AN12990

PN7160 low-power mode configuration

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Application note
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Document information

Information	Content
Keywords	NFC, PN7160, low power, discovery mode
Abstract	This application note provides guidance on how PN7160 can be configured in order to reduce current consumption by using low-power discovery mode.

Revision history

Rev	Date	Description
1.3	20210913	Security status changed into "Company public" , no content change
1.2	20210820	Security status changed into "Company restricted"
1.1	20210705	Editorial update
1.0	20210528	Initial version

1 Introduction

PN7160 implements an extreme low-power discovery mode allowing decreasing up to 100 times the current consumption of the NFC controller. This consumption reduction does not impact the user experience when properly set.

This application note depicts how to use and tune this feature.

2 Low-power discovery mode concept

PN7160 supports RF DISCOVERY defined within ACTIVITY specification from NFC Forum (see [1]). PN7160 can be configured by following guidance depicted with NCI specification (see [2]).

The discovery loop consist of 2 phases:

- POLL phase where NFCC emits RF field and sense for remote tag or peer NFC device
- LISTEN phase where NFCC hears for remote reader of peer NFC device

Average NFCC power consumption then depends on:

- Technologies enabled in the POLL phase (lead to about 5 ms to 80 ms duration)
- LISTEN phase duration
- Antenna system used by the application (impedance of the RF system)

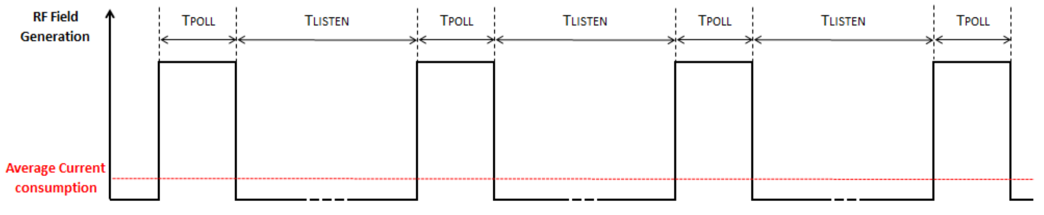

Figure 1. Regular discovery loop

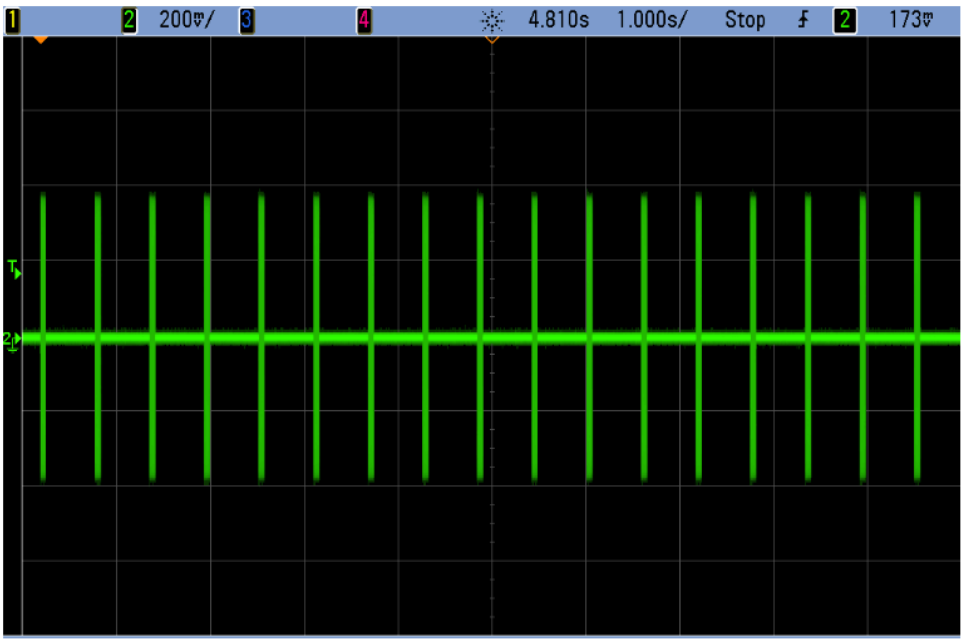

Figure 2. Oscilloscope screenshot of regular discovery loop @ 2Hz

Current consumption is one of the main criteria during an NFC design-in within an embedded equipment. PN7160 NFC controller implements two modes of low-power discovery additionally to the regular discovery mode:

- Low-power tag detector mode
- Hybrid mode

2.1 Low-power tag detector mode

It consists on replacing each POLL phase of the regular discovery loop by a short LPCD pulse (few us of RF emission), allowing the PN7160 to check any change in the antenna proximity area. Whenever a change is detected, a regular POLL phase is triggered to verify the presence of tag or peer NFC device.

The obtained new duty cycle allows achieving an extremely low current consumption.

NXP provides a proprietary extension to the NCI protocol to enable and configure this mode (refer to *PN7160 user manual* [4] for more details).

