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Connectivity Solutions

NFC – A Closer Look

May 16th, 2016

Presenters:

Matt Rose – NFC Business Development Manager

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AGENDA

NFC: What is involved?

Readers Tags Antennas	Compliance Software Design Considerations	Product Solutions: Readers NTAG Smart Labels

What is RFID?

- Radio Frequency IDentification
- Method for exchanging data between two objects
  - An active device such as a reader/writer and a passive device such as a tag
- Used in various applications to identify large numbers of objects.
  - Retail product identification
  - Asset tracking
  - Parts identification
  - Livestock identification
- In 2014, RFID market was worth $8.89 billion. Market value expected to rise to $27.31 billion by 2024.
- Implemented in various frequency bands based on application requirements.

Band		Range	Data Speed
120-150 kHz	LF	1-2 m	low
13.56 MHz	HF	10 cm/1m	low to moderate
433 MHz	UHF	1-100 m	moderate
865-900	UHF	1-12 m	moderate to high
24500-5800 HMz	SHF	1-2 m	high

What is NFC?

- Near Field Communication
- It is a subset of RFID defined by specific ISO standards
- Frequency of operation is at ISM band of 13.56 MHz
- Maximum range is 10 cm
- Data throughput: 106, 212, 424 or 848 kbps
- Defined by ISO 18092 but compatible with older ISO 14443
- The recognized standard for contactless payment via smart phones

Helicon Double Layer ion thruster

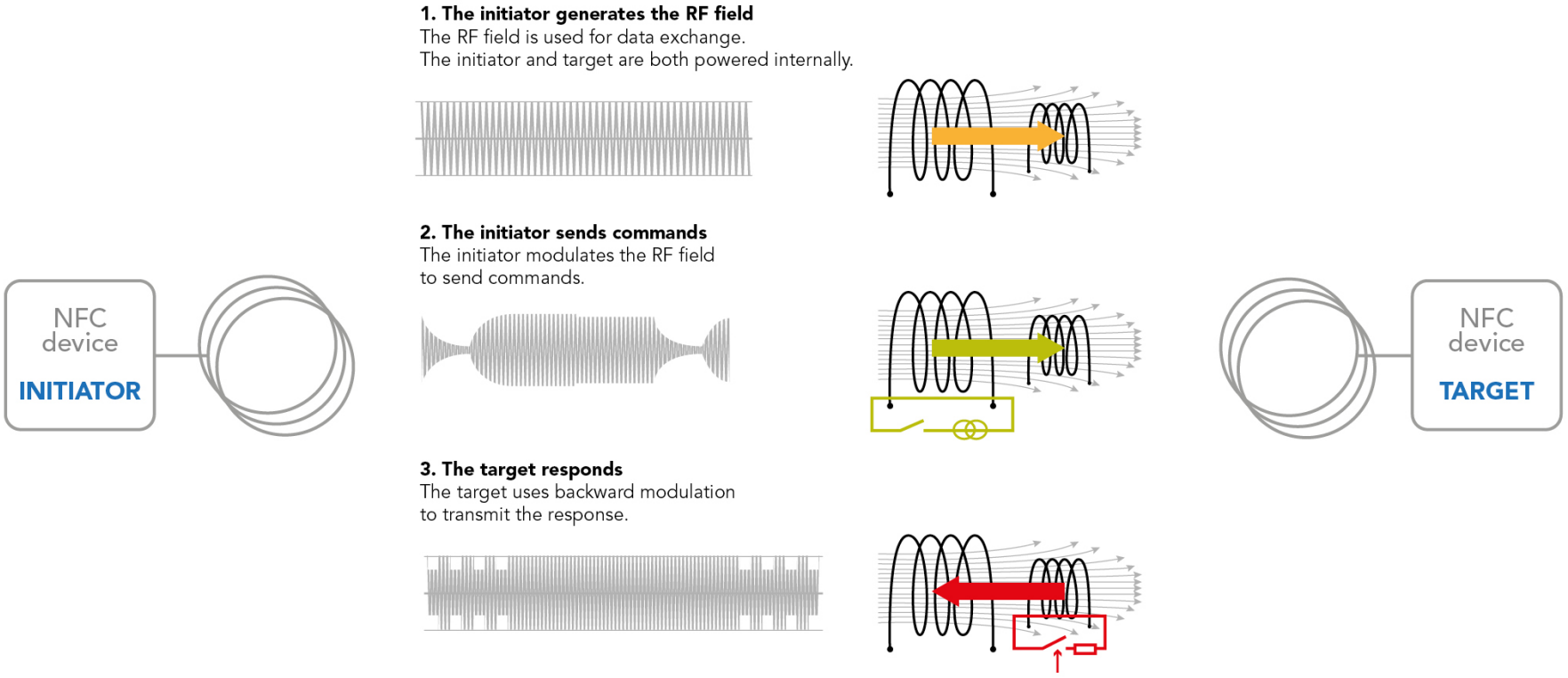
13.56 MHz most commonly used for RF plasma processes

13.56 MHz / 128 = 105.94 kHz

NFC: How is data transmitted?

Passive communication scheme

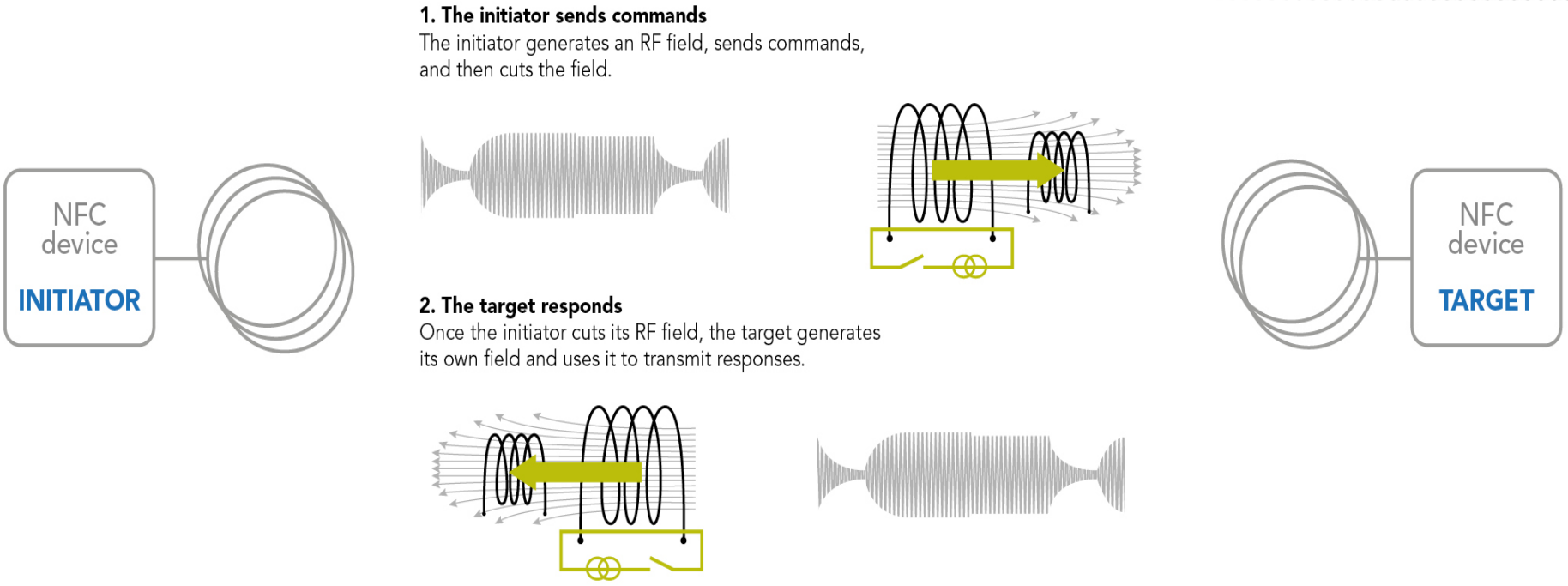
Read/write, Passive Peer to Peer and Card Emulation Modes



NFC: How is data transmitted?

