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PN5190 questions and answers

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Document information

Information	Content
Keywords	PN5190, output power, VDDPA, target current, Tx Wave shape, Rx Level, DPC Calibration, CE, FCC, MIC, Settings, EEPROM configuration
Abstract	This document provides a collection of tips and tricks for the PN5190.

Revision history

Revision history

Rev	Date	Description
1.0	20230207	Initial version

1 Introduction

This document provides a collection of tips and tricks for the PN5190.

2 How to reduce maximum output power

Normally the DPC of the PN5190 is calibrated in a way to provide the maximum possible output power. This means that the unloaded antenna is driven with the VDDPA = 5.7 V and a current close to the target current. In this case, the antenna impedance defines the output power.

In some cases it might be useful to have the antenna tuned to provide the maximum possible output power. But the use case does not require or even does not allow the maximum power. In that case the question is: **How can I reduce the (maximum) output power with settings?**

The PN5190 DPC allows 2 (independent) options to reduce the maximum output power:

1. The target current can be reduced.
2. The maximum VDDPA can be reduced.

2.1 Reduce target current

This option reduces the **overall** output power (field strength in all distances), since the target current defines not only the maximum output power. But via current reduction, which is related to the target current, it also reduces the output power at all other loading conditions. The target current is stored in EEPROM: DPC_TARGET_CURRENT (077h)

So the reduction of the target current has a similar effect like the increase of the antenna impedance.

Note: *The current reduction lookup table uses relative settings, which always refer to the target current. So changing the target current, changes the current in all VDDPA steps.*

2.2 Reduce maximum VDDPA

This option only reduces the **maximum available** output power (field strength at maximum distance), but does not change the field strength at lower distances, since at lower VDDPA the DPC controls the output power independent from the maximum available VDDPA.

The maximum VDDPA setting is stored in the EEPROM: TXLDO_VDDPA_MAX_RDR (0008h). The default setting is 0x2A, which means the maximum possible VDDPA = 5.7 V.

So the reduction of the maximum VDDPA has the same effect as reducing the supply voltage of the TX driver.

Note: *The change of the maximum VDDPA does not change the DPC as such, but only limits the maximum available power level.*

3 How to adjust TX wave shapes

The PN5190 is delivered with default settings. These default settings are prepared for the operation as ISO/IEC 14443 reader device with the 45mm x 45 mm antenna of the PNEV5190BP (refer to [5]). The NFC Cockpit ([6]) provides a second set of settings, optimized for the EMVCo operation. These settings can easily be loaded using the NFC Cockpit <Load EEPROM>, as shown in Figure 1.

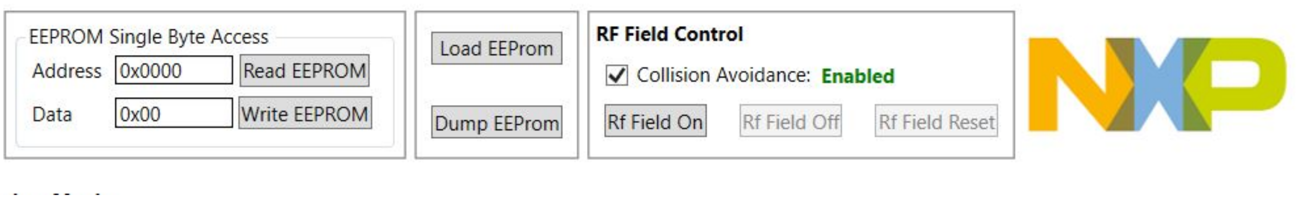

Figure 1. NFC Cockpit: Load and Dump EEPROM

The default settings provide some basic TxShaping settings, which typically work well with typical antennas. However, as soon as the overall Q-factor changes a lot or some strong coupling effects increase the influence of TestPICCs, the wave shape tests might fail in some positions, and then the TX wave shape settings can be adapted.

In principle, the best starting point is the use of the DPC Calibration of the NFC Cockpit. After starting the calibration (<Start Calibration>), we can switch to the TxShaping tab. That allows to select the protocol configuration (technology and bit rate) with <Load Protocol>. This shall automatically enable the RF field (using the DPC). The Figure 2 shows an example with the ISO/IEC14443A at 106 kbit/s. The field is enabled, as can be seen from the VDDPA and Current reading.

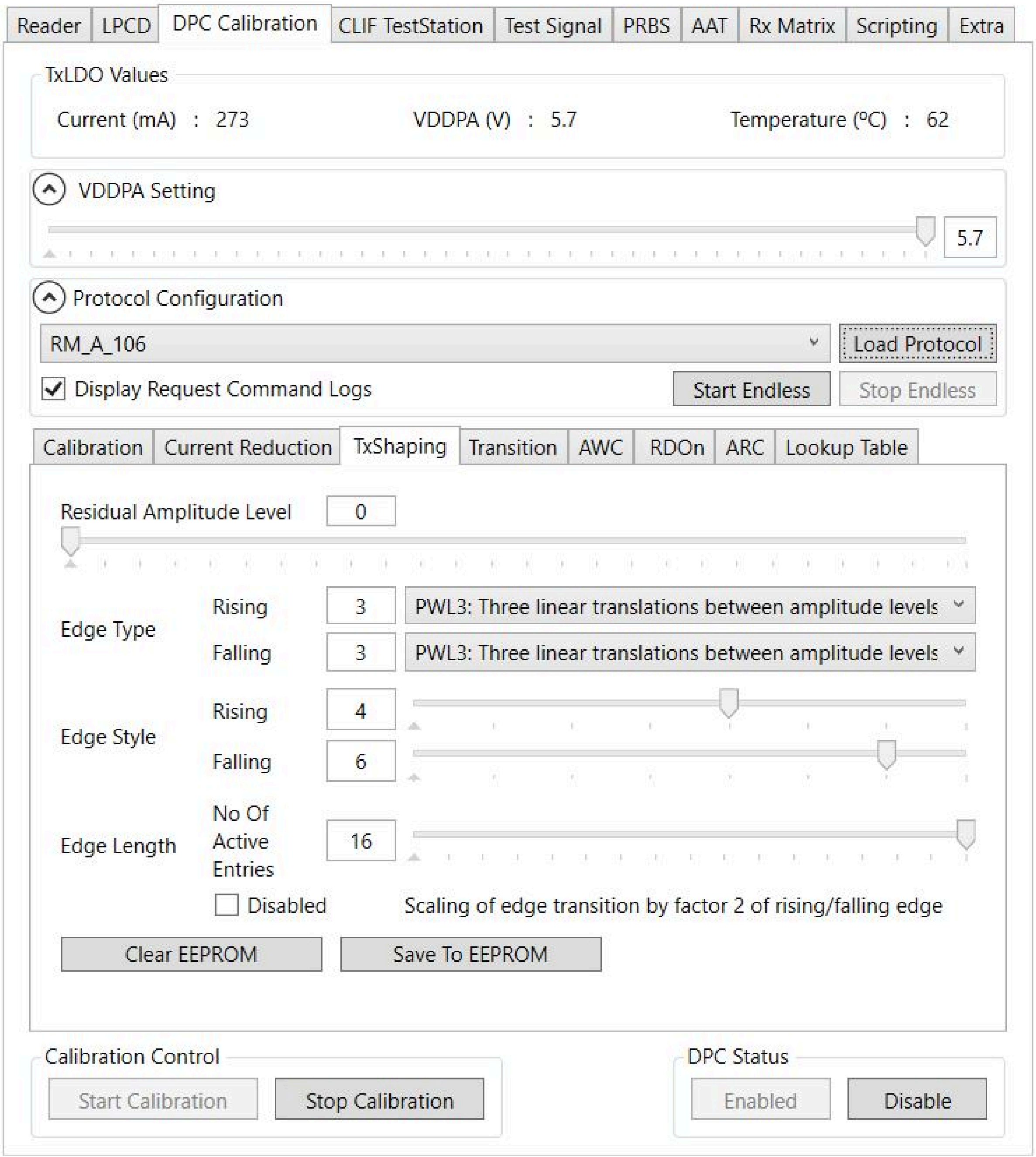

Figure 2. NFC Cockpit: TxShaping

Now it makes sense to run the test case: The NFC Cockpit allows to start the <Start Endless>, which continuously sends a request (or alike) command, and so allows to check the TX pulse shape.

