AN11783

CLRC663 *plus* Low Power Card Detection

Rev. 1.0 — 3 May 2017
413310

Application note
COMPANY PUBLIC

Document information

Info	Content
Keywords	CLEV6630B, CLRC663 *plus*, LPCD, Low Power Card Detection, Low Power
Abstract	This document describes the principle of the low power card detection (LPCD) offered by the CLRC663 *plus*. It describes how to use the LPCD and how to optimize the related settings.

Revision history

Rev	Date	Description
1.0	20170503	Initial version

Contact information

For more information, please visit: http://www.nxp.com

1. Introduction

This document describes the principle of the low power card detection (LPCD) offered by the CLRC663 *plus*. It describes how to use the LPCD and how to optimize the related settings.

The basic idea of the LPCD is to provide a function, which turns off the RF field, when no card is used. This saves energy and allows battery powered NFC Reader designs. This function must detect cards, as soon as they are approached to the reader antenna. The overall reader design must allow a low power functionality, i.e. the leakage currents in low power mode must be as low as possible. At the same time the detection of cards must work properly within the required parameters like detection speed and detection range.

The CLRC663 and CLRC663 *plus* offer a standalone LPCD function, which replaces the normal active card polling that is triggered by the host µC.

In the section 2 the principle of the LPCD and its related parameters is described. In the section 3 the usage of the LPCD with the CLEV6630B is described. This includes some hints on how to optimize the LPCD towards the own application requirements.

Note: The CLRC663 already provides the basic LPCD functionality (refer to [2]). This functionality is still valid for the CLRC663 and the CLRC663 *plus*. However, the CLRC663 *plus* offers some additional features which improve the LPCD performance.

2. Principle of LPCD

The standard NFC or RFID communication requires the reader to poll for the cards, i.e. it requires the reader to stay active. The card itself stays mute, until the reader provides the required power (field strength) and the sends the correct command (e.g. REQA or REQB for ISO/IEC 14443 communication).

In general, the low power card detection provides a functionality, which allows to power down the reader for a certain amount of time to safe energy. After some time, the reader must become active again to poll for cards. If no card is detected, the reader can go back to the power down state. This principle is shown in Fig 1.

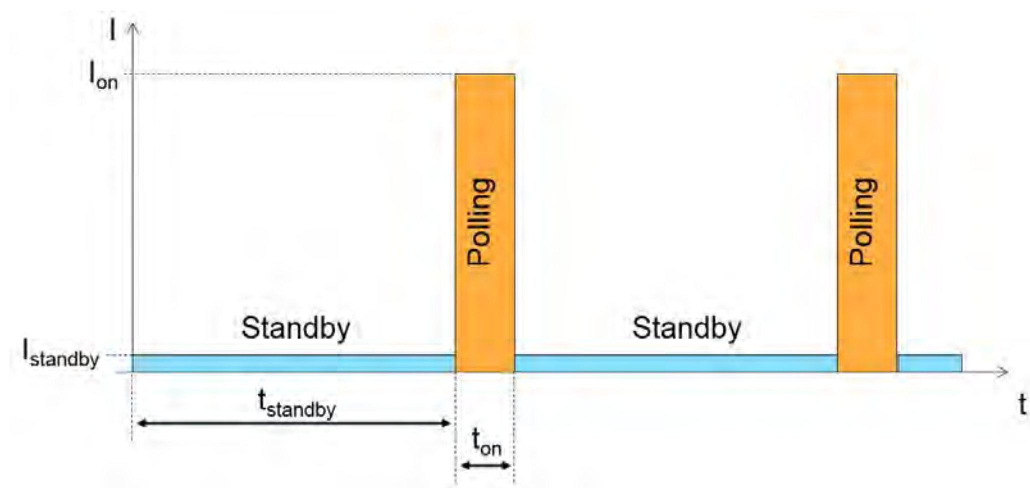


Fig 1. LPCD principle in general

For this principle", the average current can be calculated:

$$I_{average} = \frac{I_{standby} \cdot t_{standby} + I_{on} \cdot t_{on}}{t_{standby} + t_{on}} \quad (1)$$

$I_{standby}$ = current consumption in standby or power down mode

I_{on} = current consumption during the "normal" operation

$t_{standby}$ = time, where the reader is in power down (no function)

t_{on} = time of the polling operation

Note: "Polling" here means a function, which is able to detect a card being placed on the NFC Reader antenna.

Before considering the technical details of the LPCD function of the CLRC663 *plus*, the major parameters must be defined to allow an optimization of the LPCD. In some applications, the energy saving is the major parameter, e.g. because a battery life time must be increased as much as possible. In some other applications, the detection speed or the detection range might be more important.