Active Communication Scheme

Active Peer to Peer Mode



System Design Considerations

Mode(s) of operation

Protocol Support

Selecting a reader

Antenna Design and Tuning

Software Integration

NFC: Modes of Operation

Card Emulation

Peer To Peer

Card Reader

1.3 Billion NFC enabled phones on the market

Android/iOS
Intl: 82%/11%
US: 47%/47%

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13.56MHz Related Standards

ISO18092

ISO15693

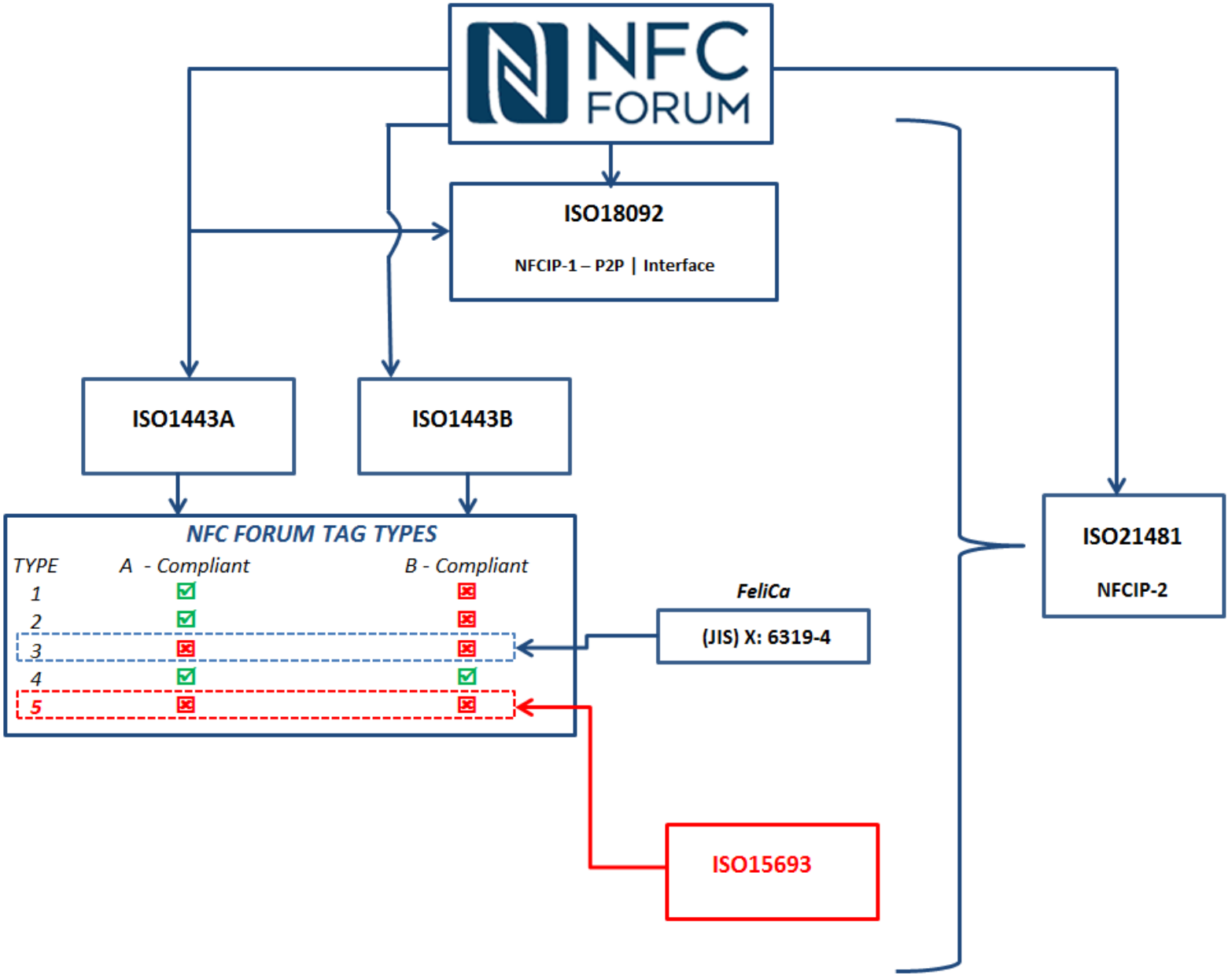
ISO14443A

ISO14443B

(JIS) X – 6319-4

ISO7816-4

ISO21481


NFC FORUM
ISO18092
NFCIP-1 – P2P | Interface
ISO1443A
ISO1443B
NFC FORUM TAG TYPES
TYPE
A - Compliant
B - Compliant
1
2
3
4
5
FeliCa
(JIS) X: 6319-4
ISO15693
ISO21481
NFCIP-2

Example – NFC Forum Compliant Reader

PN7120

Full NFC Forum-compliant controller with integrated firmware and NCI interface

Rev. 3.1 — 8 October 2015
312431

Product data sheet
COMPANY PUBLIC

3. Features and benefits

- Includes NXP ISO/IEC14443-A, Innovatron ISO/IEC14443-B and NXP MIFARE Crypto 1 intellectual property licensing rights
- ARM Cortex-M0 microcontroller core
- Highly integrated demodulator and decoder
- Buffered output drivers to connect an antenna with minimum number of external components
- Integrated RF level detector
- Integrated Polling Loop for automatic device discovery
- RF protocols supported
  - NFCIP-1, NFCIP-2 protocol (see Ref. 7 and Ref. 10)
  - ISO/IEC 14443A, ISO/IEC 14443B PICC mode via host interface (see Ref. 2)
  - ISO/IEC 14443A, ISO/IEC 14443B PCD designed according to NFC Forum digital protocol T4T platform and ISO-DEP (see Ref. 11)
  - FeliCa PCD mode
  - MIFARE PCD encryption mechanism (MIFARE 1K/4K)
  - NFC Forum tag 1 to 4 (MIFARE Ultralight, Jewel, Open FeliCa tag, DESFire) (see Ref. 11)
  - ISO/IEC 15693/ICODE VCD mode (see Ref. 8)
- Supported host interfaces
  - NCI protocol interface according to NFC Forum standardization (see Ref. 1)
  - I^2C-bus High-speed mode (see Ref. 3)

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PN7120-NCI Cont'd.

NFC controller interface (NCI)

NXP NCI extension

- NCI interface as defined by the NFC Forum does not give access to the entire functionality set.
- NXP extends NCI interface with a proprietary extension.

Features	NCI	PN7120 - NCI
RF Discovery activity (NFC Forum, EMVCo)	Partially covered	Covered
Reader/Writer ISO-DEP for NFC-A & NFC-B, T1T, T2T, T3T, T4T	Covered	Covered
Reader/Writer MIFARE Classic, MIFARE Plus, ISO15693, Kovio	Not covered	Covered
Card Emulation ISO-DEP for NFC-A & NFC-B	Covered	Covered
P2P passive (Initiator & Target)	Covered	Covered
P2P active (Initiator & Target)	Not covered	Covered
RF bit rates for Listen mode & Poll mode: 106 Kbps (NFC-A & NFC-B), 212 Kbps (NFC-F), 424 Kbps (NFC-F)	Covered	Covered
RF bit rates for Listen mode & Poll mode in technology NFC-A & NFC-B: 212 Kbps, 424 Kbps, 848 Kbps	Not covered	Covered
Configuration: Power management, RF settings, clocking schemes	Not covered	Covered
Others: Presence check	Not covered	Covered

Covered Partially covered Not covered

Reader Selection

Steps to design a contactless reader

1 Selection of **contactless reader IC**

Which transponder do we need to interact with?

- Support of various RF standards
  - Dedicated use case & application may support only ISO/IEC 14443-A
  - Open application needs to support various RF standards such as ISO/IEC14443 A&B, ISO/IEC 15693
- Application specific requirements
  - EMVCo -> payments
  - NFC Forum -> Full NFC support on P2P and R&W
- Power consumption
  - Handheld contactless reader will require low energy consumption
- Selection of the host interface
  - SPI, I^2C, RS232, UART ..
- Specific features
  - Specific data rates, timing and reading distance

Reader Security Architecture

Steps to design a contactless reader

1. Selection of **contactless reader IC**
   Which transponder do we need to interact with?
2. Selection of **Host**
   The brain and heart of our contactless reader
3. Selection of **security** architecture
   SAM or Host for key storage

- Host / MCU
  - Microcontrollers are not designed and developed to securely store and maintain cryptographic keys since they don't offer reliable protection and security mechanisms
  - They do not widely implement HW-based crypto-processors, so the execution of these crypto algorithms is not efficient
- SAM
  - It is a tamper-resistant chip that provides secure execution and secure key storage functions to the reader side
  - It carries HW based cryptography that allows one to perform complex cryptographic operations efficiently
  - ***SAM X-interface***: It supports the X-mode, which allows a fast and convenient contactless terminal development by connecting the SAM to the microcontroller and reader IC simultaneously.

