Training Mobile Knowledge

NFC Reader Design: How to build your own reader

Public

MobileKnowledge
February 2015

Agenda

- Introduction to RFID and NFC
- Contactless reader design:
  - Initial considerations and architecture
- Illustrative contactless reader schematics:
  - RFID Elektor schematic
  - CLRC663 Point of Sales schematic
- NXP portfolio
  - NFC Reader IC overview
  - LPC microcontrollers overview

Today's session

- NFC Reader Antenna design
  - Antenna principles
  - Antenna design steps
  - Environmental influences
  - Testing & antenna qualification

Next session

Introduction to RFID and NFC

RFID applications, NFC operation and communication modes

Introduction to RFID

- RFID is an abbreviation, consisting of two distinct concepts: Radio Frequency (RF) and Identification (ID)
- RFID technology is used to identify objects, operations or people by means of wireless transmission of data (and energy)
- RFID systems may be sorted by operating frequency, operating range, data rates, energy usage and security.

LF
(~120 turns)

HF
(~8 turns)

UHF
(~1 turn for the loop)

Frequency/ Technology	Operating distance	Main applications	Tag chip family
LF (125 … 134 KHz)	Up to 1 m	Animal ID, industrial, track & trace	HITAG
HF vicinity (13.56 MHz)	Up to 1 m	Libraries, Ski ticketing, item level ID	ICODE
HF proximity /NFC (13.56 MHz)	Up to 10 cm	Public transport, eGov, Banking, access, NFC phones	MIFARE, NTAG
UHF (860 … 960 MHz)	Up to 10 m	Logistics, inventory management	UCODE

NFC Technology

Modes of operation

Card emulation

Payments, Transit, Access, Identity, ...

Contactless readers

Like ISO/IEC14443 PICC

NFC device

Like ISO/IEC14443 PCD

Read/write

Product Authentication, Smart Advertising, Pairing, ...

NFC tags

Active P2P
Both devices generate RF field

Passive P2P
Extended ISO/IEC14443 PCD/PICC

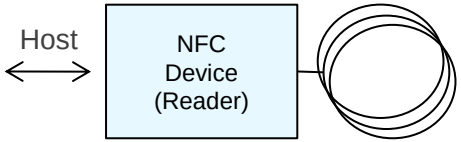
Peer-to-peer

Automotive, Social media, data exchange, games ...

Other NFC devices

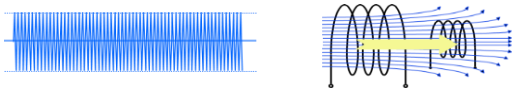
NFC communication modes

Reader/Card communication mode



1. Power

The RF field oscillates at 13,56MHz.
The card is powered through the electromagnetic coupling

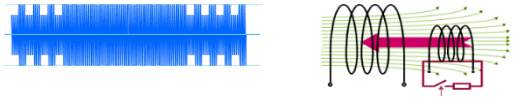


2. The Reader sends commands

The Reader modulates its RF field to send commands

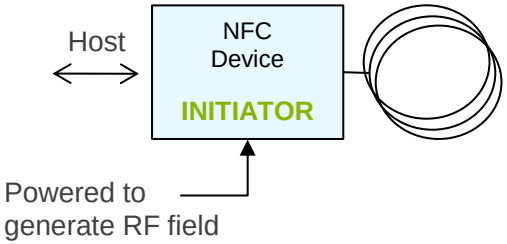
3. Answering to the Reader

By modifying its consumption, the chip modifies the RF field, which the Reader detects (Load Modulation)



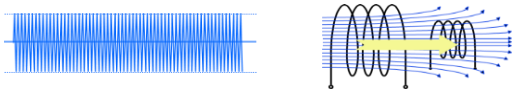
NFC communication modes

P2P passive communication mode



1. The Initiator generates an RF field

This field is used to exchange the data. Both Initiator and Target are powered internally

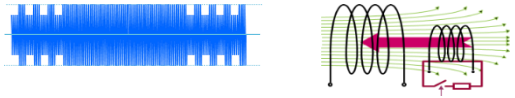


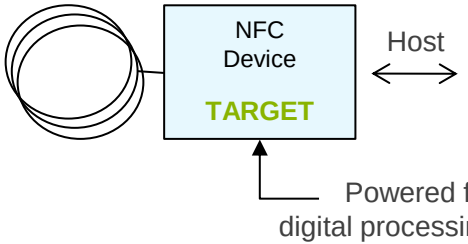
2. The Initiator sends commands

The Initiator modulates its RF field to send commands

3. The Target responds

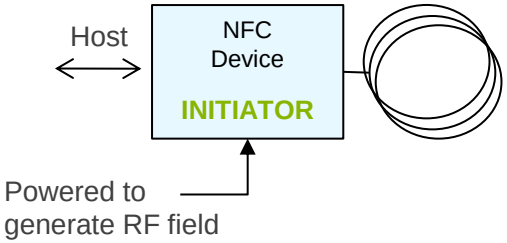
The target uses backward modulation to transmit the response (Load Modulation)





NFC communication modes

P2P active communication mode

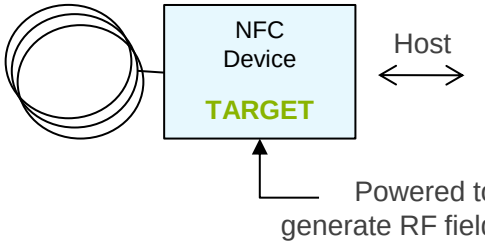


1. The Initiator sends commands

The Initiator generates an RF field, sends commands by modulating its field and then cuts the field

2. The Target responds

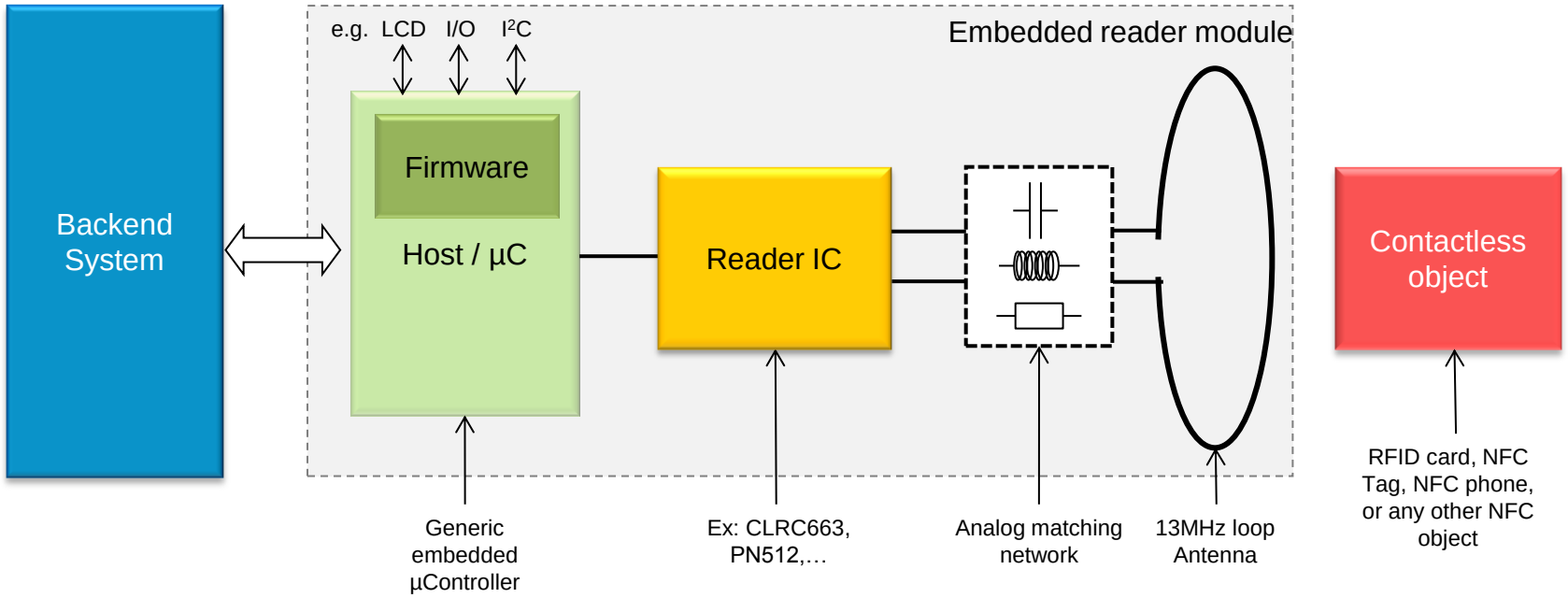
Once the Initiator cuts its RF field, the target generates its own field and uses it to transmit responses.