2.1 Polling versus LPCD

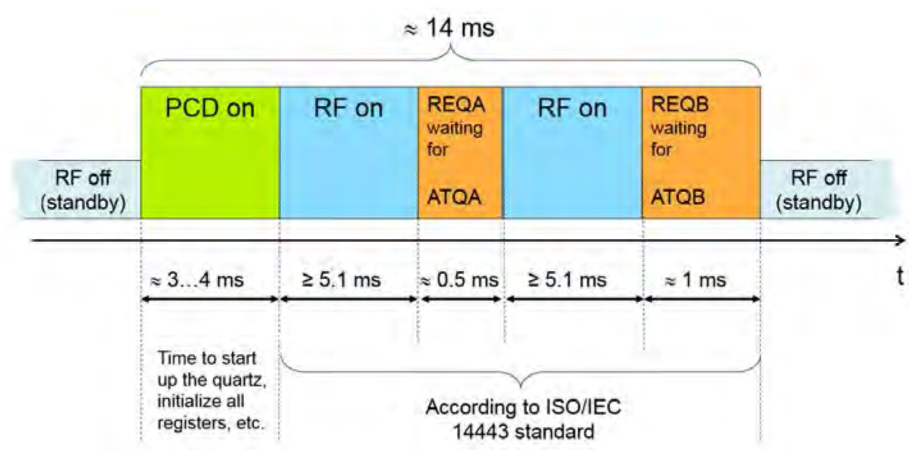
A standard polling executes the commands as requested by the corresponding standard, i.e. REQA and REQB for ISO/IEC 14443 polling. The LPCD detects the detuning and loading of the reader antenna before even starting any command sequence.

2.1.1 Standard polling without LPCD

For a standard ISO/IEC 14443 reader (PCD) the normal polling sequence must use the timing requirements of the standard. This timing requirement ends up in a polling sequence as shown in Fig 2, where the reader typically stays active for $t_{on} \approx 14$ ms.

Using a standby time of $t_{standby}$ ≈ 300 ms, a standby current of $I_{standby}$ = 5 µA and a polling current of I_{on} ≈ 150 mA, the average current consumption is quite high: $I_{average}$ ≈ 5 mA

This calculation does not include the current consumption of the host µC, which is required to control this polling sequence.



(1) This timing is based on ISO/IEC 14443 requirements.

Fig 2. PCD card polling timing

2.1.2 LPCD function of the CLRC663 *plus*

The LPCD function of the CLRC663 *plus* offers an easy to use detection with a much lower current consumption. This LPCD uses the detuning of the antenna for the card detection. After a required calibration, the host µC puts the CLRC663 *plus* into LPCD mode.

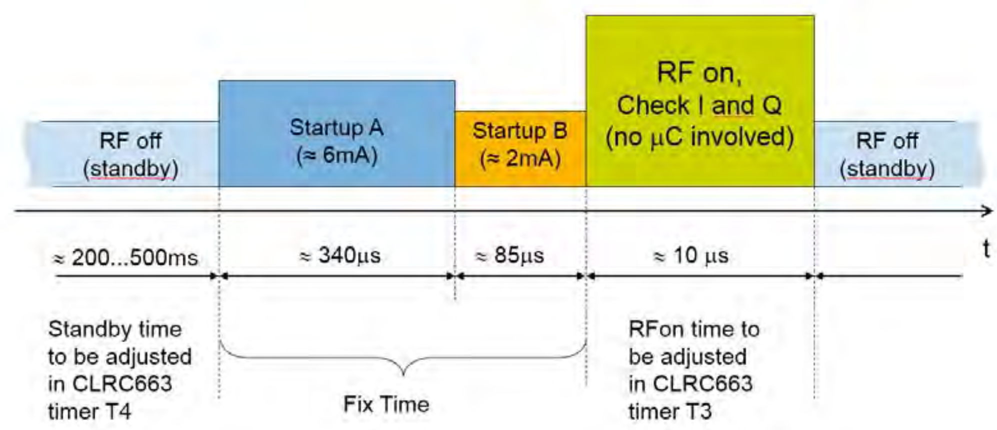
Then the CLRC663 *plus* goes into a temporary standby mode, which is controlled by the timer T4, as shown in Fig 3. When the Timer T4 elapses, the CLRC663 *plus* starts up with limited functionality (Startup A and B) and then sends a short RF pulse. The duration of the RF pulse is controlled by the timer T3. During this pulse either no card is detected or a possible detuning wakes up the CLRC663 *plus*. If no card is detected, the CLRC663 *plus* goes back into the temporary standby mode again and the Timer T4 starts again. For more details refer to section 3.

