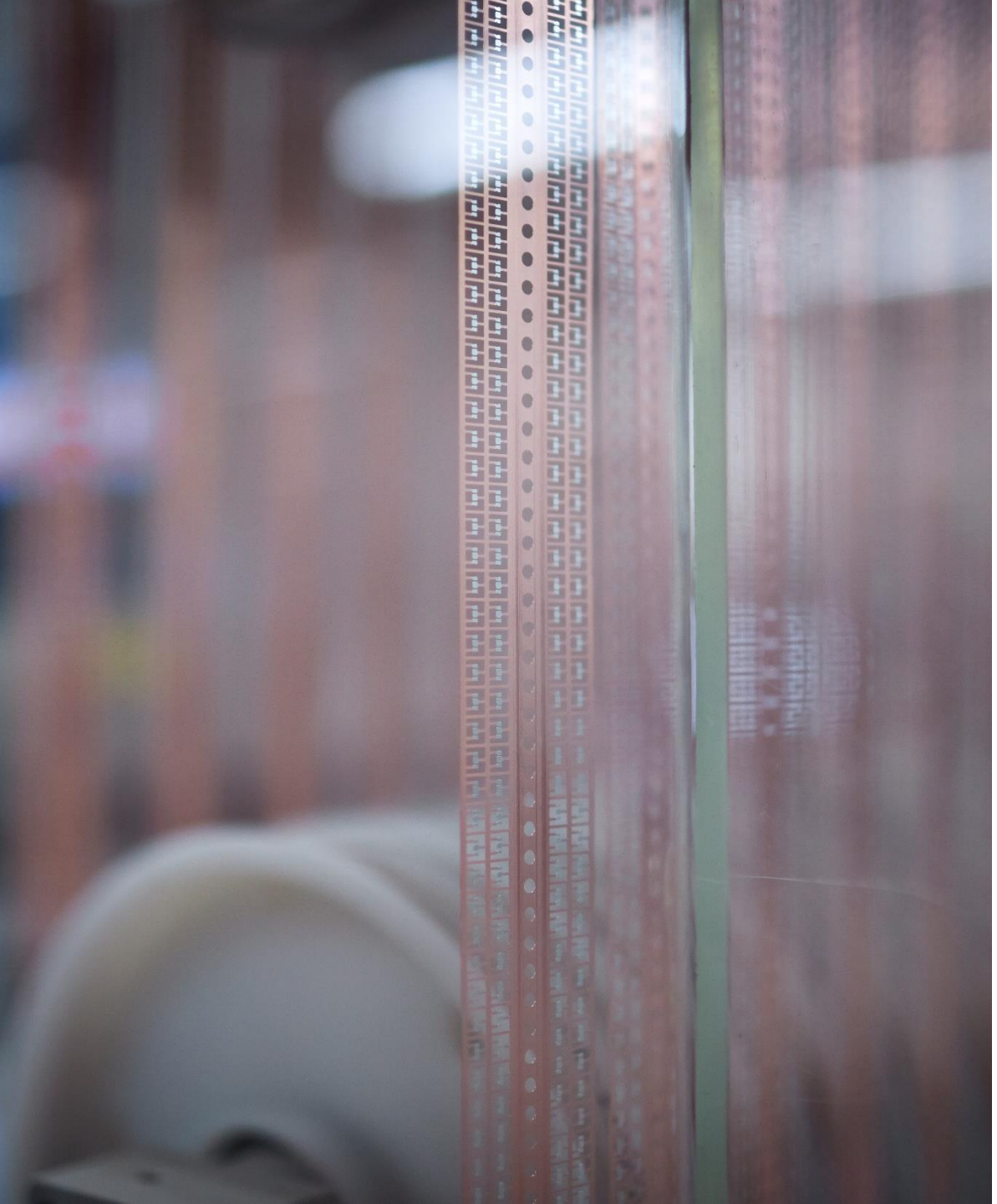
DEVICE-TO-DEVICE COMMUNICATION VIA NFC

WEBINAR SERIES:
HOW TO BUILD NFC APPLICATIONS

JORDI JOFRE
NFC READERS
NFC EVERYWHERE
07/03/2017

SECURE CONNECTIONS
FOR A SMARTER WORLD



Agenda

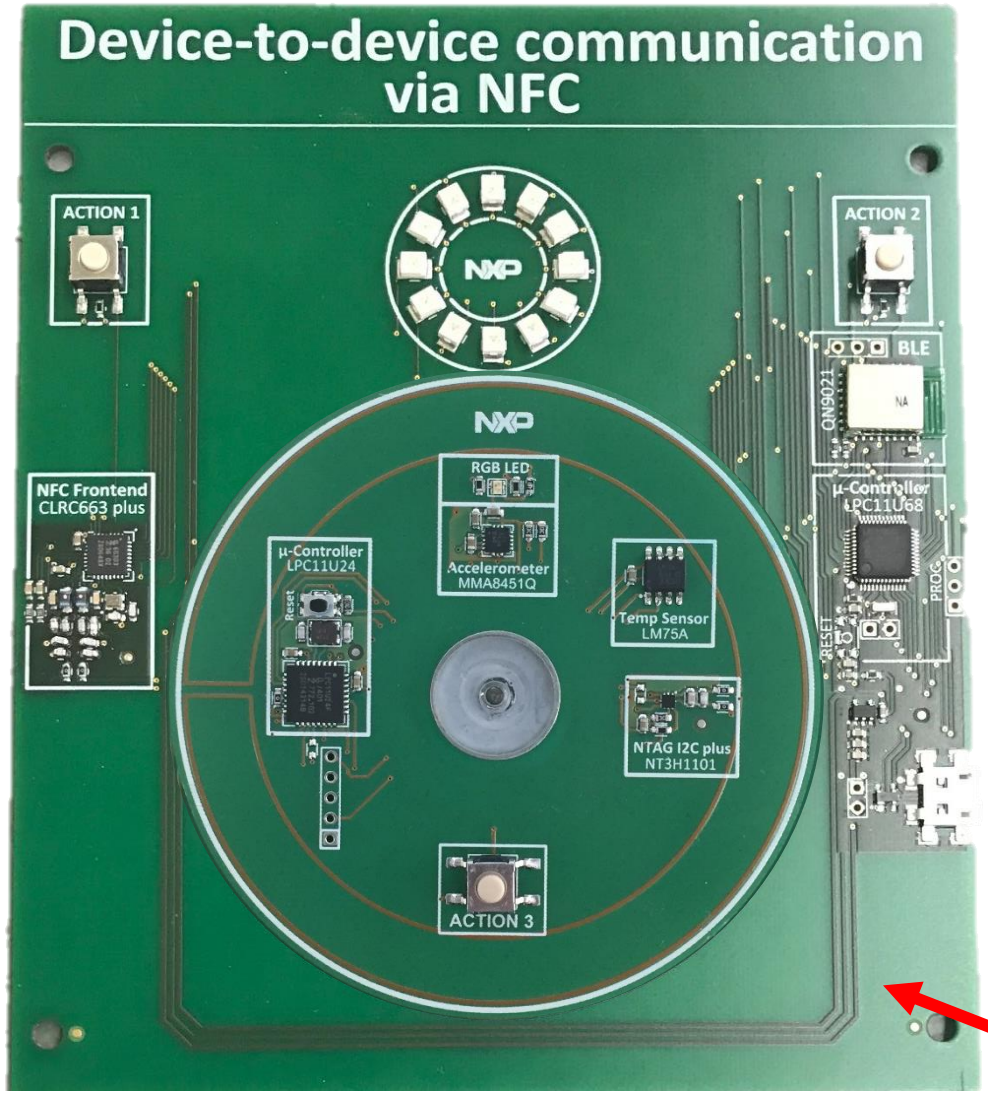
- Device-to-device communication demo
  - Demo functionality
  - Hardware details
  - Application logic
    (How the CLRC663 *plus* and NTAG I²C *plus* are used)
  - MCU code details
    (for CLRC663 *plus* and NTAG I²C *plus*)
  - Available resources

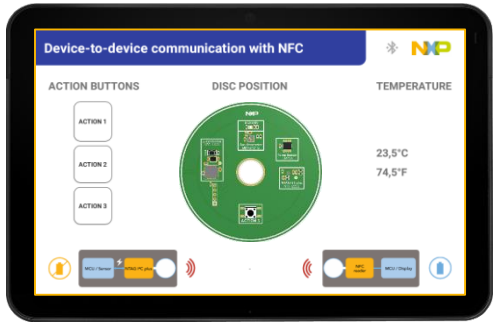
- Wrap up and Q&A

DEMO FUNCTIONALITY

Device-to-device communication via NFC demo

Elements





Optional tablet display (BLE connection)

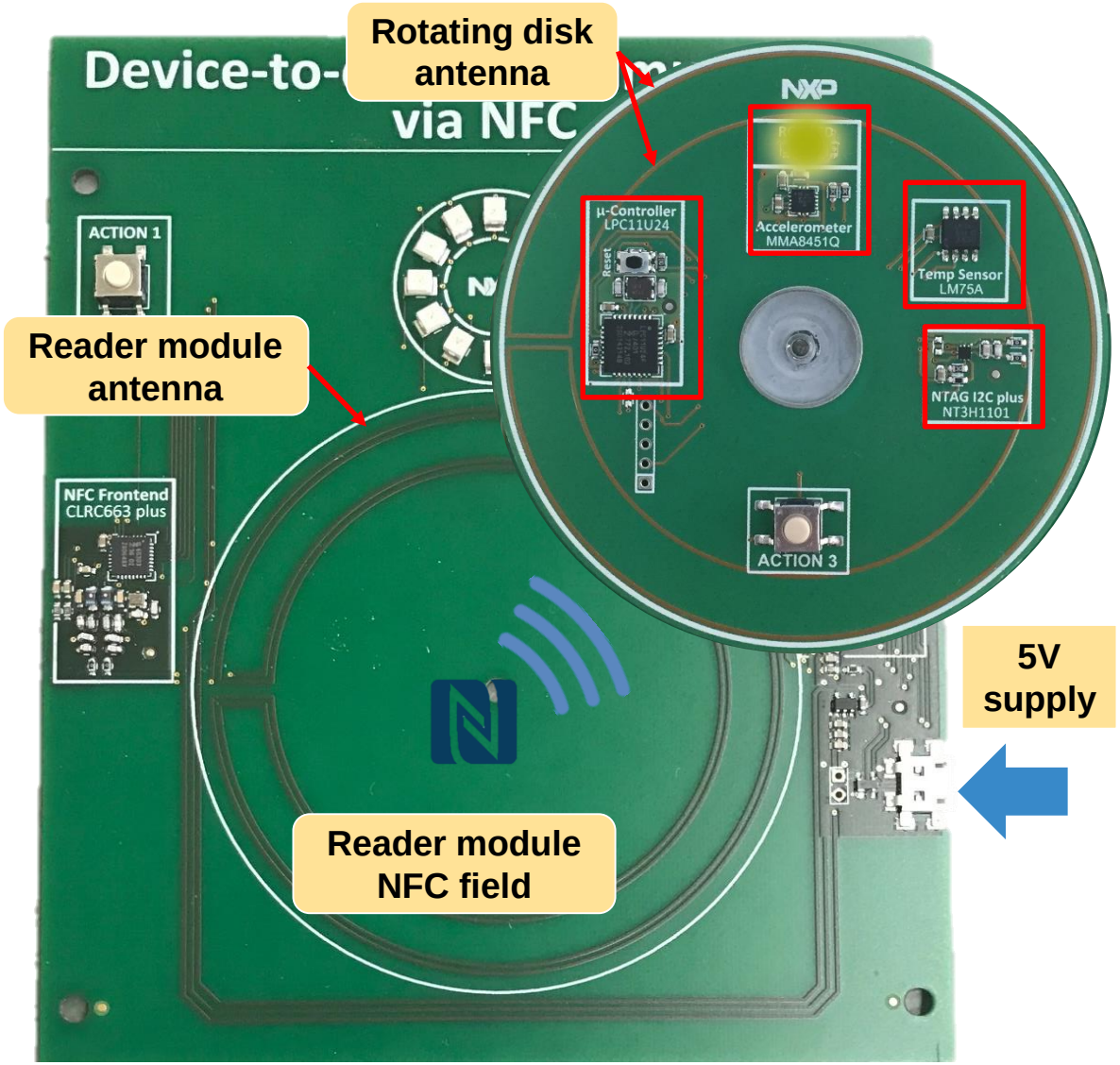
Reader module & rotating sensor communicate via NFC