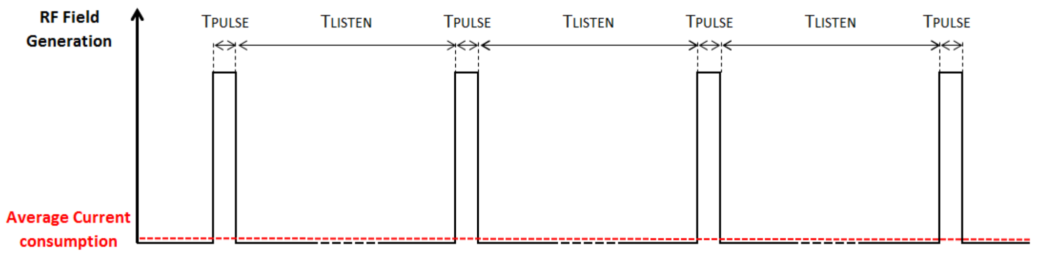

Figure 3. Discovery loop in low-power tag detector mode

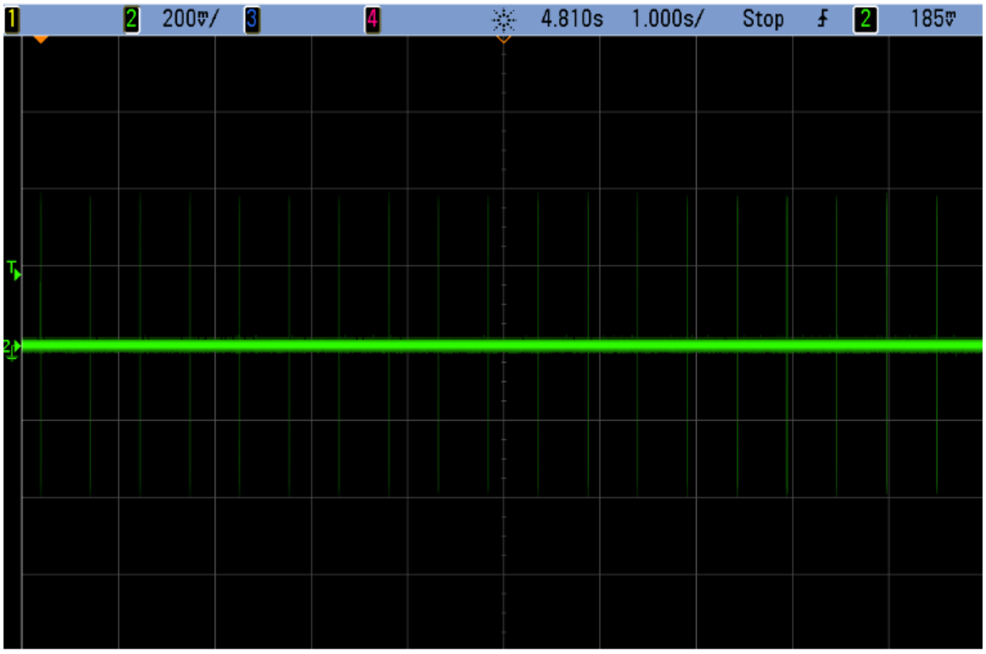

Figure 4. Oscilloscope screenshot of low-power tag detector mode @ 2 Hz

In order to improve the likelihood to catch such a Card/Tag, the PN7160 comes with a retry mechanism which performs several Technology Detection polling cycles before it switches back to LPCD (refer to *PN7160 user manual* [4] for more details).

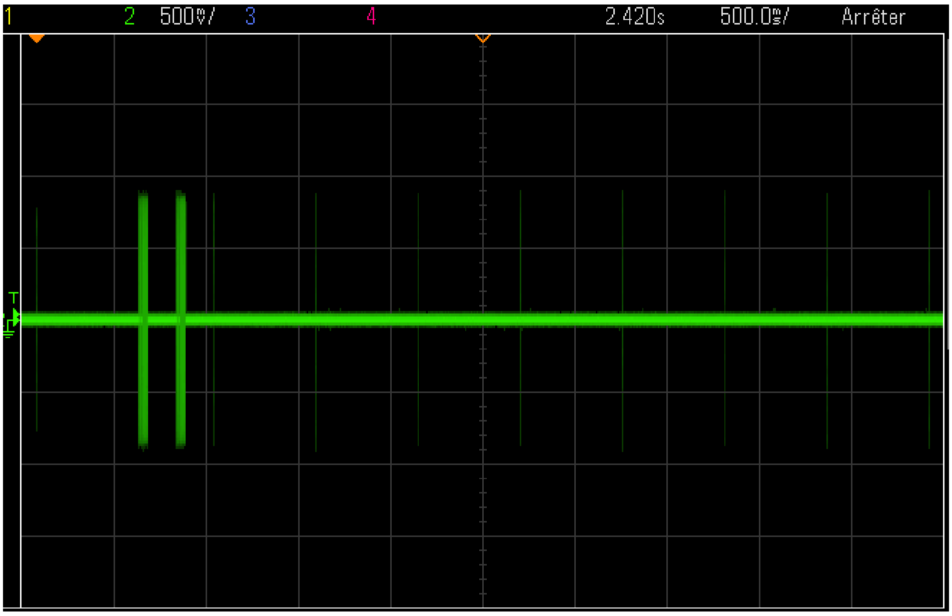

Figure 5. Oscilloscope screenshot of low-power tag detector mode @ 2 Hz with subsequent technology detection (Retries = 2 and Period = 100 ms)

2.2 Hybrid mode

The aim of hybrid discovery mode is to replace some regular POLL phases by LPCD pulses.