The LPCD runs forever, unless the CLRC663 *plus* is reset or a card is being detected. During the LPCD the host interface (e.g. SPI) is disabled and cannot and shall not be used. As soon as a card detunes the antenna from the “no detection” state, the CLRC663 *plus* wakes up and sends an IRQ to wake up the host µC.

The only way to stop the LPCD, if no wake up is detected, is a CLRC663 reset.

Using a standby time of $t_{standby}$ ≈ 300 ms, a standby current of $I_{standby}$ = 5 µA and a polling current of I_{on} ≈ 150 mA, the average current consumption is quite low now: $I_{average}$ ≈ 17 µA

This calculation does not include the current consumption of the host µC, which is **not** required to control this LPCD sequence.



(1) This timing is based on CLRC663 *plus*.

Fig 3. LPCD timing

2.2 Parameters of LPCD

The LPCD can be designed for different target applications. In battery powered readers, the current consumption in combination with the detection failure rate is the major parameter. In a standard access control reader, the detection range and especially the detection speed are more important.

The details of the current calculation and optimization including some examples is shown in section 3.

2.2.1 LPCD current consumption

The current consumption depends on many parameters. Mainly the standby current during the **standby time** and the **duration of the RF pulse** are the most important parameters influencing the average current.

For the minimization of the standby current it is important to properly connect the pins of the CLRC663 *plus*. Otherwise the leakage current e.g. through a pull up resistor might increase the standby current by some 10 or even 100 µA. That would dramatically increase the average current.

The duration of the RF pulse needs to be long enough to properly detect any card, but it should not be too long, since this increases the average current consumption. The CLRC663 *plus* offers some features like e.g. a filter, which improves the robustness, but on the other hand increases the average current consumption.

The CLRC663 *plus* allows to enable or disable the internal Tx driver charge pump. Enabling the charge pump increases the power level during the detection phase, which increases the detection range. However, it also increases the average current consumption.

The slower the detection speed, the lower the average current.

2.2.2 LPCD detection range

The LPCD detection range depends on the detuning and loading of the antenna. Normally the standard antenna design is made to minimize the loading and detuning effect as much as possible, but for the LPCD the loading and detuning is required to detect cards.

In some cases, the operating distance is (much) larger than the detection distance. Especially for cards, which have very low load, this can happen. This might be the case e.g. for ISO/IEC 15693 cards or MIFARE Classic or MIFARE Ultralight cards.

The stronger the coupling between reader and card, the better the detection range. Therefore, typically small reader antennas show a better LPCD detection range than large antennas (relative to the read range). Small tag antennas typically detune the reader less than ID1 size cards, and therefore show a smaller detection range, even if the operating range is large.

Reader antennas with higher Q (i.e. designed only for 106 kbit/s) can show a better detection range than antennas with a very low Q (e.g. due to an LCD in the antenna area or due to the higher bit rate design).

Without knowing the antenna, it is difficult to specify numbers. But the CLRC663 *plus* was designed to show a robust detection, and therefore typically has a detection range which is like the ISO/IEC 14443 operating distance.

2.2.3 LPCD detection speed

The detection speed depends mainly on the standby time. For the CLRC663 *plus* the Timer T4 is used to specify this time. This time has a direct impact on the average current consumption.

When a card is being detected with the LPCD, the CLRC663 *plus* wakes up the host µC, which then must start a standard polling sequence to select and activate the card for the required card operation.

2.2.4 LPCD detection failure rate

The inductive LPCD has the advantage that the detuning and loading of the antenna is taken to detect cards. Other devices, which do not detune or load the reader antenna, do not wake up the reader at all. Especially for handheld reader devices this reduces the number of failure detections enormously compared to a capacitive detection.

The number of failure detections has a direct impact on the average current consumption.

3. The CLRC663 *plus* LPCD

The LPCD of the CLRC663 *plus* contains two phases:

1) LPCD Calibration
2) LPCD Detection

During the LPCD Calibration the antenna circuit is calibrated for the “no detection” state. This calibration must be done once before starting the LPCD detection. It is required to put the CLRC663 *plus* into standby mode for a proper calibration, which is automatically supported by the NXP Reader Library (see [4]).

The application might use a smart handling of the re-calibration to avoid multiple failure detections e.g. due to a changed environment. A re-calibration is required after the antenna loading condition has changed without a card placed on the antenna (for whatever reason, e.g. due to temperature or other environmental changes).