Rotating disk (8 cm diameter)

Reader module (14x12 cm)

Device-to-device communication via NFC demo

Use cases



NFC application

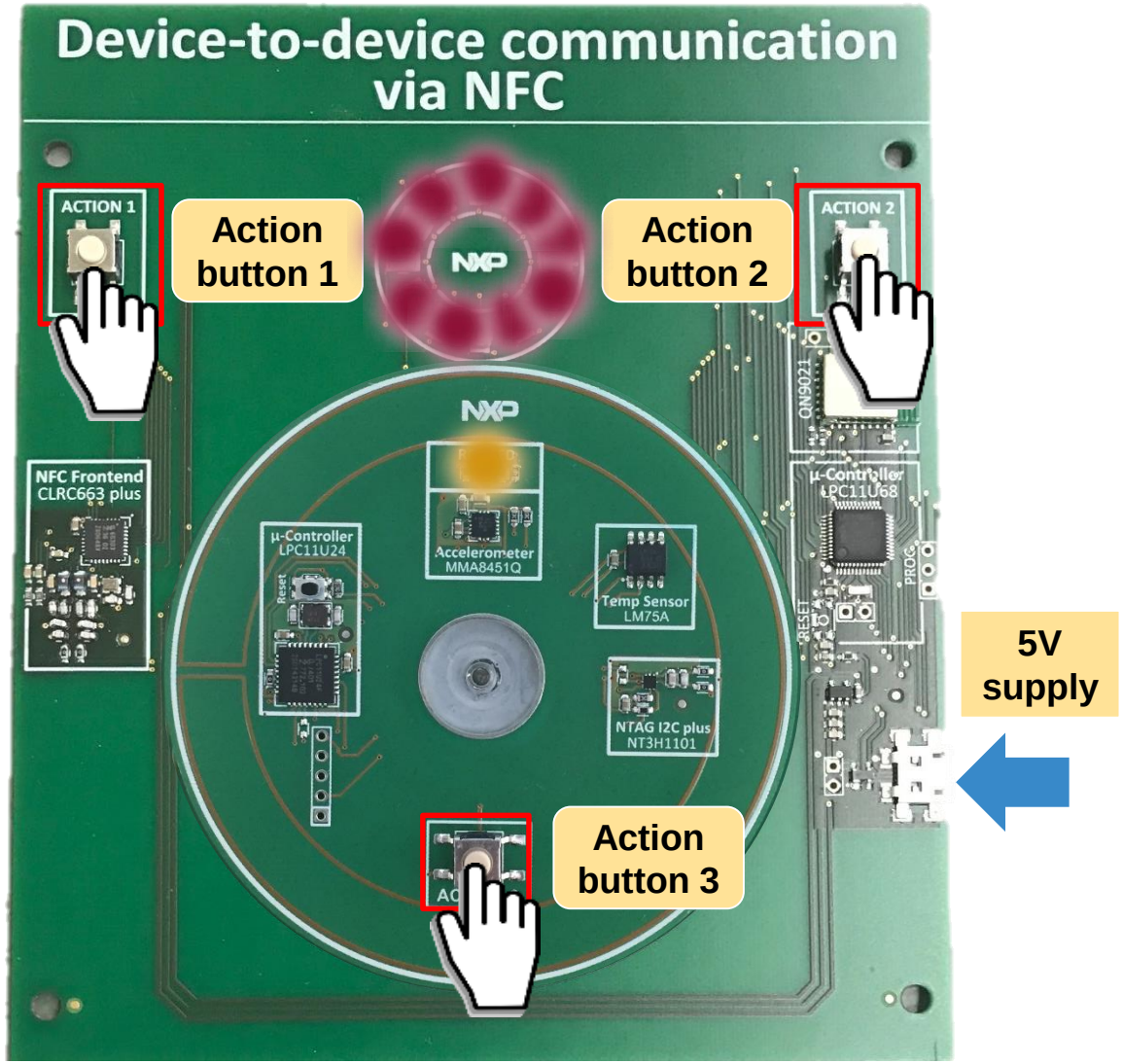
- NFC for communication with a batteryless unit. The reader's NFC field can supply and operate low-power electronics.

Demo use case:

- Once the reader module is supplied, all the electronics on the rotating disk are powered by harvesting energy from the reader module's RF field (Green LED on)

Device-to-device communication via NFC demo

Use cases (II)



NFC application

- NFC for communication between 2 devices mounted in close vicinity that need to be completely isolated (e.g. dust proof)

Demo use case 1: Bidirectional exchange of static information

Reader module → rotating disk communication:

- Action **Button 1** is pressed→ RGB LED on rotating disk turns **blue**.
- Action **Button 2** is pressed →RGB LED on rotating disk turns **red**.
- Action **Button 1 & 2** are pressed → RGB LED on rotating disk turns white.

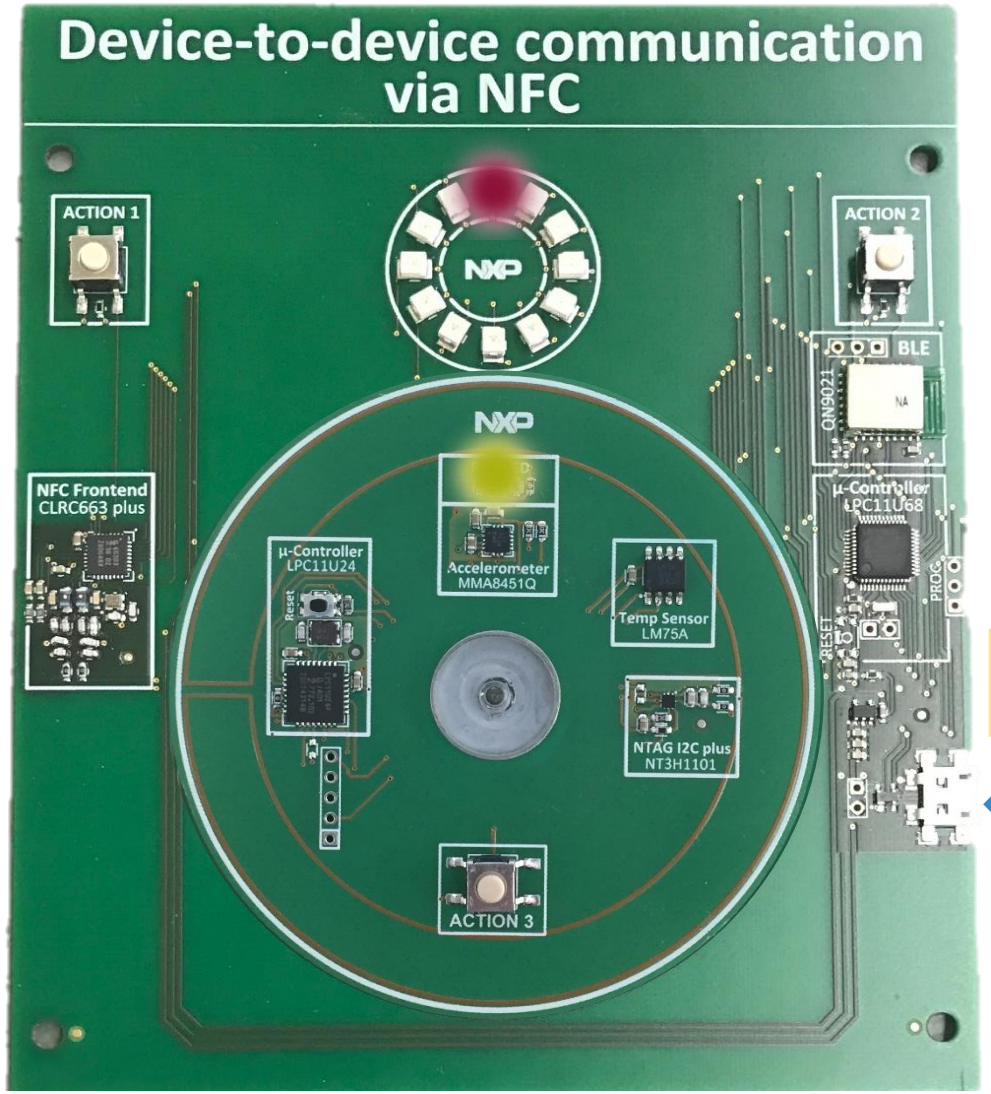
Demo use case 2: Bidirectional exchange of static information

Rotating disk → Reader module communication:

- Action Button 3 is pressed→ LED pattern on LED circle will appear.

Device-to-device communication via NFC demo

Use cases (III)



5V supply

NFC application

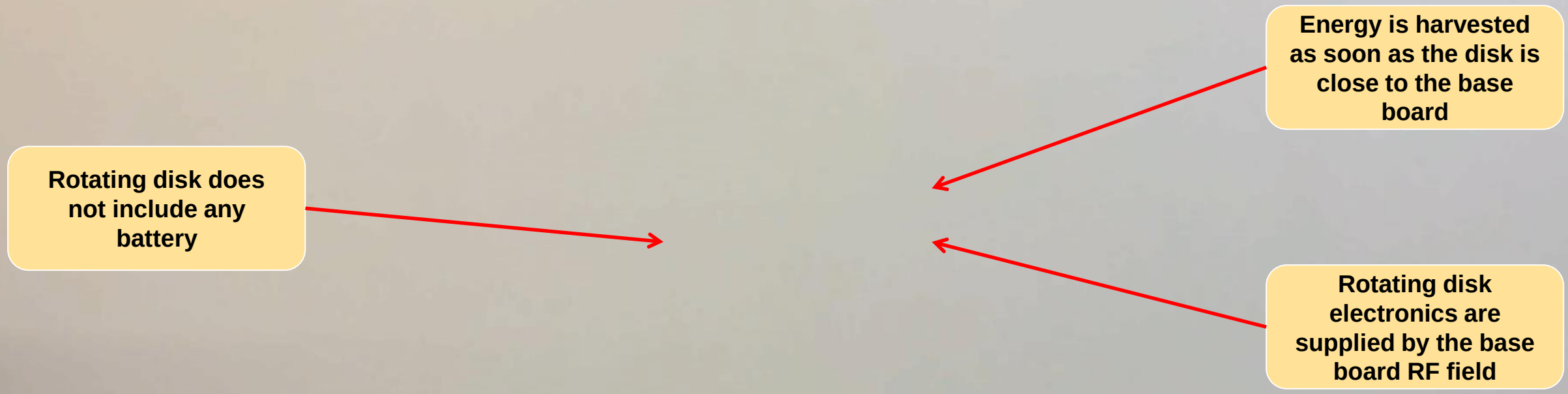
- NFC for communication with a rotating part as a cable replacement solution

Demo use case 3: Bidirectional exchange of dynamic information

- The rotating disk is able to harvest energy from the RF's field of the reader module even if the disk is moving.
- The acceleration sensor measures x,y,z coordinates of the disk, the angle is calculated and the sensor position is displayed on the LED circle on the reader board.
- Android App:
  Action button data, rotation angle and temperature information is additionally sent via BLE to connected App.