The PN5190 offers two types of TxShaping (for details refer to [3]), so the TxShaping adjustment depends on the chosen type.

3.1 With FW based shaping

The NFC Cockpit TxShaping tab already provides the adjustment options, if the FW based shaping is chosen (like shown in Figure 2). We can select or modify the Edge Type as well as the related Edge Style.

Be aware that with this adjustment in the NFC Cockpit DPC Calibration function, the NFC Cockpit emulates the PN5190 FW behavior, as soon as the user changes the Edge Type or Edge Style. This emulation re-calculates the values for the SS_TX1_RTRANS and SS_TX1_FTRANS registers and writes them into the registers. This temporarily "overrules" the PN5190 FW, but does not change the EEPROM settings. To change the EEPROM settings, use the <Save to EEPROM>, which writes the current (temporary) settings into the EEPROM.

The second video tutorial ([7]) shows an example of the FW-based TxShaping adjustment, using the PNEV5190BP in combination with an EMVCo debug test setup.

This TxShaping setting is the **static** setting, and the PN5190 FW applies these settings, when the related protocol is loaded. In addition to the static settings, the DPC offers the AWC, which allows dynamic adaptions of settings. The NFC Cockpit allows to adjust those dynamic settings in an extra tab, as shown in Figure 3.

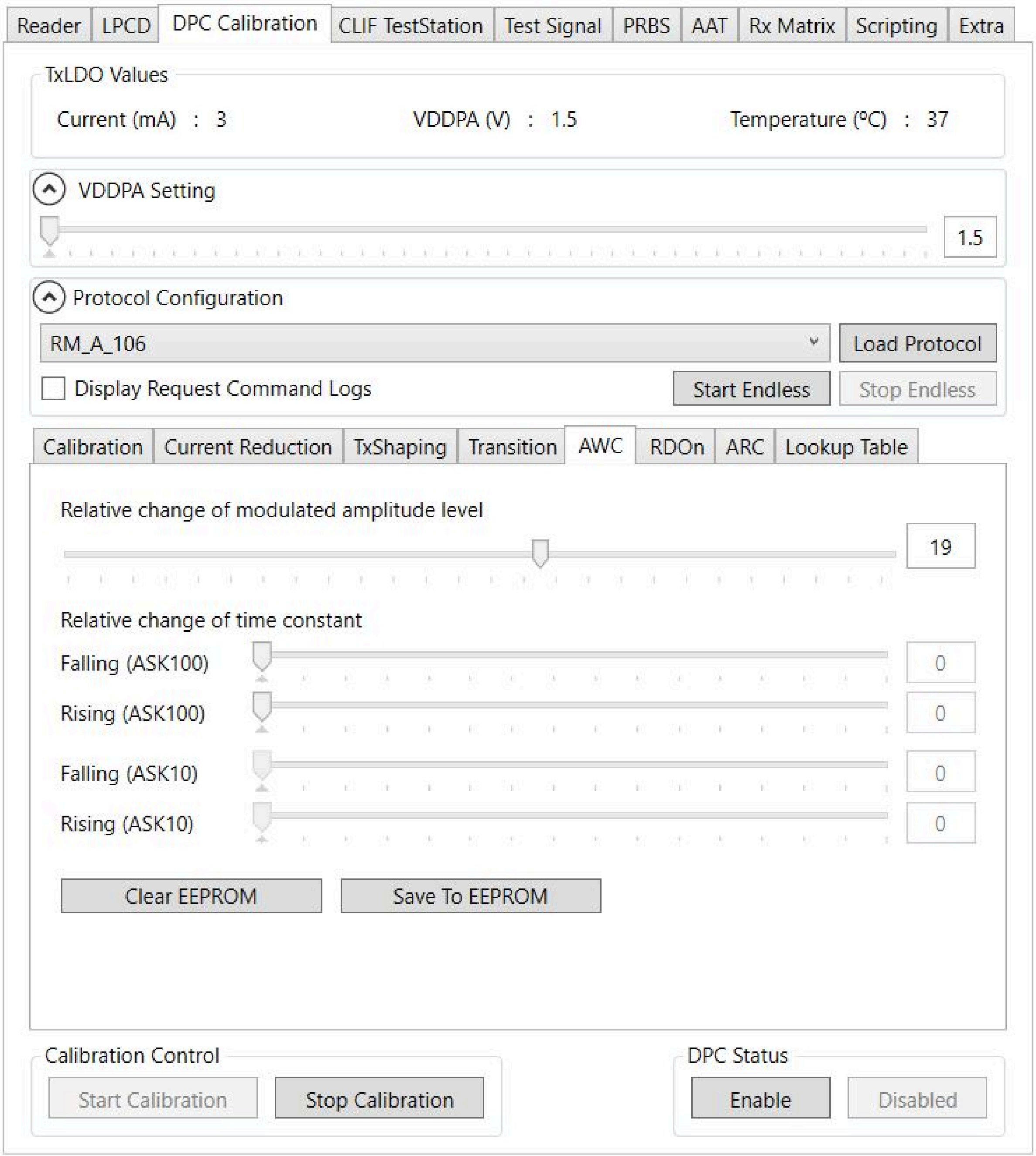

Figure 3. NFC Cockpit: AWC

Be aware that the dynamic settings need an extra entry per VDDPA. The NFC Cockpit automatically disables the DPC to allow the manual VDDPA control, as soon as we switch to the AWC tab. The AWC applies changes to the static settings (relative values).

3.2 With LUT based shaping

As soon as we chose the Look-Up Table (LUT) based shaping, i.e. as soon as we chose the Edge Type to be 3, 4 or 5 as shown in Figure 4, the Edge Style defines the LUT, which is taken by the PN5190 FW to load the SS_TX1_RTRANS and SS_TX1_FTRANS registers.