Contactless reader design

Initial considerations & architecture

Basic contactless reader architecture

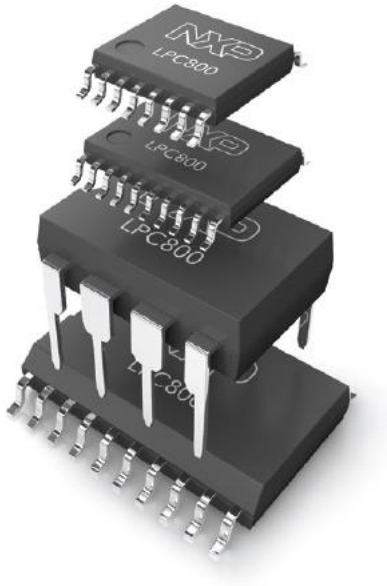


Steps to design a contactless reader

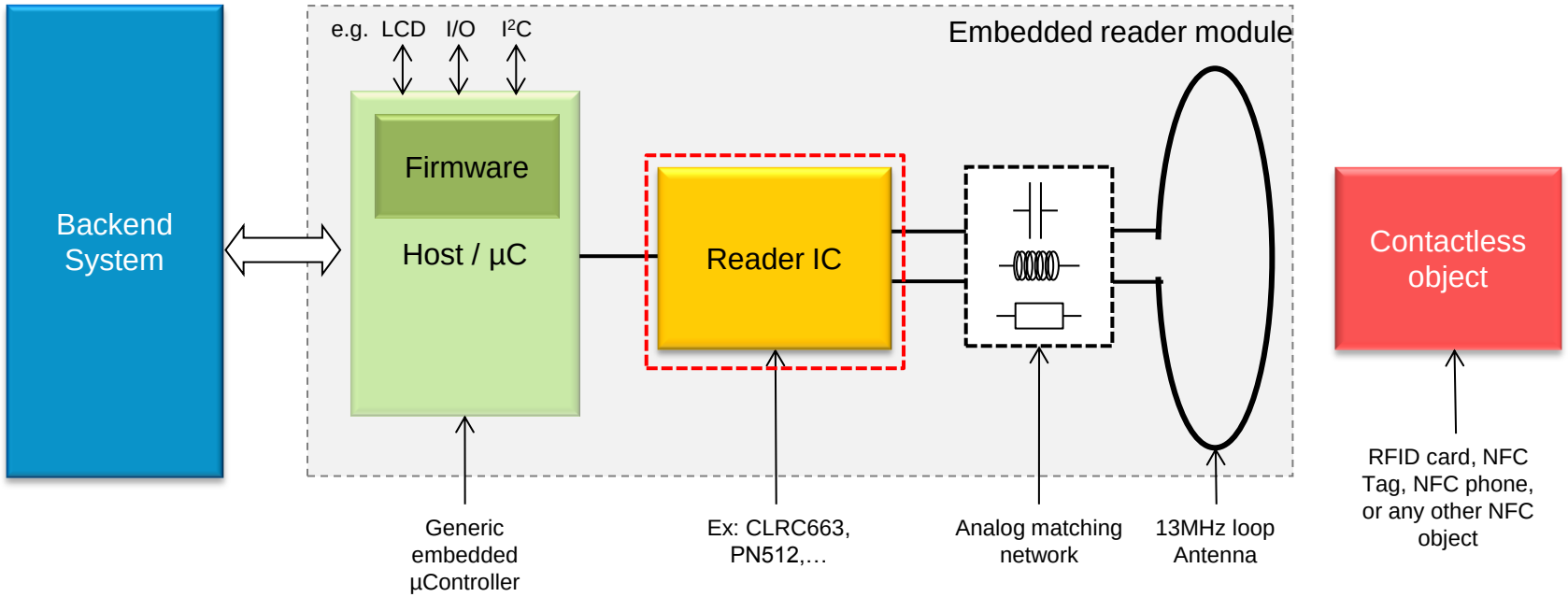
1. Selection of **contactless reader IC**
   Which transponder do we need to communicate with?
2. Selection of **Host**
   The brain and heart of our contactless reader
3. Selection of **security** architecture
   SAM or Host for key storage
4. **Antenna** design

Next session

5. **GO!**



Basic contactless reader architecture



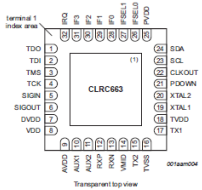
Contactless reader design

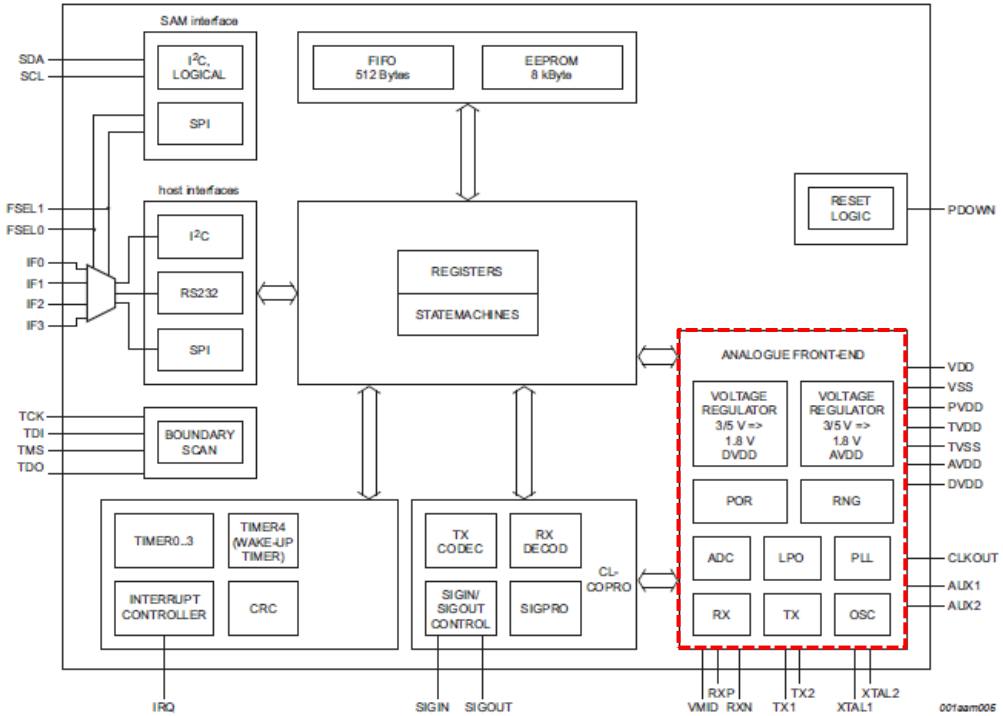
Step 1: Selection of contactless reader IC

- 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
- Security handling
  - Some applications will require SAM support (integrated/external)
- Selection of the host interface
  - SPI, I^2C, RS232, UART ..
- Specific features
  - Specific data rates, timing and reading distance

Reader IC module

e.g. CLRC663 reader IC



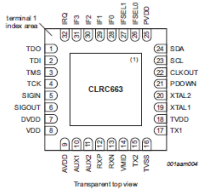


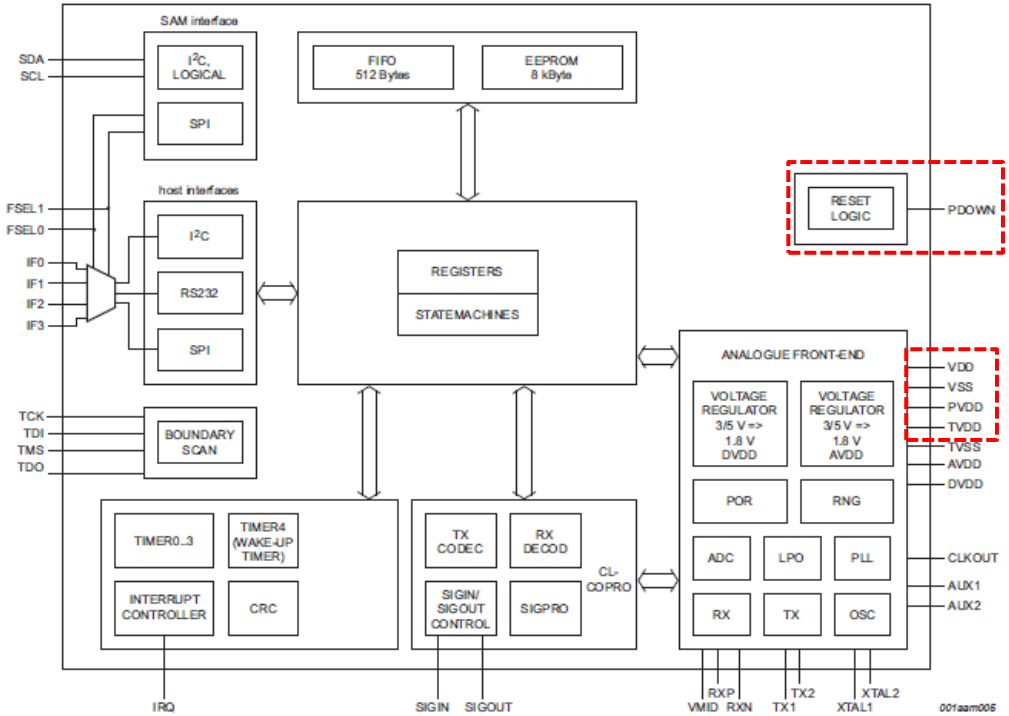
Analog frontend

- The analog interface handles the modulation and demodulation of the antenna signals for the contactless interface.
- Analog test signals (pin AUX1 and AUX2)
  - For optimizing / debugging hardware in terms of performance and noise (AN11019)
- Clock signal (pin XTAL1 and XTAL2)
  - Act as time basis for generation of the carrier sent out as well as for the coder and decoder synchronous system.
  - Clock jitter must be as small as possible.
- IntegerN PLL clock line
  - It can serve as a clock source to a MCU, which avoids the need for a second crystal oscillator in the reader system. (pin CLKOUT)

Reader IC module

e.g. CLRC663 reader IC



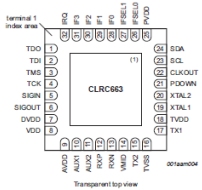


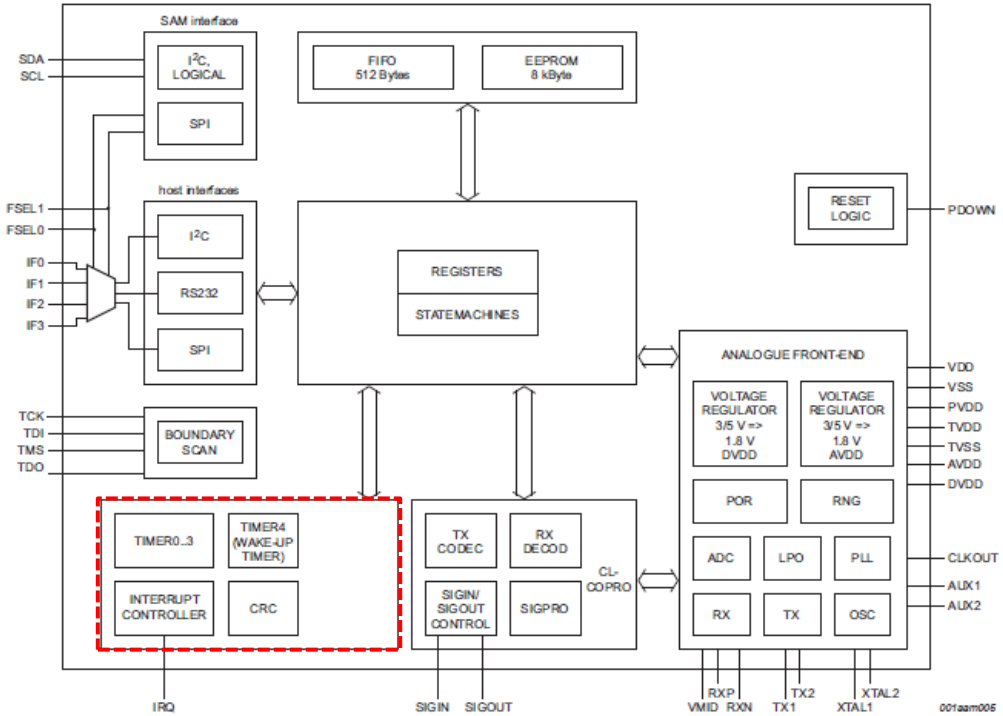
Power management

- Supply concept
  - Three supply pins VDD, PVDD and TVDD. Can be supplied in range from 3.3V to 5V.
    - Pin TVDD can be supplied by 3.3V or 5V (for higher field strength)
    - Pin PVDD and VDD should be supplied at 3.3V to operate with a 3.3 V supplied MCU.
  - Independent of the voltage, it is recommended to buffer these supplies with blocking capacitors (VDD and PVDD min 100 nF; TVDD min 100 nF parallel to 1 uF)
- Power-down (8nA-40nA), standby mode (3-6µA) and modem off (0.45 – 0.5 mA) energy saving options
- Low Power Card Detection (LPCD):
  - Energy saving mode in which the reader IC is not fully powered permanently