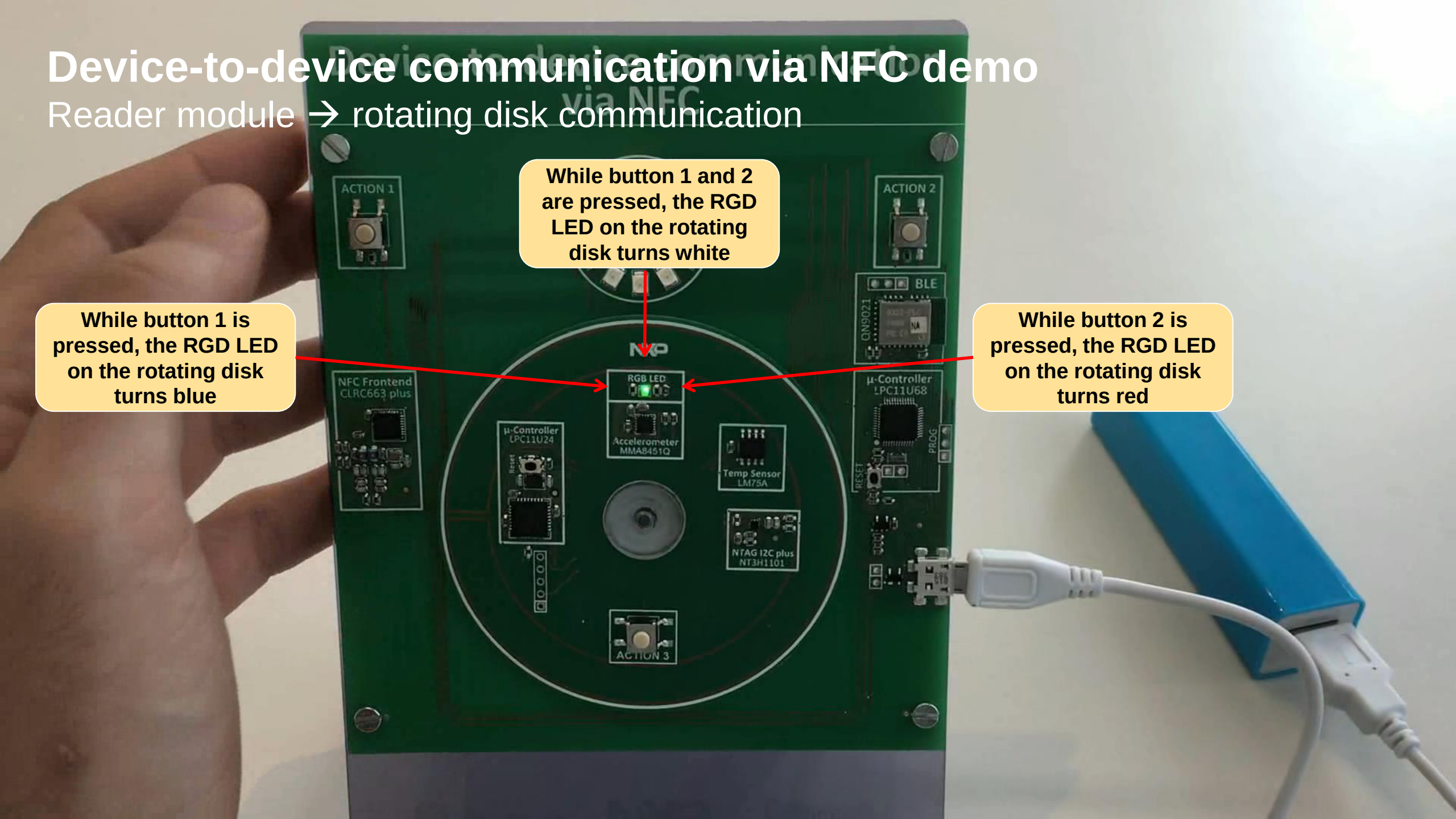
Device-to-device communication via NFC demo

Energy harvesting



Device-to-device communication via NFC demo

Reader module → rotating disk communication

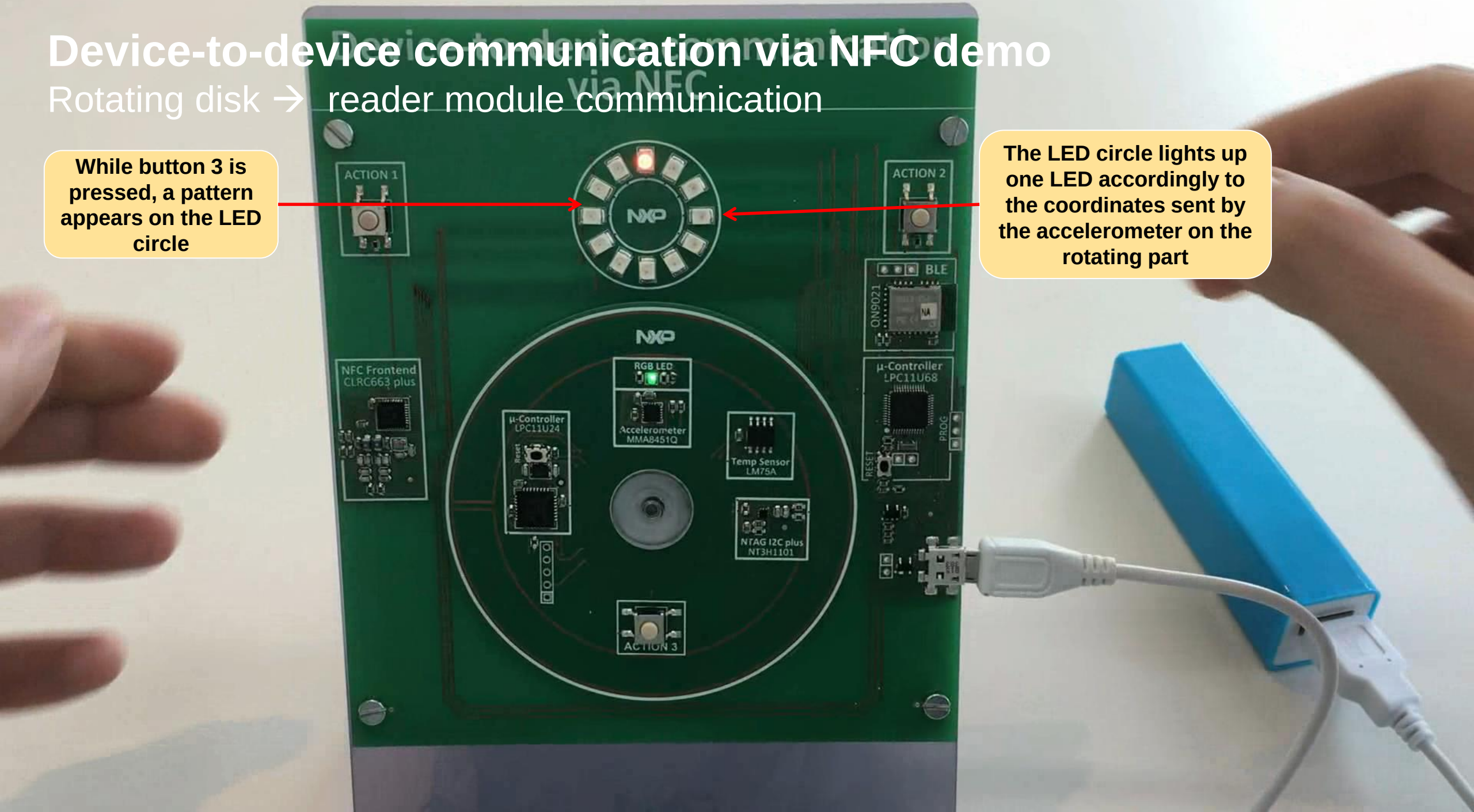


Device-to-device communication via NFC demo

Rotating disk → reader module communication

While button 3 is pressed, a pattern appears on the LED circle

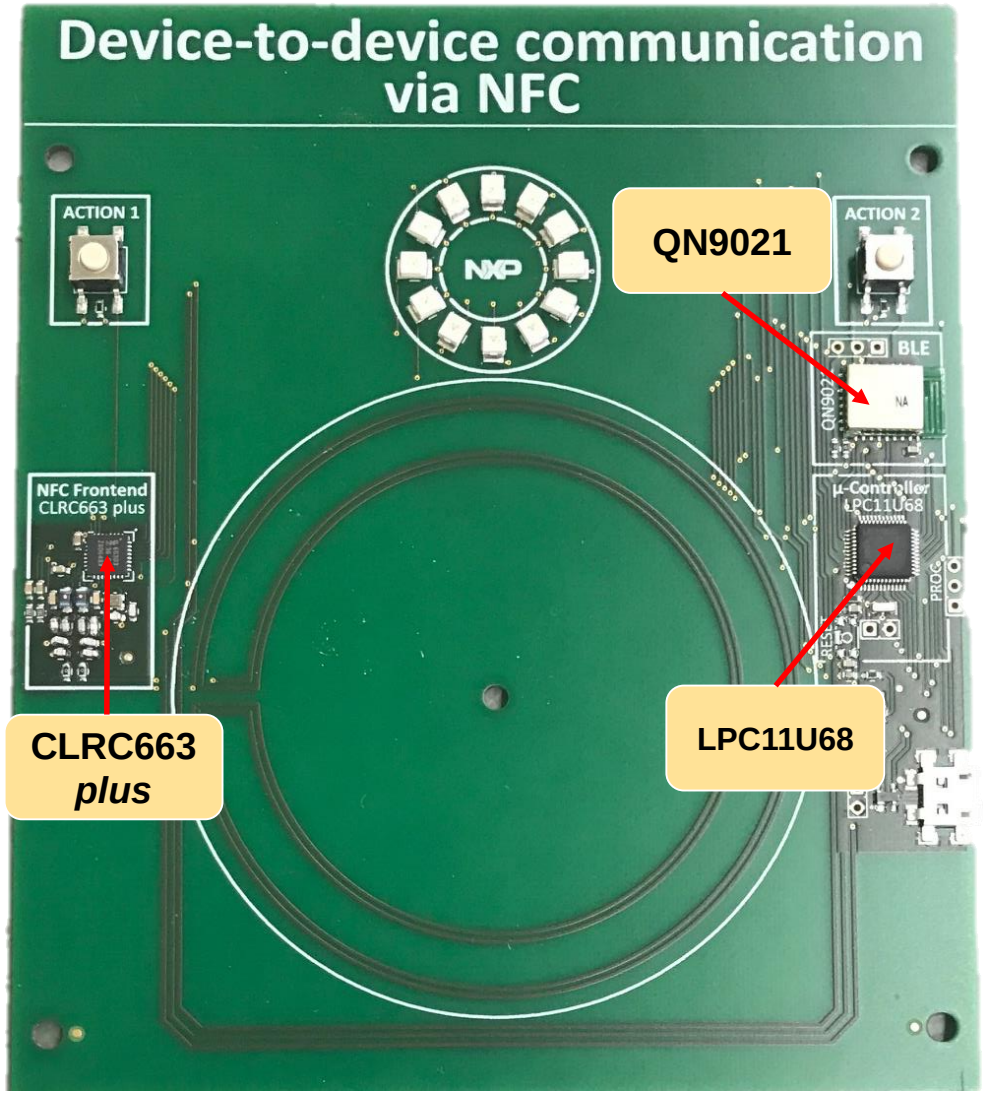
The LED circle lights up one LED accordingly to the coordinates sent by the accelerometer on the rotating part