The LPCD of the CLRC663 *plus* can be used in the same way like the CLRC663 LPCD, but on top the CLRC663 *plus* offers some additional features to optimize the LPCD. The following settings in the LPCD_OPTIONS can be configured in the LPCD_Options register (0x3A):

- LPCD_CHARGEPUMP
- LPCD_FILTER
- LPCD_Q_UNSTABLE
- LPCD_I_UNSTABLE

Note: Even with a card on the antenna, the LPCD calibration can be performed. Then the “no detection” state is calibrated together with this card on the antenna. Starting the LPCD detection in such case results in “no wake up” as long as the card stays on the antenna. In this case the CLRC663 *plus* wakes up, as soon as the card is removed.

3.1 LPCD_CHARGEPUMP

Setting the bit 3 in the LPCD_Options register (0x3A) enables the charge pump during the LPCD detection. This increases the output power at the TX pins, i.e. the RF field strength during the RF on time. This results in up to 2.5 higher detection range, but also in 30…40% higher current consumption.

For the minimum TVDD the minimum RF on time ≥ 55µs with LPCD_CHARGEPUMP = 1.

3.2 LPCD_FILTER

Setting the bit 2 in the LPCD_Options register (0x3A) enables the LPCD filter. This filter reduces the risk of fail detections especially in case of spike noise, but also increases the current consumption.

Enabling the LPCD_FILTER enables an CLRC663 *plus* algorithm, which samples 16 times during the RF on time instead of sampling just once. If no wake up is detected during this period, the CLRC663 *plus* restarts T4 and goes back to LPCD mode ("standby").

If a wake up is detected during this first period, another sampling of 16 times is started. If no wake up is detected during this second period, the CLRC663 *plus* restarts T4 and goes back to LPCD mode ("standby").

If a wake up is detected during this second period, another sampling of 16 times is started. If no wake up is detected during this third period, the CLRC663 *plus* restarts T4 and goes back to LPCD mode ("standby").

The CLRC663 *plus* wakes up, if a wake up is detected in the third period, too.

This algorithm increases the RF on time by the factor of two or three in case of instability (normal case, i.e. no wake-up detection).

Table 1. LPCD_FILTER

First period	Second period	Third period	Duration	Result
No wake up	-	-		Return to LPCD
Wake up detected	No wake up	-		Return to LPCD
Wake up detected	Wake up detected	No wake up		Return to LPCD
Wake up detected	Wake up detected	Wake up detected		Wake up

This filter allows to use a threshold of 0, operating much more stable.
Note: the threshold of 0 always contains a high probability of false wake ups. This needs to be considered, when choosing the optimum settings per application.

3.3 LPCD_Q_UNSTABLE and LPCD_I_UNSTABLE

In combination with the LPCD_FILTER (enabled), the LPCD_Q_UNSTABLE (bit 1) and the LPCD_I_UNSTABLE (bit 0) indicate, whether during calibration and / or detection the least significant bit of the Q channel or the I channel value started to toggle.

Since the LPCD_FILTER always results in the lower value (in case of toggling), this information can be used to increase the threshold to 0 / +1 (instead of -1 / +1), before restarting the LPCD mode. This increases the stability and robustness, without losing too much detection range.

The NXP Reader Library [4] offers this as "high detection range option".

3.4 The low power design

For the low power design the correct circuitry around the CLRC663 *plus* is important. Especially the correct connection of "unused" pins is a major topic.

3.4.1 CLEV66303 unused pins

One important factor to realize a low average current consumption is the standby current. The low standby current can only be achieved, if every pin of the CLRC663 *plus* is connected properly. Otherwise a leakage current, caused by a floating pin or a high resistance pull up resistor might cause an enormously overall increased current consumption.

The Table 2 shows the recommended settings of unused pins. Those recommendations are valid for the UART interface, for I2C, for SPI and I2C-L. The only difference between the different interfaces is the use of the IF0, IF1, IF2 and IF3.