Reader IC module

e.g. CLRC663 reader IC





Interrupt controller

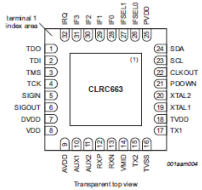
- Handles the enabling / disabling of interrupt requests.
- All of the interrupts can be configured by firmware.
- Indicates certain events by setting bit IRQ in the appropriate register and if activated, by pin IRQ.
  - The signal on pin IRQ may be used to interrupt the host. Allows the implementation of efficient host software.

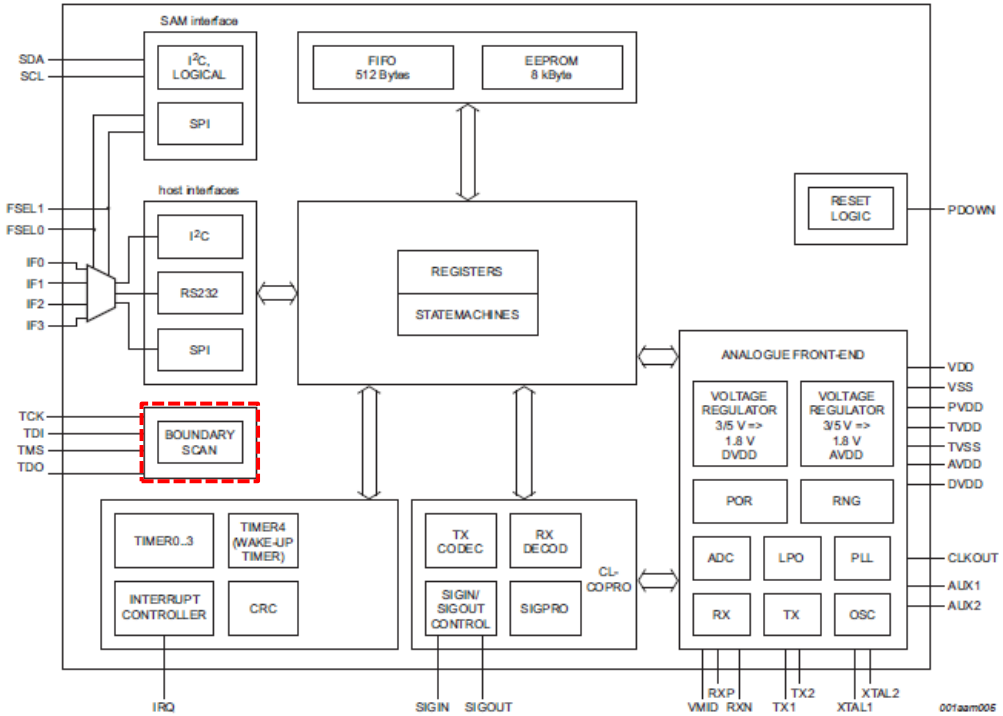
Timer module

- The external host may use these timers to manage timing relevant tasks such as time-out counter, watch-dog counter or periodical triggers.

Reader IC module

e.g. CLRC663 reader IC



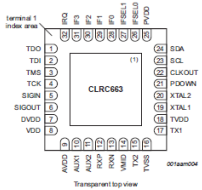


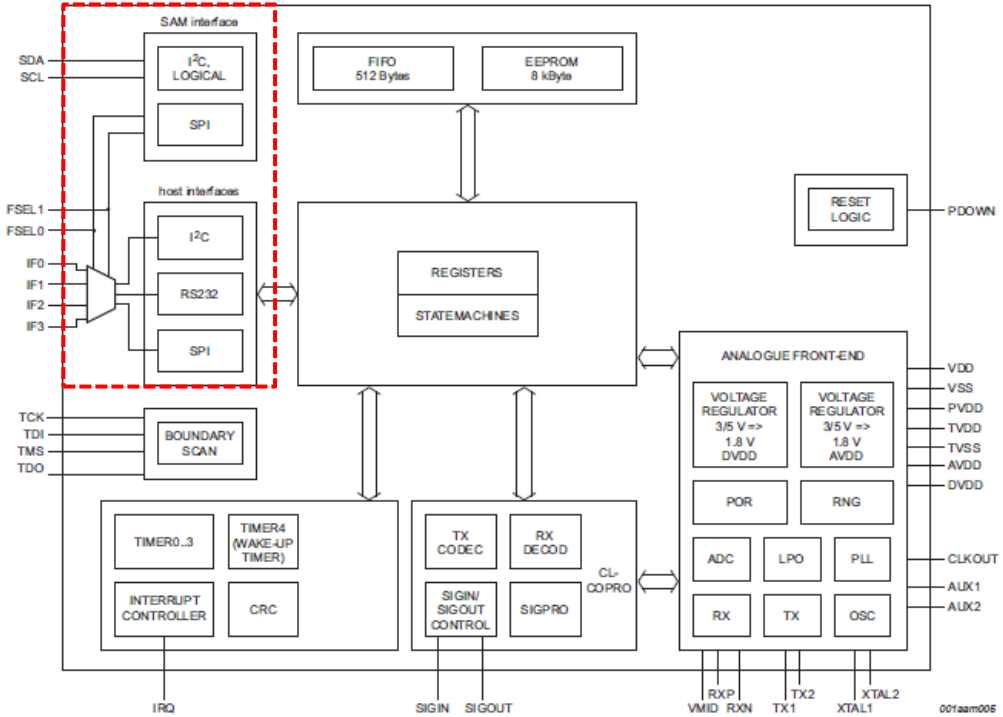
Boundary scan interface

- Interface according to IEEE 1149,1
- Implements a four line interface between the chip and the environment (Test Clock, Test Mode Select, Test Data Input and Test Data Output).
- Allows testing interconnections without using physical test probes.
- It uses its own description language (BSDL = Boundary Scan Description Language)

Reader IC module

e.g. CLRC663 reader IC





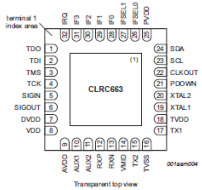
Host interface selection

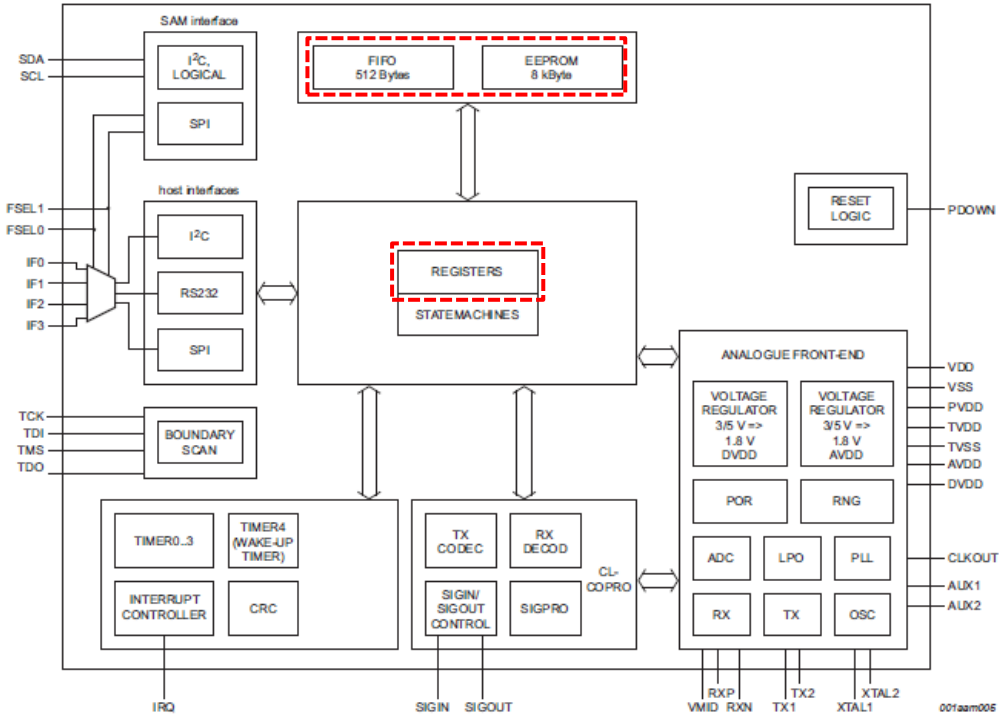
- Support direct interfacing of various hosts (SPI, I²C, UART) interface type.
- Host interface type is selected by means of the logic levels on the control pins after Reset Phase (pin IFSEL0, IFSEL1)
- NXP reader ICs implement a dedicated I²C interface to integrate MIFARE SAM (SAM X-interface, will be explained later).

