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PN7150 Low Power Mode Configuration

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Document information

Info	Content
Keywords	NFC, PN7150, low power, discovery mode
Abstract	This application notes provides guidance on how PN7150 can be configured in order to reduce current consumption by using low power discovery mode

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Revision history

Rev	Date	Description
1.1	20160523	Security status changed into "COMPANY PUBLIC"
1.0	20151120	First official release of the document

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1. Introduction

PN7150 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.

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

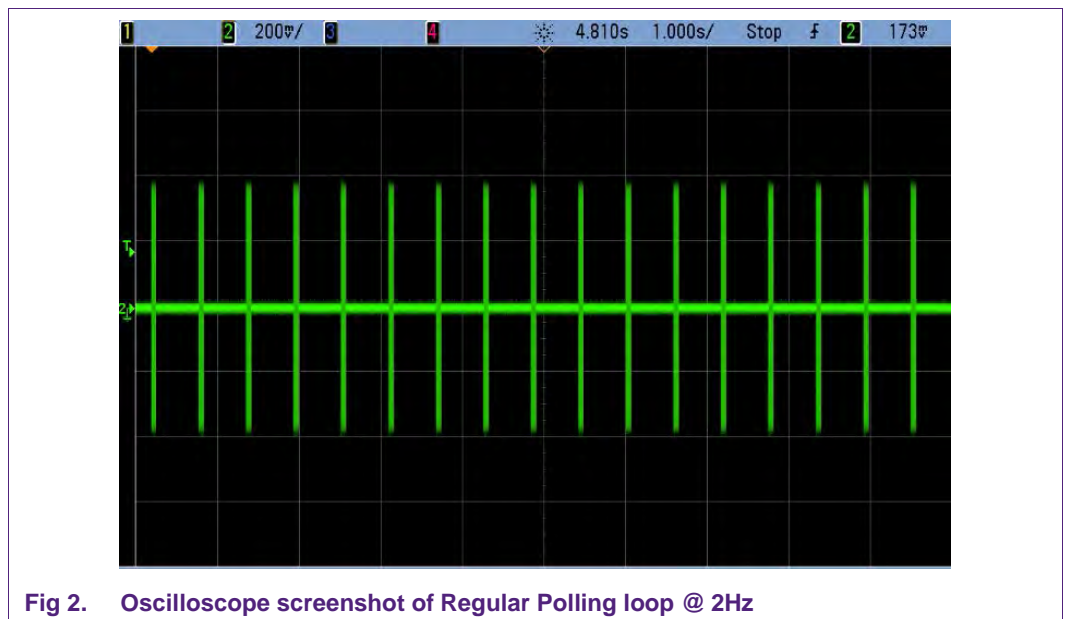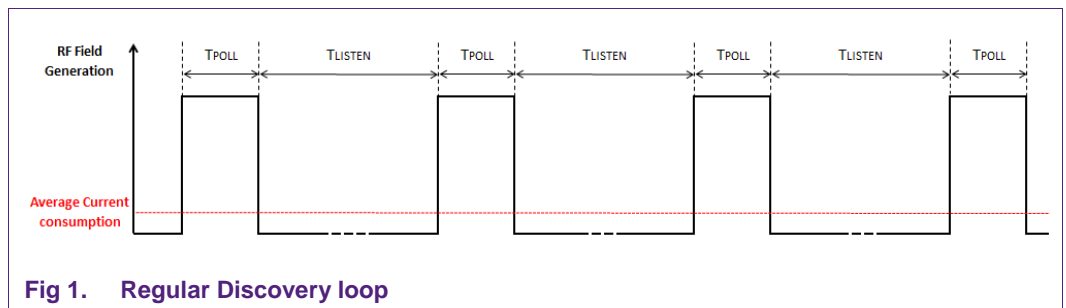## 2. Low Power Discovery Mode concept

PN7150 supports `RF DISCOVERY` defined within ACTIVITY specification from NFC FORUM (see *[1]*). PN7150 can be configured by following guidance depicted with NFC specification (see *NCI specification [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 5ms to 80ms duration)
- LISTEN phase duration
- Antenna system used by the application (impedance of the RF system)