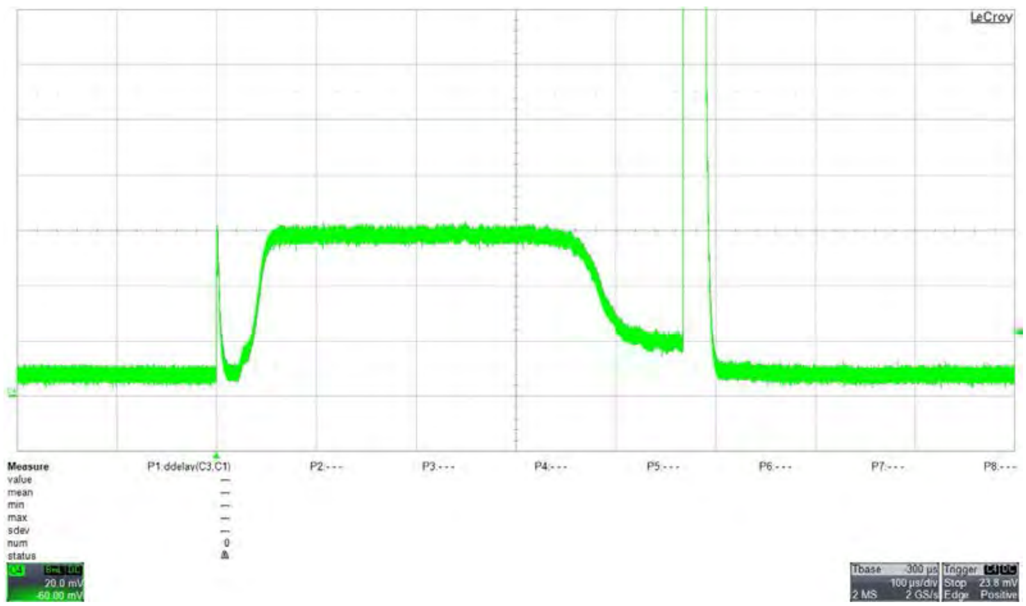
Note: the corresponding register settings must be checked and set properly, otherwise "artificial" shortcuts can increase the current consumption. Example SIGOUT: it does not make sense to set the SIGOUT internally to "1" and then connect externally to GND.

Table 2. CLRC663 *plus* unused pins

Pin #	Pin name	Type	Supply	Pin configuration
22	CLKOUT	O	PVDD, DVDD	GND
28	IF0	I/O	PVDD, DVDD	/Rx
29	IF1	I/O	PVDD, DVDD	PVDD
30	IF2	I/O	PVDD, DVDD	Open or PVDD
31	IF3	I/O	PVDD, DVDD	PVDD
26	IFSEL0	I	PVDD, DVDD	GND
27	IFSEL1	I	PVDD, DVDD	GND
24	SDA	I/O	PVDD, DVDD	GND
23	SCL	O	PVDD, DVDD	GND
32	IRQ	O	PVDD, DVDD	GND / IRQ
21	PDOWN	I	PVDD, DVDD	GND
6	SIGOUT	O	PVDD	GND
4	TCK	I	PVDD, DVDD	Open or PVDD
2	TDI	I	PVDD, DVDD	Open or PVDD
1	TDO	O	PVDD, DVDD	GND
3	TMS	I	PVDD, DVDD	Open or PVDD
10	AUX1	O	AVDD	Open
11	AUX2	O	AVDD	Open
5	SIGIN	I	PVDD, DVDD	GND

3.4.2 CLRC663 *plus* current measurement

To control the proper function of the low-power design a current measurement is very useful. The problem of measuring the average current consumption of only a few µA is related to the LPCD cycle, which on one hand causes a current consumption of up to 200 mA (during the short t_{RFOn}), and on the other hand a current consumption of typically $I_{Standby}$ = 3 µA, as can be seen in Fig 4.



(1) Measured with differential probe

Fig 4. Current consumption during the CLRC663 *plus* LPCD detection

3.4.2.1 Current measurement option 1:

Typically, the dynamic range of a high accurate source meter allows a maximum current of up to 100 mA while measuring with a resolution of 0.1 µA. In this case the most reasonable measurement can be done with the following adaptation:

Reduce the I_{RFOn} and increase the $t_{Standby}$. For the standby current measurement, the I_{RFon} does not matter, so for this measurement the TX-outputs can be left open. This reduces the I_{RFOn} to less than 100 mA.

Then it might be helpful to increase the standby time (Timer T4) to some seconds to allow a proper current measurement.

3.4.2.2 Current measurement option 2:

Use the standby mode of the CLRC663 *plus* to measure the standby current consumption. The current consumption in the standby mode is the same like the standby current during the $t_{Standby}$ of the LPCD. In this case the dynamic range of the current measurement device does not matter.

3.5 The LPCD calibration

During the LPCD Calibration the CLRC663 *plus* defines the I- and Q-channel signal levels for the “no detection” state, and stores it in the Register 0x42 and 0x43:

Register 0x42: LPCD_Result_I register

Register 0x43: LPCD_Result_Q register

3.5.1 Reading I and Q values

The following script shows the operation of calibration, which sets the relevant Tx and Rx register, sets T3 and T4 (with default values), executes the AutoLPCD and AutoRestart, and reads the I and Q values for the “no card state:

The I and Q values can be read from the lines 44 and 45.

3.5.2 Calculation of the detection window values

These values I and Q can then be read and taken as input for the calculation of the detection window. For this calculation, a threshold must be defined. The recommendation uses the threshold value TH = 1.