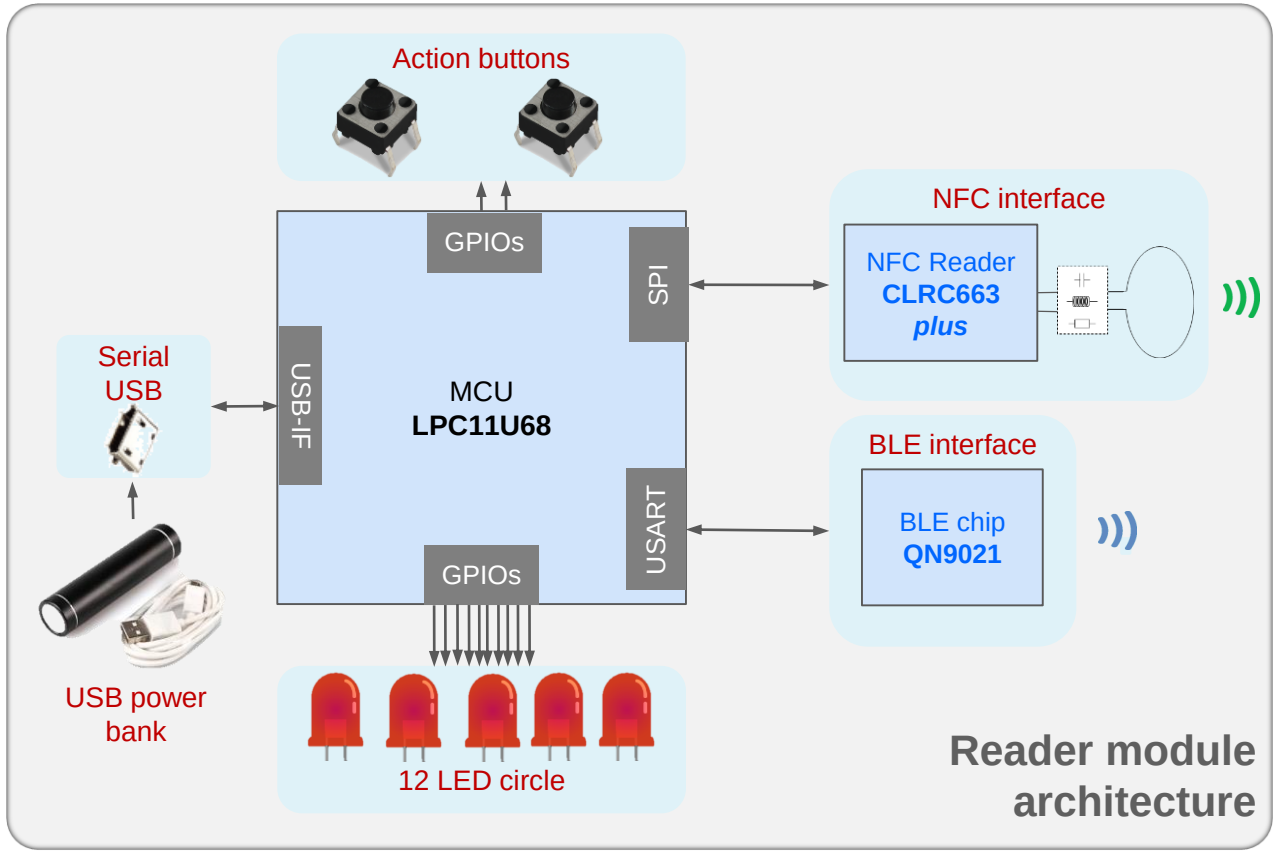


HARDWARE DETAILS

Reader module architecture

Board based on CLRC663 *plus*



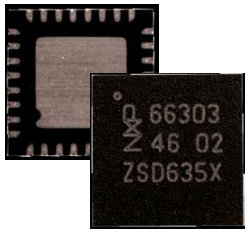


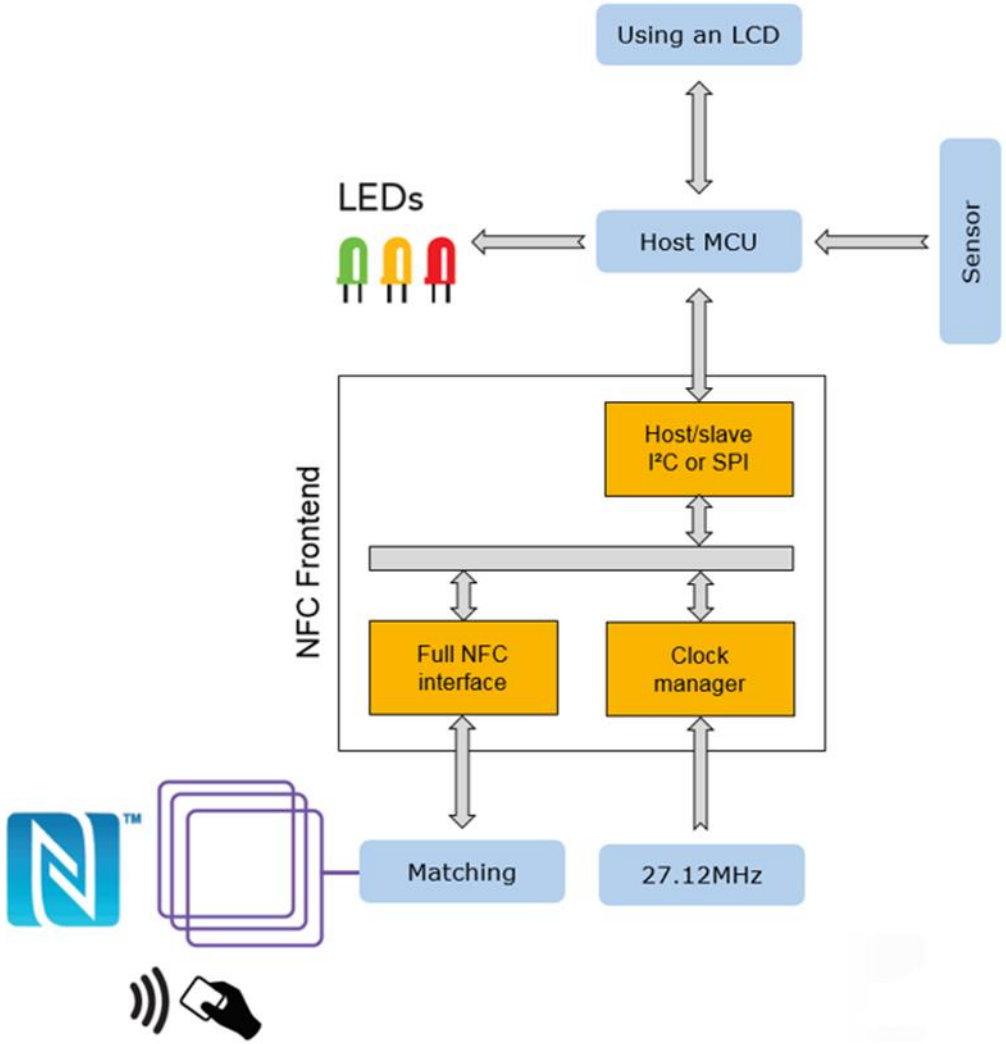
Rotating disk

Android App

* HW schematics are available

CLRC663 *plus* product highlights





Best performance at lowest power consumption
Extended LPCD (Low Power Card Detection) range with new configuration options.
Low supply voltage for battery support down to 2.5V

Design flexibility
Max. operating Tx current of 350mA with limiting value of 500mA.
Chip temperature range from -40 ºC to 105ºC

Backward compatibility
Pin-to-pin compatible to CLRC663

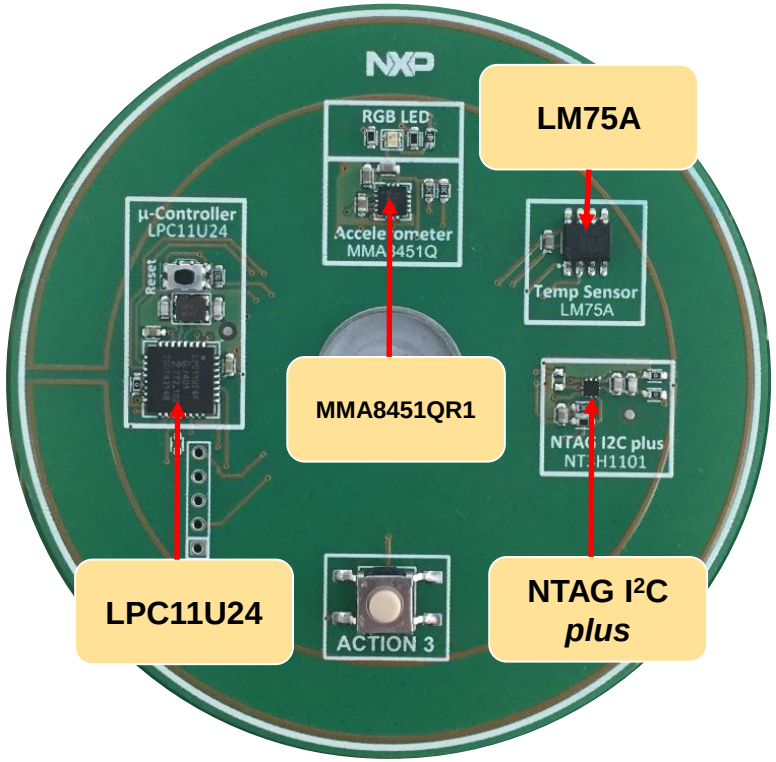
Faster time-to-market
Complete support package including EMVCo compliant NFC SW Library and NFC Cockpit for easy antenna configuration

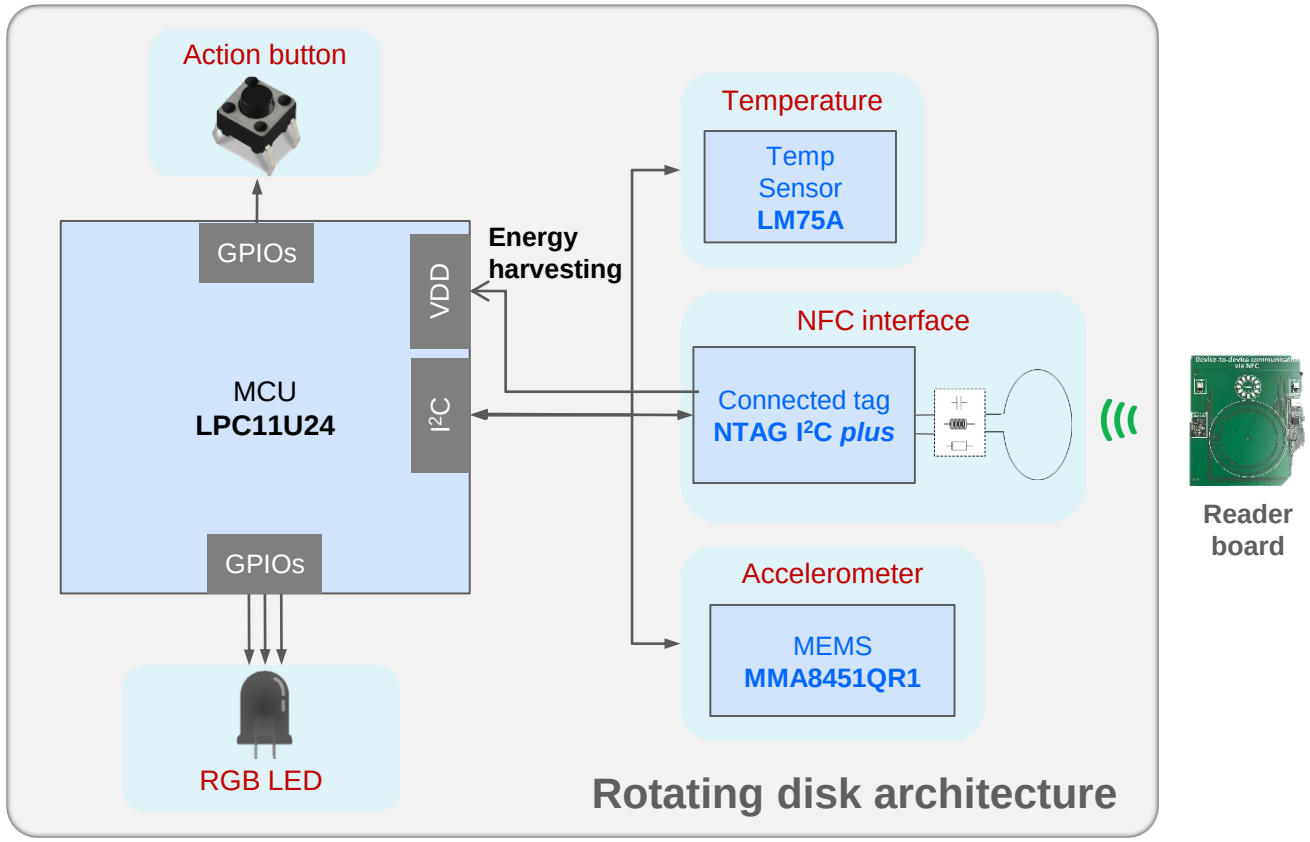
* More CLRC663 *plus* info on product launch

