ST25R NFC Reader Family

www.st.com/st25r

June 2017
ST25R Series Benefits

• The ST25R family is an integrated reader IC for contactless applications with several benefits:
  • **Outstanding analog performance**
    • No external amplifier to achieve high field strength required
    • Automatic antenna tuning
    • Lowest power wakeup
    • Excellent P2P compatibility

  • **Fastest time to market**
    • reduced time to market at our customers significantly

  • **Proven solution**
    • The ST25R family is a market proven solution used in the consumer and automotive space.
    • Ensures best customer experience

  • **Full integration into the STM32 library**
ST25R Main Markets

Payment
- Faster EMVco certification
- Reduced BOM

Access
- Low power wakeup
- Works in metal housing

Automotive
- Working in Metal environment
- Allows small antenna design

Gaming
- Power for special features
- Drives multiple antennas

Transport
- Phone compatibility
- Fast, reliable reads

eGovernment
- Fast transaction time with big data
- Drives multi Antenna
ST25R

Use cases
NFC for payment

Payments & Home Banking

Today’s Mobile POS versions (mPOS) let small businesses and individuals support cashless transactions with minimal investment.

Enhanced user experience

NFC lets you do more than just process payments, it allows to collect data from the customer’s smartcard or smartphone.
POS requirements

EMVCo field strength requirement
EMVCo mandates certain field strength requirements. ST25R391x offers >1.4Watt combined with dynamic power output. No additional booster circuitry is required. This is critical as the designs are getting smaller and antennas closer to the display/batteries.

P2P compatibility with mobile phones
ST25R391x was tested and optimized against multiple phones. This is important for upcoming standards for mobile payment as well as couponing.

Fastest time to market
The ST25R391x library is continuously updated with every new EMVCo revision. LVL1 firmware available as source and integrated in the ST MCU environment. Analog & digital features like high output power, dynamic power output, modulation depth adjustment help to ease design challenges.
NFC for Access control

Smart locks
NFC-enabled smartphone/device can be used to configure the lock, to grant temporary access to friends, visitors, maintenance or cleaning.

Hotel access
Hotel guests can gain quicker access to their rooms from by just tapping their card or NFC phone/device to the lock.
Access control requirements

**Average Power Consumption**
The entry function continuously checks for cards. Therefore the average power consumption must be minimized to obtain longest battery lifetime. ST25R391x offers lowest power wakeup functionality down to 5µA.

**Range & antenna size**
The antenna must be optimized to fit into door handles or tuned to the influence of different materials, often also metal. A reasonable range, sometimes even up to 10cm, must be reached. ST25R391x up to 1.4W and automatic antenna tuning.

**Time to unlock**
The time window between presentation of the entry key (phone/card) must be within a certain timeframe to avoid the feeling of latency. A relatively short time should be targeted.
NFC for connected homes

**Pay per view**

NFC makes it easy to pay for streaming services

Just tap your NFC smartphone for configuring, while authentication feature let you safely access your online accounts, gaming, or social media.

**Second screen & remote UI**

NFC: quick and secure pairing to any connected device

With just a tap to a router the secure key is exchanged. Tapping a TV will turn your Phone into a second screen.
Connected home benefits

**Protocol & platform agnostic**
NFC supports any kind of protocol and is in a large population of phones.

**NFC is Easy & Flexible**
No manual entry of Exchange keys. No power supply required for the tag side. Preconfiguring of devices is possible. One tap commissioning possible.

**Save through proximity**
Key exchange on short range. Can be enhanced by SE.
NFC for Entertainment

**Gaming**

Figurines come to life now, by using NFC to connect to a gaming console. Add new powers or weapons, and store experience in the figurine. The figurine can interact with the player without battery as the entire power is provided by the NFC field.
Benefits in Entertainment

**Power requirements of multiple tags and functions**
Advanced figurines add special functions like audio output, LED and other effects giving a better gaming experience.
Possibility to multiplex a high amount of antennas without sacrificing performance. ST25R391x supports this with highest output power of up to 1.4W and the possibility to power multiplexed antenna matrix.