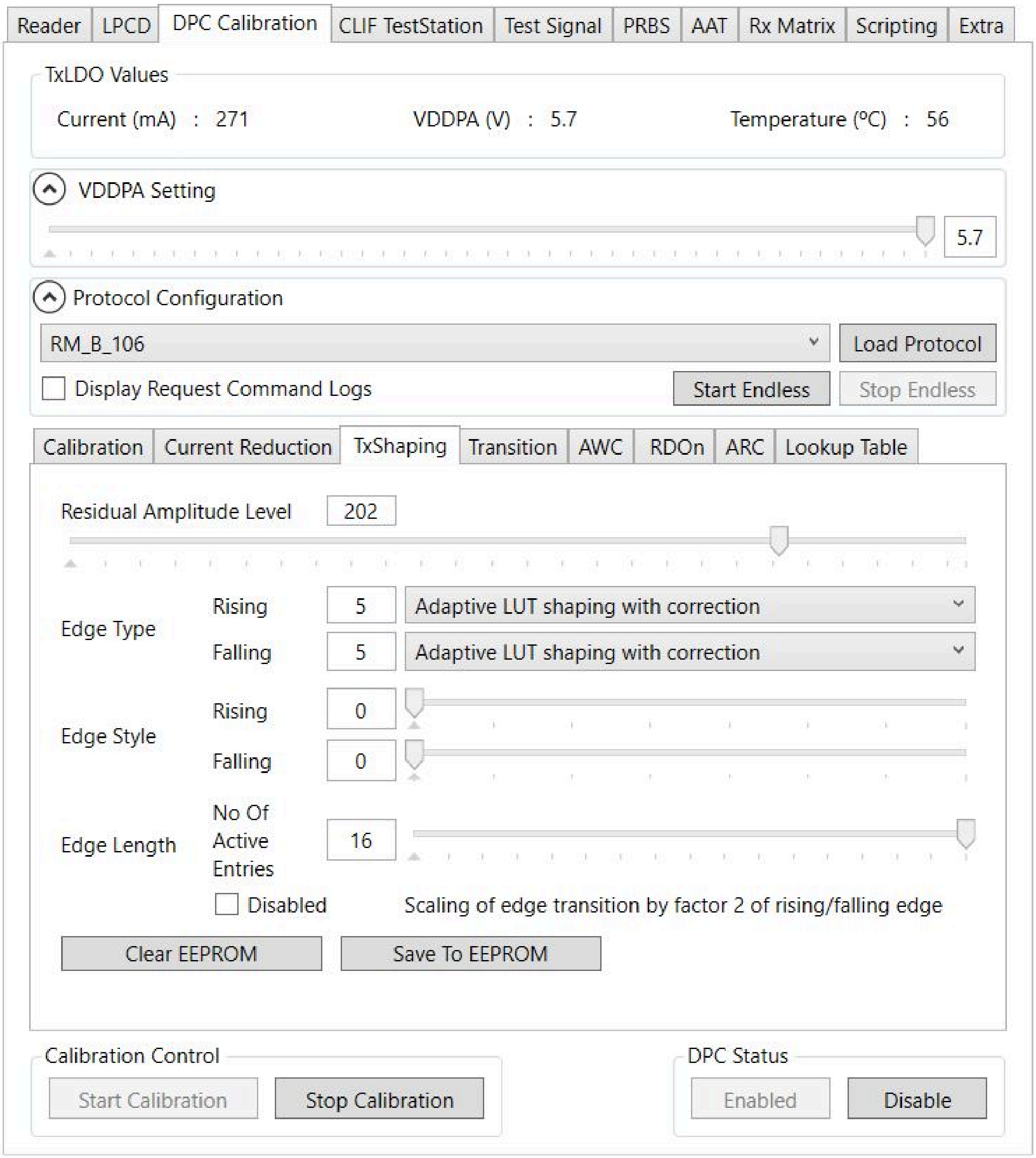

Figure 4. NFC Cockpit: LUT based Shaping

The LUT can be manually written, using the <Write EEPROM>, or the NFC Cockpit can be used to adjust the registers and then write a complete LUT at once. To adjust the registers and then save the the complete LUT, use the Transition tab as shown in Figure 5. Select the relevant protocol and <Load Protocol>. That makes the PN5190 FW applying the TxShaping settings, which loads the SS_TX1_RTRANS and SS_TX1_FTRANS registers. Then <Read Registers> loads the current register values into the NFC Cockpit tab.

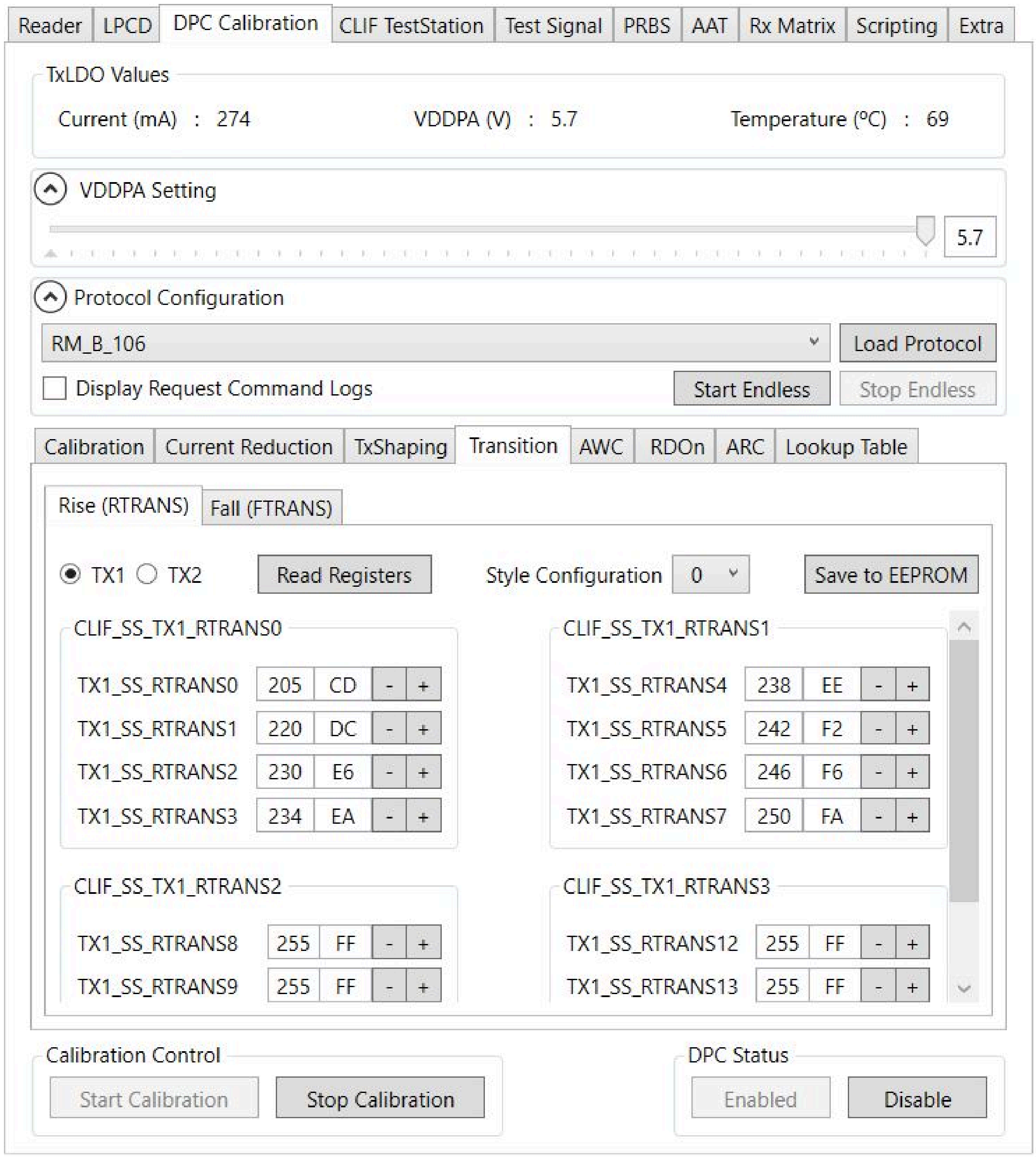

Figure 5. NFC Cockpit: Transition

Now the <Start Endless> can be activated, which allows to test the TxShaping with a continuous command being send. The register values can now be modified, either by typing in a new value between 0 and 0xFF, or by using the +/- buttons. The effect can immediately be seen on the TX Shape, i.e. the NFC Cockpit writes every new register value into the corresponding register.