Training Mobile Knowledge

Rotating disk architecture

Passive board based on NTAG I²C *plus*





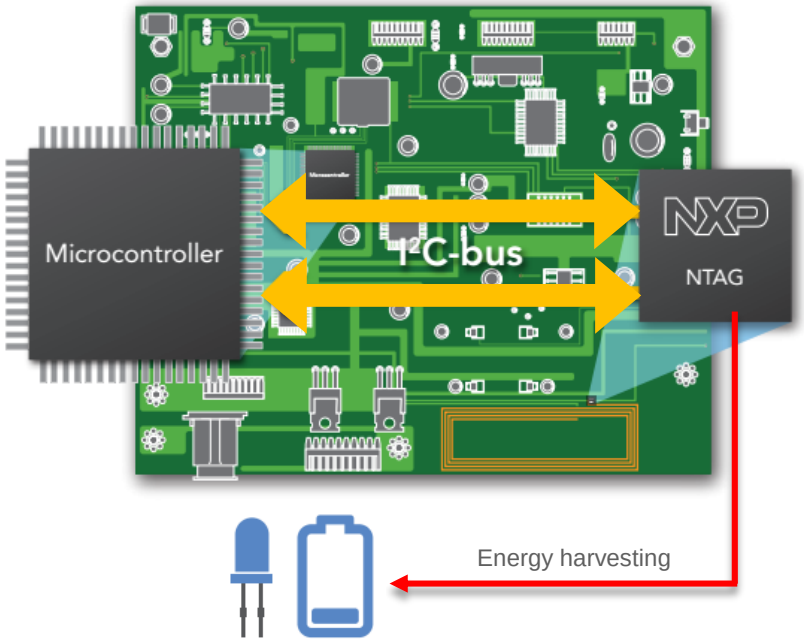
Reader board

* HW schematics are available

Training Mobile Knowledge

NTAG I²C *plus* product highlights

The NTAG I²C *plus* connects to the microcontroller via the I²C serial bus interface



NFC-enabled mobile device connects to the MCU via the NFC interface, using the I²C as the communication conduit

- Field Detection
- Energy harvesting
- SRAM memory
- SRAM mirroring
- Pass-through mode
- Memory access management
- Originality signature

Training Mobile Knowledge

How to use NTAG I²C *plus* SRAM for bidirectional data exchange

- The pass-through mode provides:
  - The SRAM for bidirectional data transfer from an NFC device to an I²C bus master
  - Triggering mechanisms for the synchronization of the data transfer.

- The data transfer signaling can be done though:
  - The Field Detection pin
  - Polling / reading specific NTAG I²C *plus* registers.

- NFC to I²C data transfer signaling:
  - The host polls **SRAM_I2C_READY** to learn if new data has been written by the RF interface in the SRAM.
  - A trigger on the FD pin (FD voltage goes from **HIGH** to **LOW**) indicates to the host that data is ready to be read from SRAM.
- I²C to NFC data transfer signaling:
  - The NFC interface polls **SRAM_RF_READY** to learn if new data has been written by the I²C interface in the SRAM.
  - A trigger on the FD pin (FD voltage goes from **LOW** to **HIGH**) indicates to the host that data has been read from SRAM by the NFC interface.

Register bit	Use
PTHRU_ON_OFF	Detect if the pass-through mode is still enabled (gets reset in case of RF or I2C power down)
TRANSFER_DIR	Defines the data flow direction for the data transfer
I2C_LOCKED	Detect if memory access is currently locked to I2C
RF_LOCKED	Detect if Memory access is currently locked to RF
SRAM_I2C_READY	Detect if there is data available in the SRAM buffer to be fetched by I²C
SRAM_RF_READY	Detect if there is data available in the SRAM buffer to be fetched by RF
RF_FIELD_PRESENT	Shows if a RF field strong enough to read the tag is there

Table. Register bits which can be used for communication synchronization

Important:
Read / write operations to the termination page of the SRAM is what trigger register flags.

AN11579 - How to use the NTAG® I²C and NTAG I²C plus for bidirectional communication

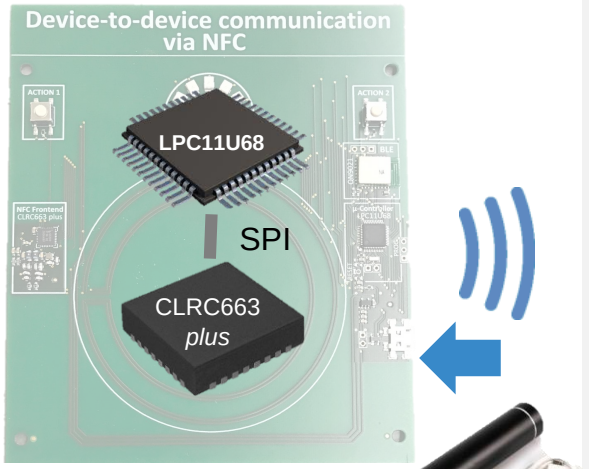
Training Mobile Knowledge

APPLICATION LOGIC

READER MODULE → ROTATING DISK COMMUNICATION

Reader module → rotating disk communication

Energy harvesting



1. Once base board is powered, it starts generating RF field

Page address (HEX)	Byte number within a page			
	0	1	2	3
0x00				
0x01				
0x02				
0x03				
0x04				
0x05				
…	… …	NTAG I²C plus		… …
0xF0				
…	….			
0xFB				
0xFC				
0xFD				
0xFE				
0xFF				

Fig. Simplified NTAG I²C *plus* memory map (NFC interface perspective)

NTAG I²C *plus* energy harvesting pin (Vout)

I²C

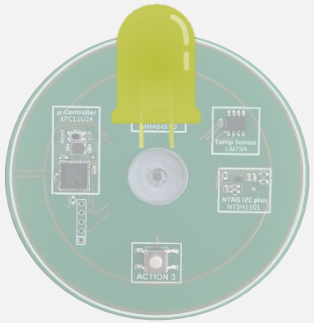
2. MCU powers up harvesting energy from the RF field

GPIO 16 - red

GPIO 17 - green

GPIO 18 - blue

3. MCU changes GPIO 17 to HIGH level



4. LED turns on green

Rotating disk

SRAM mirror memory area (volatile memory)

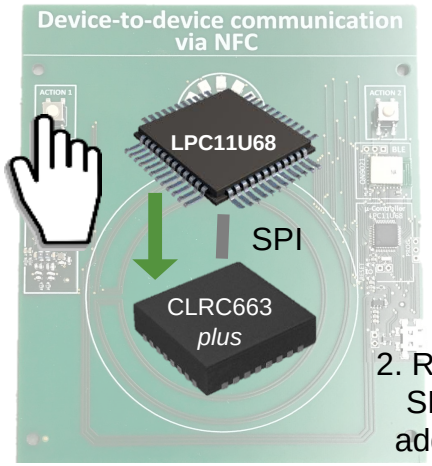
EEPROM memory area (non-volatile memory)

*Rotating disk electronics are supplied by the base board RF field

Training Mobile Knowledge

Reader module → rotating disk communication

Action button 1



1. MCU GPIO 4 is in HIGH level

2. Reader writes SRAM page address 0xFF

Page address (HEX)	Byte number within a page			
	0	1	2	3
0x00				
0x01				
0x02				
0x03				
0x04				
0x05				
…	… …	NTAG I²C plus		… …
0xF0				
…	….			
0xFB				
0xFC				
0xFD				
0xFE				
0xFF	**0x00**	0x00	0x00	**0x01**

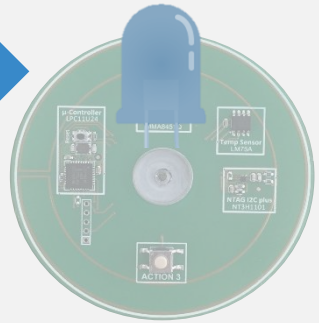
Fig. Simplified NTAG I²C *plus* memory map (NFC interface perspective)

I²C

3. MCU reads config from SRAM

GPIO 16 - red
GPIO 17 - green
GPIO 18 - blue

4. MCU changes GPIO 18 to HIGH level



5. LED turns on blue

Data flow direction (SRAM in pass through mode)

Rotating disk

SRAM mirror memory area (volatile memory)

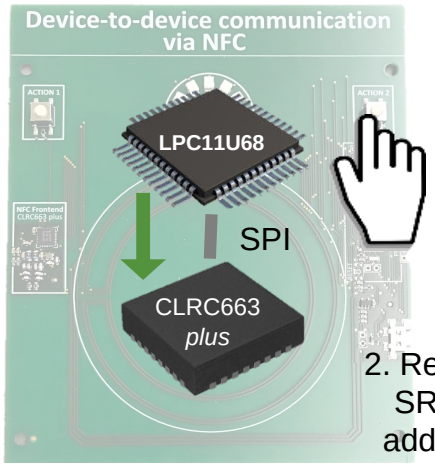
EEPROM memory area (non-volatile memory)

*Rotating disk electronics are supplied by the base board RF field

Training Mobile Knowledge

Reader module → rotating disk communication

Action button 2



1. MCU GPIO 5 is in HIGH level

2. Reader writes SRAM page address 0xFF

Page address (HEX)	Byte number within a page			
	0	1	2	3
0x00				
0x01				
0x02				
0x03				
0x04				
0x05				
…	… …	NTAG I²C plus		… …
0xF0				
…	….			
0xFB				
0xFC				
0xFD				
0xFE				
0xFF	**0x00**	0x00	0x00	**0x02**

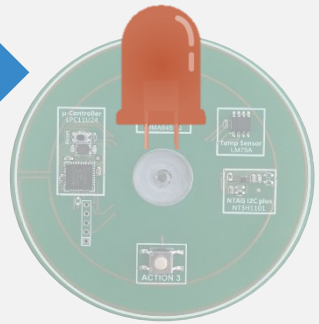
Fig. Simplified NTAG I²C *plus* memory map (NFC interface perspective)

I²C

3. MCU reads config from SRAM

GPIO 16 - red
GPIO 17 - green
GPIO 18 - blue

4. MCU changes GPIO 16 to HIGH level



5. LED turns on red

Data flow direction (SRAM in pass through mode)

Rotating disk

SRAM mirror memory area (volatile memory)