Fig 1.   Regular Discovery loop

Fig 2.   Oscilloscope screenshot of Regular Polling loop @ 2Hz

Current consumption is one of the main criteria during a NFC design-in within an embedded equipment. PN7150 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 PN7150 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 *PN7150 User Manual [4]* for more details).
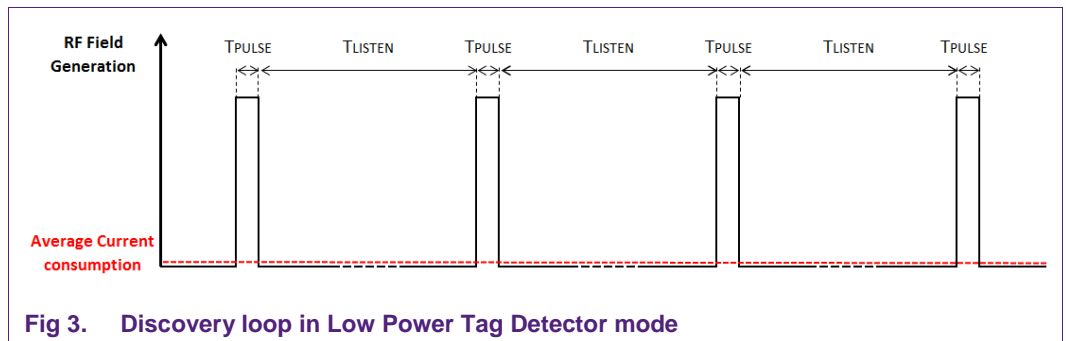
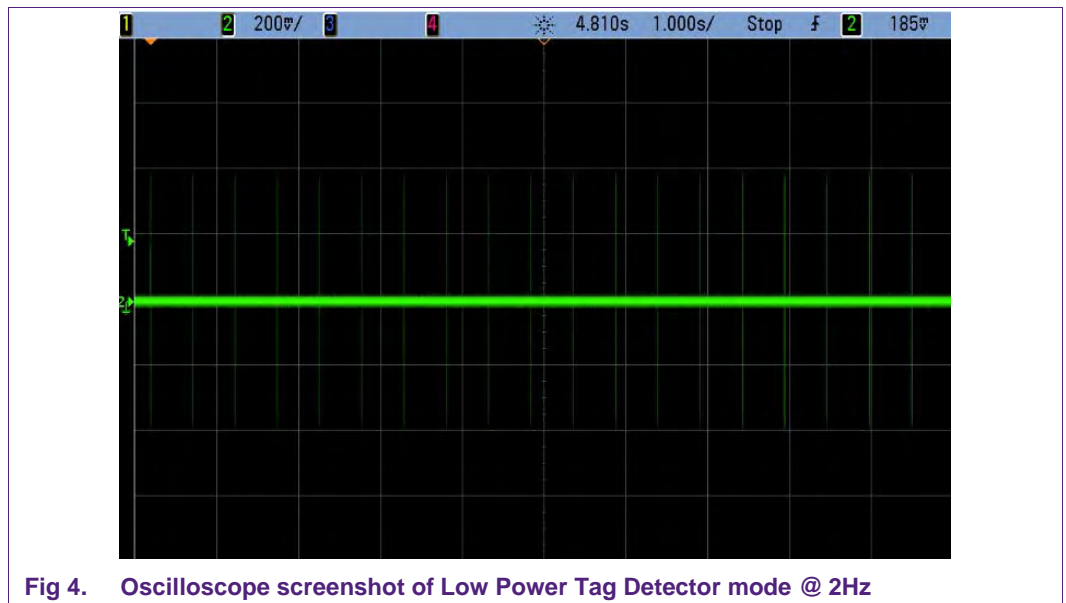**Fig 3.   Discovery loop in Low Power Tag Detector mode**