NXP NFC Reader Solutions

Part Number	CLRC663	MFRC631	MFRC630	SLRC610	MFRC523	MFRC522	PN5180	PN7462 Integrated MCU	PN7120 Integrated MCU	PR601 (CLRC663 + MCU)	PRH601 (CLRC663+ LPC1227+ HITAG)
Standards & Protocols											
Standards	ISO/IEC 14443 A and B ISO/IEC 18092 ISO/IEC15693 ISO/IEC 18000-3 mode 3 Felica Mifare NFCIP-1 EMVCo	ISO/IEC 14443 A and B Mifare EMVCo	ISO/IEC 14443 A Mifare	ISO/IEC15693 ISO/IEC 18000-3 mode 3 ICODE EPC UID/ EPC OTP	ISO/IEC 14443 A and B Mifare EMVCo	ISO/IEC 14443 A Mifare	ISO/IEC 14443 A and B ISO/IEC 15693 ISO/IEC 18000-3M3 ISO/IEC 18092 ISO/IEC 21481 Mifare ICODE Felica EMVCo NFC Forum	ISO/IEC 14443 A and B ISO/IEC 15693 ISO/IEC 18000-3M3 ISO/IEC 18092 ISO/IEC 21481 Mifare ICODE Felica EMVCo NFC Forum	ISO/IEC 14443 A and B ISO/IEC 18092 ISO/IEC15693 Felica Mifare NFCIP-1 NCIP-2 EMVCo	ISO/IEC 14443 A and B ISO/IEC 18092 ISO/IEC15693 Felica Mifare NFCIP-1 EMVCo	ISO/IEC 14443 A and B ISO/IEC 18092 ISO/IEC15693 Felica HITAG EMVCo
Mode of communication	Reader/Writer P2P: Passive Intiator	Reader/Writer	Reader/Writer	Reader/Writer	Reader/Writer	Reader/Writer	Reader/Writer P2P: active + passive intiator/target Card emulation	Reader/Writer P2P: active + passive intiator/target Card emulation	Reader/Writer P2P: active + passive intiator/target Card Emulation	Reader/Writer, P2P: Passive Intiator	Reader/Writer, P2P: Passive Intiator
NFC Forum Tag type support	1, 2, 3, 4, 5	1, 2 , 4	1, 2 , 4	5	1, 2 , 4	1, 2 , 4	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5
Datarate (kbps)	848	848	848	26.48	848	848	848	848	848	848	848
Product Features											
Host Interface	SPI, I2C, UART	SPI, I2C, UART	SPI, I2C, UART	SPI, I2C, UART	SPI, I2C, UART	SPI, I2C, UART	SPI	SPI, I2C, USB, HSUART	I2C	SPI, I2C, UART	SPI, I2C, UART
Max Output power (mW)	1125	1125	1125	1125	200	200	1250	1050	500	1500	2000
Package	QFN-32	QFN-32	QFN-32	QFN-32	QFN-32	QFN-32	QFN-40, TFBGA64	QFN-64	VFBGA49	LQFP100	LQFP100
Microcontroller	host needed	host needed	host needed	host needed	host needed	host needed	host needed	ARM Cortex M0	ARM Cortex M0	ARM Cortex M0	ARM Cortex M0
Distance Prox/Vic (cm)	12	12	12	16	5	5	12	12	7	16	16
Temperature range [°C]	-25 to + 85	-25 to + 85	-25 to + 85	-25 to + 85	-25 to + 85	-25 to + 85	-30 to + 85	-40 to + 85	-30 to + 85	-25 to + 70	-25 to + 70
Security	Yes, Mifare Classic Security	Yes, Mifare Classic Security	Yes, Mifare Classic Security	-	Yes, Mifare Classic Security	Yes, Mifare Classic Security	Yes, Mifare Classic Security	Yes, Mifare Classic Security	Yes, Mifare Classic Security	Yes, Mifare Classic Security	Yes, Mifare Classic Security
Application	Payment Pre-paid utility metering Connected home Internet of things Smart manufacturing Gaming	NFC Reader application where good RF performance is needed, and need to read both Type A and Type B tags	Access management Building automation networks Public transport Smart manufacturing	Reader application where customer only wants to read I-CODE tags.	Cost sensitive solution, need to read both type A and B tags	Payment eMetering	Payment Pre-paid utility metering Connected home Internet of things Gaming	Access management Secure transactions, USB readers, Gaming	Linux windows Android Systems, Connected healthcare systems Internet of things Pay-per-view Video on demand Gaming	Connected home, Internet of things, Smart manufacturing, access management, Building automation network, Public transport	Small formfactor for access systems Industrial devices with high RF performance requirements Multi frequency applications with 125 kHz and 13.56 MHz support

NFC Forum tags

Standard TAG types

NFC Forum introduced standardized technology architecture, initial specifications and tag formats for NFC compliant devices:

1. **NFC Forum Data Exchange Format** (NDEF), defines a message encapsulation format to exchange information

2. **Record Type Definition** The RTD specification provides a way to efficiently define record formats for new applications and gives users the opportunity to create their own applications based on NFC Forum specifications of TEXT, URI, Smart Poster, and Generic Control.

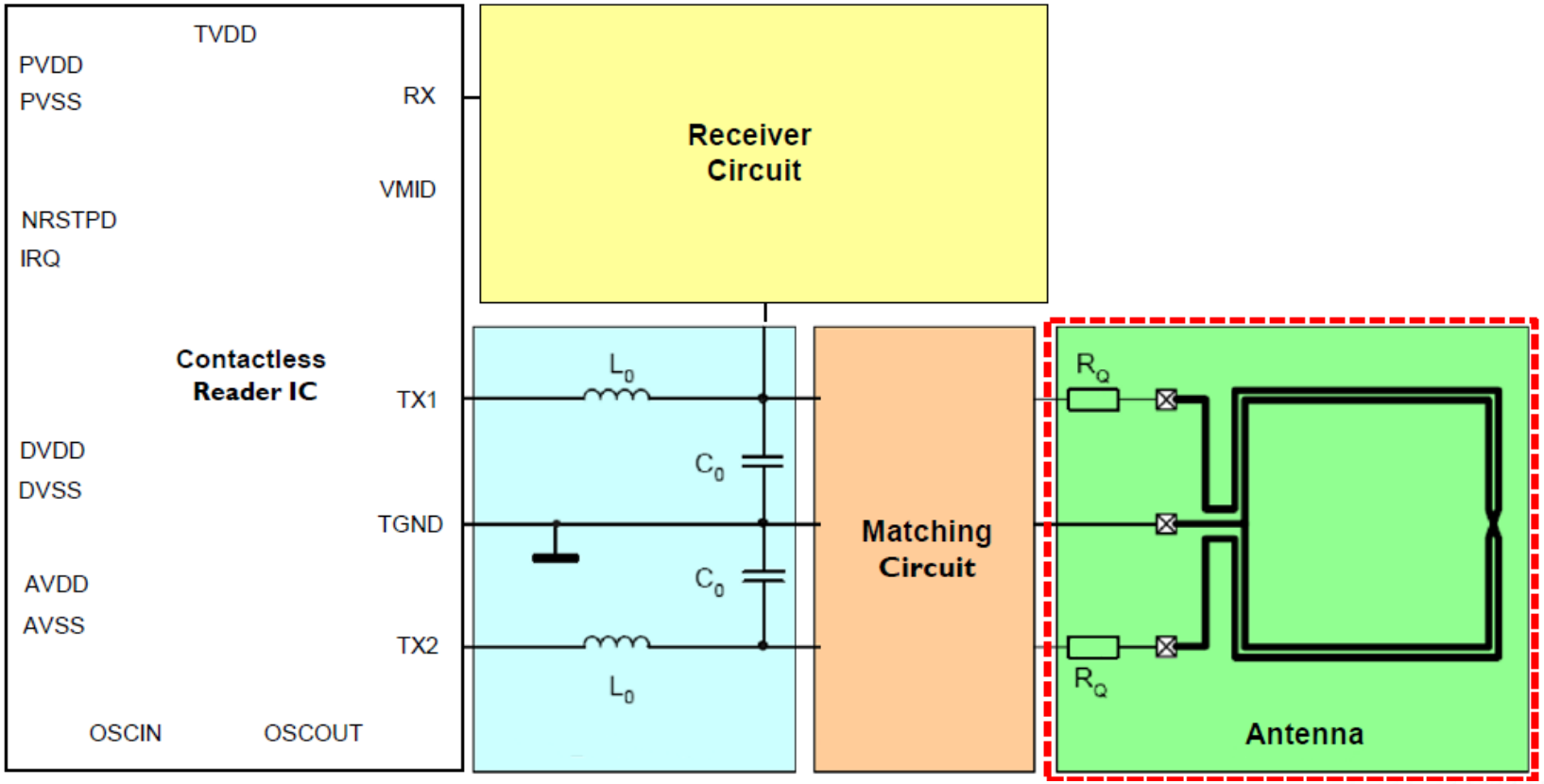
Tag Type	Description
Tag 1 Type	Read, re-writeable. Users can configure tag to be read-only. Based on ISO14443A Standard Memory: 96 to 2k bytes Data throughput: 106 kpbs
Tag 2 Type	Read, re-writeable. Users can configure tag to be read-only. Based on ISO14443A Standard Memory: 48 to 2k bytes Data throughput: 106 kpbs
Tag 3 Type	Based on Sony standard FeliCa Memory: up to 1M bytes Data throughput: 212 kbps
Tag 4 Type	Read, re-writeable or read-only Based on ISO14443A and B standard Memory: up to 32K bytes Data throughput: 106 and 424 kbps
Tag 5 Type	Read, re-writeable or read only Based on ISO15693 *ICODE* Memory up to 2528bits Data throughput: Max 53 kbps