**Maximum freedom**
Reader portal is independent on placement => allows to be placed on metal table or next to metal objects.
Influence of multiple tags/figurines on the reader is reduced and therefore show a better gaming experience.

**Power consumption for battery operation**
Optimized for operation in battery powered gaming devices. Capacitive wakeup allows even lower power-up with the touch of a hand with a consumption of only 5µA.
NFC for Automotive

Car access
Convenient access to the car and distribution of keys online to a NFC enabled phone

Personal Settings
Just sit in, and the entire cockpit will fit the driver wish
Your NFC phone will take care of secure pairing!

Diagnostics
No physical connection is anymore required for car diagnostics, which helps on safety
Automotive user experience

Large operating volume
Door handles are in metal environment and allow space for small antennas only; there is an influence of metalized windscreens if placed behind those. Coins, pencil and other metallic objects as well as wireless chargers are detuning the antenna in the middle console. ST25R3914/15 offers highest output power combined with automatic antenna tuning.

Short interaction time
The entry function continuously checks for cards. The time window for interaction must be low to ensure best user experience. ST25R3914/15 offers low power wakeup functionality combining capacitive & inductive sensors.

Wide Interoperability
Communication should work immediately. No retries or different placement required. ST25R3914/15 offers excellent P2P compatibility with NFC devices.
ST25 Readers
ST25R3911B NFC / RFID Reader

1.4W High Power Payment reader solution

- Use cases
  - Ideal for **Payment** Applications
  - Access Control, Gaming, eGovernment

- Key features
  - NFC forum compatible (no passive target)
  - 1.4W output power at 5V
  - Passes EMVco & PBOC certification without external power amplifier
  - Automatic Antenna Tuning
  - **VHBR** support up to 6.8Mb/s
  - -40°C to 125°C temperature range

- Key benefits
  - Low power operation & standby
  - Works in challenging environment
  - Enhanced fast transfer rate for Passport
  - Easy-to-use evaluation / development kits
  - Reference designs, application notes
ST25R3912-13 NFC / RFID Reader

**Smallest Footprint, High Power solution**

**ST25R3912**

- **Use cases**
  - Ideal for **Payment** with small handheld mPOS
  - Access Control, Gaming

- **Key features**
  - NFC forum compatibility (no passive target)
  - Passes EMVco & PBOC certification without external power amplifier
  - 1W output power at 5V
  - Inductive Wake up and AAT (AS3913 only)
  - Small 3x2.8 **WLCSP** package (3912 only)
  - -40°C to 85°C temperature range

- **Key benefits**
  - No need of external boost
  - Low power operation & Standby
  - Support market Standard Crypto
  - Smallest Footprint
  - Easy-to-use evaluation / development kits
  - Reference designs, application notes
ST25R3914-15 NFC / RFID Reader

High Power Automotive solution

**Use cases**
- Ideal for **Automotive** applications
  - Keyless entry and start and driver authentication
- Data transfer, pairing, in car payment

**Key features**
- NFC forum compatibility (no passive target)
- AEC Q100 certified
- 1W output power at 5V
- Capacitive / Inductive Wake up
- Antenna Auto Tuning (3914 only)
- -40°C to 125°C temperature range