Fig 4.   Oscilloscope screenshot of Low Power Tag Detector mode @ 2Hz

In order to improve the likelihood to catch such a Card/Tag, the PN7150 comes with a retry mechanism which performs several Technology Detection polling cycles before it switches back to LPCD (refer to *PN7150 User Manual [4]* for more details).
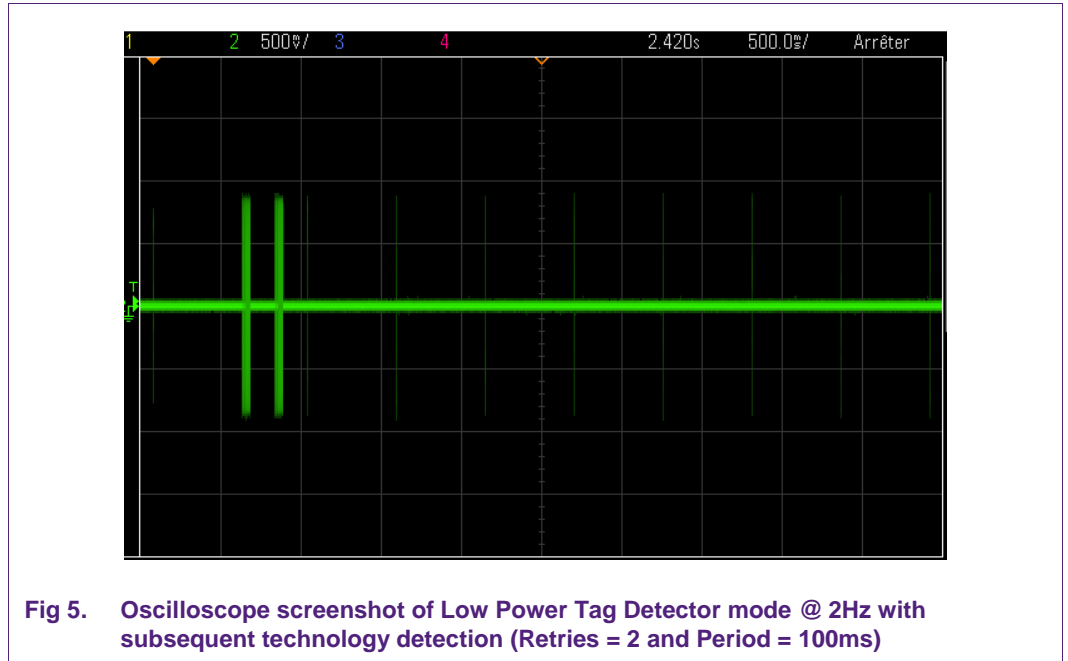

Fig 5. **Oscilloscope screenshot of Low Power Tag Detector mode @ 2Hz with subsequent technology detection (Retries = 2 and Period = 100ms)**

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 provide 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 *PN7150 User Manual [4]* for more details).
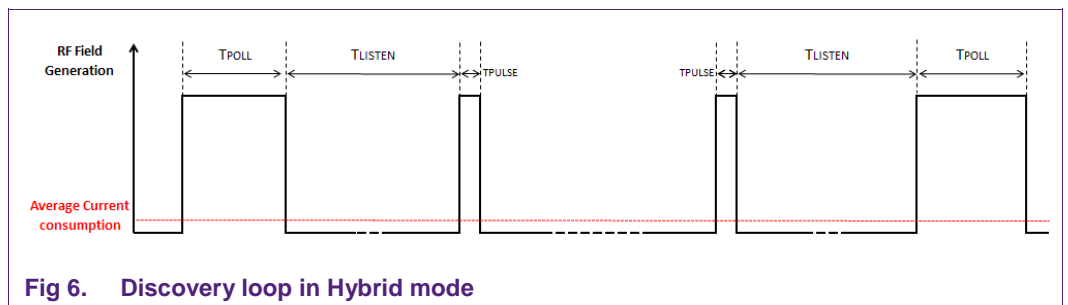

Fig 6. **Discovery loop in Hybrid mode**

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

3. Power consumption overview

Current consumption of PN7150 depends on hardware integration within platform.