http://members.nfc-forum.org/specs/spec_list/

MIFARE

- MIFARE is NXP's well-known brand for a wide range of contactless IC products.
- Typical read/write distance of 10 cm (4 inch)
- Used in more than 40 different types of application worldwide.
  - Electronic ticketing, Road tolling, Airline tickets, Access control for events, Student cards, NFC tags
- 50 million reader and 5 billion card components sold,
  - MIFARE products are proven and more reliable than any other interface technology in the market.
- MIFARE Smart Card IC range :
  1. MIFARE Ultralight – primarily used for contactless automatic fare collection systems
  2. MIFARE Classic – the original, first product to fit into an ISO contactless smart card
  3. MIFARE DesFire- ideal for transport schemes, identity applications
  4. MIFARE Plus – security and performance for cost sensitive automated fare collection, access control markets
- MIFARE Reader IC range:
  1. Part of the NFC Frontend solutions: MFRC522, MFRC523, MFRC631, MFRC630

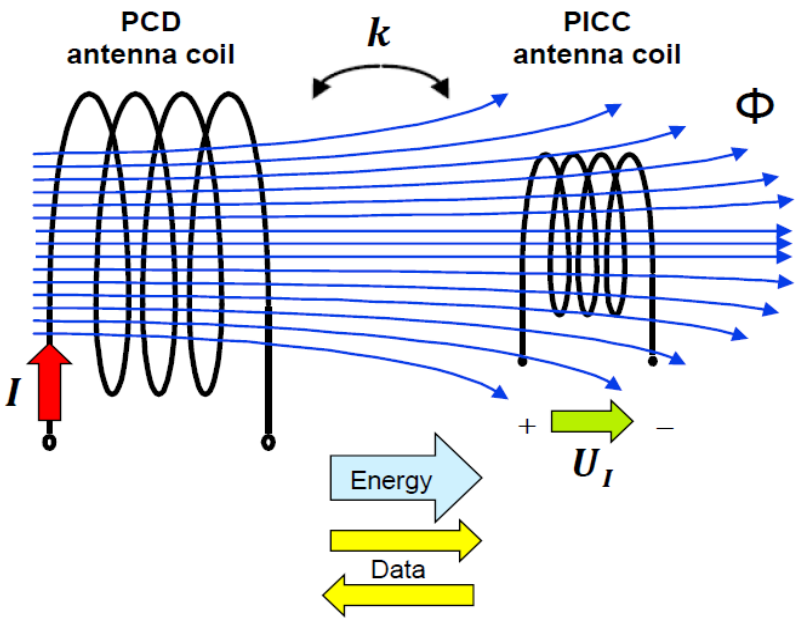
Antenna Design Considerations



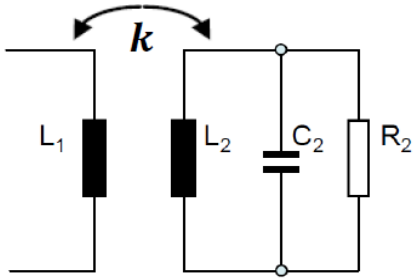
Antenna Design Considerations

NFC antenna: Transformer principle

Coupling coefficient



- The coupling coefficient depends on:
  - The geometric dimensions of both conductor loops.
  - The position of the conductor loops in relation to each other
  - The magnetic properties of the medium (μ_0)



$0 < k < 1$

k =1 → total coupling

k =0 → full decoupling

$$k = \mu_0 \cdot \frac{r^2}{2\sqrt{(r^2+x^2)^3}} \cdot \frac{A_2}{\sqrt{L_{01} \cdot L_{02}}}$$

Permeability constant | *Geometrical quantity* | *"Fixed"*

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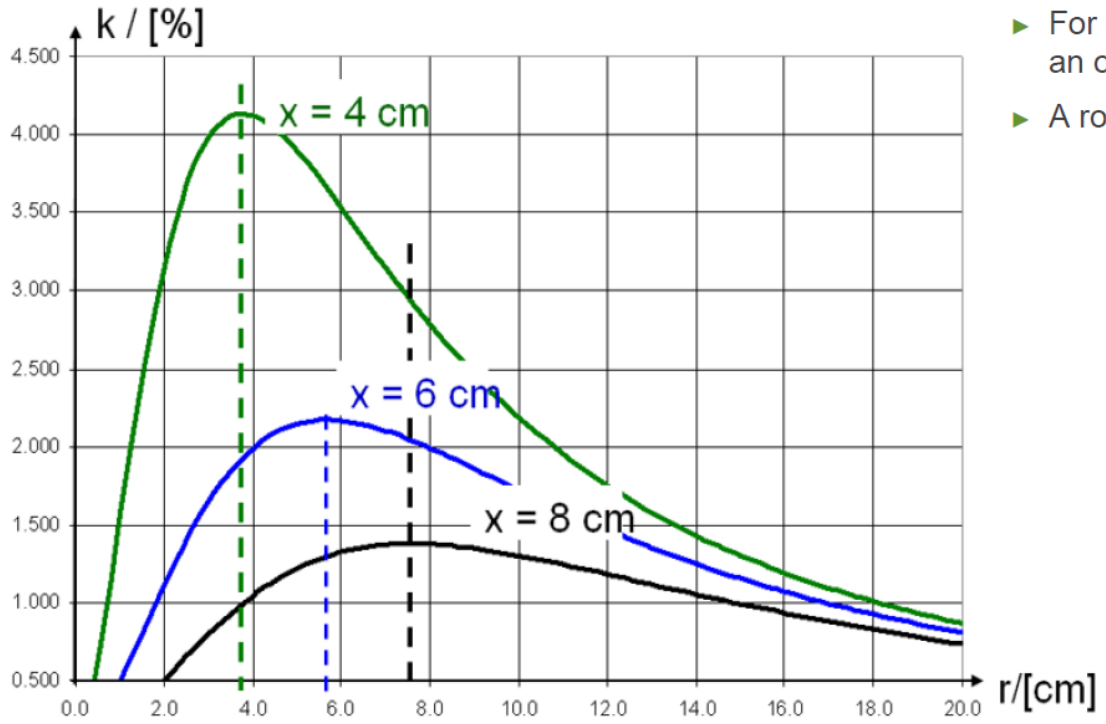
Antenna Design Considerations

Optimum antenna size



- For every read range x of an NFC system, there is an optimal antenna radius R.
- A rough approximation is that :

$$k = \mu_0 \cdot \frac{r^2}{2\sqrt{(r^2+x^2)^3}} \cdot \frac{A_2}{\sqrt{L_{01} \cdot L_{02}}}$$