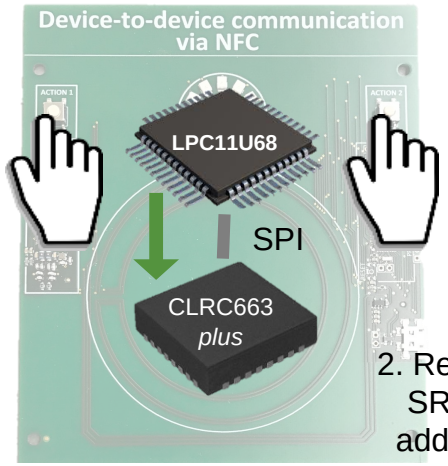
EEPROM memory area (non-volatile memory)

*Rotating disk electronics are supplied by the base board RF field

Training Mobile Knowledge

Reader module → rotating disk communication

Action button 1&2

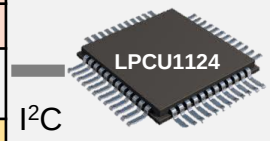


1. MCU GPIO 4, 5 are in HIGH level

2. Reader writes SRAM page address 0xFF

Page address (HEX)	Byte number within a page			
	0	1	2	3
0x00				
0x01				
0x02				
0x03				
0x04				
0x05				
…	… …	NTAG I²C plus		… …
0xF0				
…	….			
0xFB				
0xFC				
0xFD				
0xFE				
0xFF	**0x00**	0x00	0x00	**0x03**

Fig. Simplified NTAG I²C *plus* memory map (NFC interface perspective)

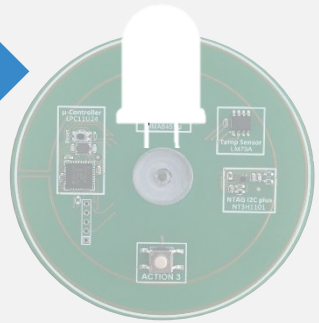


I²C

3. MCU reads config from SRAM

GPIO 16 - red
GPIO 17 - green
GPIO 18 - blue

4. MCU changes GPIO 16, 17, 18 to HIGH level



5. LED turns on white

Data flow direction (SRAM in pass through mode)

Rotating disk

SRAM mirror memory area (volatile memory)

EEPROM memory area (non-volatile memory)

*Rotating disk electronics are supplied by the base board RF field

Important: It is what is written in **SRAM** what **controls** the behavior of the **disk RGB LED**, demonstrating **data exchange** between the two embedded systems.

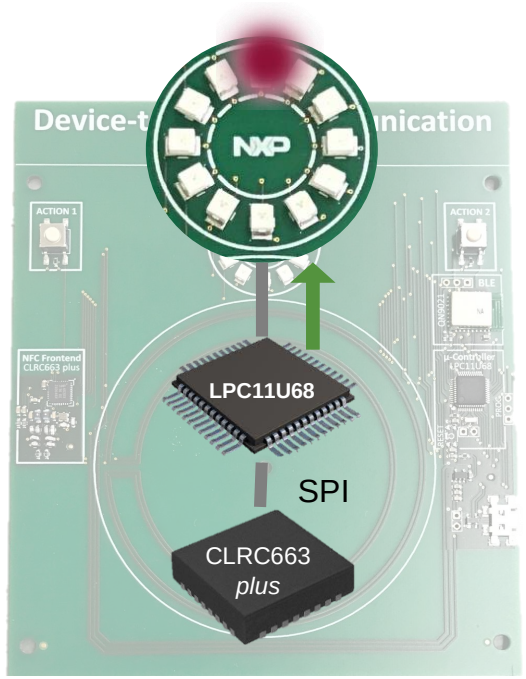
Training Mobile Knowledge

APPLICATION LOGIC

ROTATING DISK→ BASE BOARD COMMUNICATION

Rotating disk → Reader module communication

Accelerometer (I)



4. MCU calculates angle and sets to HIGH level the appropriate GPIO (steps of 30 degrees)

3. Reader reads SRAM

Page address (HEX)	Byte number within a page			
	0	1	2	3
0x00				
0x01				
0x02				
0x03				
0x04				
0x05				
…	… …			… …
0xF0				
…	….			
0xFB				
0xFC				
0xFD			Cz	Cz
0xFE	Cy	Cy	Cx	Cx
0xFF	T1	T2		

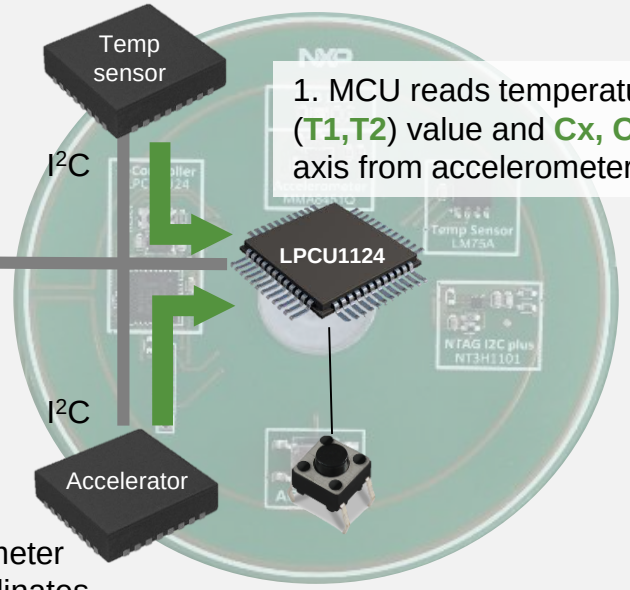
Fig. Simplified NTAG I²C *plus* memory map (NFC interface perspective)

2. MCU writes into SRAM

I²C

Rotating disk

Temperature reading occupies two bytes (T1,T2)



1. MCU reads temperature (T1,T2) value and Cx, Cy, Cz axis from accelerometer

Accelerometer axis coordinates occupy 6 bytes (Cx, Cy, Cz)

SRAM mirror memory area (volatile memory)

EEPROM memory area (non-volatile memory)

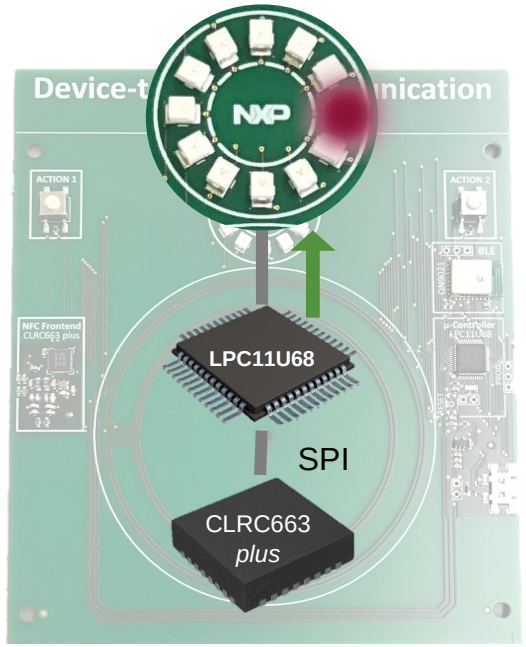
Data flow direction (SRAM in pass through mode)

*Rotating disk electronics are supplied by the base board RF field

Training Mobile Knowledge

Rotating disk → Reader module communication

Accelerometer (II)



5. MCU calculates angle and sets to HIGH level the appropriate GPIO (steps of 30 degrees)

4. Reader reads SRAM

Page address (HEX)	Byte number within a page			
	0	1	2	3
0x00				
0x01				
0x02				
0x03				
0x04				
0x05				
…	… …			… …
0xF0				
…	….			
0xFB				
0xFC				
0xFD			Cz	Cz
0xFE	Cy	Cy	Cx	Cx
0xFF	T1	T2		

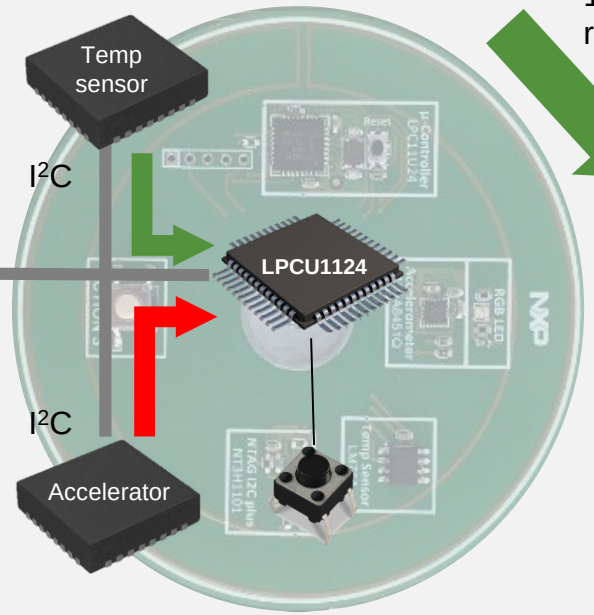
Fig. Simplified NTAG I²C *plus* memory map (NFC interface perspective)

3. MCU writes into SRAM

I²C

Rotating disk

1. Disk rotates 90º



2. MCU reads temperature value and the **updated** **Cx, Cy, Cz** coordinates from accelerometer

*Rotating disk electronics are supplied by the base board RF field

SRAM mirror memory area (volatile memory)

EEPROM memory area (non-volatile memory)

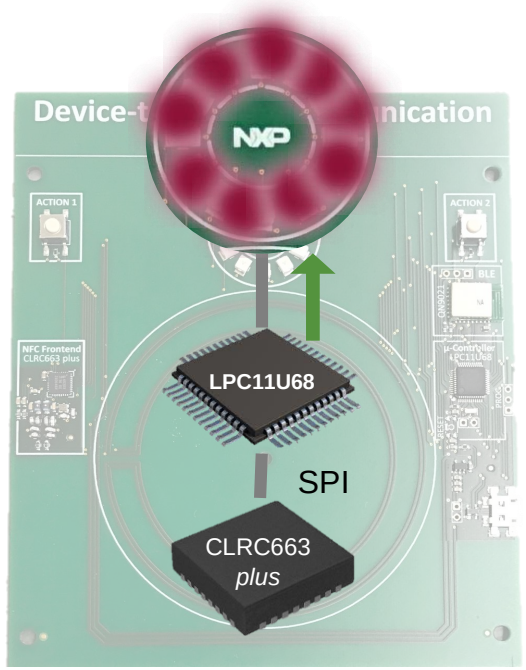
Data flow direction (SRAM in pass through mode)

Important: The **LED circle** operation is directly **controlled** by the **disk position** coordinates sent via the **SRAM**!