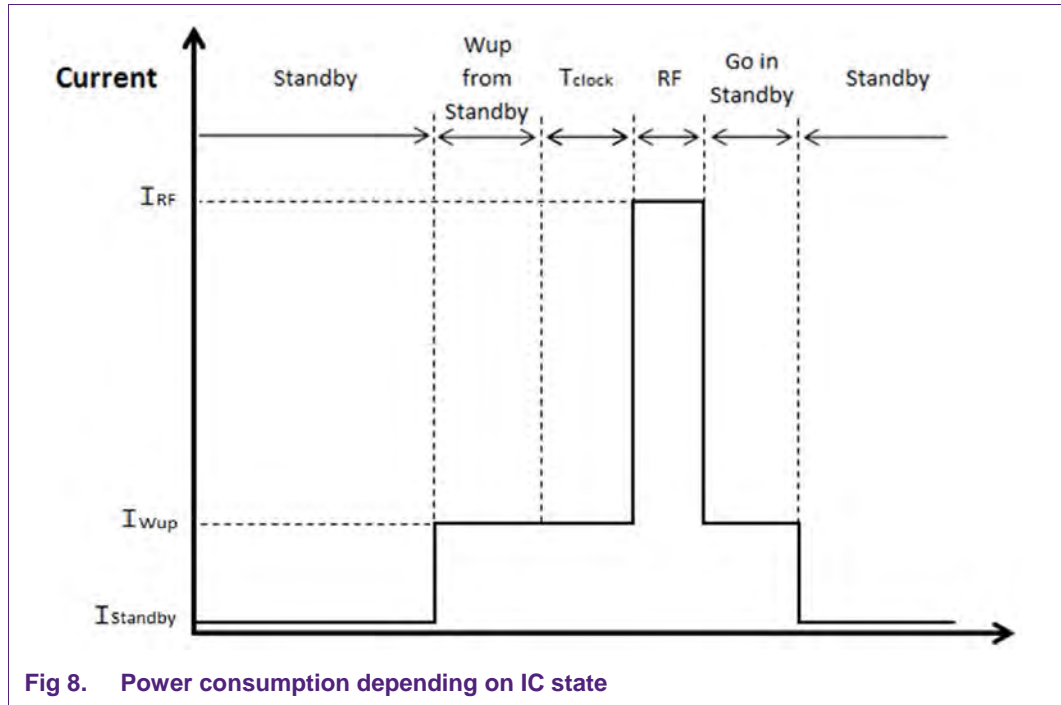Below figure depict the current consumption according the PN7150 IC state:

Fig 8. Power consumption depending on IC state

The wake-up time is about 2.5ms and the time to switch back in standby is a few hundreds of µs.

The current consumption is standby state is about 20µA and about 6mA in wake-up state, while in RF emission state it highly depends on the antenna impedance and matching circuitry (refer to PN7150 Product Datasheet *[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
    - RF pulse, in Low Power Tag Detector mode, is about 150µs
- Duration of clock establishment
    - Using XTAL T_{clock} is only few us
    - Using an external system clock T_{clock} is from 1ms to 10ms (depending on platform capability)

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Reference configuration used for the overview:

- Clock: XTAL

- Antenna matching impedance: 28Ohms

- T_{POLL} = 60ms

- Hybrid mode: 1 regular RF polling for 3 RF pulses are considered

Table 1. **Current consumption of discovery modes**

Discovery loop mode	Discovery loop frequency	
	1Hz	**2Hz**
Regular	6,037mA	12,053mA
Hybrid	1,623mA	3,411mA
Low Power Tag Detector	75uA	130uA

Here is a view of current consumption in Low Power Tag Detector mode with different configurations (antenna impedance and clock):

Table 2. **Current consumption depending on configuration**

Discovery loop mode	Z = 80Ohms XTAL	Z = 28Ohms XTAL	Z = 28Ohms SysClock 1ms	Z = 28Ohms SysClock 4ms
Low Power Tag Detector @2Hz	113uA	130uA	139uA	165uA

4. Configure Low Power mode

4.1 Host interface parameter description

You can find below parameters needed to configure the PN7150 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 *PN7150 User Manual [4]*.