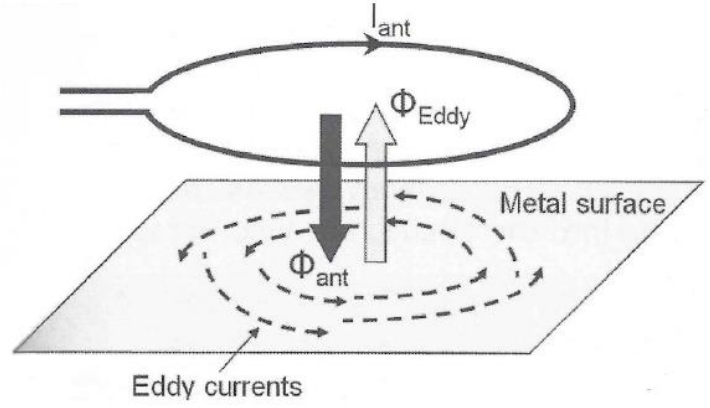
$$r = x$$

Antenna Design Considerations

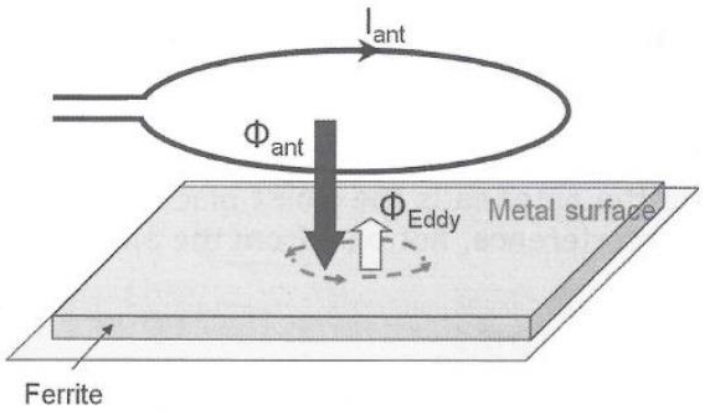
Metal environment influences

Eddy currents

- Metal surfaces in the immediate vicinity of the reader antenna have several negative effects.
- Our reader antenna's magnetic field generates eddy currents in metallic surfaces.
- These eddy currents produce a magnetic flow opposite to that of the reader device



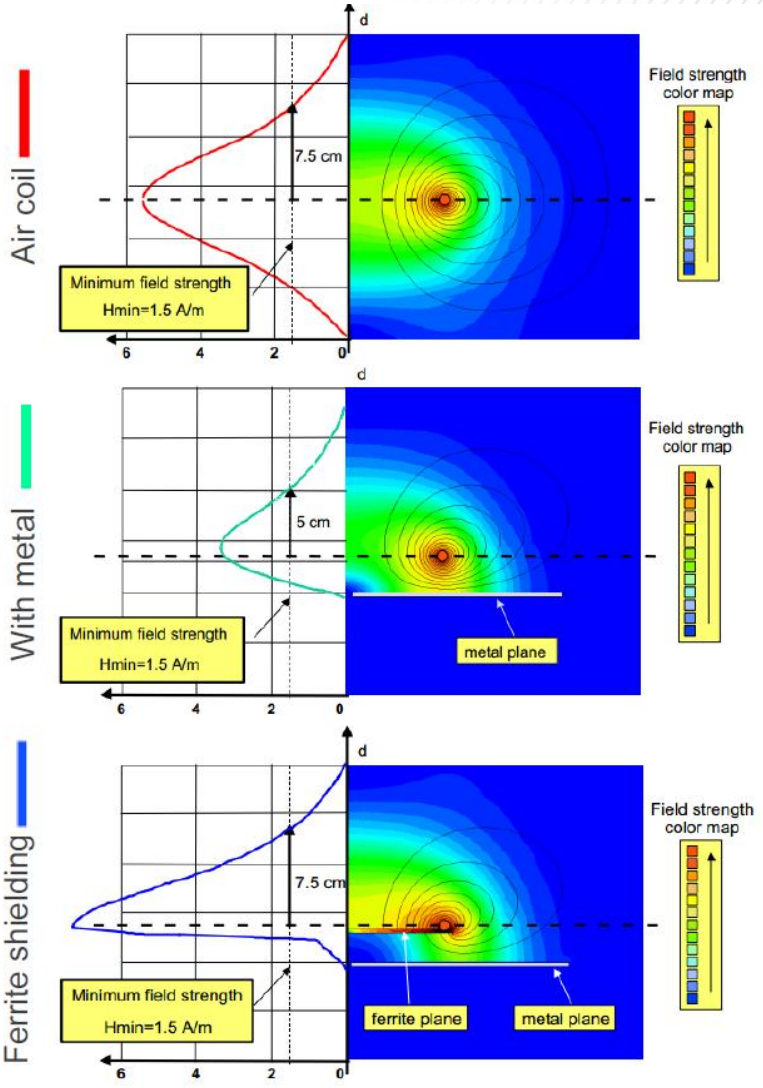
- Ferrites are basically poor electrical conductors but are very good at propagating magnetic flux (mostly of iron oxide Fe2O3)
- The ferrite material "shields" the metal behind it.
- It significantly reduces the generated eddy currents



Antenna Design Considerations

Shielding and environment impact

- The figures show three different field strength characteristics over reading distance x, for the same antenna coil:
  - Free air coil (7.5 cm)
  - Coil surrounded by a metal plate (5 cm)
  - Coil surrounded by a metal plate shielded by a ferrite plate (7.5 cm)
- We can achieve almost original operating distance using ferrite shielding. However, the ferrite detunes the antenna and produces:
  - Increase inductance
  - Increase Q-factor
  - Changed magnetic field distribution
- C ntenna must be suited to its environment.



NXP Training Mobile Knowledge

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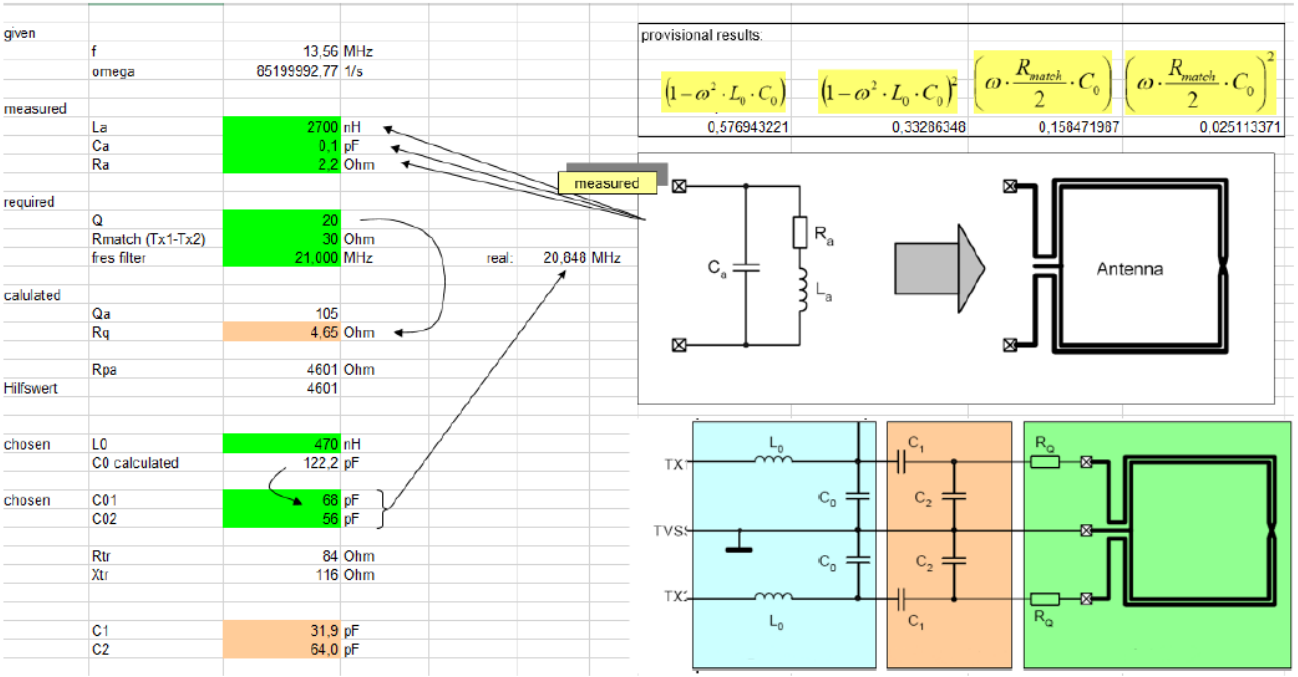
Antenna Tuning

NFC antenna matching

Step 5: Calculate matching components (II)

- We input the following values into the excel sheet:
  - Antenna coil measured / estimated values (L_a, C_a, R_a)
  - Q-factor
  - Target impedance (Rmatch).