Pin	Pin Symbol	UART	SPI	I²C
28	IF0	RX	MOSI	ADR1
29	IF1	-	SCK	SCL
30	IF2	TX	MISO	ADR2
31	IF3	1	NSS	SDA
26	IFSEL0	0	0	1
27	IFSEL1	0	1	0

Reader IC module

e.g. CLRC663 reader IC





Register bank

- The register bank contains the settings for the analog and digital functionality.
- Recommended protocol settings (AN11022)

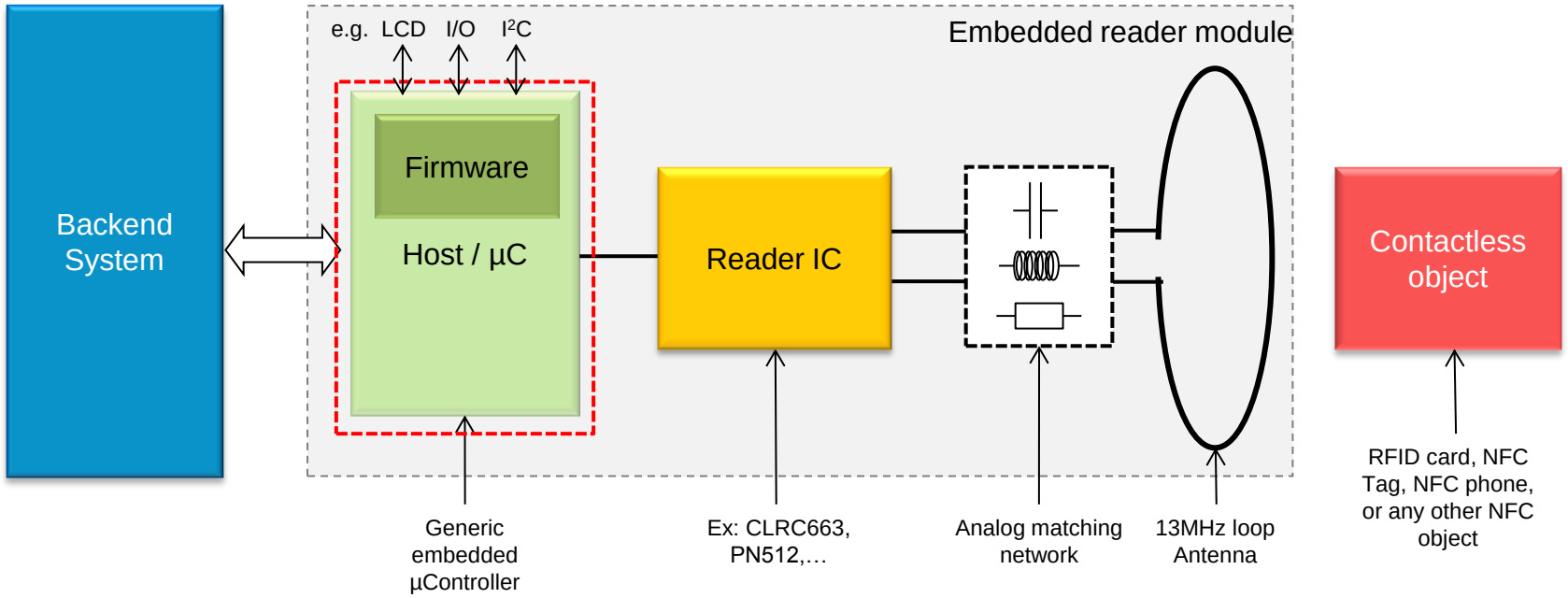
Integrated EEPROM

- Register settings of the device can be preconfigured in the EEPROM.
- ***Load protocol:*** A single host command allows loading the register settings for another contactless protocol.

FIFO

- Buffer that handles 512 byte send and receive

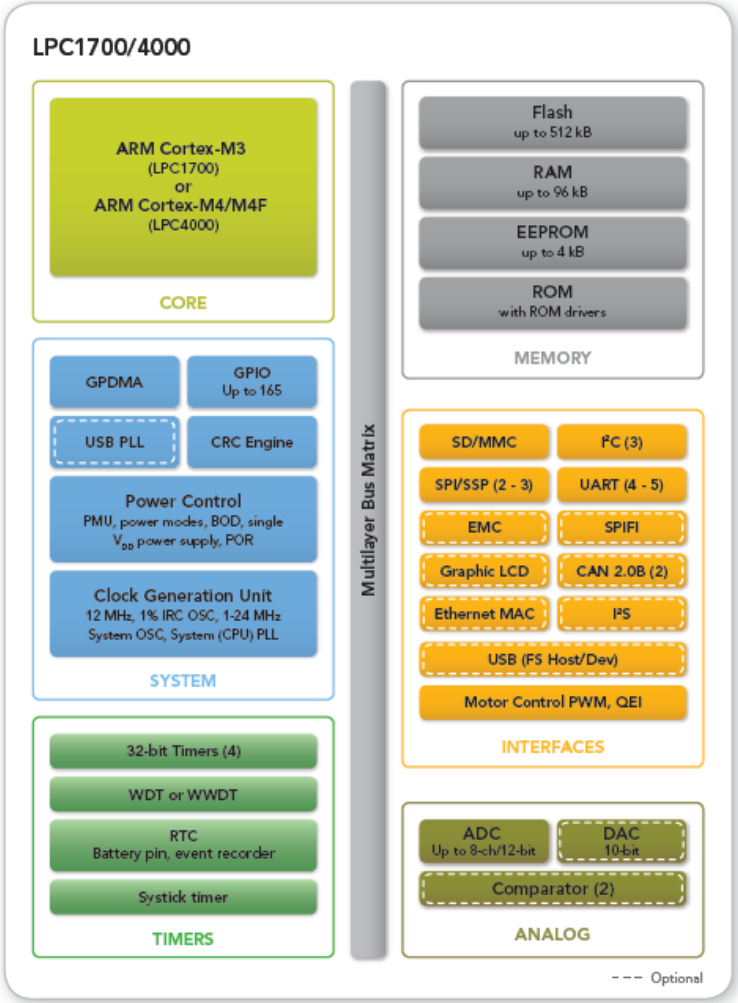
Basic contactless reader architecture



Contactless reader design

Step 2: Selection of Host

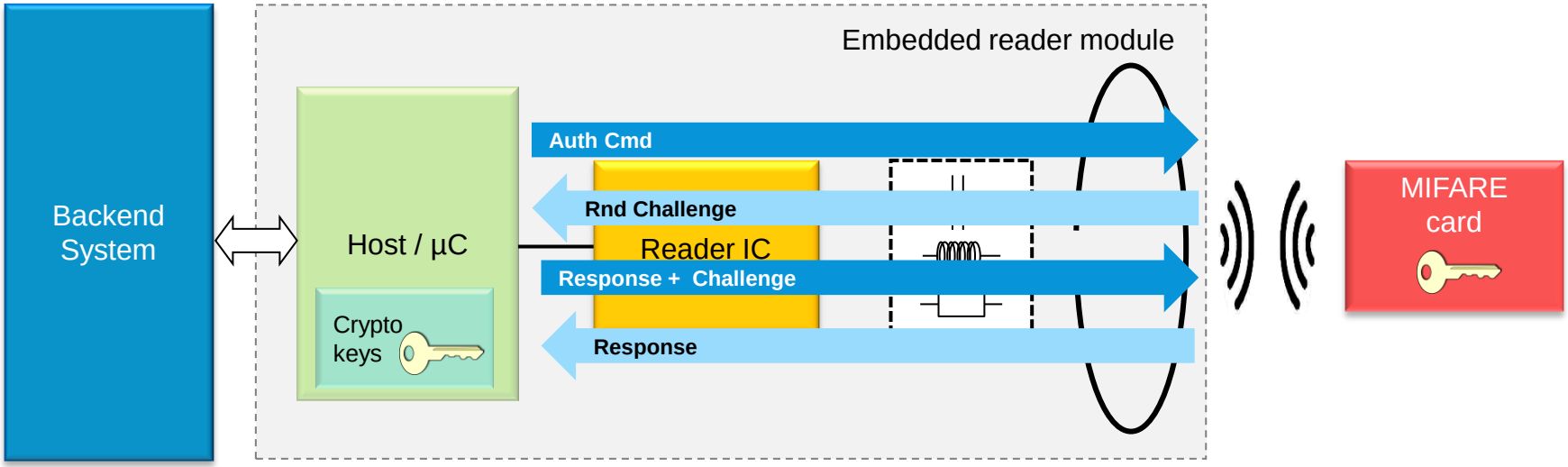
- External interfaces
  - Serial, USB, Ethernet
  - RF connectivity (BL, Wifi, Zigbee,…)
- SW architecture
  - How heavy or light are the processing power requirements (MCU clock)
- Host architecture
  - Impact on development environment and source code libraries
- Memory requirements
  - Flash, RAM, ROM
- Power requirements
- Specific requirements
  - Secure EEPROM to store keys?
  - Crypto accelerators?
- Manufacturer support



Contactless reader design

Step 3: Selection of security architecture (Host)