With this threshold TH the minimum and maximum I and Q values can be calculated:

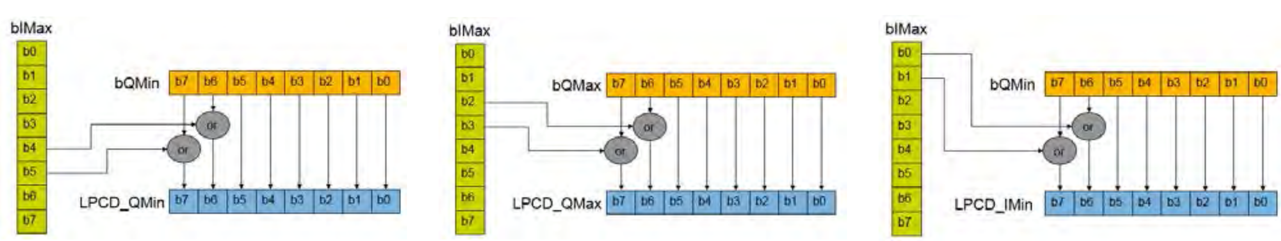
$$bQMin = Q - TH \qquad (2)$$

$$bQMax = Q + TH \qquad (3)$$

$$bIMin = I - TH \qquad (4)$$

$$bIMin = Q + TH \qquad (5)$$

With these four values the final window values can be prepared as shown in Fig 5.



a. LPCD_QMin b. LPCD_QMax c. LPCD_IMin

Fig 5. Calculation of the LPCD_QMin, LPCD_QMAx, and LPCD_IMin

These three values must then be stored in the three register 0x3F, 0x40 and 0x41:

Register 0x3F: LPCD_Qmin register

Register 0x40: LPCD_QMax register

Register 0x41: LPCD_IMin register

The calibration itself is supported by the NFC Reader Library [4]. The principle of the LPCD calibration and detection can be tested and evaluated with NFC cockpit [5].

Note: The I- and Q-channel function in LPCD is different than during normal Rx mode.

3.6 The LPCD detection

After the window values are written into the three registers as described in section 3.5, the Timer T3 and T4 must be programmed properly. Timer T3 defines the standby time ($t_{standby}$), while Timer T4 defines the RFon time (t_{RFon}). With these two times the detection speed as well as the average current consumption is defined:

$$I_{average} = \frac{I_{standby} \cdot t_{standby} + I_{StartupA} \cdot t_{StartupA} + I_{StartupB} \cdot t_{StartupB} + I_{RFon} \cdot t_{RFon}}{t_{standby} + t_{StartupA} + t_{StartupB} + t_{RFon}} \quad (6)$$

with

$I_{standby}$ = current consumption in standby or power down mode ≤ 5 µA

$I_{StartupA}$ = current consumption during StartupA ≈ 6 mA

$I_{StartupB}$ = current consumption during StartupA ≈ 2 mA

I_{RFon} = current consumption during the “normal” operation ≤ 200 mA

$t_{standby}$ = time, where the reader is in power down (no function)

$t_{StartupA}$ = time for StartupA ≈ 340 µs

$t_{StartupB}$ = time for StartupA ≈ 85 µs

t_{RFon} = time of the RF carrier switched on

The standby current $I_{Standby}$ depends on the correct definition of unused pin (see section 3.4.) Typically, this current is:

$I_{Standby}$ ≈ 3 µA

The current consumption during RFon (t_{RFon}) is defined due to the overall antenna design. Typically, this current with unloaded antenna is

I_{RFon} ≈ 100… 150 mA (high output power reader)

I_{RFon} ≈ 60… 100 mA (battery powered reader)

The average current is mainly defined with the two times for the LPCD:

$t_{Standby}$ and t_{RFon}.

The standby time defines the detection speed and typically is:

$t_{Standby}$ ≈ 200…300 ms (fast reader)

$t_{Standby}$ ≈ 300…1000 ms battery powered reader)

The RFon time depends on the antenna design and the chosen settings. It must be long enough to allow a proper detection. A longer time does neither improve nor disturb the functionality, but increases the average current consumption. Typically, this time can be:

3 µs ≤ t_{RFon} ≤ 10 µs -> normal operation (Charge pump & LPCD_FILTER disabled)

3 µs ≤ t_{RFon} ≤ 10 µs -> operation with TVDD = 5V, Charge pump enabled & LPCD_FILTER enabled

Note: the LPCD_FILTER enabled automatically increases the RF on time in case of instability, before waking up.

Note: For the normal operation, it makes sense to start with t_{RFon} = 10 µs, and try lower values, until the detection fails. Typically, this might happen at t_{RFon} ≤ 2 µs. Then a margin must be considered for the final chosen value, since on one hand there are tolerances in the overall antenna circuitry, and on the other hand the low power clock for the timer T3 and T4 during the LPCD is not very accurate.