As soon as the TxShaping is good, the complete registers can be written into one of the four available LUTs, using the Edge Style value from 0 to 3 and clicking <Save to EEPROM>. It makes sense to use the same Edge Style value that is being used in the TxShaping setting for that protocol.

The third video tutorial of [7] shows an example with the LUT based shaping.

Note: *The details of the TxShaping are described in [3].*

4 How to adjust the RX level

The PN5190 as delivered by NXP, uses default settings, which include RX settings for each protocol. For ISO/ IEC 14443 as well as EMVCo, there are two sets of settings available in the NFC Cockpit package, which are optimized for the 45 mm x 45 mm antenna. Other antenna sizes might require a re-adjustment of some RX settings.

Note: *Make sure that the HFAttenuator value is properly set, using the correct RX coupling resistor. Refer to [2] for details.*

Even though the PN5190 RX typically does not require many adjustments, it makes sense to consider the two different approaches:

EMVCo:

For EMVCo typically the best sensitivity is required to pass all analog tests, especially with small antennas. Normally EMVCo does not require the use of ARC.

ISO/IEC 14443:

ISO/IEC14443 (and NFC) normally require to limit the sensitivity quite a lot, especially under strong coupling conditions to meet the EMD low-level requirements. Especially with small antennas, this typically requires to use the ARC.

Note: *The PN5190 RX, its test signals and adjustment options are described in [3].*

Starting with the default settings (either with the ISO/IEC14443 ones or the EMVCo ones), there are **only a few RX settings**, which might be required to be adjusted:

BBA Gain: The BBA gain normally shall not be changed from default.

MF Gain: The MF Gain can be changed in combination with the RxThreshold (= "DGRM_SIGNAL_DETECT_TH_ OVR_VAL") and maybe the IIR filter.

IIR filter: Enabling the IIR filter attenuates the I and Q channel signal significantly.

RxThreshold: The RxThreshold (= "DGRM_SIGNAL_DETECT_TH_ OVR_VAL") is the major setting to adjust the sensitivity.

Before changing any settings, it is recommended to check the system noise floor. The PN5190 CTS offers an easy way to retrieve analog test signals, and the NFC Cockpit provide the Signal Detection Threshold (SDT) function as part of the CTS tab. Refer to [3] for all details. Keep in mind that MF Gain, IIR filter and also the VDDPA setting can influence the noise level. Make sure that your RxThreshold is not lower than the SDT with margin 6.

5 Why the DPC calibration fails

The [Figure 6](#) shows an **example** of a non-working DPC calibration:

The target current of 306 mA has not been changed, but the current reduction LUT calibration shall be filled with new values:

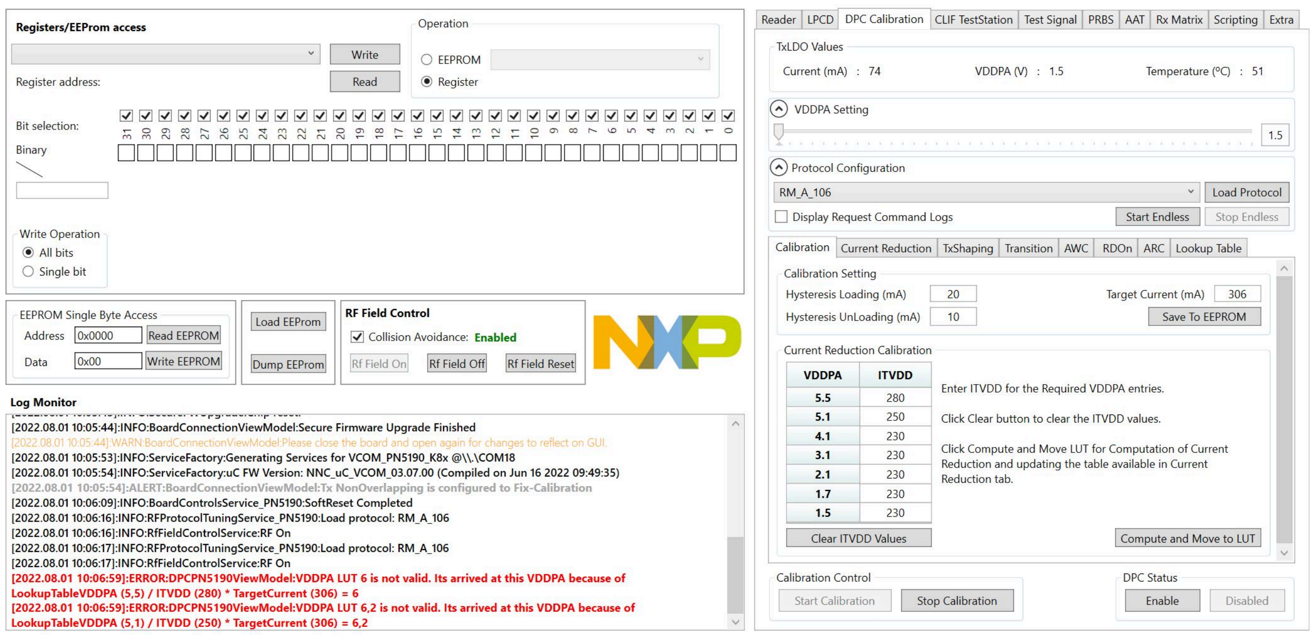

Figure 6. Bad DPC calibration

After the new values for the 7 VDDPA entries have been done, the <Compute and Move to LUT> causes errors. Why?

The DPC, its calibration and the details about the current reduction look table is described in [2].

The DPC requires a **decreasing load versus decreasing VDDPA**, otherwise there can be ambiguous DPC conditions. In this example, the target current of 306 mA at VDDPA = 5.7 V means a load = 18.63 Ω.

The VDDPA = 5.5 V with 280 mA means a load = 19.64 Ω. So with a lower VDDPA we want to see a higher load, which does not work. Another issue is the LUT entry: with the load = 19.64 Ω and a target current = 306 mA, the VDDPA entry must be at VDDPA = 6.0 V, which does not exist.

The [Figure 7](#) shows the calibration with the lowest possible current but using the same target current. It can be seen that the load slowly decreases versus VDDPA, and that the first LUT entry is 35 mA for the entry at VDDPA = 5.6 V to get 271 mA at VDDPA = 5.0 V .

Target current:	306	mA

VDDPA	ITVDD	Power Transfer	Current reduction	Total load	Warning
[V]	[mA]	[V]	[mA]	[Ω]	
5,7	306		0	18,63	OK
5,6	301		5	18,60	OK
5,5	296		10	18,58	OK
5,4	291		15	18,56	OK
5,3	286		20	18,53	OK
5,2	281		25	18,51	OK
5,1	276		30	18,48	OK
5,0	271		35	18,45	OK

Current reduction LUT

VDDPA	Current reduction	
[V]	[mA]	hex
5,7	0	0
5,7	0	0
5,7	0	0
5,7	0	0
5,7	0	0
5,7	0	0
5,7	0	0
5,6	35	23

Figure 7. Good DPC LUT

With that calibration, the DPC can now work, and all (shown) entries are unambiguous.

Note: *The excel sheet to allow a more detailed DPC calibration as shown in Figure 7 can be found in [4].*

6 How to support CE, FCC and MIC tests

The design recommendations as given in [2] provide guidelines to meet all requirements to support CE, FCC, and MIC certification. However, tests are required to be executed to prove the compliance. These tests are supported by the PN5190 functions as well as the NFC Cockpit.