- The excel sheet calculates the values for the matching circuit and damping resistor.
  - R_Q, C_1 and C_2



http://www.nxp.com/documents/other/AN11246_239810.zip

SOFTWARE TOOLS

NXP Reader libraries

NXP provides software reader libraries to support their hardware products. The library is written in C language providing an API that allows the customer to create their own custom software stack and applications for their contactless reader.

The NXP Generic Reader library

- Supports system development for MIFARE Classic, Ultralight series and products based on ISO/IEC 15693 standard. This library is available for free download on the NXP website.

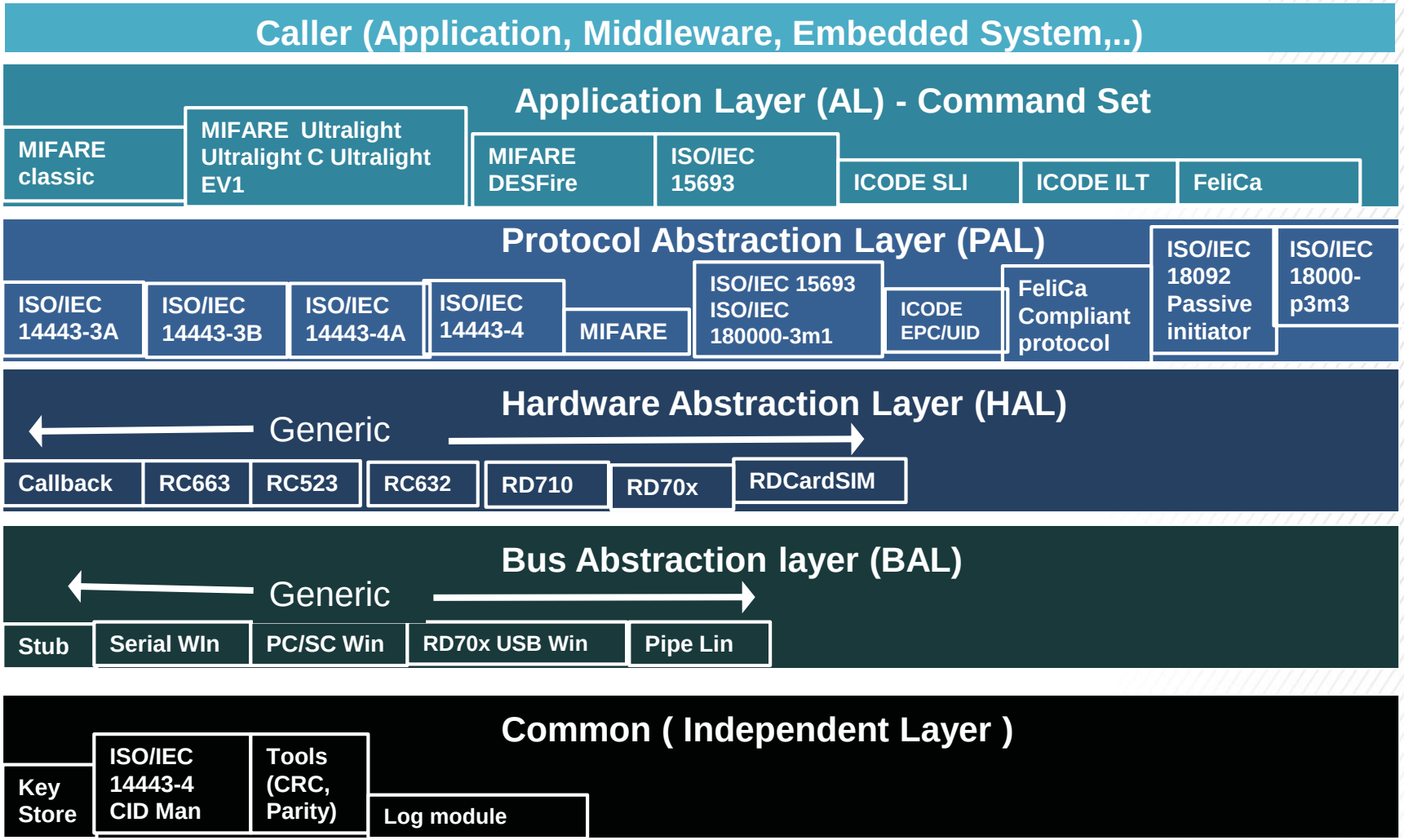
The NXP Export Controlled Reader library

- Supports system development for MIFARE Plus and MIFARE DESFire. This is available through DocStore and is subject to NDA with NXP.

The NXP NFC Reader library

- Supports system development for contactless readers communicating with other NFC devices. This library is available upon request .

Reader Library Model



Fully compiled: 60 k

Compliance Testing

NTAG I2C tag IC does not require FCC testing as it is a receiver.

NFC readers for mobile payments require:

FCC testing	FCC Part 15 B unintentional emissions testing
	FCC Part 15.225 Radio testing (radiated and conducted)
	FCC/IC Approval
	Approx. $10k
EMVco payment certification testing	Level 1- terminals, cards, and contact testing
	Level 2- software testing
	Level 1: Approx. $10k , Level 2: approx. $30k
	ESD Testing (2kV HBM) $4k

Product Solutions & Show-and-Tell

NTAG Plus

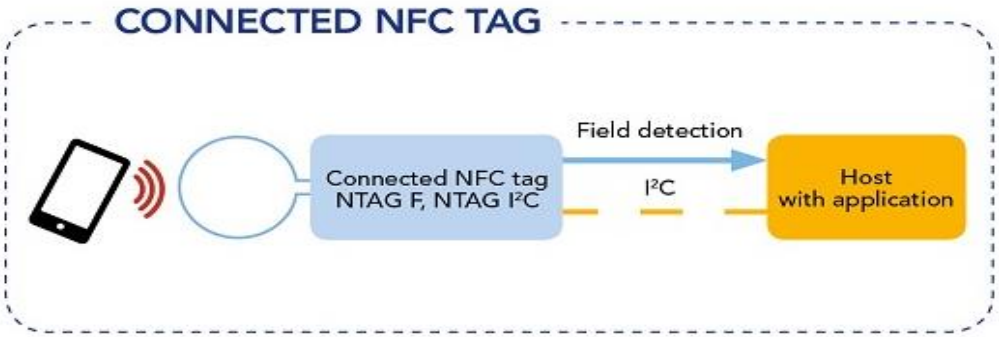
PN5180

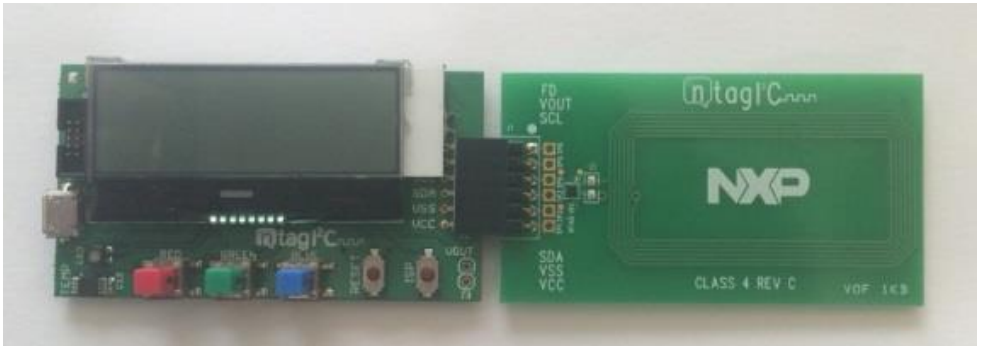
PN7120

Energy Harvesting with NTAG

NTAG Plus: Add NFC to any **MCU**

- NTAG family provides both passive RF and I²C interface
- Some tags have additional interfaces: field detection, power harvesting or I²C
- NTAG I²C products are an excellent choice for applications that are meant to communicate with smartphones, for smart manufacturing and for embedded electronics
- Ideal for exchange of configuration data, diagnostic data or small firmware updates





- NTAG I2C Part Number:
  - NT3H1101W0Fxx
- NTAG I2C Evaluation Board:
  - OM5569/NT312D or E,699