Table 3. Discovery loop NCI Host Interface definition

Name	NCI Tag	Length	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 4. Discovery loop proprietary Host Interface definition

Name	Prop. Tag	Length	Default value	Description
Tag_Detector_CFG	0xA040	1	0x00	Tag detector setting as follows: - 0x00 Tag Detector disabled - 0x01 Tag Detector enabled - 0x81 Tag Detector with trace enabled
Tag_Detector_Threshold_CFG	0xA041	1	0x04	Sets the detection level
Tag_Detector_Period_CFG	0xA042	1	0x19	Time in steps of 8us to wait 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 (10ms steps)

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PN7150 proposed a trace mechanism allowing to tune the sensitivity of the LPCD feature, later described in chapter *4.3*. The format of the notification message is the following:

Table 5.   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
3	2	0xXXXX	Current reference value [Little endian coded]
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 you want a specific duty cycle.

4.2.1 Enable Regular Mode

- **Proprietary Tag "Tag_Detector_CFG":**
   o   Set to 0x00
- Other proprietary tags are disregarded.

4.2.2 Enable Hybrid Mode

- **Proprietary Tag "Tag_Detector_CFG":**
   o   Set to 0x01 in order to enable the Tag Detector
- **Proprietary Tag "Tag_Detector_Threshold_CFG":**
   o   Tune according to the system (see *4.3*)
- **Proprietary Tag "Tag_Detector_Period_CFG":**
   o   Keep to default value
- **Extension Tag "Tag_Detector_Fallback_Cnt_CFG":**
   o   This value has to be specified: If you want 1 regular POLL phase every N LPCD pulses, this tag has to be set to N+1 (e.g. setting this parameter to 0x04 lead to 1 regular POLL phase every 3 LPCD pulses)

4.2.3 Enable Low Power Card Detection Mode

- **Proprietary Tag "Tag_Detector_CFG":**
   o   Set to 0x01 in order to enable Tag Detector

- **Proprietary Tag "Tag_Detector_Threshold_CFG":**

  o Tune according to the system (see *4.3*)

- **Proprietary Tag "Tag_Detector_Period_CFG":**

  o Keep to default value

- **Extension Tag "Tag_Detector_Fallback_Cnt_CFG":**

  o Set to 0x00

4.3 Determining LPCD sensitivity

In order to define easily the threshold for the system, PN7150 provides trace functionality sharing measurement values from internal HW modules for each LPCD pulse. Thanks to the information raised in these messages the adequate threshold level can be determined for the current system.

4.3.1 Pre-requisite

- DUT: system based on PN7150 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.
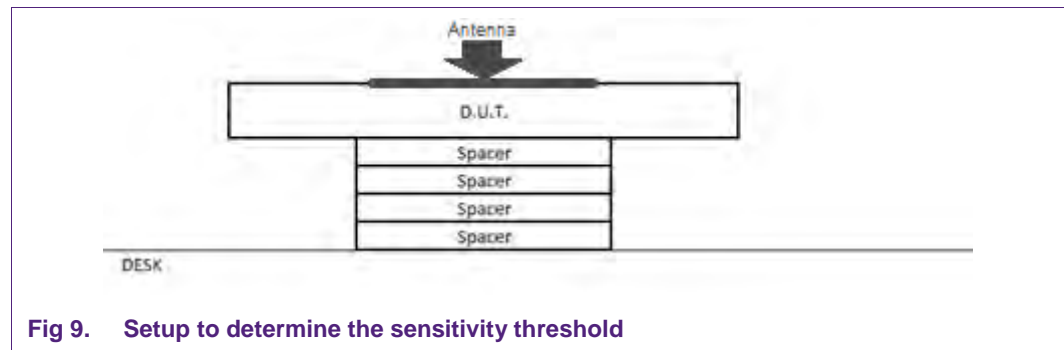

Fig 9. Setup to determine the sensitivity threshold

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.