6.1 CE and FCC tests

To measure the levels of radiated unwanted harmonics, for the CE or FCC test of an NFC reader device, it is required to enable the RF carrier and send data with a typical modulation. Normally this includes a card being placed into the operating volume to enable a reasonable use case.

The Figure 8 shows a typical option to operate the PN5190 as required. The related protocol settings are loaded (<Load Protocol>), then the RF carrier is enabled (<RF Field On>). A reasonable cycle time of, e.g., 200 ms needs to be chosen, and the <Endless REQA> needs to be selected, followed by <Start REQA>.

Placing a ISO/IEC 14443 type A card into the operating volume returns a valid ATQA every second command.

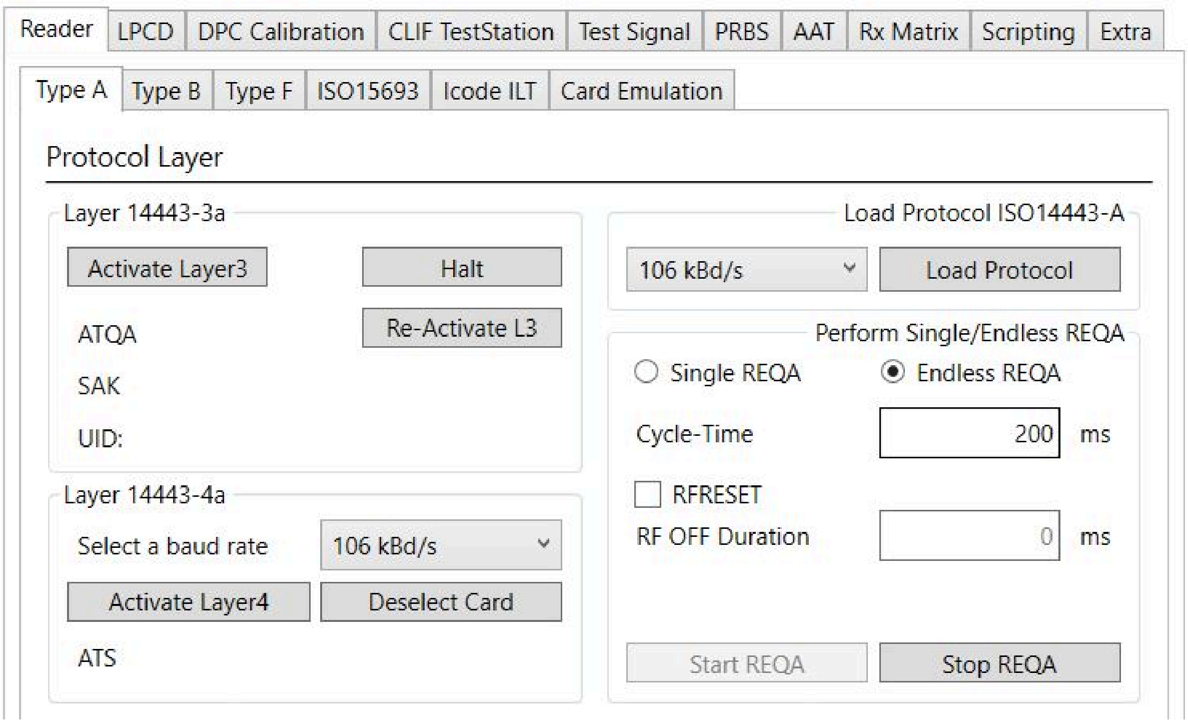

Figure 8. NFC Cockpit: Endless REQA

To measure the immunity behavior of the device, the same setup can be used, since the endless REQA returns a valid ATQA every second time, as long as the system operates as intended.

Note: *NFC and HF RFID systems require the* ***RF carrier being enabled*** *to operate tags as well as to transmit and receive data.*

The Figure 9 shows a screenshot of such a REQA - ATQA communication. Channel A (green) shows a test signal, which is only used to trigger the oscilloscope. The channel B (blue) shows the signal of a field probe.

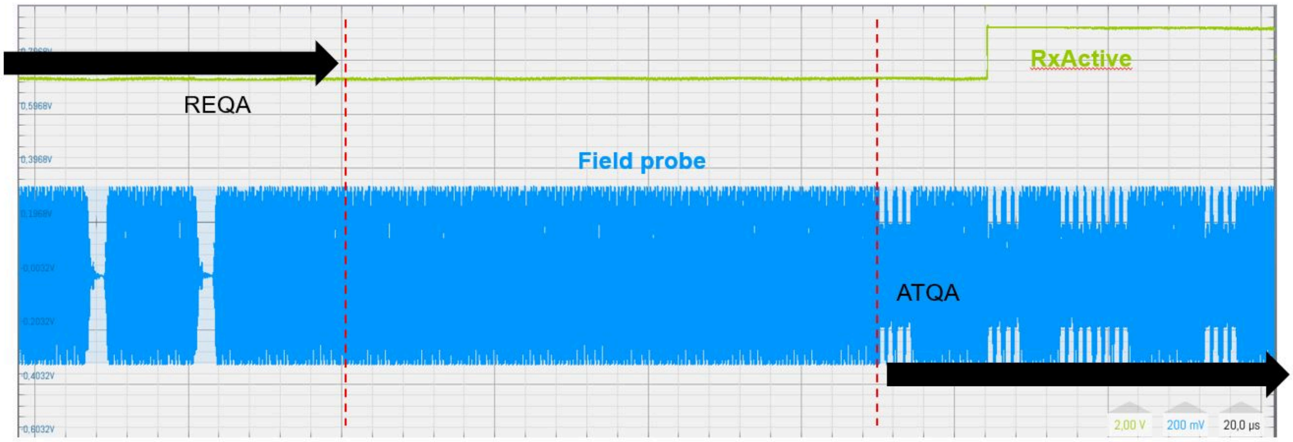

Figure 9. REQA-ATQA example screenshot

6.2 MIC tests

In Japan, the EMC tests require the device under test to send an endless PRBS sequence. The PN5190 supports this with the command PRBS_TEST (refer to [8]).

It is required to perform a "load protocol" (LOAD_RF_CONFIGURATION), followed by an RF_ON, before executing the PRBS_TEST. Afterwards the PN5190 sends endless PRBS data, modulating the RF carrier using the enabled protocol.

The NFC Cockpit provides the PRBS function as shown in Figure 10. The protocol and bit rate needs to be selected, and then <Start PRBS> loads the protocol settings, enables the RF and executes the PRBS_TEST command until stopped by the user.