Training Mobile Knowledge

Rotating disk → Reader module communication

Action button 3



4. MCU set to HIGH level the 12 GPIOs controlling the 12 LEDs.

3. Reader reads SRAM

Page address (HEX)	Byte number within a page			
	0	1	2	3
0x00				
0x01				
0x02				
0x03				
0x04				
0x05				
…	… …			… …
0xF0				
…	….			
0xFB				
0xFC				
0xFD			Cz	Cz
0xFE	Cy	Cy	Cx	Cx
0xFF	T1	T2	0x01	

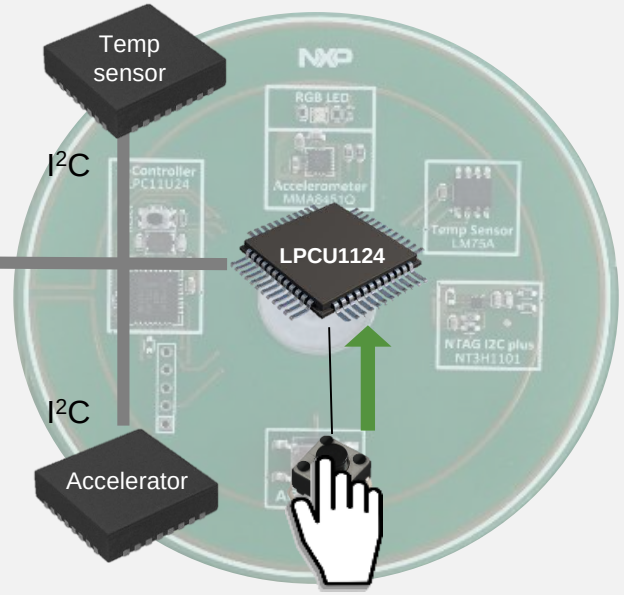
Fig. Simplified NTAG I²C *plus* memory map (NFC interface perspective)

2. MCU writes into SRAM

I²C

I²C

I²C



1. While user presses action button 3, the LPC11U24 GPIO 12 is in HIGH level.

Rotating disk

SRAM mirror memory area (volatile memory)

EEPROM memory area (non-volatile memory)

Data flow direction (SRAM in pass through mode)

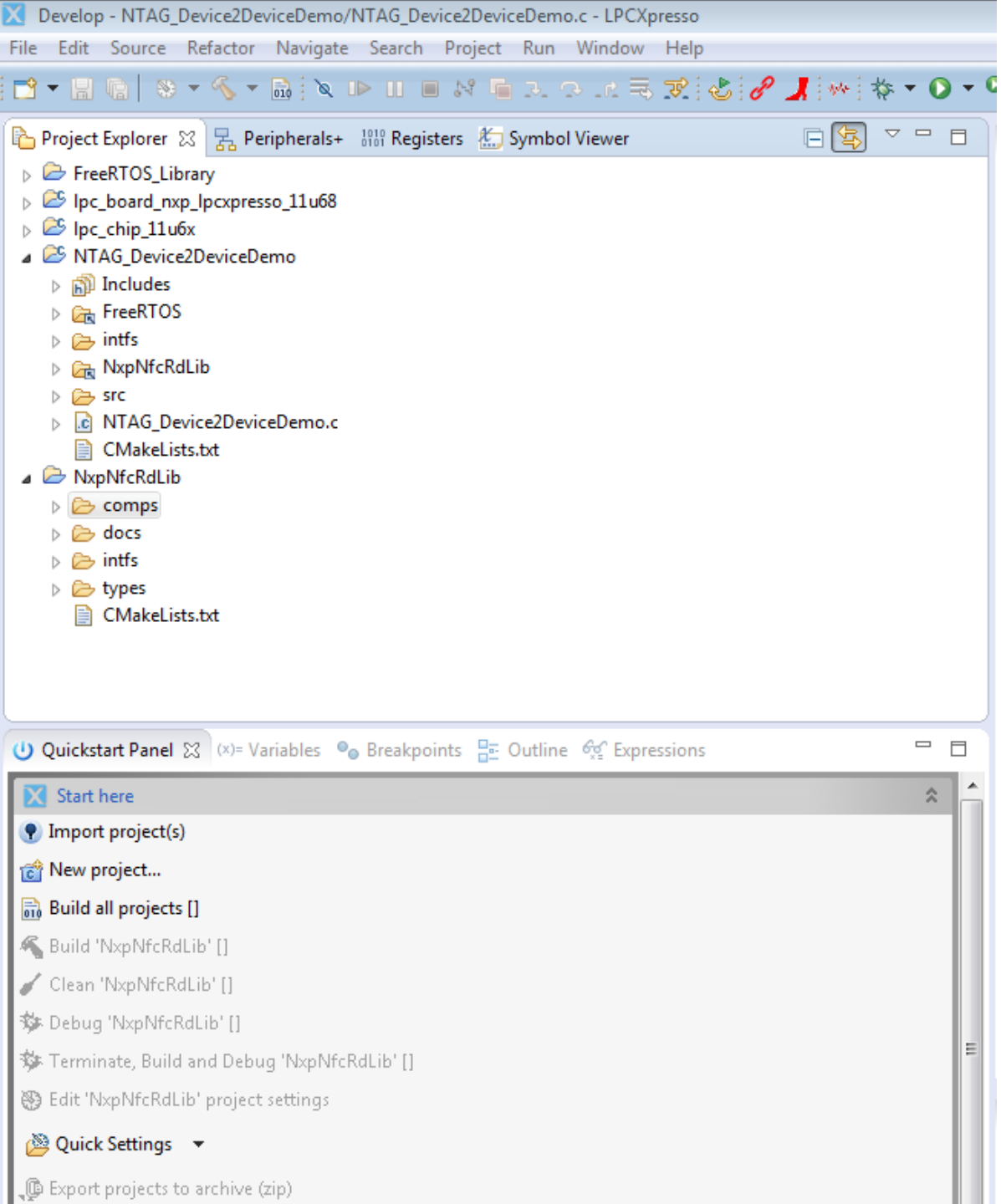
*Rotating disk electronics are supplied by the base board RF field

Important: The **LED circle pattern** is triggered by a specific data byte sent via the **SRAM**!

Training Mobile Knowledge

MCU CODE DETAILS

READER MODULE (CLRC663 *PLUS*)



Reader module MCU code

FreeRTOS Library

FreeRTOS is an open source real-time operating system (RTOS) for embedded systems supporting many different architectures and compiler toolchains.

Lpc_chip_11u6x_lib & nxp_lpcxpresso_11u68b

LPCOpen software libraries (drivers and middleware) supporting development on top of LPC MCU solutions. These two libraries bring support to LPC11U68 LPCXpresso board.

NTAG_Device2DeviceDemo

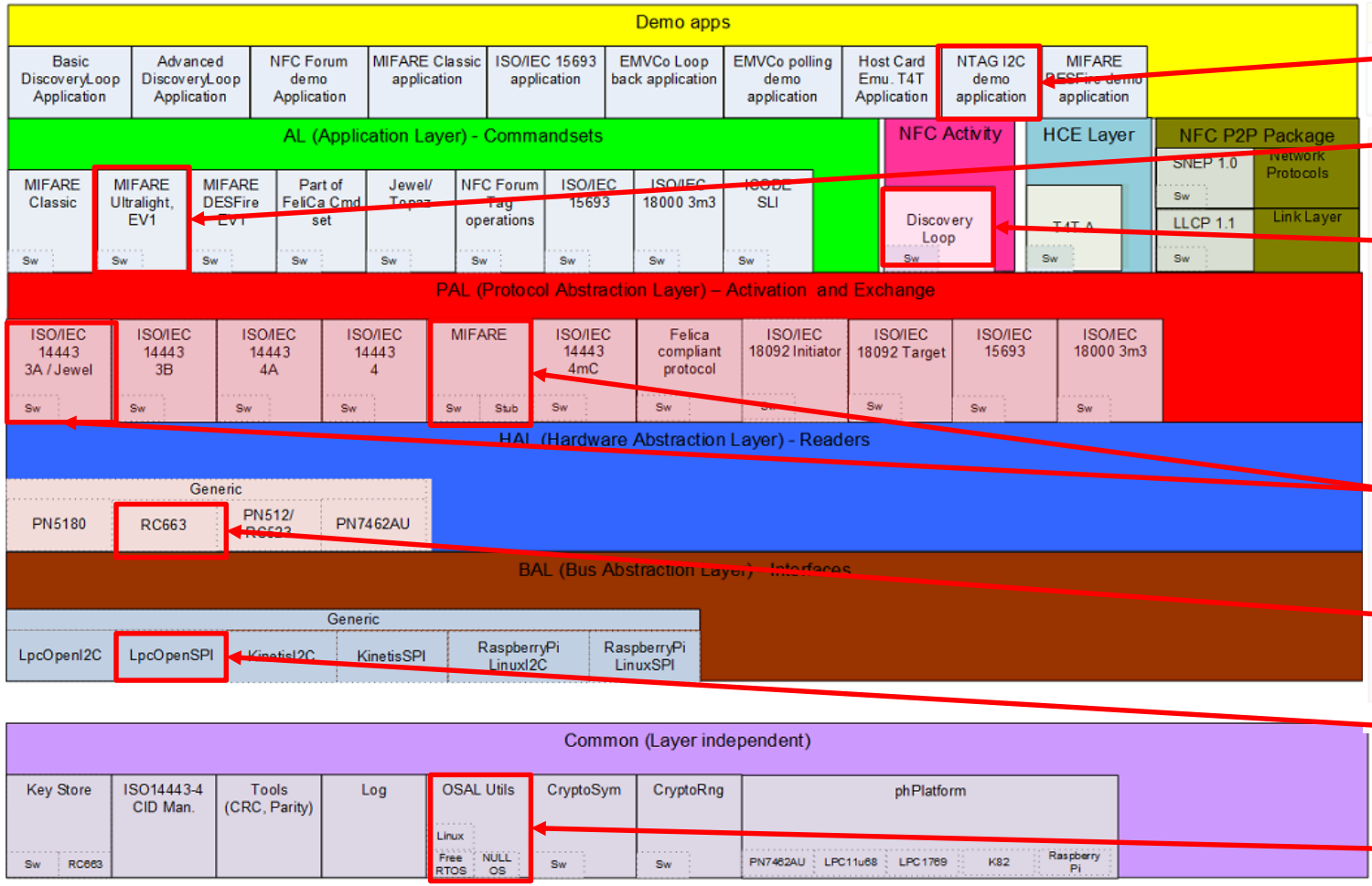
Implements the logic supporting the device-to-device communication demo for the reader module. More on the next slides.

NxpNfcRdLib

The NXP's software stack for creating and developing contactless applications. It is written in C language, it is based on modular multi-layer software architecture, and can support multiple design environments and platforms.

* Source code is available

Reader module MCU code leverages on the NFC Reader Library



7. We re-use an existing sample code

6. Initialize the NTAG I²C *plus* command set

5. Initialize discovery loop for card detection

4. Initialize the RF protocols (ISO14443-3, MIFARE)

3. Initialize the NFC reader IC (CLRC663)

2. Initialize the host controller interface

1. Initialize the OSAL implementation of FreeRTOS component

* More Info and source code: http://www.nxp.com/pages/:NFC-READER-LIBRARY

NFC Reader Library components are initialized following a bottom to top approach

NTAG_Device2DeviceDemo **application workflow**

Power on reset

Init GPIOs controlling LEDs

For BT tablet connection

UART init

BAL,HAL, PAL and AL components

Initialize NFC Reader Library components

OSAL thread create

Create thread for rotating disk operation

For ISO14443 Type A and Type V detection

Discovery loop configuration

Start discovery loop

If (SAK=0x00 and ATQA= 0x44) → **NTAG I²C *plus* tag** detected

While (tag detection)

Detection of a vicinity or other type A tag

Read **PTHROUGH_ON_OFF** register bit until is set

Wait until pass through mode is enabled

Read **TRANSFER_DIR** register bit until is set to 1

Wait until *RF to I²C* direction is set

Get action buttons

Write SRAM

SRAM_RF_READY register bit is set

Wait until I2C has written in SRAM

Read SRAM

Calculate angle from accelerometer axis coordinates

Button 3 pressed?