This mode allows reducing significantly the average current consumption of the NFC controller in comparison to the regular discovery loop, if the LPCD could not be used (infrequent cases where low-power tag detector mode provides reduced user experience).

NXP provides several proprietary parameters which can be configured through CORE_SET_CONFIG_CMD from the device host in order to enable this mode and define the amount of LPCD pulse (refer to *PN7160 user manual* [4] for more details).

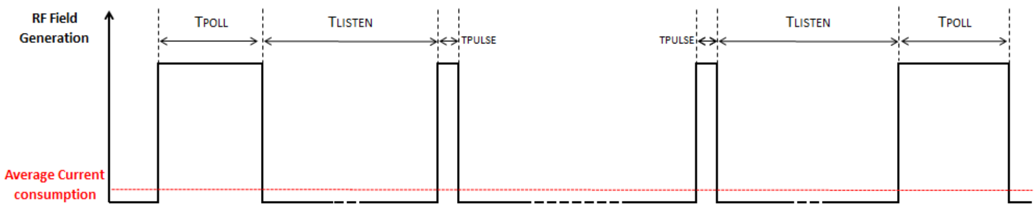

Figure 6. Discovery loop in hybrid mode

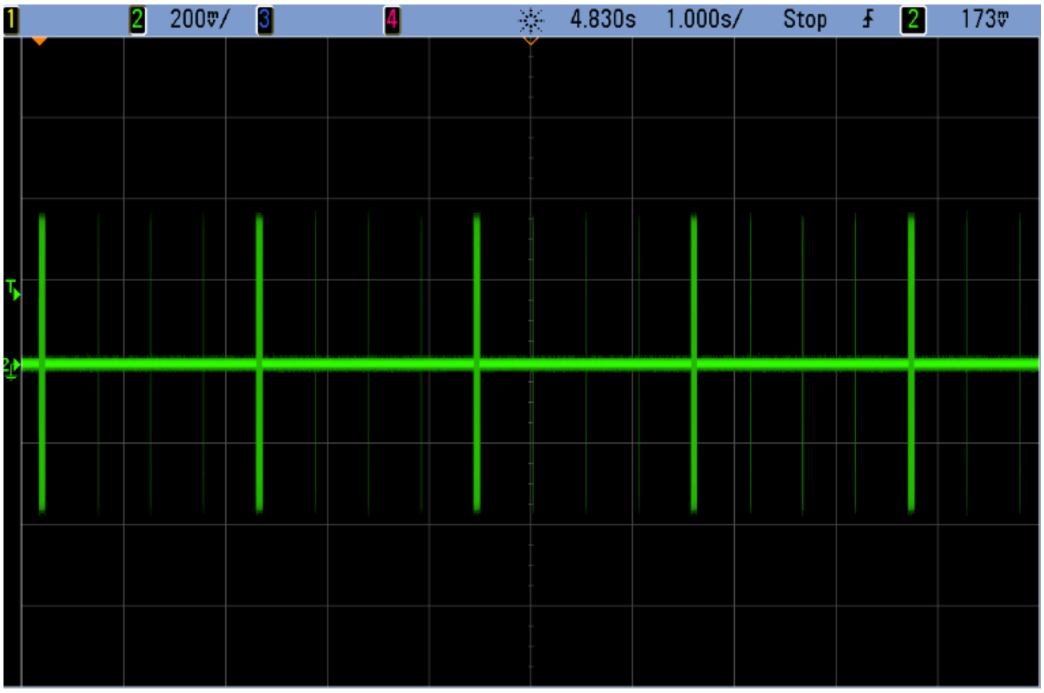

Figure 7. Oscilloscope screenshot of hybrid mode with POLL phase every 3 LPCD pulses @ 2 Hz

3 Power consumption overview

Current consumption of PN7160 depends on hardware integration within platform.

Below figure depict the current consumption according to the PN7160 IC state:

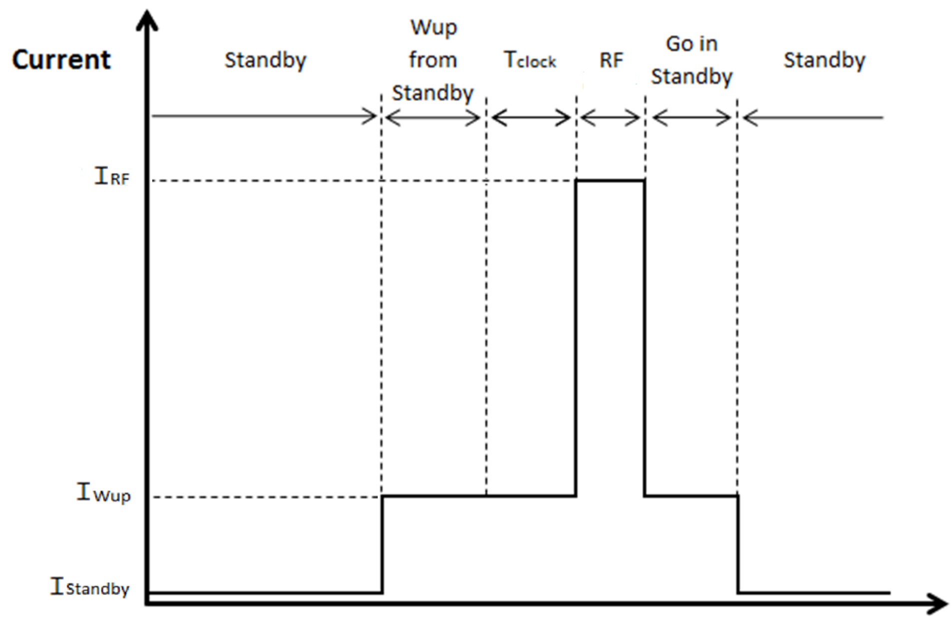

Figure 8. Power consumption depending on IC state

The wake-up time is about 2 ms and the time to switch back in standby is a few hundreds of µs.

The current consumption in standby state is about 20 µA and about 6 mA in wake-up state, while in RF emission state it highly depends on the antenna impedance and matching circuitry (refer to PN7160 product data sheet [3] for more details about power consumption figures).

Following parameters impact the overall current consumption of the system:

- Duration of RF emission
  - T_{POLL}, in Regular and Hybrid modes, relates to the Technologies enabled in the discovery loop
  - Low-power tag detector RF pulse duration is about 200 µs but depends on the configurable delay inserted before the measurement
- Duration of clock establishment
  - Using XTAL T_{clock} is only few us
  - Using an external system clock T_{clock} is from 1 ms to 10 ms (depending on platform capability)

Reference configuration used for the overview:

- Clock: XTAL
- Antenna matching impedance: 25 Ohms

- TXLDO configuration to 3.0 V
- T_{POLL} = 60 ms
- Hybrid mode: 1 regular RF polling for 3 RF pulses is considered

Table 1. Current consumption of discovery modes

Discovery loop mode	Discovery loop frequency	
	1 Hz	2 Hz
Regular	7.853 mA	15.052 mA
Hybrid	2.013 mA	3.849 mA
Low-power tag detector	67 µA	115 µA

4 Configure low-power mode

4.1 Host interface parameter description

You can find below parameters needed to configure the PN7160 in regular, hybrid or low-power tag detector modes.

All those parameters can be modified by using the `CORE_SET_CONFIG_CMD` from NCI standard (see *NCI specification* [2]). Proprietary part is described in *PN7160 user manual* [4].

Table 2. Discovery loop NCI host interface definition

Name	NCI Tag	Len	Default value	Description
Total_Duration	0x00	2	0xE803	Total duration of the single discovery period in [ms-Little endian coded] TLISTEN = Total_Duration - TPOLL

Table 3. Discovery loop proprietary host interface definition

Name	Prop. Tag	Len	Default value	Description
TAG_DETECTOR_CFG	0xA040	1	0x00	Tag detector setting as follows: - 0x00 Tag detector disabled - 0x01 Tag detector enabled - 0x09 Tag detector enabled with fake detection reported - 0x81 Tag Detector with trace mode
TAG_DETECTOR_THRESHOLD_CFG	0xA041	1	0x04	Sets the detection level
TAG_DETECTOR_PERIOD_CFG	0xA042	1	0x0F	Time in steps of 8us to wait for the measurement
TAG_DETECTOR_FALLBACK_CNT_CFG	0xA043	1	0x50	Hybrid mode setting as follows: - 0x00 hybrid disabled - 0xXX Regular RF polling triggered after XX LPCD pulse
TechDet_AFTER_LPCD_CFG	0xA061	1	0x00	Technology detection retry: -bits 0..2: Number of retries -bits 3..7: Period (10 ms steps)

PN7160 proposed a trace mechanism allowing to tune the sensitivity of the LPCD feature, later described in chapter Section 4.3. The format of the notification message is the following:

Table 4. Format definition of notification message in trace mode

Offset	*Length*	*value*	*Description*
0	1	0x6F	NXP proprietary NTF
1	1	0x13	TAG DETECTOR message
2	1	0x04	Length of the message

Table 4. Format definition of notification message in trace mode...*continued*

Offset	*Length*	*value*	*Description*
3	2	0xXXXX	Current reference value [Little endian coded]. Higher bit (bit 15) is RFU, its value shall not be considered.
5	2	0xXXXX	Last measurement value [Little endian coded]

4.2 Description of main configuration

Whatever the mode used, NCI tag “Total_Duration” has to be set if for specific duty cycle.

4.2.1 Regular mode

- **Proprietary tag “TAG_DETECTOR_CFG”:**
  – Set to 0x00
- Other proprietary tags are disregarded.