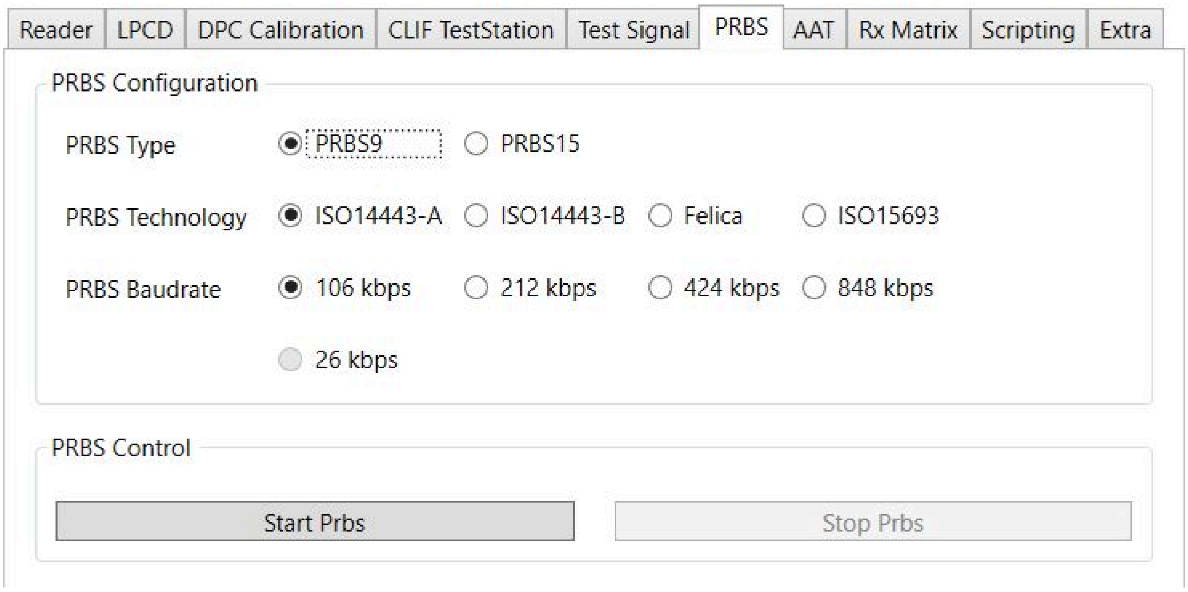

Figure 10. NFC Cockpit: PRBS

7 How to handle configuration settings

Every antenna design typically requires an own set of analog settings. The PN5190 provides a non-volatile memory area to store such settings. This memory is split into two sections:

1. EEPROM configuration area
2. RF configuration area

7.1 EEPROM settings

This area is defined and described in detail in the data sheet ([1]) in section 9.26. All of these settings are used by the PN5190 FW during certain operations. A manipulation of these settings influences the behavior of the PN5190, so every EEPROM write shall be used carefully. This area contains many lookup tables, for example, the ones for the DPC. The NFC Cockpit provides a direct single-byte read and single byte write-access as shown in Figure 11.

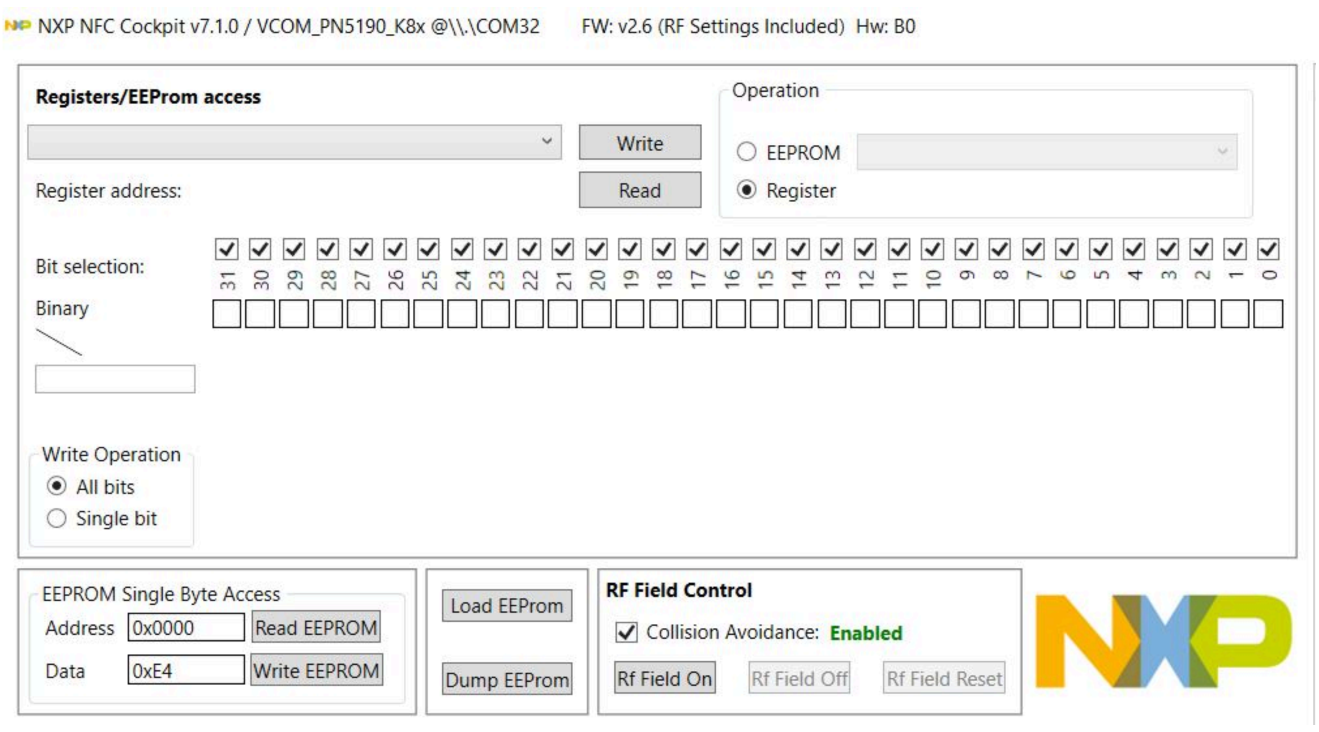

Figure 11. NFC Cockpit: Direct EEPROM Access

However, the NFC Cockpit functionality also provides an indirect read and write-access, which is linked to the used high-level function, for example, related to the DPC Calibration.

7.2 RF configuration settings

Some settings are linked to an “RF protocol”, i.e. to the used RF technology. These settings are stored in the RF Configuration area, and normally loaded from EEPROM into the PN5190 registers with a <Load Protocol> (i.e. a LOAD_RF_CONFIGURATION command). So each defined “protocol” has its own set of RF configuration settings for the TX as well as for the RX in the RF Configuration area.

Typically, the default settings are not required to be modified. However, also the RF configuration settings can be modified, for example, to adjust the modulation index for ISO/IEC 14443 type B communication.

The NFC Cockpit provides a direct EEPROM read and write (GET_ RF_CONFIGURATION and UPDATE_RF_CONFIGURATION), as shown for the DGRM_RSSI register in Figure 12.