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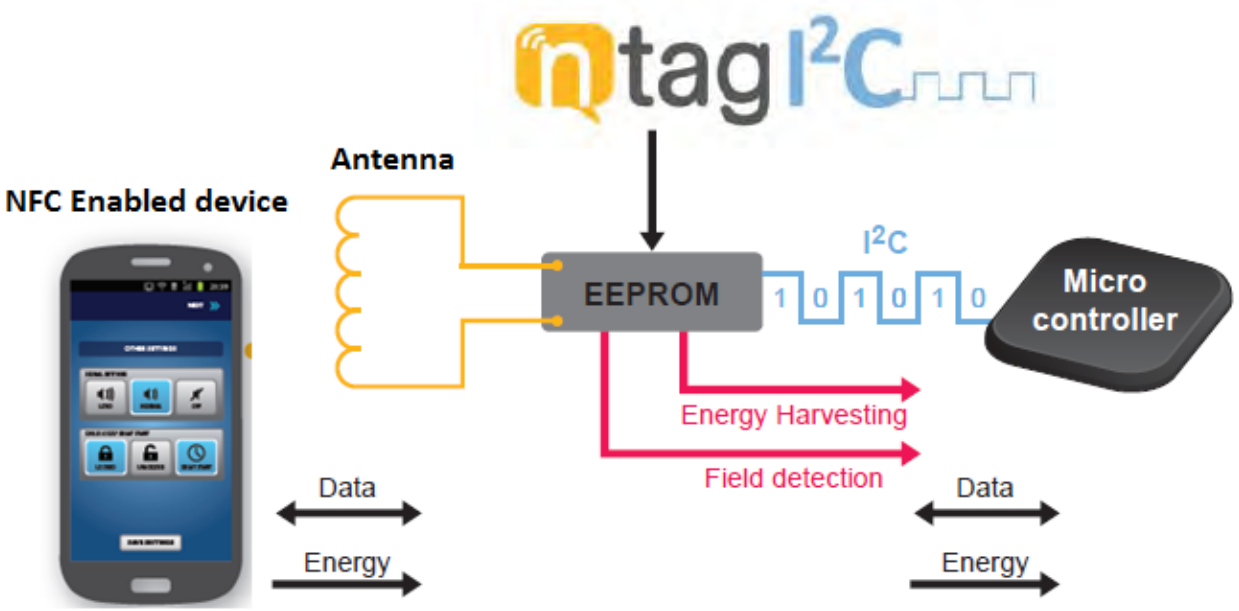
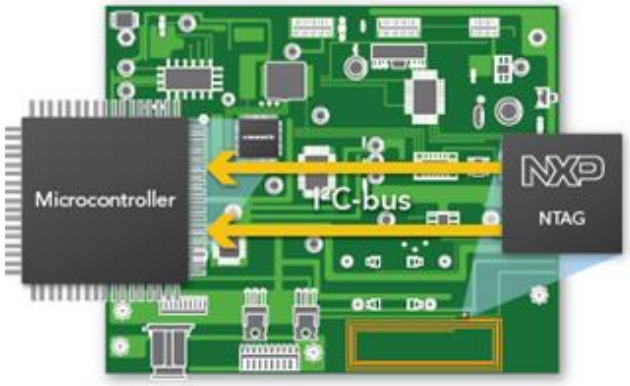
NTAG: How it works

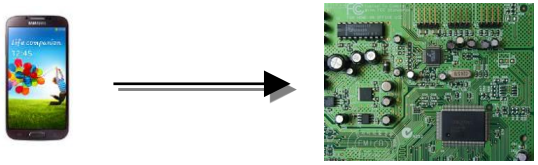


NTAG I2C tag IC connects to host microcontroller via the I2C serial bus interface