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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 PN7150 (on the host interface).

For instance, if the system run android environment (refer to Android SDK for more information), use the following command from a computer connected through ADB (use 'find' instead of 'grep' from windows):

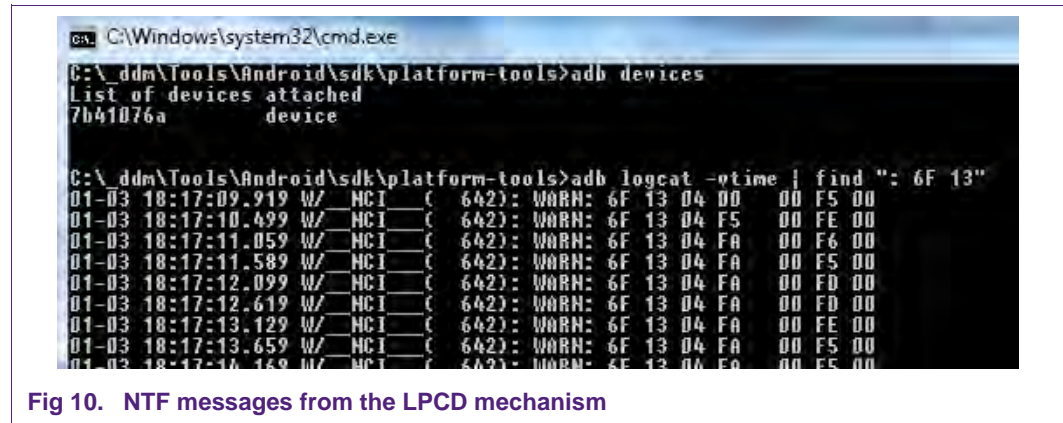*adb logcat –vtime | grep "6f 13"*

Fig 10. NTF messages from the LPCD mechanism

Step 3: Evaluate the sensitivity for the default threshold

For instance, if the system run android environment, use the following command (use 'find' instead of 'grep' 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.

PN7150 in this mode will always set its reference value around the middle of measurements dispersion. To define the threshold maximum and minimum measurements have to be considered:

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

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 run android environment, use the following command (use 'find' instead of 'grep' 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 6. **Impact of wrong detection on the current consumption**

Wrong detection rate	0,00%	0,01%	0,10%	1,00%	2,00%	5,00%	10,00%	20,00%	50,00%
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 (12uA).

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 Fig 3).

4.4 Determining reader communication range

4.4.1 Required material

- DUT: system based on PN7150 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 1cm has to be inserted between the NFC coil and the desk. Then another 1cm spacer will be positioned between the tag under and the NFC coil.

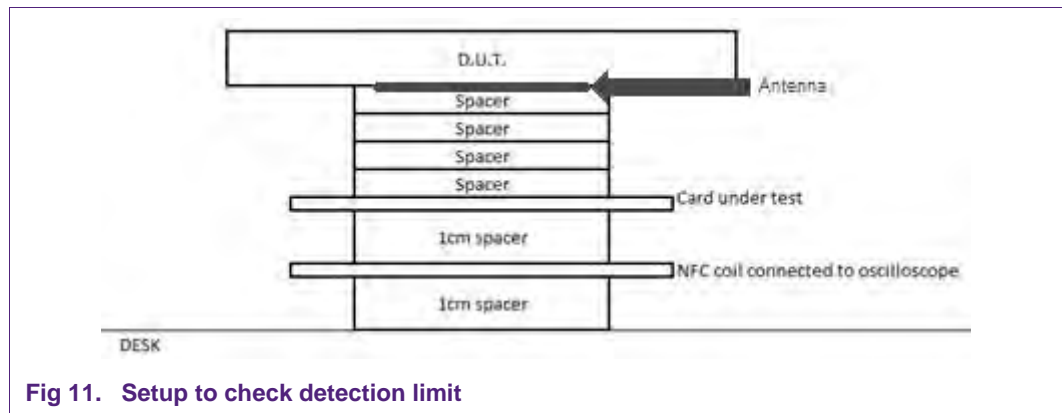Oscilloscope will be useful in order to identify if the LPCD is triggered or not.