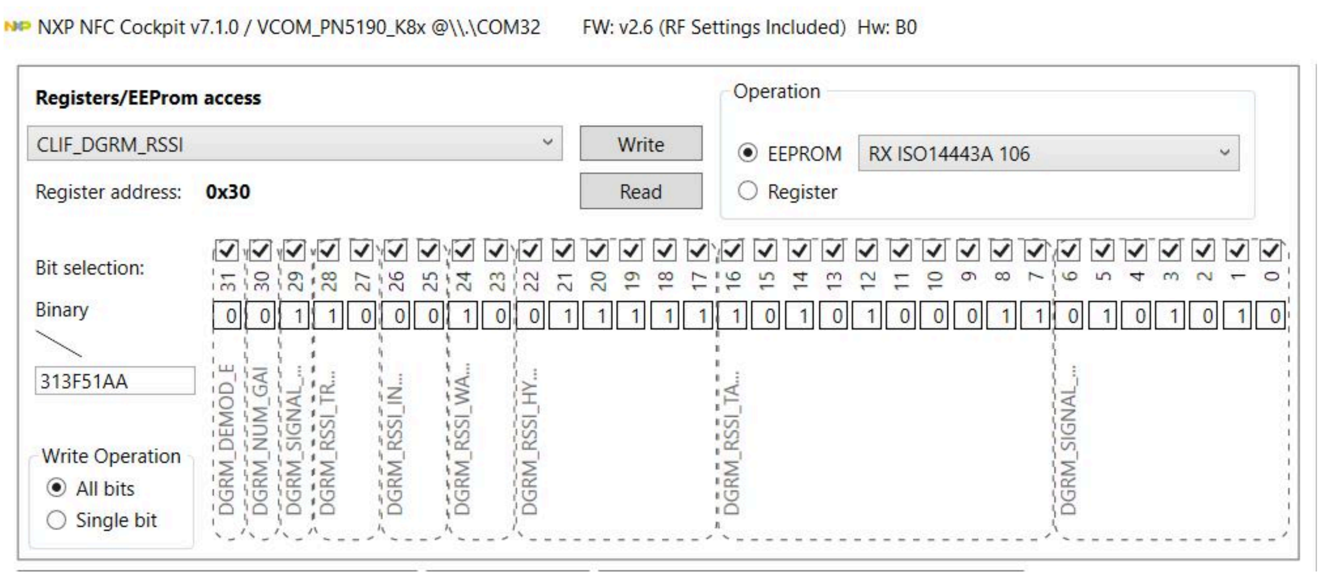

Figure 12. NFC Cockpit: RF configuration access

The user is required to select the protocol and a register. It is strongly recommended to either read a register directly from EEPROM or from the register itself only after the correct RF protocol had been loaded, before writing back some settings into the EEPROM. This EEPROM Read and Write (GET_ RF_CONFIGURATION and UPDATE_RF_CONFIGURATION) always contains the full 32 bit of one register.

7.3 Handling during development

To simplify the handling of settings, the NFC Cockpit provides a <Load EEPROM> and <Dump EEPROM>. The <Dump EEPROM> reads all documented settings from the PN5190 EEPROM and dumps them into an XML-file. The <Load EEPROM> asks the user to select such an XML file, and then stores all settings into the PN5190 EEPROM.

So normally, every antenna design should have its own XML file of settings, and loading that complete file into the PN5190 then defines the proper functionality for this antenna design, e.g. for an EMVCo CL L1 certification. It is recommended to save such a complete file as part of the POS terminal design documentation.

Note: *Be aware that updating the FW with a x.**0**x version overwrites all the settings. This has the advantage that after the update that all settings are reset to default values. Updating the FW with a 0x**F**x version does not overwrite any settings at all.*

7.4 Handling during production

As soon as all settings are fixed for a design, they are required to be written into every production device.

The writing of all settings (using the WRITE_E2PROM and UPDATE_RF_CONFIGURATION) takes quite some time, so it might be a better idea to write-only the modified settings. The easiest way is to dump the default settings with the NFC Cockpit (dumped right after an update of the FW with a x.0x version) and then to dump the device settings. A file comparison of both XML files then derives the delta: all the differences must be written during production.

8 How to use the RDON function

The DPC uses the TxLDO to reduce the RF output power. In the range between 2.2 V and 5.7 V, this function provides the same function of the TX driver for all VDDPA levels. However, the Tx driver function slightly changes below VDDPA = 2.2 V. Normally this has no impact on other functions.

However, in case of some critical wave shapings, the limits of rising and falling edges might change, which then can easily cause some compensation being required in the dynamic shaping settings.

An easier solution might be the (optional) use of the RDON function. The idea is to limit the minimum VDDPA level to 2.2 V. Then between VDDPA = 2.2 V and VDDPA max everything works without any dynamic shaping settings. This can be done with the DPC_TXLDOVDDPALow (EEPROM address 0x7D).

However, limiting the minimum available VDDPA to for example, 2.2 V might then cause still too much current and too much RF field strength with a card in close distance. So a further RF output power reduction might be required.

This further power reduction (beyond the minimum available VDDPA) then can be done via the RDON function. Enabling the DPC_RDON_Control (EEPROM address 0x7F = 0x01) enables the RDON. The RDON mechanism further reduces the TX output power via TX driver settings rather than lower VDDPA, as soon as the DPC reaches the lowest allowed VDDPA (DPC_TXLDOVDDPALow) and still needs to further reduce the output power. The RDON then works fully automatically as part of the DPC and does not need to be configured.

It is not recommended to change the RDON settings.

Note: *The reduction of output power increases the PN5190 internal losses. This normally is covered inside the TxLDO. As soon as the RDON is enabled, the losses inside the TX driver increase, too. This can cause overheating, if not covered properly in the PCB layout.*

9 What to consider without DC-DC

A typical use of the PN5190 includes the DC-DC, which then is controlled automatically by the DPC. This controlled DC-DC provides the optimum input for the TxLDO, which then results in minimum losses, i.e. the minimum self-heating.

As soon as the DC-DC is not used, some settings need to be considered.

9.1 TxLDO voltage drop

As soon as the DC-DC is not used, the self-heating needs to be checked carefully. Especially, if the VUP is supplied externally with levels higher than VBAT, the TxLDO losses can increase a lot, if the DPC reduces the VDDPA.

To avoid overheating, the firmware uses a maximum limit of the TxLDO voltage drop, which is set in the EEPROM settings (DPC_TXLDO_MAX_DROP). As soon as this voltage drop is reached, the DPC does not further reduce the VDDPA.

This voltage drop can be configured in DPC_TXLDO_MAX_DROP (EEPROM address 0x81). The default is set to 3.6 V.

Example: The VUP is externally supplied with 5.5 V. Then the VDDPA cannot be lower than 1.9 V, as long as the default DPC_TXLDO_MAX_DROP is used.

Note: *Be careful when increasing the DPC_TXLDO_MAX_DROP! This might overheat the PN5190 in some corner case operation!*

9.2 Maximum VDDPA

The maximum VDDPA shall only be set to a value of VUP – 300 mV, if the TxLDO is used.

A typical use case might be the operation without DC-DC, but with TxLDO being used, as for example, shown in configuration example 3 in [1]. The VBAT = VUP drives the TxLDO, which provides the VDDPA.

Example: The VBAT is 5.0 V, so the maximum VDDPA (as set in TXLDO_VDDPA_MAX_RDR, EEPROM addr. 0x08) shall not be higher than 0x20 => VDDPAmax = 4.7V.

10 How to improve EMC

The general target of the electromagnetic compatibility (EMC) related design is to control the way of electromagnetic interference (EMI), to decrease the emission of unwanted electromagnetic energy and to increase the immunity against electromagnetic disturbance. All this is relevant in the frequency range from 0 Hz up to several GHz for magnetic fields, electrical fields and electromagnetic fields. The specific challenges for NFC or RFID Reader devices are

- Electrostatic discharge (ESD)
- 13.56 MHz (operating frequency) operation
- Radiation of 27.12 MHz and other harmonics up to the GHz range

To avoid EMI issues, it is important to understand:

- Where which signals are generated.
- How which signals are distributed (conducted and radiated).
- Which coupling mechanisms take place (conductive, inductive, capacitive, radiative).

This AN does not replace generic EMI guidelines, but only focuses on NFC and RFID-specific topics. NXP provides a recorded online webinar for the NFC antenna design, which contains one session (session #6) about EMC-related topic. For details refer to [9].

10.1 ESD

Electrostatic discharge (ESD) normally is not much of an issue for the NFC reader device, since no electrical contacts are exposed. As soon as parts of the antenna might be detachable and electrical contacts might be exposed, additional ESD protection might be required. An example is shown in Figure 13.