4.2.2 Low-power card detection mode

- **Proprietary tag “TAG_DETECTOR_CFG”:**
  – Set to 0x01 in order to enable Tag Detector
- **Proprietary tag “TAG_DETECTOR_THRESHOLD_CFG”:**
  – Tune according to the system (see Section 4.3)
- **Proprietary tag “TAG_DETECTOR_PERIOD_CFG”:**
  – Tune to optimize the LPCD pulse duration versus false detection, starting from default value (16 * 8 µs = 128 µs)
- **Extension tag “TAG_DETECTOR_FALLBACK_CNT_CFG”:**
  – Set to 0x00

4.2.3 Hybrid mode

- **Proprietary tag “TAG_DETECTOR_CFG”:**
  – Set to 0x01 in order to enable Tag Detector
- **Proprietary tag “TAG_DETECTOR_THRESHOLD_CFG”:**
  – Tune according to the system (see Section 4.3)
- **Proprietary tag “TAG_DETECTOR_PERIOD_CFG”:**
  – Tune to optimize the LPCD pulse duration versus false detection, starting from default value (16 * 8 µs = 128 µs)
- **Extension tag “TAG_DETECTOR_FALLBACK_CNT_CFG”:**
  – Set to specify regular polling frequency: For 1 regular POLL phase every N LPCD pulse, it must be set to N+1 (e.g. setting it to 4 leads to 1 regular POLL phase every 3 LPCD pulse)

4.3 Determining LPCD sensitivity

In order to define the threshold for the system, PN7160 provides trace functionality sharing measurement values from internal HW modules for each LPCD pulse. Thanks to this information adequate threshold level can be determined for the current system.

4.3.1 Pre-requisite

- DUT: system based on PN7160 IC
- Non-electromagnetic spacers of few centimeters
- Oscilloscope with NFC coil

4.3.2 Procedure

- **Step 1: Preparation**

Place the DUT on top of a spacer in order to have some distance from the desk and turn the DUT antenna upward.

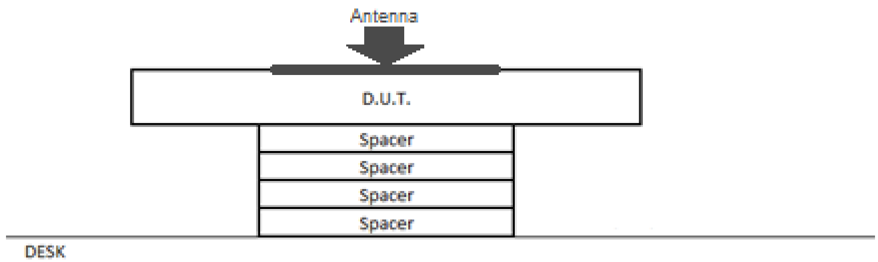

Figure 9. Setup to determine the sensitivity threshold

Then ensure that no external interference could impact the measurement, for instance avoid having other electronic devices around.

- **Step 2: Set the DUT in low-power tag detector with trace mode**

Enable the TRACE mode by setting the proprietary Tag “TAG_DETECTOR_CFG” to 0x81.

Then set the Tag “TAG_DETECTOR_THRESHOLD_CFG” to 0x10 defining the first threshold to evaluate. Verify if this configuration is well applied by reading back the parameter value with CORE_GET_CONFIG_CMD.

Check that TRACE messages are broadcasted by the PN7160 (on the host interface).

For instance, if the system runs android environment, use the following command from a computer connected through ADB (use ‘find’ instead of ‘grep’ when run from windows):

adb logcat –vtime | grep “6f 13”

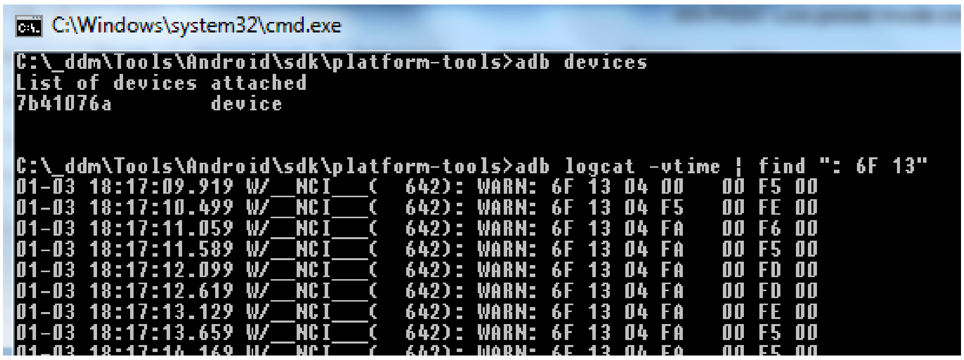

Figure 10. NTF messages from the LPCD mechanism

- **Step 3: Evaluate the sensitivity for the default threshold**

For instance, if the system runs android environment, use the following command (use ‘find’ instead of ‘grep’ when run from windows):

adb logcat –vtime | grep “6f 13” > DUT_threshold_10.txt

Wait some minutes in order to obtain around 2500 messages; then abort the process.

- **Step 4: analyze logs**

Extract from the logs the list of values measured by the LPCD module.

$$\frac{(Max - Min)}{2} = \text{Threshold}$$

To define the threshold maximum and minimum measurements have to be considered:

Update the threshold to its new value by modifying Tag “TAG_DETECTOR_THRESHOLD_CFG”, then evaluate the new sensitivity set.

For instance, if the system runs android environment, use the following command (use ‘find’ instead of ‘grep’ when run from windows):

adb logcat –vtime | grep “6f 13” > DUT_threshold_XX.txt

Wait in order to have a large amount of data (more than 5000). Extract from the logs the number of times the LPCD was triggered due to wrong detection.