Then with these values the LPCD Detection can be started.

3.7 LPCD features (CLRC663 *plus* only)

Following table show the features that can be used for LPCD. In the default settings, all features are disabled and the LPCD is optimized for low power consumption. Enabling the features increases the stability and the performance of the LPCD but also causes a higher current consumption.

Table 3. LPCD features

Name	Bit No.	Description
LPCD_CHARGEPUMP	3	If set, the TX-driver charge pump is switched on during RF-ON of the LPCD. This will allow for a better LPCD detection range (higher transmitter output voltage) at the cost of a higher current consumption. If this bit is cleared, the output voltage at the TX drivers will be = TVDD-0.4V. If this bit is set, the output voltage at the TX drivers will be = TVDD.
LPCD_FILTER	2	If set, The LPCD decision is based on the lowest value of 64 samples instead of a single sample. Enabling LPCD_FILTER allows to compensate for noisy conditions at the cost of a longer RF-ON time required for sampling.
LPCD_Q_UNSTABLE	1	If bit 2 of this register is set, bit 1 indicates that the Q-channel ADC value was changing during the LPCD measuring time. Note: Only valid if LPCD_FILTER (bit 2) = 1
LPCD_I_UNSTABLE	0	If bit 2 of this register is set, bit 0 Indicates that the I-channel ADC value was changing during the LPCD measuring time. Note: Only valid if LPCD_FILTER (bit2) = 1

Table 4 shows the detection range measurement results of the CLEV6630B. The board was operated with external power supply at room temperature.

Table 4. Example of LPCD range

Detection range in mm

Card type	Standard	Charge pump enabled	LPCD_FILTER enabled	Charge pump + LPCD_FILTER enabled
Threshold	+/- 1	+/- 1	+/- 0	+/- 0
MIFARE Ultralight	10.8	16.2	28.6	24.9
NTAG	18.6	24.0	36.7	32.6
MIFARE DESFire EV2	19.4	24.0	38.9	34.7
JCOP DIF	12.0	17.5	30.4	26.7
ISO RefPICC Class 6	4.2	7.3	18.0	22.7
EMVCo RefPICC	26.5	29.5	57.4	66.2

3.8 LPCD application software handling

The NFC Reader Library [4] provides the LPCD functionality, which consists of mainly the LPCD calibration and the LPCD detection. The functional flow is shown in Fig 6.

After LPCD calibration the LPCD detection is started in the unloaded condition. The CLRC663 goes into LPCD mode, until either a wake-up event (“card detected”) ends the LPCD mode or the CLRC663 is reset.

As soon as a card (or anything else) loads and detunes the antenna, the CLRC663 wakes up, and a standard polling loop or discovery loop detects, whether a card caused the detected detuning of the antenna, or the antenna was simply detuned due to some environmental changes (like temperature change).

In the latter case the LPCD needs to be recalibrated and started again.

The polling loop or discovery loop selects the card, if a card caused the wake up, and then the transaction can take place.

There are two options of continuing, after the transaction has finished:

3.8.1 Option 1: Check card removal

In typical smart phone like applications the reader software performs a “presence check” after the transaction, which keeps a continuous communication alive (e.g. with R-blocks, as described in the ISO/IEC 14443), as long as the card is present in the RF field. As soon as the card is being removed from the field the presence check ends, and the LPCD is recalibrated and started again in the unloaded condition.

3.8.2 Option 2: Recalibrate and restart LPCD

The presence check might result in higher power consumption due to the continuous card communication, as long as the card is still present. So, the alternative is to directly recalibrate and start the LPCD after the transaction has finished.

This causes the LPCD to calibrate with the card still being present in the RF field (i.e. loading the antenna). As soon as the card then is being removed from the field, the

LPCD will detect the detuning (from loaded to unloaded) and wake up. The polling loop or discovery loop then will detect no card and re-calibrate and re-start the LPCD a second time.