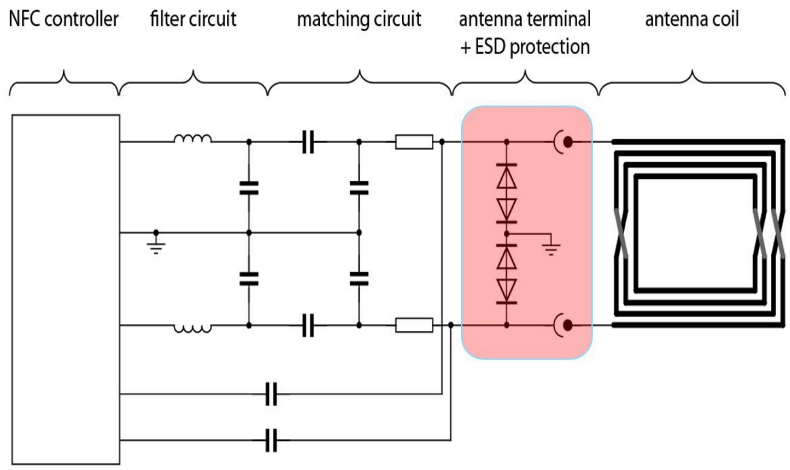

Figure 13. NFC antenna circuit with specific ESD protection

Note: *Be aware of voltage range limitations of such ESD protection diodes. Such limitations might cause saturation and clipping effects, which then disturb the NFC functionality and increases the radiation of unwanted harmonics.*

10.2 Radiation of unwanted harmonics

The Figure 14 shows a block diagram of an NFC Reader device. It indicates the typical “hot spots”, i.e. the critical areas, where, e.g., unwanted harmonics are generated or distributed, or where those unwanted harmonics can cause issues.

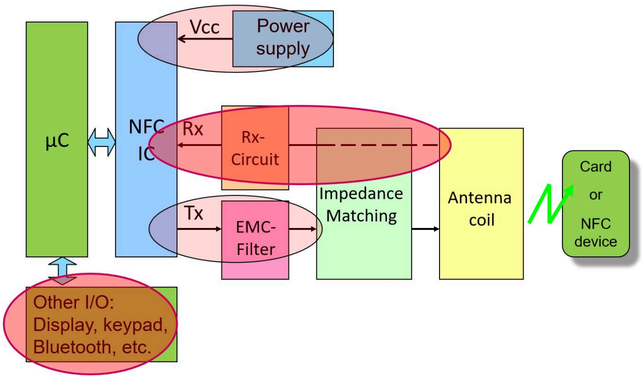

Figure 14. NFC Reader block diagram with EMI critical areas

The biggest amount of RF energy is generated in the output stage of the PN5190. The principle of an efficient output stage to drive up to 2 W output power into an NFC antenna is shown in Figure 15.

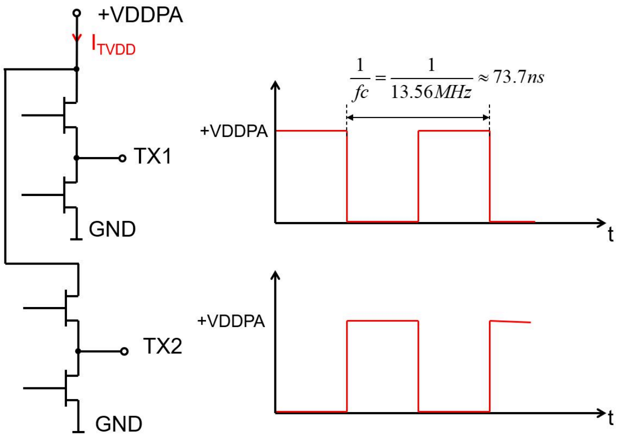

Figure 15. Principle of an efficient NFC TX driver

This principle indicates that at both TX pins the signals contain a high amount of harmonics. The standard NFC antenna design provides a proper filtering, using a second order low-pass filter connected to each TX pin, as shown in Figure 16.

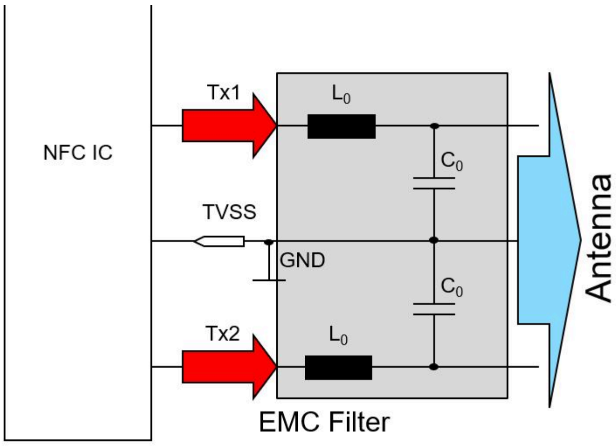

Figure 16. NFC TX EMC filter

The traces as well as the used inductors must able to cope with the power level. The capacitors must be NP0 capacitors.

The layout is very important, i.e. the whole EMC filter shall be located as close to the TX pins as possible, and the TX traces and the GND traces shall be as short and low impedance as possible.

It is highly recommended to use the layout recommendations from [2]. For the PN5190, those layout recommendations include the RF part around TX and RX traces, but also the power supply part. It is obvious that the TX driver as shown in Figure 15 also causes current peaks with a frequency of 13.56 MHz and its harmonics on the related power traces.

On top of that, the PN5190 internal DC-DC can be a source of radiated unwanted harmonics, if the layout is done in a bad way. Following the design recommendations does not only avoid EMC problems, but also guarantees a proper NFC function.

11 How to use PRD pins

The pin removable detection (PRD) is a feature which might be helpful to get a better security grade for EMVCo. It allows an MCU to detect, whether the PN5190 is removed or not.

Let us imagine, someone wants to "hack" the system, and removes the PN5190. Then he connects the SPI, which normally might be hidden in inside PCB layers, to an external PN5190 device to emulate the original PN5190. This hack scenario then allows to trace the SPI communication in all details. With the PRD, the MCU can detect that the PN5190 has been removed and then can block the operation.

To support this function, the PN5190 in the VFBGA64 package provides the PRD1 and PRD2 pins. Those are just two pins, which are internally (inside PN5190) connected to each other, but which have no other function or connections. So if an MCU drives a certain signal into PRD1, the same signal must be visible at PRD2. That is all.

Those two pins can be left floating or tied to GND, if the PRD is not used.

12 Abbreviations

Table 1. Abbreviations

Acronym	Description
AWC	adaptive wave control
DPC	dynamic power control
EMC	electromagnetic compatibility
EMI	electromagnetic interference
ESD	electrostatic discharge
FW	firmware, here PN5190 firmware
LUT	lookup table
MF	matched filter
PRBS	pseudo random bit stream
RX	receive, receiver
SDT	signal detection threshold
TX	transmit, transmitter
VDDPA	supply voltage for the TX driver, normally controlled by the PN5190 internal TxLDO

13 References

[1] PN5190 data sheet https://www.nxp.com/doc/PN5190

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[5] PNEV5190BP (PN5190 evaluation board) https://www.nxp.com/products/:PNEV5190BP

[6] NFC Cockpit https://www.nxp.com/products/:NFC-COCKPIT

[7] PN5190 DPC and waveshaping tutorial video DPC and waveshaping video tutorial

[8] PN5190 Instruction layer https://www.nxp.com/doc/PN5190_add

[9] NFC antenna training webinar https://www.nxp.com/pages/nfc-antenna-design:TIP-NFC-ANTENNA-DESIGN

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