Fig 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 (45mm * 25mm). TVDD supply option used is Configuration 1: supply connection in case the battery is used to generate RF field (refer to PN7150 Product Datasheet *[3]* for more details and others options).

5.2 Definition of the sensitivity threshold of this reference device

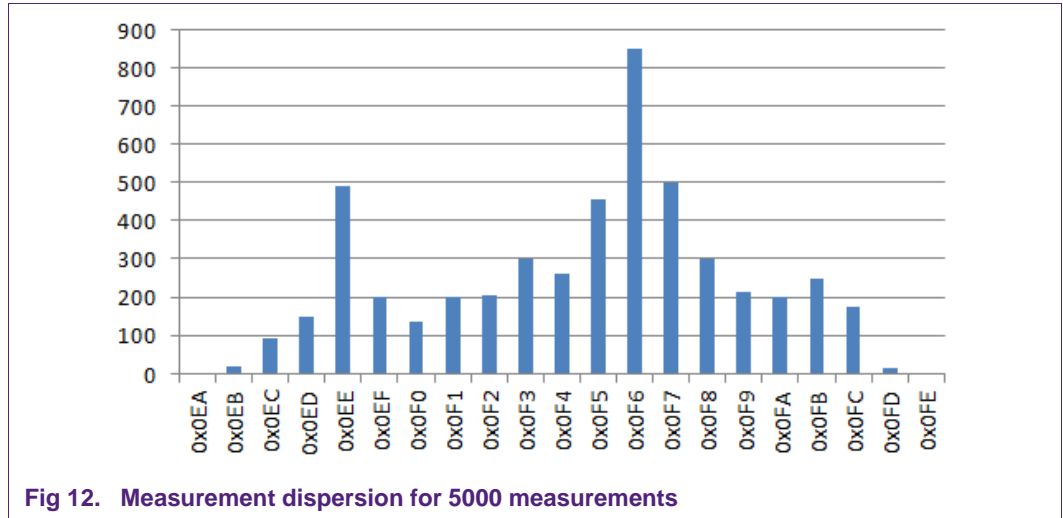On this reference device, here are results of the threshold definition study:

Fig 12. Measurement dispersion for 5000 measurements

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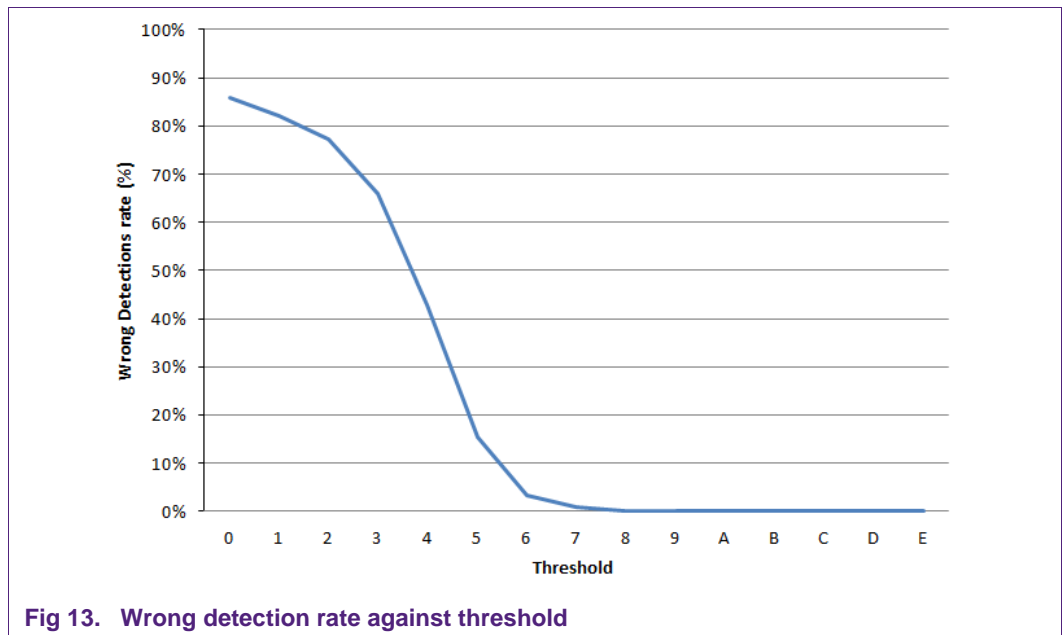