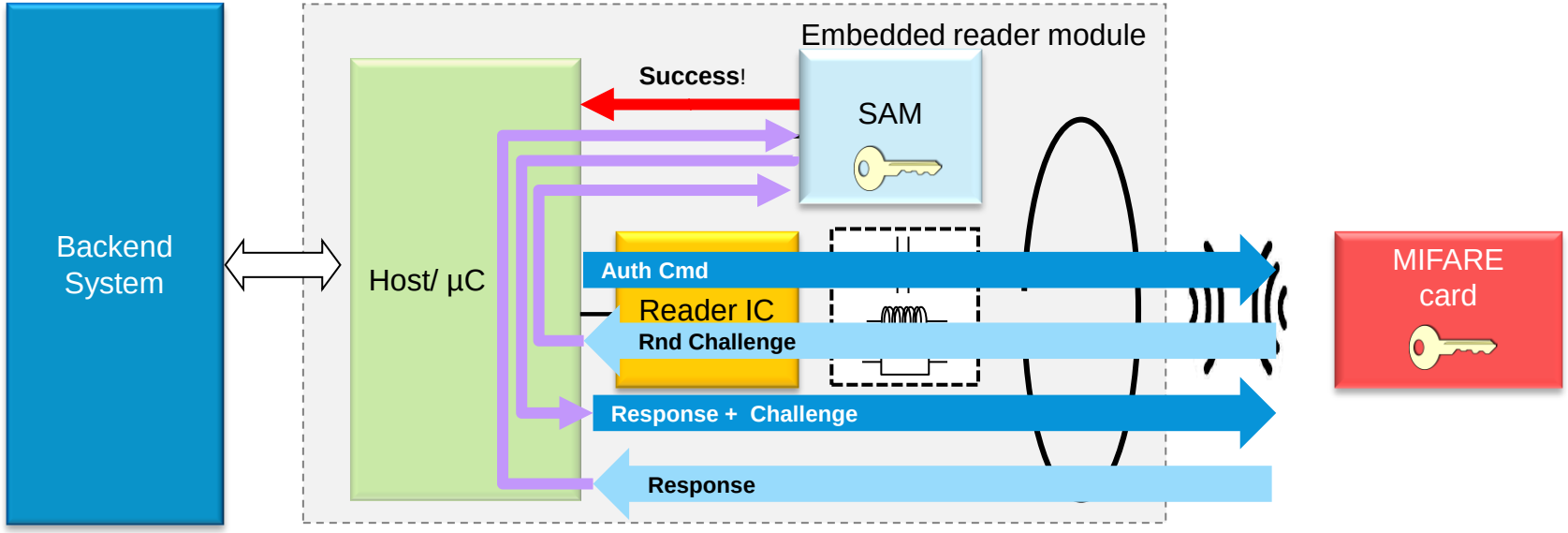
- Microcontrollers are not designed and developed to securely store and maintain cryptographic keys since they don't offer reliable protection and security mechanisms



Contactless reader design

Step 3: Selection of security architecture (SAM S-interface)

- SAM device carries HW based cryptography that allows one to perform complex cryptographic operations efficiently and to securely store and protect keys



Contactless reader design

Step 3: Selection of security architecture (SAM X-interface)

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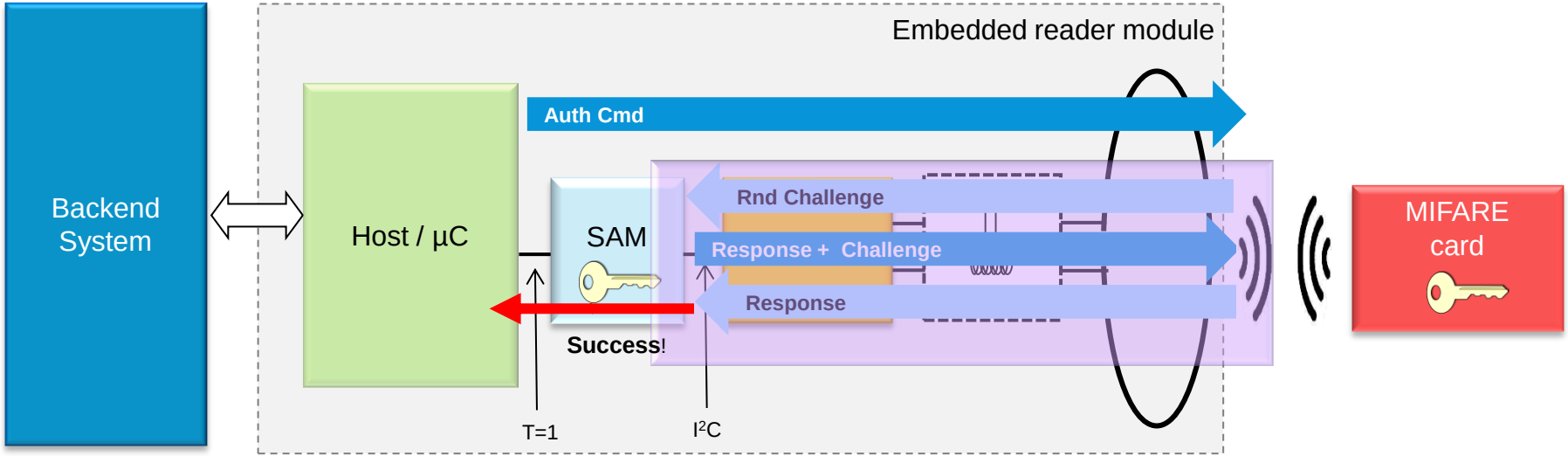
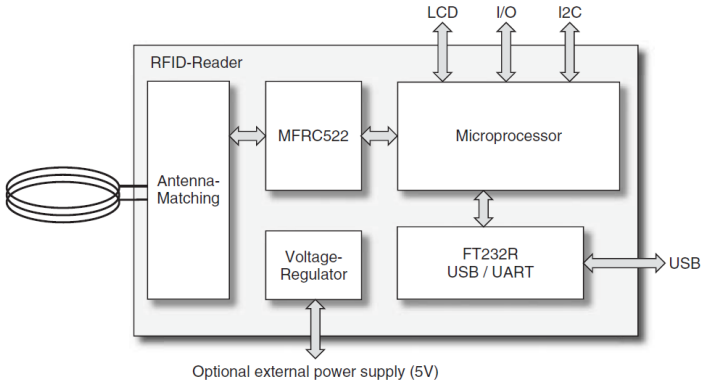


Contactless reader

e.g. RFID Elektor reader schematic

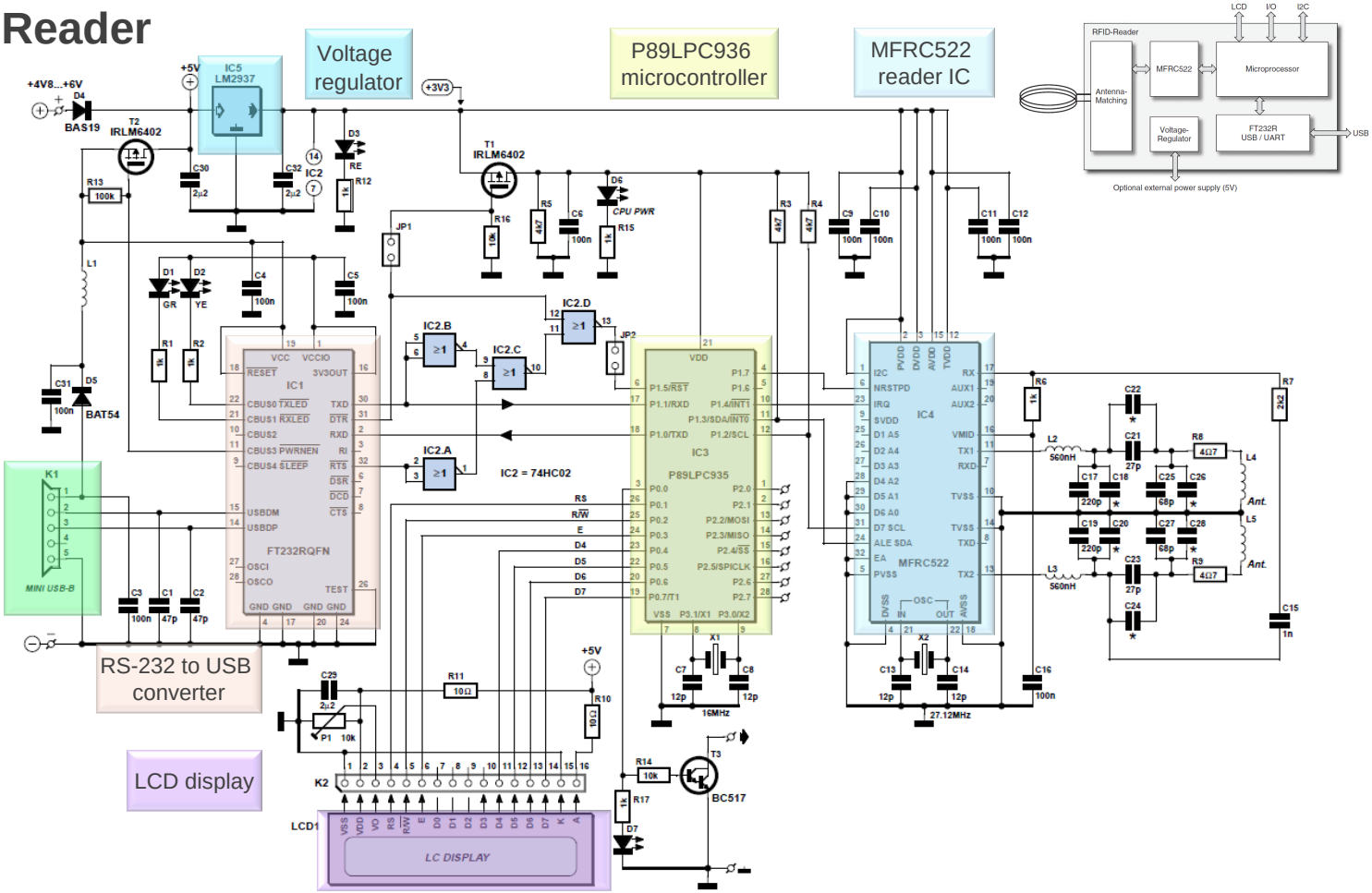
Elektor RFID reader

- Elektor RFID reader is compatible with MIFARE and ISO/IEC 14443-A international standard.
- It was designed to make the device as universal as possible.
- Features:
  - Compatible with MIFARE and ISO/IEC14443-A cards
  - USB interface for PC connection
  - MFRC522 reader IC (NXP)
  - P89LPC936 microcontroller (NXP 8051-based MCU)
  - I^2C and SPI interfaces
  - Available 8-bit I/O output
  - Programming tools available