- **Step 5: Optional – Fine-tune this threshold**

Depending on the final application, it could be interesting to either maximize power saving or maximize RF performance.

You can find below a table which summarizes the impact of wrong detections on the overall current consumption:

Table 5. Impact of wrong detection on the current consumption

Wrong detection rate	0.00 %	0.01 %	0.1 %	1 %	2 %	5 %	10 %	20 %	50 %
Current consumption (mA)	0.139	0.140	0.151	0.256	0.370	0.700	1.209	2.101	4.063

This table shows that a threshold with a wrong detection rate below 1 per 1000 has a limited impact.

If you want to increase or decrease the threshold, perform again ***step 4*** in order to verify the wrong detection rate.

- **Step 6: Verify the overall behavior**

Once final value of threshold is defined, you could verify the overall RF behavior with a scope (see Figure 4).

4.4 Determining reader communication range

4.4.1 Required material

- DUT: system based on PN7160 IC
- Non-electromagnetic spacers of different thickness (1 / 2 / 5 / 10 mm)
- Oscilloscope with NFC coil
- Tags to evaluate

4.4.2 Procedure

- **Step 1: Preparation**

Prepare the setup as depicted within the figure below.

A spacer of 1 cm has to be inserted between the NFC coil and the desk. Then another 1 cm spacer will be positioned between the tag under and the NFC coil.

Oscilloscope is useful in order to identify if the LPCD is triggered or not.

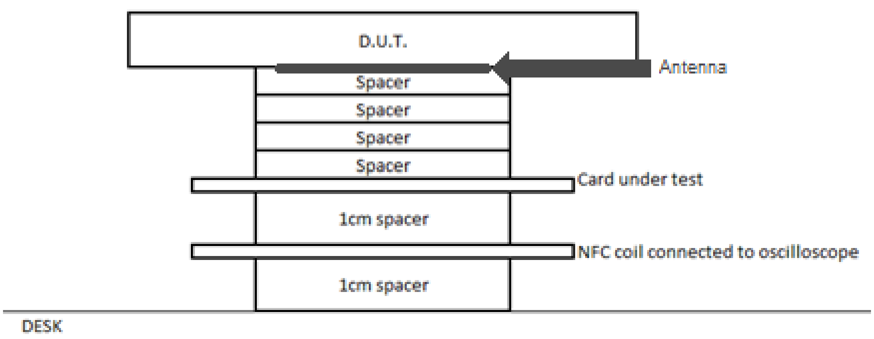

Figure 11. Setup to check detection limit

- **Step 2: Find detection limit**

Enable the regular discovery mode (see 4.2.1).

For each tag:

1. Start with no spacer between the card under test and the DUT

2. Place the DUT on top of the tag under test;
3. Verify that tag is detected several times (stability of the measurement):
   a. If yes: remove the DUT, add more spacer and go back to 2;
   b. If no: Tag detection limit is reached;

- **Step 3: Verifying detection limit**

Apply the procedure of ***Step 2*** for the hybrid or low-power detector mode (see 4.2.2 or 4.2.3) instead of the regular discovery mode, in order to confirm the same tag detection limit is reached in the targeted configuration.

5 Example with a reference device

5.1 Device description

Device is equipped with a 4 turn antenna (40 mm * 40 mm). TVDD supply option used is Configuration 1: the battery voltage is directly used to generate the RF field (refer to PN7160 product data sheet [3] for more details and others options).

5.2 Definition of the sensitivity threshold of this reference device

On this reference device, here are results of the threshold definition study:

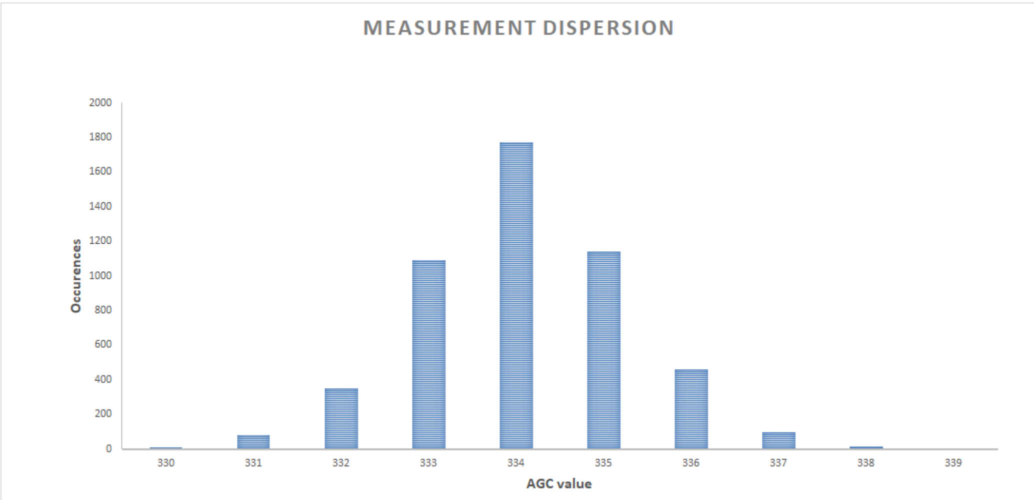

Figure 12. Measurement dispersion for 5000 measurements

For this device, below is the evolution of the wrong detection rate versus the threshold:

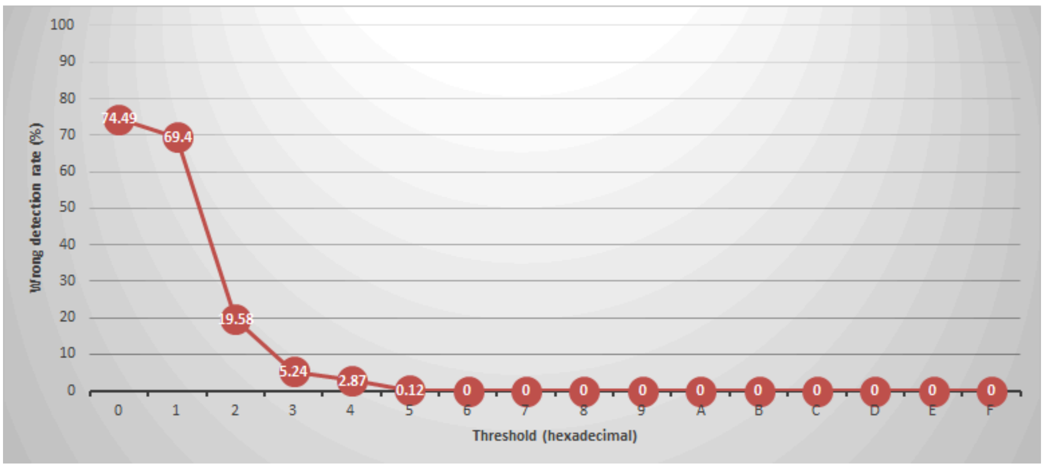

Figure 13. Wrong detection rate against threshold

Below is a summary of the impact of the threshold on the reader range of the LPCD feature:

Table 6. Detection range of the LPCD depending on the threshold

Card/Device	Regular discovery mode	Threshold in low-power detector mode			
		3h	4h	5h	6h
ICODE DNA	63mm	50mm	46mm	38mm	36mm
FeliCa RC-S962	53mm	51mm	42mm	40mm	40mm
MIFARE 1K	49mm	36mm	32mm	31mm	30mm
MIFARE Plus S	38mm	37mm	36mm	35mm	32mm
NTAG 216	62mm	50mm	40mm	36mm	31mm
MIFARE Ultralight C	34mm	33mm	32mm	30mm	26mm
MIFARE DESFire	40mm	32mm	30mm	29mm	29mm
MIFARE DESFire EV2	50mm	43mm	35mm	30mm	28mm
Samsung Galaxy S9 phone	65mm	35mm	30mm	27mm	25mm
Wrong detection rate	**N/A**	**5.24%**	**2.87%**	**0.12%**	**0.00%**
Expected current consumption	**20mA**	**1.38mA**	**749uA**	**182uA**	**158uA**

There are 3 cases to consider in order to define the threshold value:

- Case 1: Detection range just meets acceptance criteria in regular discovery mode.
  A Low threshold (i.e. 3h and below) has to be set. User experience will be favored compared current consumption (no margin at RF side).
- Case 2: Detection range is greater than acceptance criteria in regular discovery mode.
  A medium threshold (i.e. 4h or Ah) has to be set. Giving an excellent trade-off between current consumption and user experience.
- Case 3: Detection range is far greater than acceptance criteria in regular discovery mode
  A high threshold (i.e. Ah or more) has to be set. Current consumption will be favored compared to user experience (because we have margins at RF side).

6 How to spy RF activity by using a scope

6.1 Pre-requisite

- NFC device (the DUT)
- Oscilloscope with NFC coil or oscilloscope probe with alligator clip ground lead

6.2 Procedure

- **Step 1 – Set the oscilloscope**

Set the X scale to a large value (i.e. 1 s per division).

Set the Y scale to 200 mV per division.

Set the mode to AUTO and place the trigger on the left part of the screen.

- **Step 2 – Observe RF activity**

Bring the NFC coil or the oscilloscope probe on top of the device antenna:

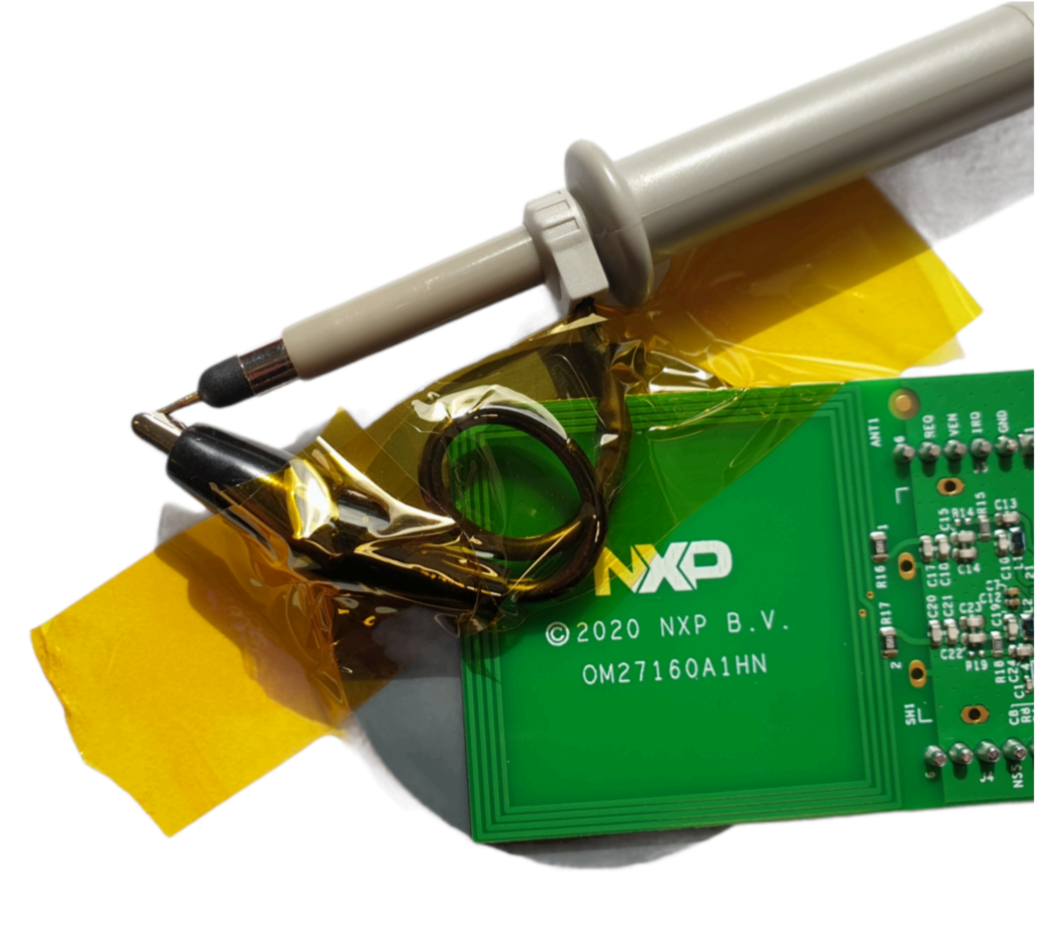

Figure 14. Spying RF activity of an NFC device using a probe

The best in class approach is to put some distance between the device and the oscilloscope probe in order not to bring noise:

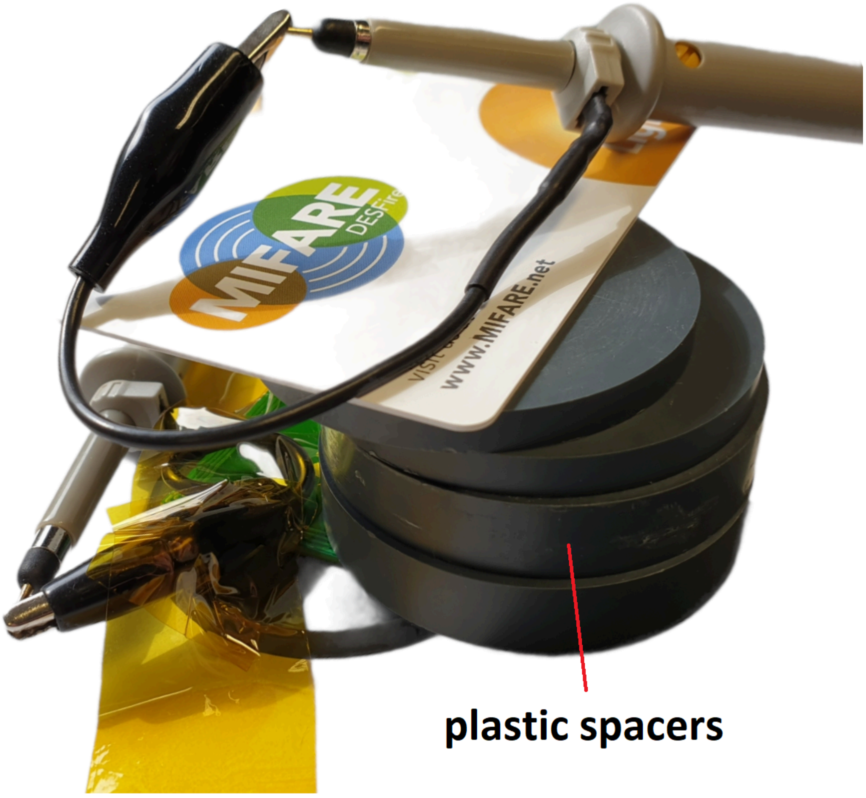

Figure 15. Recommended approach to spy RF activity

7 Abbreviations

Table 7. Abbreviations

Acronym	Description
ADB	Android Debug Bridge
DUT	Device Under Test
HW	Hardware
IC	Integrated Circuit
mm	Millimeter
NFC	Near Field Communication
NFCC	NFC Controller
RF	Radio Frequency
LPCD	Low-Power Card Detection
Z	Impedance

8 References

[1] NFC Forum Activity Specification, version 1.1

[2] NFC Forum NFC Controller Interface, version 2.0

[3] PN7160 product data sheet

[4] UM11495 - PN7160 user manual

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