NFC tag IC can be self-contained module or integrated into PCB

NTAG I2C applications

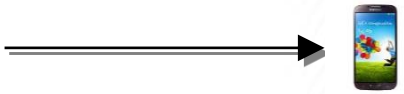


Product Configuration

Recipes

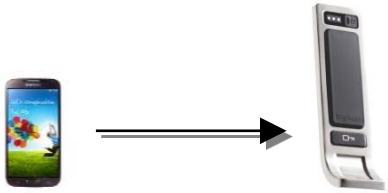
Power-down error codes/troubleshooting

Firmware Upgrades



Warranty Information

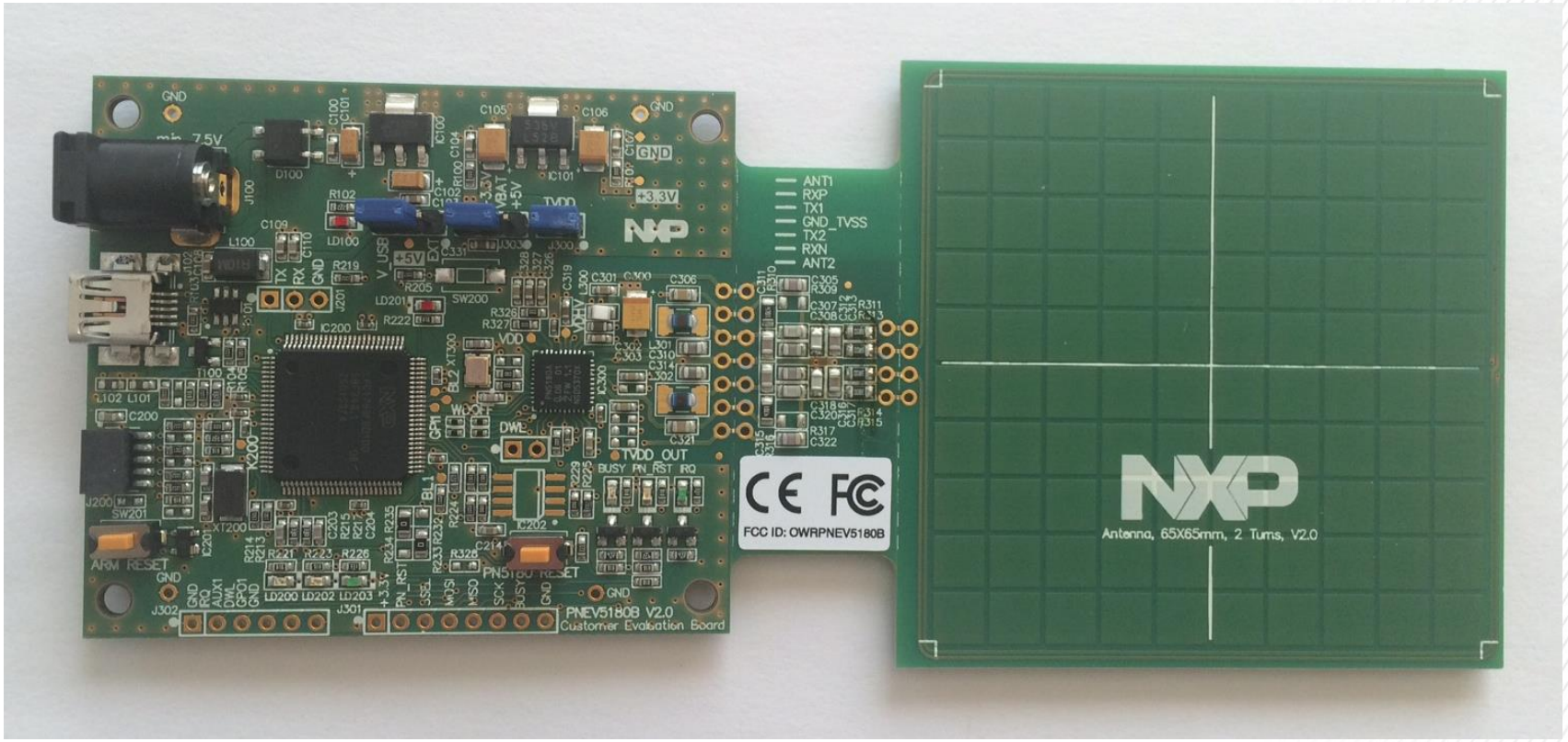
Bluetooth pairing



E-lock

Product Calibration

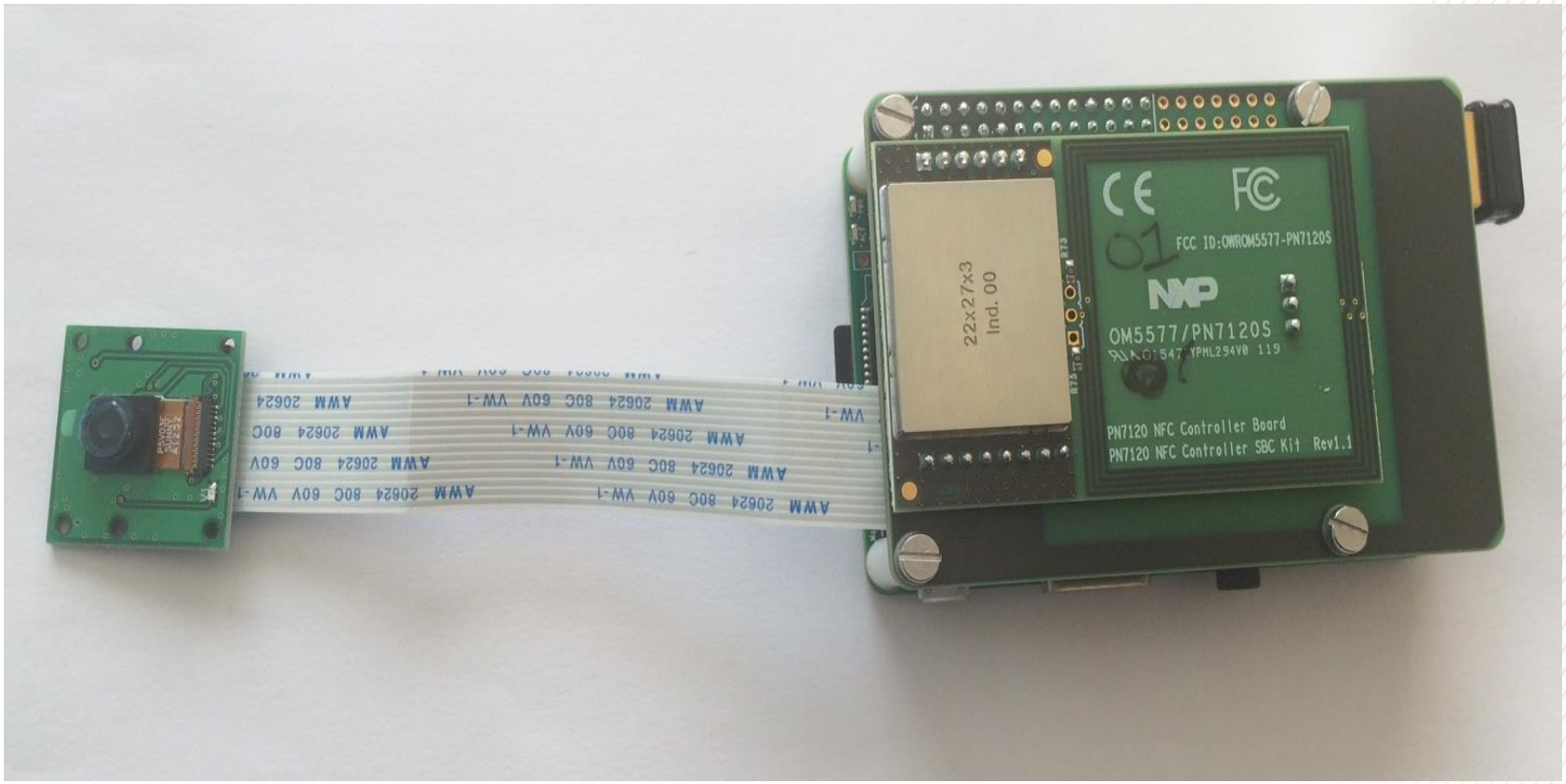
Demo: NFC Cockpit – PN5180



What it does:

Read tags!

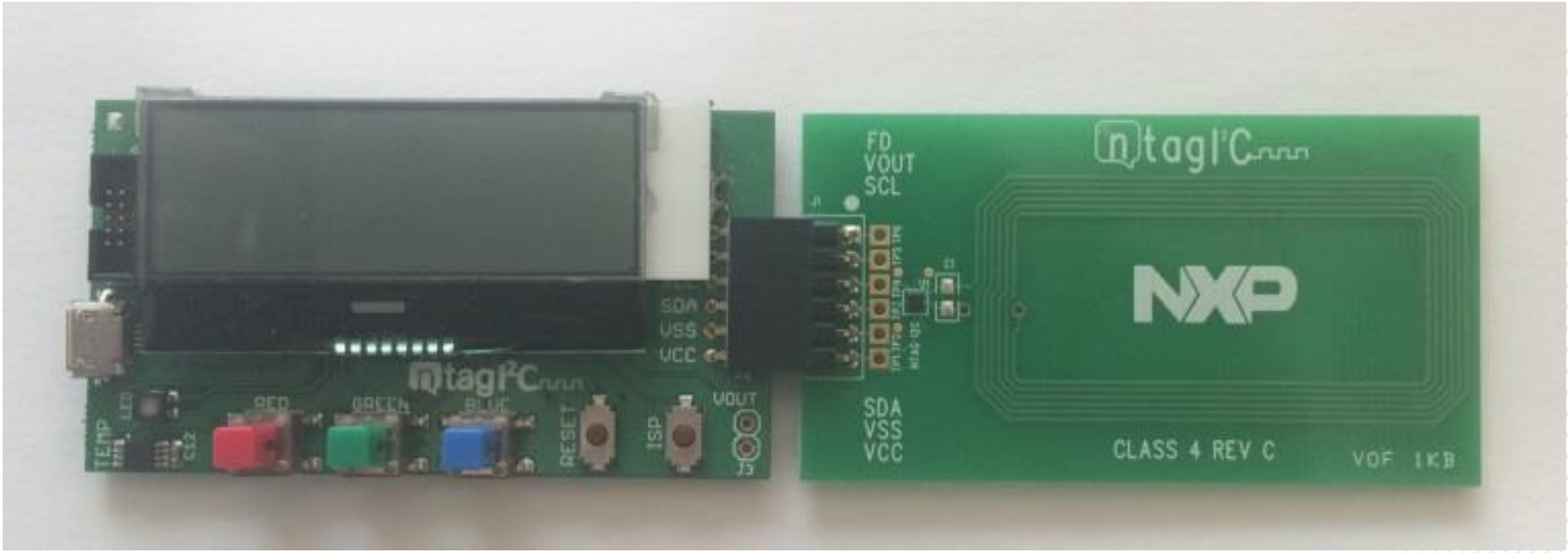
Demo: PN7120



What it does:

Authenticates Wi-Fi, streams video and reads tags!

Demo: NTAG plus



What it does:

Uses Android NFC to power switches, LED and an LCD

Demo: Energy Harvesting with NTAG

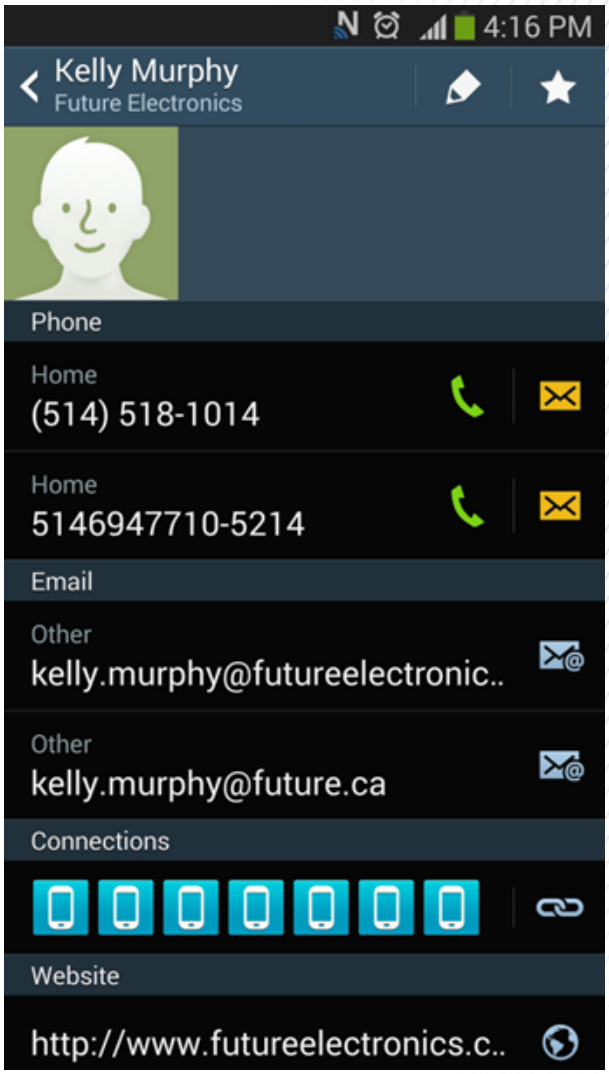
What it does:

Uses NFC, coin cell or solar to power an LCD to advertise pricing and other product info on a shelf display

Demo: NTAG Sniffer Board

NT3H1101 / NT3H1201

NFC Forum Type 2 Tag Compliant IC with I2C Interface



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