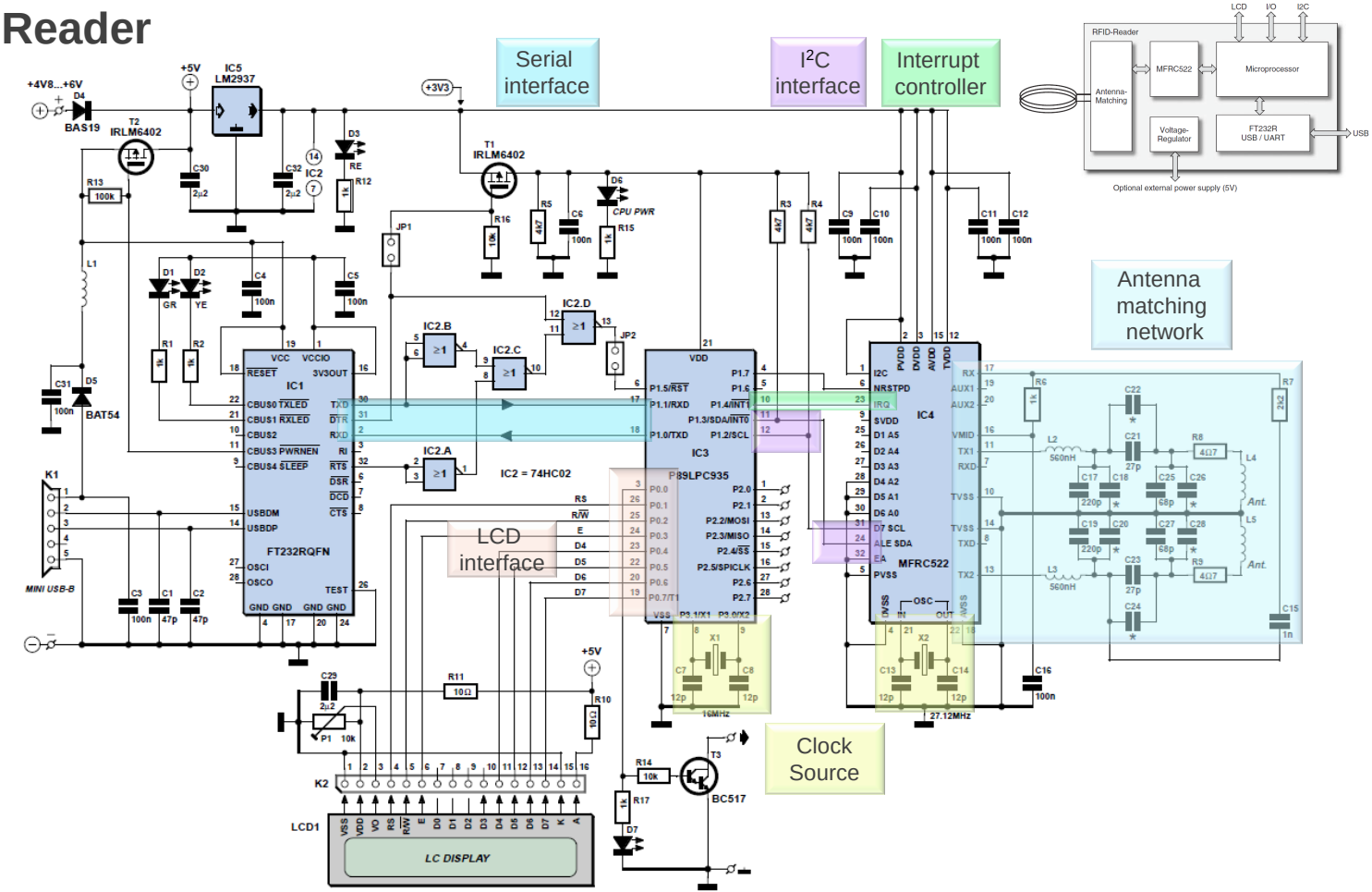
Elektor RFID Reader

Schematic



Elektor RFID Reader

Schematic



Contactless reader

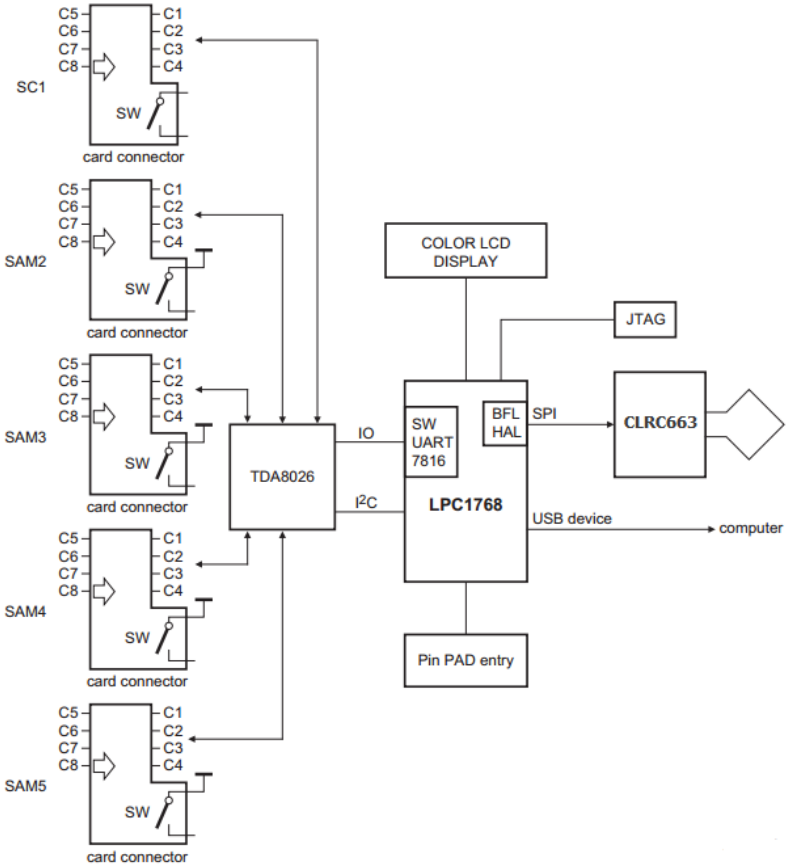
e.g. CLRC663 POS schematic

Point of sales

Based on CLRC663 reader IC

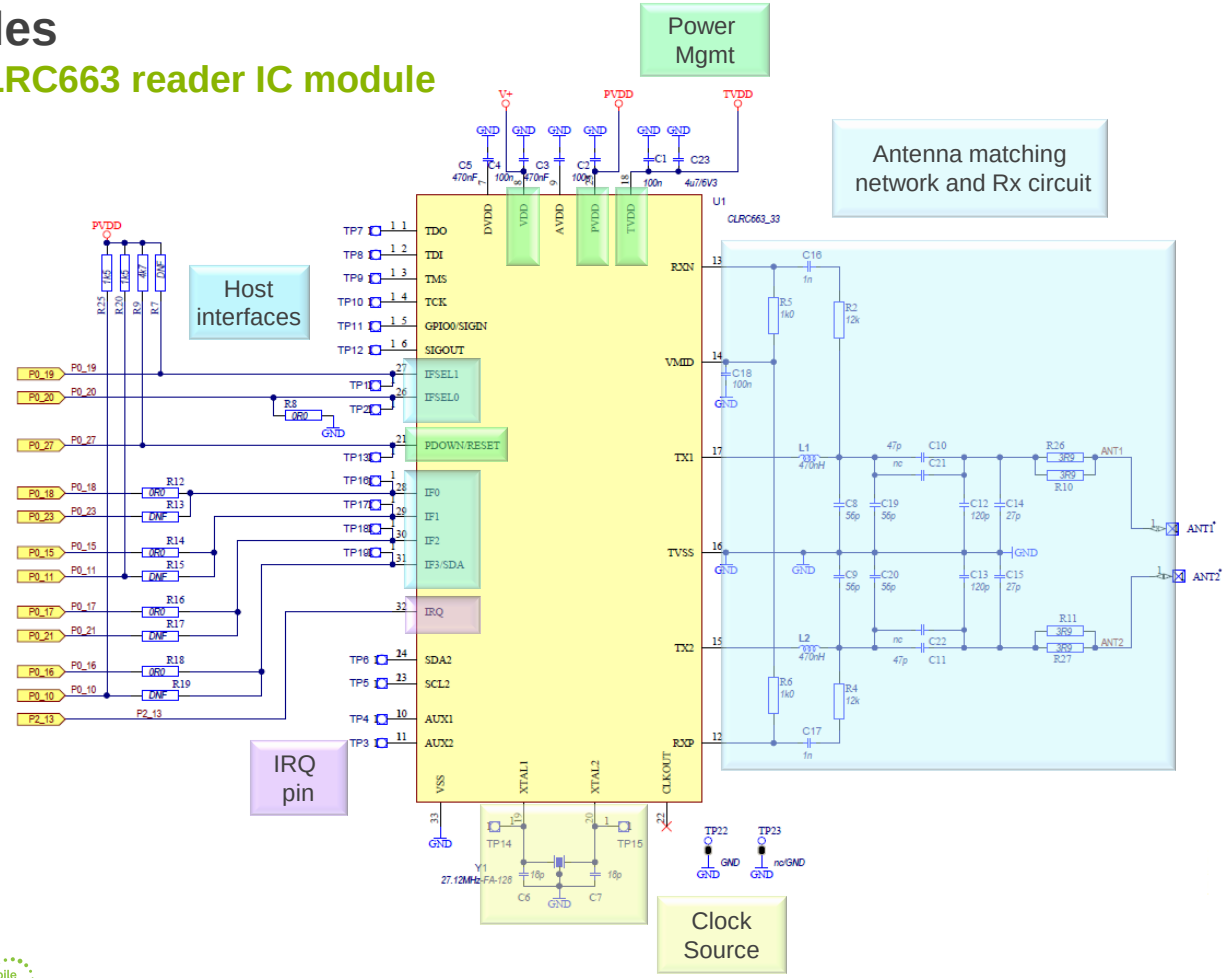
- OM5597/RD2663 is a development kit of a cost effective EMV compliant Point of Sales Terminal based on NXP components.
- It provides an EMV Level 1 compliant software stack for contactless as well as contact payment based on CLRC663 and TDA8026.
- The user interface is composed of an LCD screen and a keyboard.

