHz radio, GFSK -120 dBm @ 1.2 Kbps, +15 dBm power output without amp • Can also use KW01 RF Transceiver based on Kinetis sub-1 GHz radio and ARM Cortex®-M0+ MCU with 128 KB flash, 16 KB RAM <1 GHz Transceiver for 290–340 MHz, 424–510 MHz, and 862-1020 MHz frequency bands with high sensitivity: down to -120 dBm at 1.2 kb/s • IPv6 Protocol Stack from Nivis which runs on Freescale K60 Microcontrollers (MCU) featuring Ethernet Crypto MCUs Kinetis MCU with crypto-acceleration unit for AES128 link layer security	

Freescale Reference Designs *(continued)*

Data Concentrator

Reference Design	Features	Image
Data concentrator based on QorIQ P1025	• Based on P1025-RDB, this reference design includes on-board ZigBee chip • P1025: e500-based microprocessor running up to 667 MHz • Interfaces to support Wi-Fi, powerline com, PLM, M-Bus, GPRS and others • Running DLMS/COSEM client stack from Kalki Technologies (IEC 62056) on-board security engine	
Data concentrator based on MCF5441x	• Based on ColdFire V4 core 250 MHz processor: MCF54415/MCF54418 • Supports DDR2, SPI and NAND flash • Connectivity: 10/100 Mb/s IEEE 1588 USB H/D/OTG, CAN • On-board security engine • Application code written in Linux	

Smart Plug

Reference Design	Features	Image
Smart plug (SMAC) based on MC9S08GW64	• Low accuracy smart AC energy meter based on MC9S08GW64 • Customizable energy consumption monitoring • Appliance control • Appliance power control • Wireless control via SMAC • Compatible with any IR remote for precise appliance control • Remote control via main home energy meter through SMAC • Designed for smart energy appliances	

Freescale in Smart Grid Standards

Freescale is an active participating member in several leading smart grid standards bodies and committees.

Promotor and Contributing Member

- ZigBee Alliance: Freescale contributed to the creation and project management of Smart Energy profile specification
- IPSO (IP for Smart Objects) Alliance
- 6LoWPAN
- G.hn
- ETSI Board SmartGrid strategic topic: Freescale is a member of this board and one of the champions of the SmartGrid strategic topics
- Home Gateway Initiative (HGI) Smart Energy champion

Contributing Member

- IEEE 802.15/IEEE 802.15g Smart Utility Network (SUN) wireless standard
- ETSI M2M and ETSI M/441 strategic team (M/441 is the EC mandate to define smart meter)

Participating Member

- Smart Grid Interoperability Panel (NIST)
- Pecan St. Project, TX
- ITU-T SmartGrid focus group

Third-Party Partners

Freescale works closely with several third-party partners to provide useful hardware and software tools and reference designs to make designing a new product simpler and faster. Below are our key partners who provide solutions for the smart energy and smart grid space.

Metrology

- Larsen & Toubro
- Kalki Technologies
- AllGo Systems

Energy Gateway

- Microsoft
- QNX
- Atheros
- ThinkEco
- Aricent Technologies
- CEL (California Eastern Laboratories)

Home Area Networking

- Develco
- AMiHo
- Greenspan
- Redpine
- Atheros

Data Aggregator/Concentrator

- Kalki Technologies
- IXXAT
- GDA Technologies

Substation Automation

- TQS
- SystemCorp (IEC61850 Stack)

EV Charging Station

- Auronic (Grid-Vehicle Comms Stack)
- I2SE (EV Charger Board)

Featured Freescale Energy-Efficient Solutions

8-bit Microcontrollers

- S08LL: S08 Ultra-Low-Power Segment LCD
- S08QB: Ultra-Low-Power 8-bit Microcontroller Family
- S08QE: Flexis 8-bit HCS08 Microcontrollers

32-bit Microprocessors

- K30
- K22
- K60

Metrology Microcontrollers

- KM1
- KM3

Wireless Microcontrollers

- KW01
- KW20

32-bit Applications Processors

- i.MX Family of Applications Processors, QorIQ and PowerQUICC

Acceleration

- MMA7660FC: Three-Axis Digital Output Accelerometer
- MMA8453Q: Three-Axis, 12-bit Digital Accelerometer

Digital Signal Controllers

- MC56F8006/2 Digital Signal Controller

Touch Sensors

- MPR03x, MPR121: Proximity Capacitive Touch-Sensing Controller

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Freescale is a recognized leader in the design of high-performance, energy-efficient semiconductor products. Underscoring this, Freescale has introduced the Energy-Efficient Solutions mark to highlight selected products that excel in effective implementation of energy efficiency technologies that deliver market-leading performance in the application spaces they are designed to address.

Energy Efficient Solutions ™

100%
postconsumer waste fiber

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