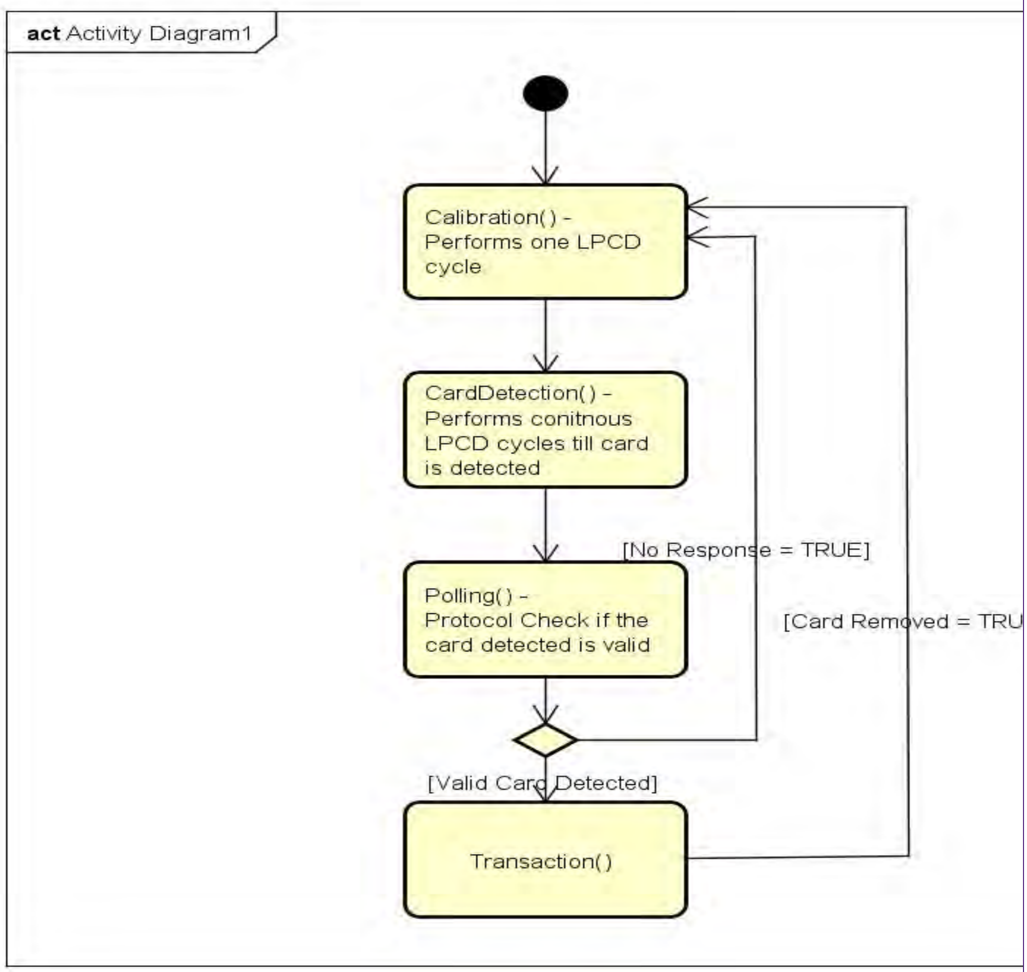


Fig 6. LPCD calibration and detection

4. References

[1] CLRC663 *plus* datasheet, www.nxp.com

[2] AN11145, CLRC663, MFRC631, MFRC 630, SLRC610 Low Power Card Detection, www.nxp.com

[3] CLEV66303 script files, www.nxp.com

[4] NXP NFC Reader Library, www.nxp.com

[5] NFC Cockpit, www.nxp.com

5. Legal information

5.1 Definitions

Draft — The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

5.2 Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. NXP Semiconductors takes no responsibility for the content in this document if provided by an information source outside of NXP Semiconductors.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the *Terms and conditions of commercial sale* of NXP Semiconductors.

Right to make changes — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

Suitability for use — NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors and its suppliers accept no liability for inclusion and/or use of NXP Semiconductors products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

Applications — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

Export control — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from competent authorities.

Translations — A non-English (translated) version of a document is for reference only. The English version shall prevail in case of any discrepancy between the translated and English versions.

5.3 Licenses

Purchase of NXP ICs with NFC technology

Purchase of an NXP Semiconductors IC that complies with one of the Near Field Communication (NFC) standards ISO/IEC 18092 and ISO/IEC 21481 does not convey an implied license under any patent right infringed by implementation of any of those standards. Purchase of NXP Semiconductors IC does not include a license to any NXP patent (or other IP right) covering combinations of those products with other products, whether hardware or software.

Purchase of NXP ICs with ISO/IEC 14443 type B functionality

This NXP Semiconductors IC is ISO/IEC 14443 Type B software enabled and is licensed under Innovatron's Contactless Card patents license for ISO/IEC 14443 B.

The license includes the right to use the IC in systems and/or end-user equipment.

RATP/Innovatron Technology

5.4 Trademarks

Notice: All referenced brands, product names, service names and trademarks are property of their respective owners.

MIFARE — is a trademark of NXP B.V.

MIFARE DESFire — is a trademark of NXP B.V.

MIFARE Ultralight — is a trademark of NXP B.V.

NTAG — is a trademark of NXP B.V.

6. Contents

Date of release: 3 May 2017
413310

Document identifier: AN11783