http://www.nxp.com/demoboard/OM5597.html



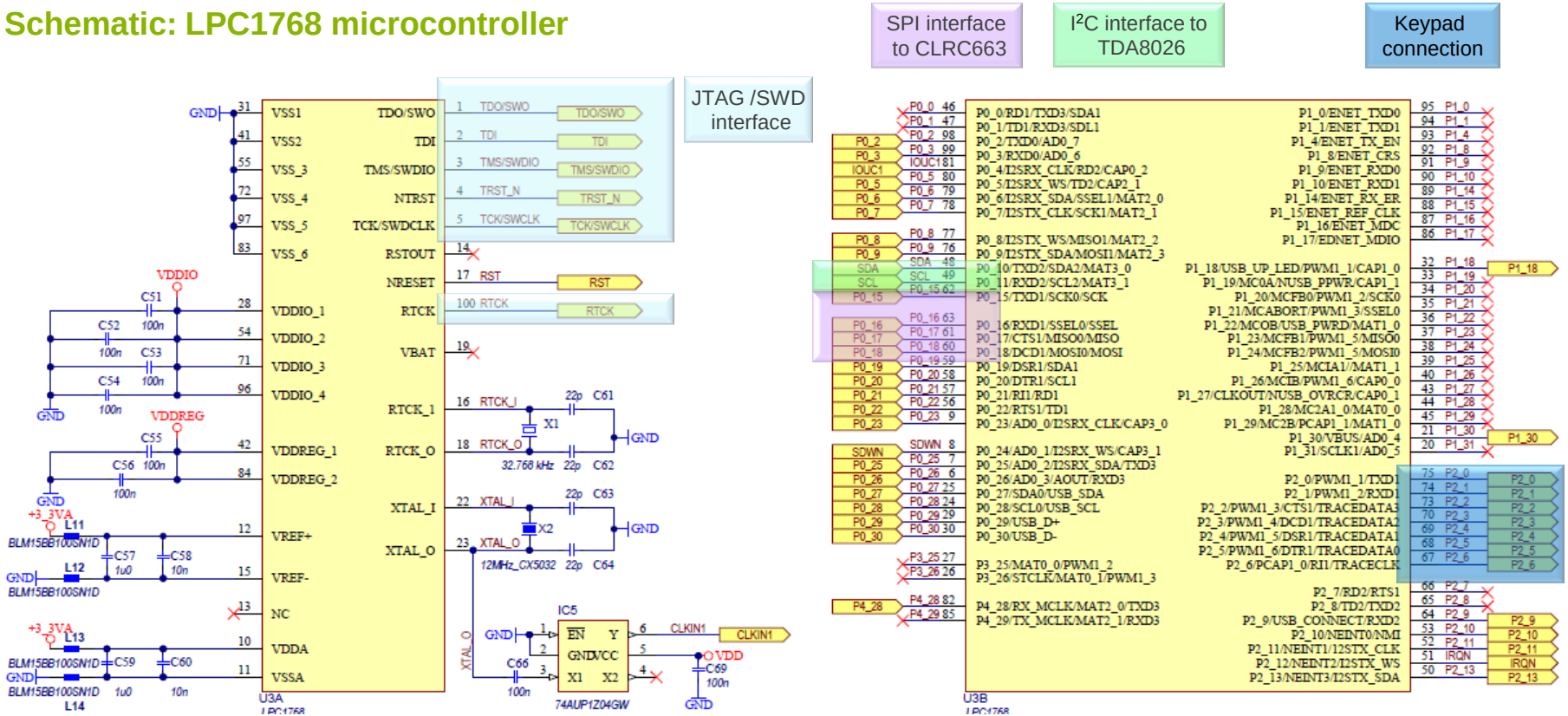
Point of sales

Schematic: CLRC663 reader IC module



Point of sales

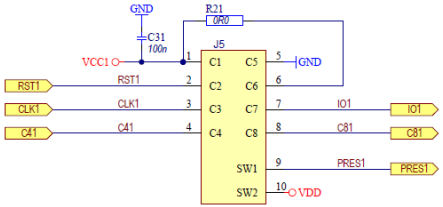
Schematic: LPC1768 microcontroller



Point of sales

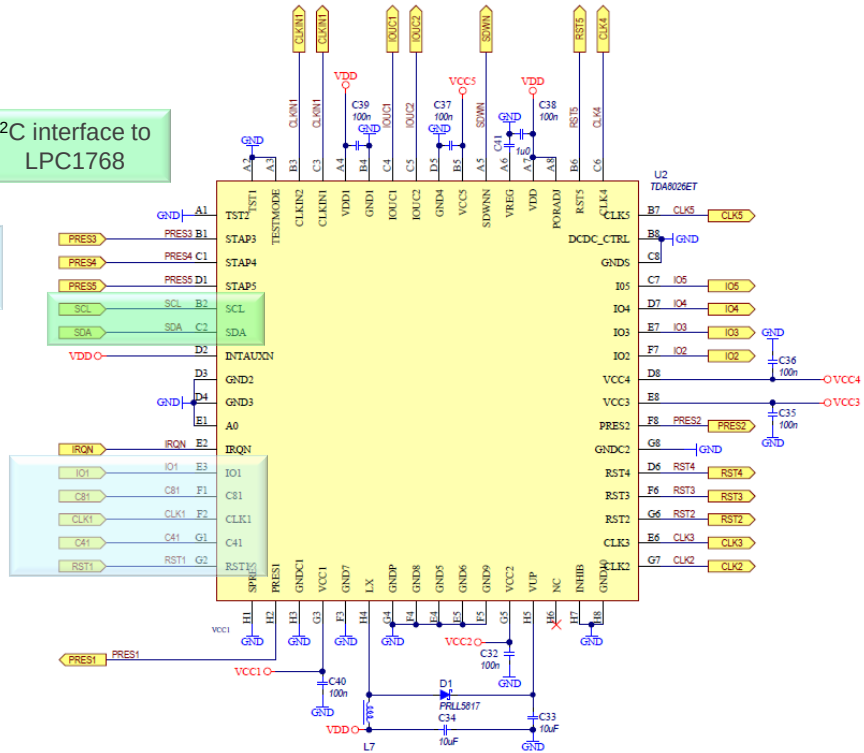
Schematic: TDA8026 and SAM

- The TDA8026 can handle up to 5 SAM modules and is connected via I²C to the LPC1768