Fig 13. Wrong detection rate against threshold

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

Table 7.   Detection range of the LPCD depending on the threshold

Card/Device	Regular discovery mode	Threshold in Low Power Detector mode				
		0x08	**0x09**	**0x0A**	**0x0C**	**0x0E**
ISO15693	58mm	46mm	45mm	43mm	38mm	33mm
TOPAZ	37mm	35mm	35mm	35mm	33mm	31mm
FELICA	31mm	31mm	30mm	30mm	30mm	29mm
MIFARE 1K	41mm	39mm	39mm	38mm	35mm	28mm
MIFARE 4K	28mm	27mm	25mm	24mm	22mm	20mm
MIFARE plus X	22mm	21mm	21mm	20mm	19m	19mm
NTAG203	38mm	34mm	32mm	32mm	31mm	29mm
NTAG210	57mm	38mm	35mm	34mm	32mm	30mm
MIFARE UL	40mm	38mm	36mm	36mm	34mm	27mm
MIFARE ULC	20mm	20mm	20mm	20mm	19mm	19mm
DESFIRE	19mm	19mm	19mm	19mm	19mm	18mm
P2P against GS3	30mm	29mm	28mm	28mm	27mm	25mm
Wrong detection rate	N/A	0,22%	0,02%	0,00%	0,00%	0,00%
Expected current consumption	12mA	232uA	210uA	207uA	207uA	207uA

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

Case 1: Detection range just meet acceptance criteria in regular discovery mode

⇨ A Low threshold (i.e. 0x08 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. 0x09 or 0x0A) 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. 0x0B or more) has to be set. Current consumption will be favored compared to user experience (because we have margins at RF side).

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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. 1s per division).
Set the Y scale to 200mV 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:
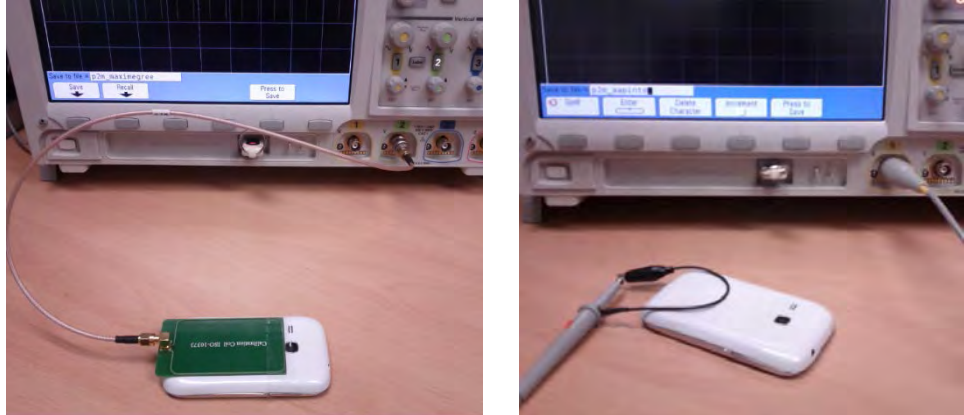

Fig 14. Spying RF activity of a NFC device using a coil or a probe

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

Fig 15. Recommended approach to spy RF activity

7. Abbreviations

Table 8.   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

[2] NFC FORUM NFC Controller Interface, version

[3] PN7150 Datasheet

[4] UM10936 - PN7150 User Manual

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