Yes

Send data to tablet via BT

Display angle

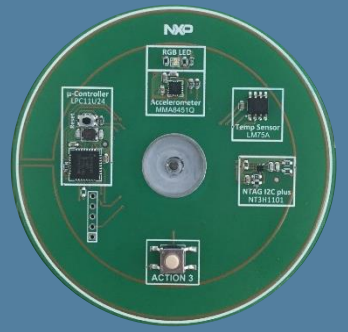
Trigger LED pattern on the LED circle

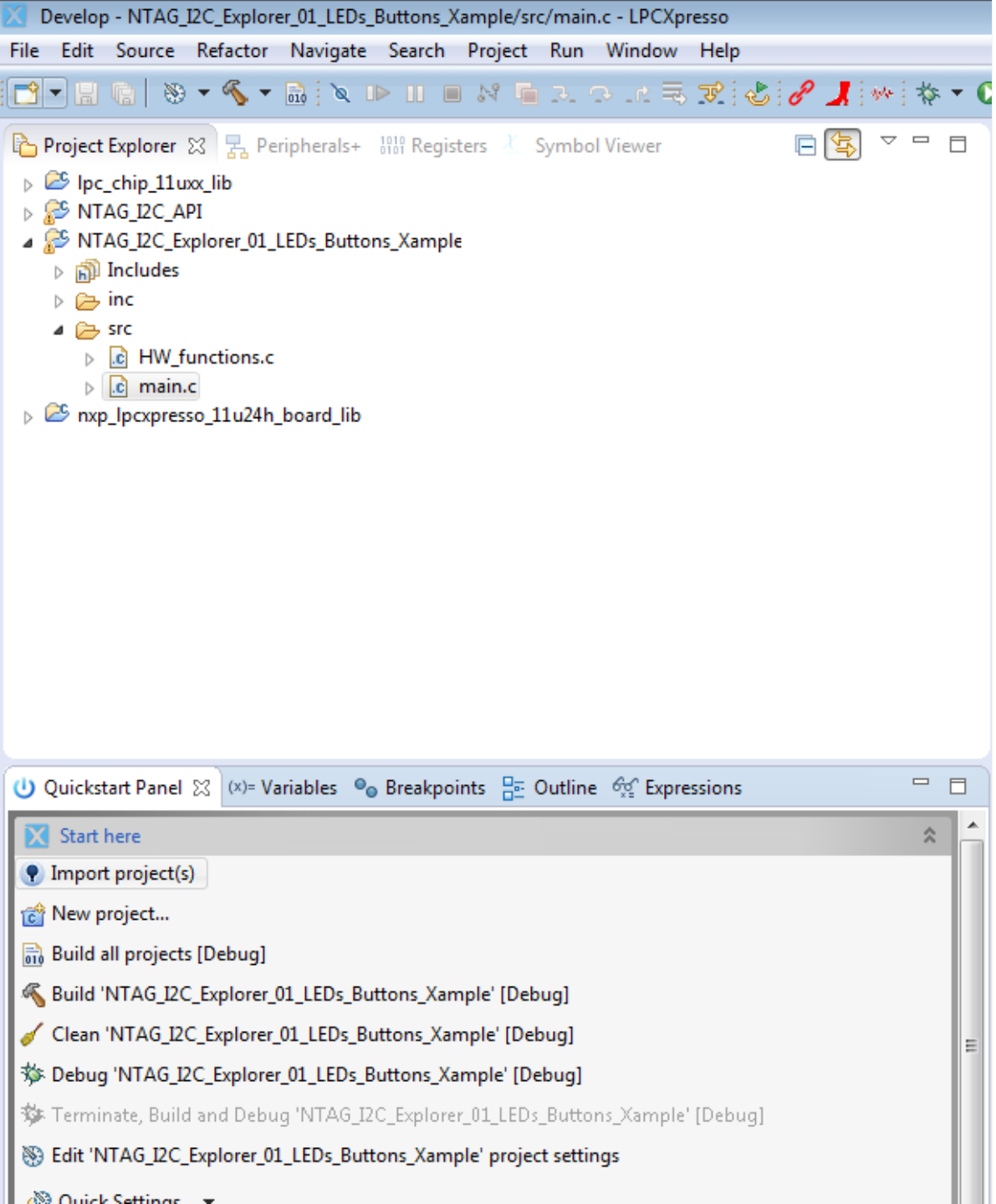
Activate the corresponding LED depending on the calculated angle

Iterates here while the reader module is powered

MCU CODE DETAILS

ROTATING DISK (NTAG I²C *PLUS*)





Rotating disk MCU code

Lpc_chip_11uxx_lib & nxp_lpcxpresso_11u24h_board_lib

LPCOpen software libraries (drivers and middleware) supporting development on top of LPC MCU solutions. These two libraries bring support to LPC11U24 LPCXpresso board

NTAG_I2C_ API

Implements the NTAG I²C *plus* command set and offers an API to developers to communicate with NTAG I²C *plus* from the I²C interface.

Memory operations (I²C side)

```
NTAG_ReadBytes (NTAG_HANDLE_T ntag, uint16_t address,uint8_t *bytes,
uint16_t len);
NTAG_WriteBytes(NTAG_HANDLE_T ntag, uint16_t address, const uint8_t
*bytes, uint16_t len);
```

Register operations

```
NTAG_ReadRegister (NTAG_HANDLE_T ntag, uint8_t reg, uint8_t *val);
NTAG_WriteRegister(NTAG_HANDLE_T ntag, uint8_t reg, uint8_t mask,
uint8_t val);
```

Setting SRAM for pass-throug mode operation

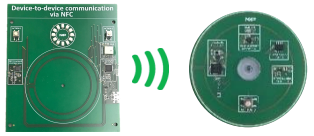
```
NTAG_SetPthruOnOff(NTAG_HANDLE_T ntag, BOOL on)
NTAG_SetTransferDir(NTAG_HANDLE_T ntag, NTAG_TRANSFER_DIR_T dir)
```

NTAG_I2C_Explorer_01_LEDs_Button_Xample

Implements the logic supporting the device-to-device communication demo. More on the next slide

* Source code is available

NTAG_I2C_Explorer_01_LEDs_Button_Xample application workflow



Power on by energy harvesting

Enable NTAG I²C *plus pass through* mode

PTHROUGH_ON_OFF register bit is set

While (1)

Set *RF to I²C* direction

TRANSFER_DIR register bit is set to 1

Wait until RF has written in SRAM

SRAM_I2C_READY register bit is set

Read SRAM 0xFF page address

Check last byte (btn)

While button 1 is pressed, **btn=0x01**

While button 2 is pressed, **btn=0x02**

While action button 1&2 are pressed, **btn=0x03**

Turn disk LED to blue

Turn disk LED to red

Turn disk LED to white

Check if disk action button is pressed

Read Temperature sensor

Read accelerometer axis coordinates

Set *I²C to RF* direction

TRANSFER_DIR register bit is set to 0

Write SRAM

Wait until RF has read SRAM

SRAM_RF_READY register bit is cleared

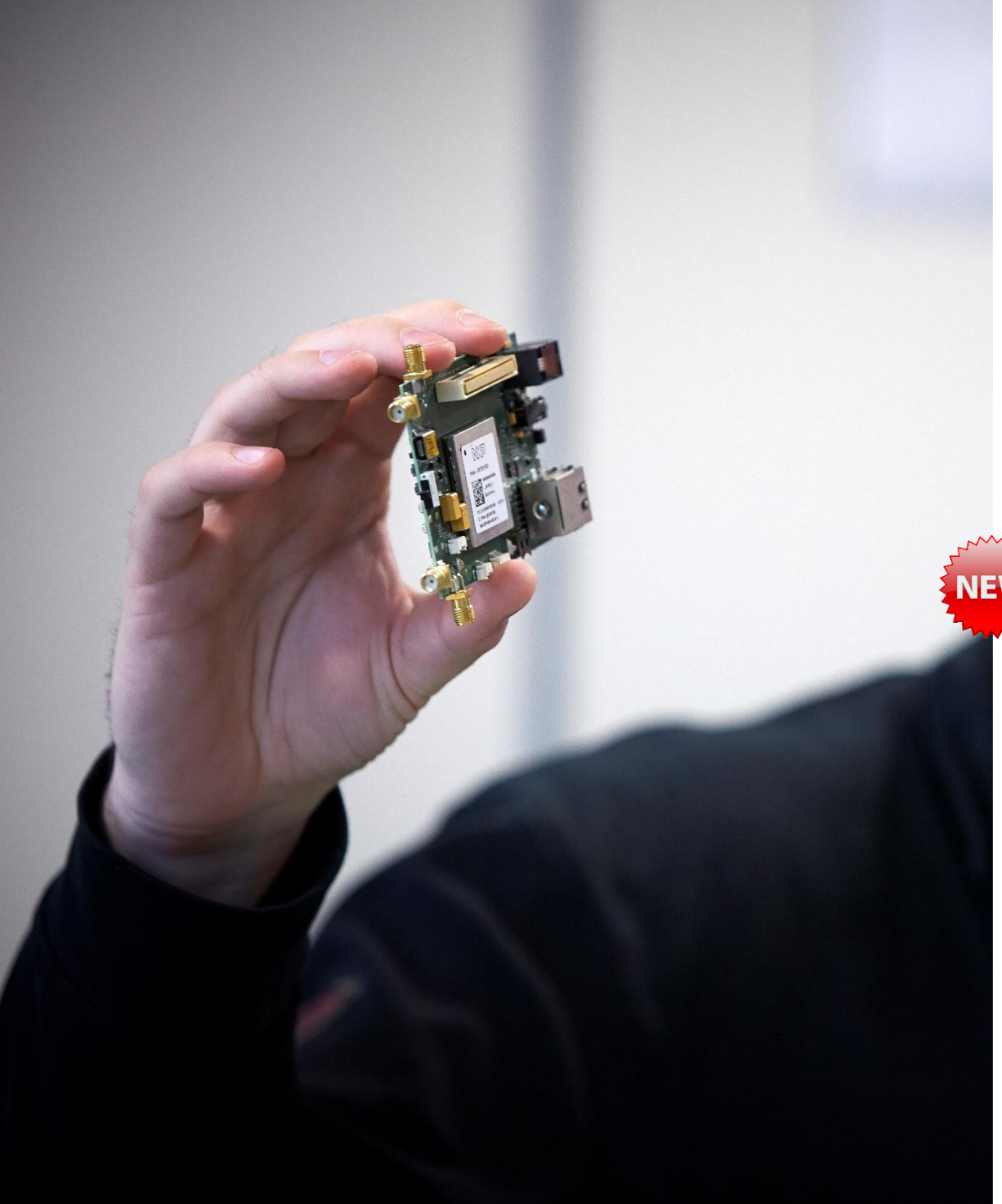
Iterates here while RF field is present

Training Mobile Knowledge

EVERYTHING YOU NEED TO BUILD YOUR

DEVICE-TO-DEVICE COMMUNICATION VIA NFC

SOLUTION IS HERE!



Summary of available resources

- More info about our NFC products:
  - CLRC663
  - NTAG I²C *plus*

NEW

- Check our post on the DemoLab section in our NXP community for:
  - Demo description
  - Source code
  - Schematics
  - Video recording

  https://community.nxp.com/docs/DOC-333917

MobileKnowledge

Software development in Android and iOS
Embedded software for MCUs
JCOP, Java Card operating Systems
Hardware design and development
Digital, analog, sensor acquisition, power management
Wireless communications WiFi, ZigBee, Bluetooth, BLE
Contactless antenna RF design, evaluation and testing

MIFARE® product-based applications
End-to-end systems, readers and card-related designs
EMVco applications
Readers, cards, design for test compliancy (including PCI)
Secure Element management
GlobalPlatform compliant backend solutions
Secure services provisioning OTA, TSM services

We help companies leverage the mobile and **contactless revolution**

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(Spain)

Get in touch with us
www.themobileknowledge.com
mk@themobileknowledge.com

Device-to-device communication via NFC

Jordi Jofre (Speaker)
Angela Gemio (Host)

Thank you for your kind attention!

Please remember to fill out our **evaluation survey** (pop-up)

Check your email for **material download** and on-demand **video** addresses

Please check NXP and MobileKnowledge websites for **upcoming webinars** and **training sessions**

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