I²C interface to LPC1768

SAM slot #1

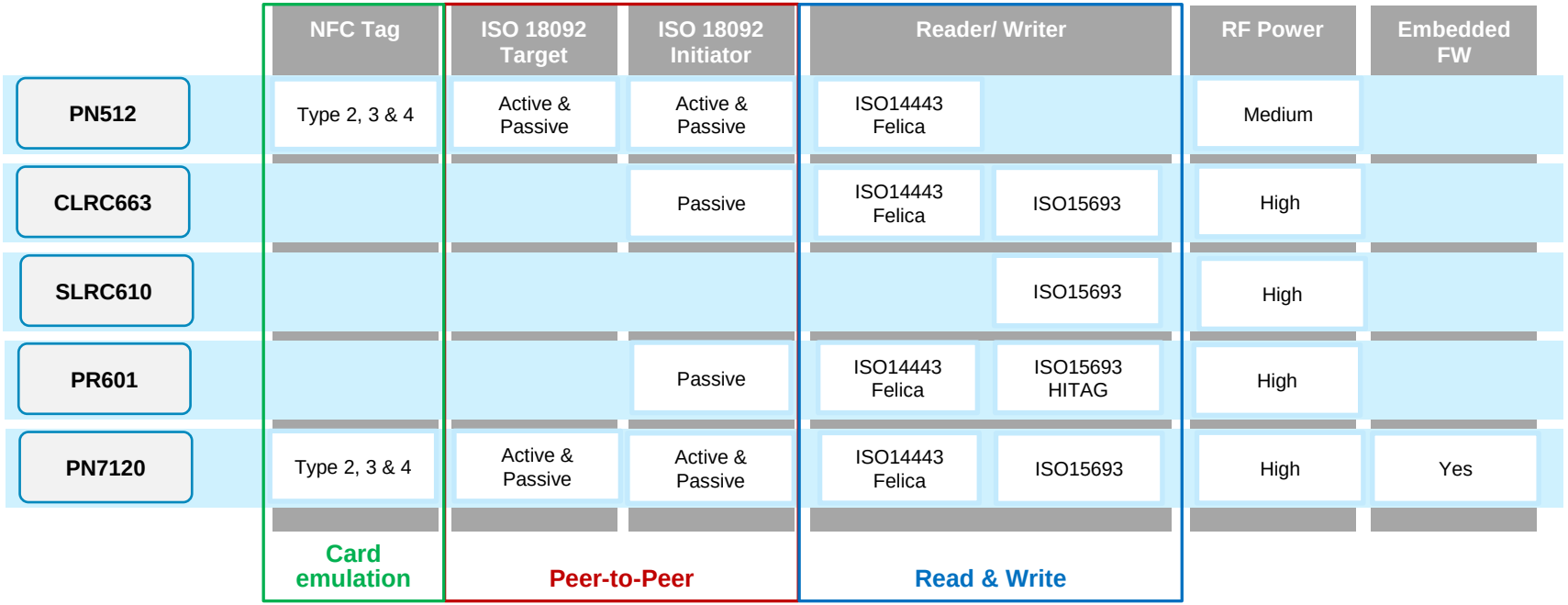


NXP Portfolio

NFC Readers

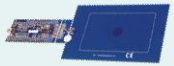
NFC Readers IC portfolio

Overview



NFC Readers IC portfolio

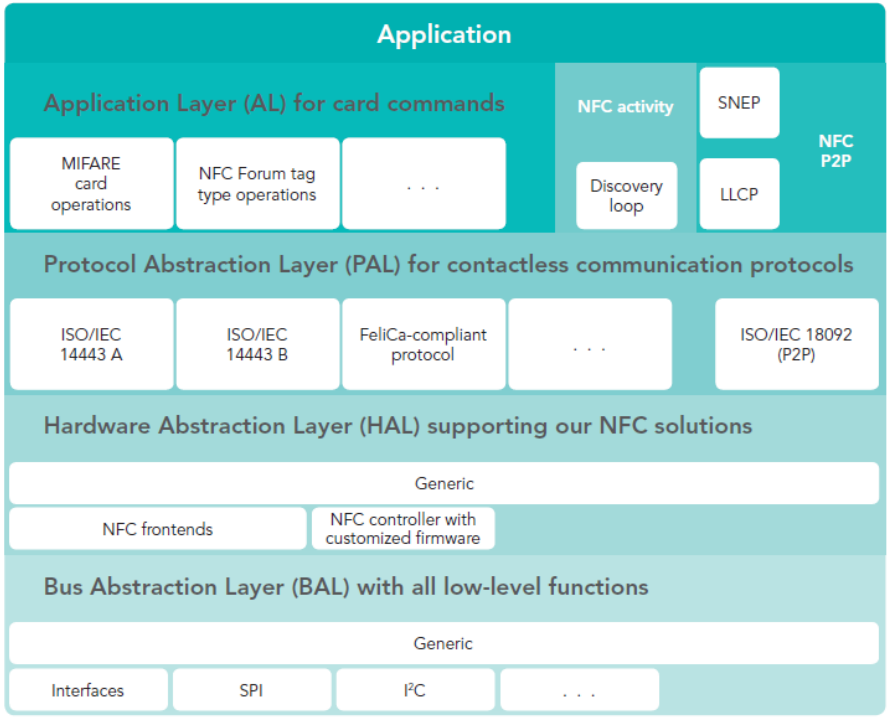
Hardware support: Evaluation boards

Product	Board	Photo	Description	More info
PN512	PNEV512B		A two-board combination that stacks a PN512 board on an LPC-Link prototyping board, for use with NXP's LPC microcontrollers. NFC Forum-compliant reader IC.	www.nxp.com/demoboard/PNEV512B.html
PN512	PNEV512R		An expansion board, designed for use with Raspberry Pi, which is a card-sized ARM-based, computer-running Linux.	www.nxp.com/demoboard/PNEV512R.html
CLRC663	CLEV663		Evaluation board for multi-protocol CLRC663. Testing reader IC functionalities.	www.nxp.com/demoboard/CLEV663.html
CLRC663	CLEV663B		A two-board combination, with a CLRC663 board stacked on an LPC-Link prototyping board for use with NXP's LPC microcontrollers	www.nxp.com/demoboard/CLEV663B.html
PR601	PREV601M		Microboard with PR601 and 13,56MHz antenna. Powered by a single battery, and supported by the NFC Reader Library	www.nxp.com/demoboard/PREV601M.html
PN7120	In development	-	NFC Forum-compliant development board with Raspberry Pi interface	Available in 2015

NFC Readers IC portfolio

SW support: NFC Reader Library

- The NFC Reader Library is a modular software library written in C language
  - Components can be added / subtracted without disturbing the rest of the stack.
- Provides an API which makes it easy to create a software stack and applications for an NFC IC.
  - Implement all the lower-layer functions
    - SPI, I²C
  - Implement the drivers for NFC ICs
  - Implement the contactless protocol
  - Implement APIs to operate with MIFARE and NFC Forum tags.
  - All components needed for communication in P2P
- The application and protocol layers operate independently of the microcontroller
  - These layers are not bound to or dependent on any specific hardware.



NXP Portfolio

LPC microcontrollers

LPC microcontrollers portfolio

Overview

- Entry-level LPC microcontrollers

Series	ARM core	Flash/RAM (max kB)	Description
LPC800	30 MHz Cortex-M0+	32/8	Exceptional power efficiency, small packages
LPC1100	50 MHz Cortex-M0+ or M0	256/32	Low power, broad feature and package selection, USB, CAN
LPC1200	45 MHz Cortex-M0	128/8	Noise immunity for industrial applications

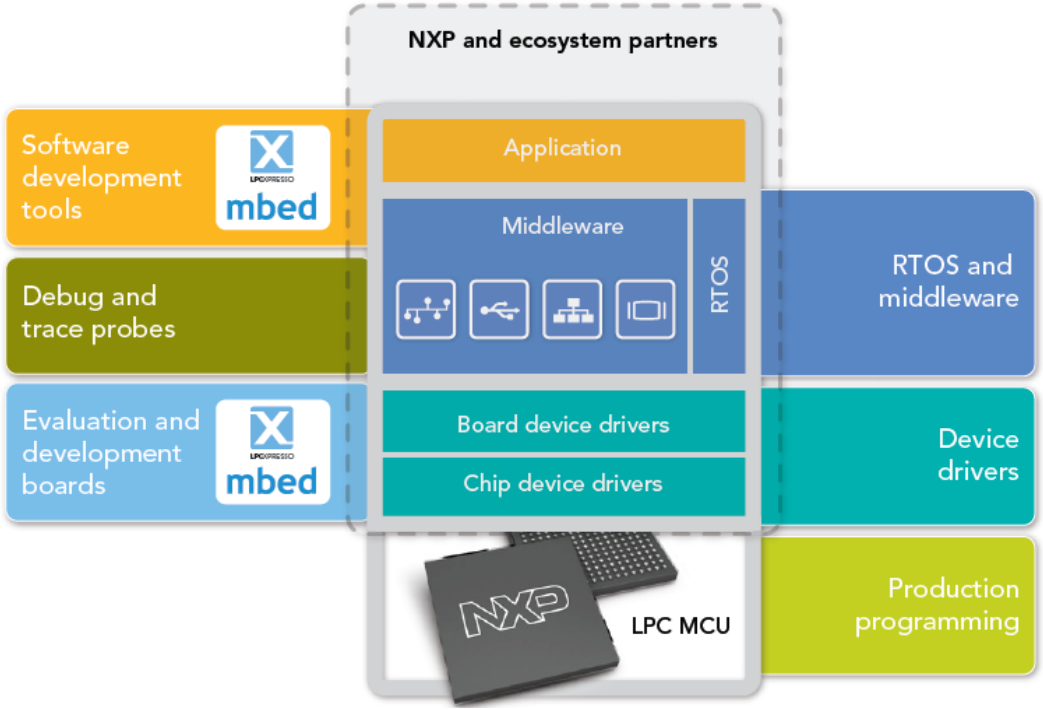
- High performance LPC microcontrollers

Series	ARM core	Flash/RAM (max kB)	Description
LPC1300	Up to 72 MHz Cortex-M3	64/12	Performance and basic connectivity
LPC1500	Up to 72 MHz Cortex-M3	256/36	High-precision motor control, CAN, USB
LPC1700	Up to 120 MHz Cortex-M3	512/96	High performance, advanced connectivity, USB, graphic LCD controller
LPC4000	Up to 120 MHz Cortex-M4 or M4F	512/96	High performance with DSP options, advanced connectivity, USB, graphic LCD controller
LPC1800	Up to 180 MHz Cortex-M3	1024/136 0/200	Best performance, multi-high-speed connectivity, USB, graphic LCD controller
LPC4300	Up to 204 MHz Cortex-M4F & M0+	1024/136 0/282	Best performance with DSP and dual-core options, multi-high-speed connectivity, USB, graphic LCD controller
LPC54100	Up to 100 MHz Cortex-M4F & M0+	512/104	Best-in-class power consumption, scalable performance, small package

LPC microcontrollers portfolio

Developer ecosystem

- SW development tools
  - LPCXpresso IDE and mbed IDE.
  - Popular tool chains from IAR, Keil and other vendors provide support for LPC products.
- Debug and trace probes
  - ARM MCUs provide either JTAG and / or SWD ports.
- Evaluation and development boards
  - LPCXpresso boards, mbed boards, Full-featured develop. Boards (Embedded Artists, Keil, IAR and NGX)
- RTOS, middleware and drivers
  - Free chip and board-level drivers, middleware such as TCP/IP stacks, graphic libraries, USB drivers, etc.



Further information

NFC Reader Design: How to build your own reader

- NFC Everywhere
  www.nxp.com/nfc
- NFC controller and frontend solutions
  http://www.nxp.com/products/identification_and_security/nfc_and_reader_ics/
- RFID: MIFARE and Contactless Cards in Application
  www.amazon.com/RFID-MIFARE-Contactless-Cards-Application/dp/1907920145
- LPC microcontrollers
  http://www.nxp.com/products/microcontrollers
- LPC Zone
  www.nxp.com/lpczone
- LPCXpresso
  www.nxp.com/lpcxpresso
- LPCWare
  www.lpcware.com
- Trainings & webinars:
  http://www.nxp.com/products/related/customer-training.html

MobileKnowledge

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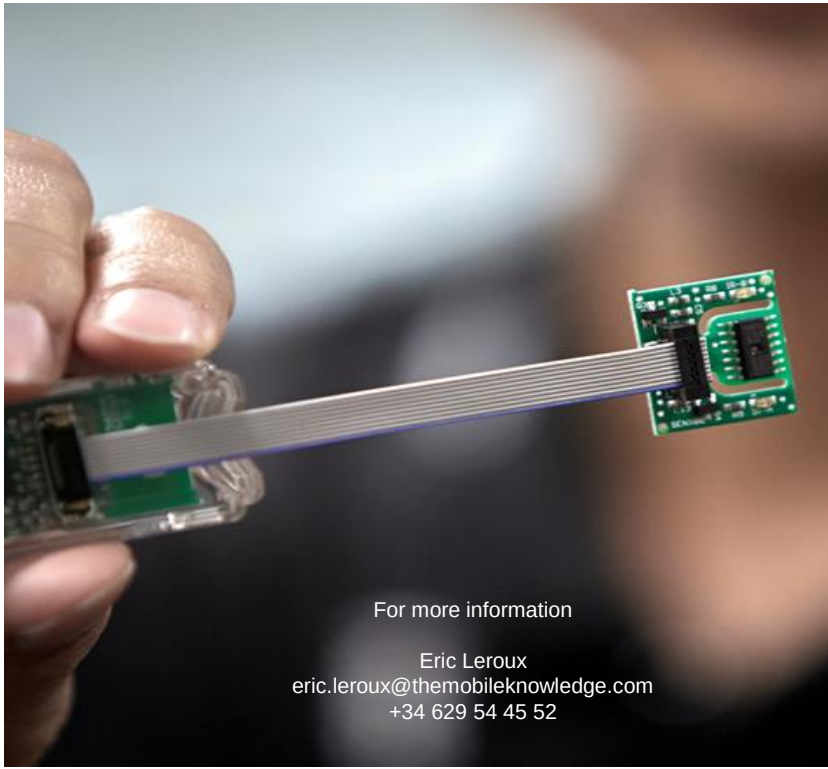
- We are a global competence team of hardware and software technical experts in all areas related to contactless technologies and applications.
- Our services include:
  - Application and system Design Engineering support
  - Project Management
  - Technological Consulting
  - Advanced Technical Training services
- We address all the exploding identification technologies that include NFC, secure micro-controllers for smart cards and mobile applications, reader ICs, smart tags and labels, MIFARE family and authentication devices.



NXP Training Mobile Knowledge