**Key benefits**
- No external power amplifier required
- Low power operation & Standby
- Reliable performance even in metallic environment
- Faster design times
- Easy-to-use evaluation / development kits
- Reference designs, application notes
<table>
<thead>
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</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Mid-Range Reader</td>
<td>High-Perf Reader &amp; NFC initiator suited for Payment / Passport applications</td>
<td>High-Perf Reader &amp; NFC initiator suited for Automotive</td>
<td>ISO14443A/B ISO15693 &amp; FeliCa by Transparent mode</td>
<td>ISO14443A/B ISO15693 FeliCa</td>
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<td>Card emulation mode</td>
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<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>P2P mode</td>
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<td>-</td>
<td>-</td>
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<td>RF speed</td>
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<td>6.8Mbps (VHBR)</td>
<td>848kbps</td>
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<td>Payment : EMVco, PBOC, mini-pay</td>
<td>Automotive: AECQ100</td>
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<td>Advanced features</td>
<td>AAT, Ind wake-up</td>
<td>AAT, DPO, Cap &amp; Ind wake-up</td>
<td>DPO, Ind wake-up</td>
<td>AAT, DPO, Cap &amp; Ind wake-up</td>
<td>DPO, Cap &amp; Ind wake-up</td>
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<tr>
<td>Interface</td>
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<td>SPI 6Mbps</td>
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<td>Power supply</td>
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<td>2.4V – 5.5V</td>
<td>2.4V – 5.5V</td>
<td>2.4V – 5.5V</td>
<td>2.4V – 5.5V</td>
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<td>Output power</td>
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<td>-40°C to +125°C</td>
<td>-40°C to +125°C</td>
<td>-40°C to +125°C</td>
<td>-40°C to +125°C</td>
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<td>Package</td>
<td>32-pin QFN (5x5mm) / Wafer</td>
<td>32-pin QFN (5x5 mm) / WL CSP</td>
<td>32-pin QFN (5x5 mm)</td>
<td>32-pin QFN (5x5 mm)</td>
<td>32-pin QFN (5x5 mm)</td>
</tr>
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</table>

**P2P**: Peer to Peer mode  
**VHBR**: Very High Baud Rate  
**AAT**: Automatic Antenna Tuning  
**Cap & Ind wake-up**: Capacitive and Inductive wake-up
ST25R – Features
Automatic Antenna Tuning

- **AAT increases Range & Field strength**
  - AAT increases the range of an HF reader in bad environmental conditions and sustains maximum output power to the field with best efficiency.

- **AAT compensated for environment**
  - Automatic antenna tuning analyses the phase shift of the antenna and retunes automatically.

- **AAT reduces production cost**
  - The antenna can be tuned with an automatic procedure during production to fine adjust the design to different housings.

- **Multiple Tag placement**
  - Multiple tags in the field can be compensated to transfer a maximum of power for each.
  - Ideal for **Gaming** applications.

**Higher Range through AAT**
AAT: How to implement

There are **three possibilities** to implement AAT on ST25R3911B

- HW based with the chip internal algorithm
- SW based, optimized for phase
- SW based, optimized for amplitude

While the HW based algorithm is fixed the SW based algorithm can be altered to certain needs if required.

In general tuning the Antenna is done in the following steps:

- Measure the antenna
  - D8 Measure Phase
  - D3 Measure Amplitude
- Adjust the antenna
  - Antenna Calibration register 21h-23h
  - This registers will dis/connect the capacitors connected to the TRIMx_x pins and therefore change the impedance of the antenna.
AAT: When to implement

AAT can be used at any given timeframe by using the calibrate antenna D8 command. In terms of usability there are certain aspects where AAT has the highest benefits: Tuning of the

- module after production
- system during startup/shutdown
- antenna in continuous mode

At what times can AAT be used looking at the standard:

- As part of the polling loop
- Before communication/transaction
AAT after a H-field switch on as part of the polling loop:

- Listen before talk
- Switch on unmodulated alternating H-field until settled
- Execute AAT
- Emit unmodulated H-field
- Poll for cards in the operating volume, e.g. REQA,…

It is allowed to do AAT after the alternating H-field is switched on and settled. There are no further restrictions.
Dynamic Power, Gain & Squelch

- Achieve min/max power limits easier
  - The ST25R series allows to adjust the output power dynamically via Dynamic Power Control

- Optimal performance from weak to strong card response
  - ST25R series allows to adopt to different power level of card responses via Active Gain Control

- Improved noise immunity
  - Squelch feature allows to scale the signal level to have improved immunity against noise
Automatic modulation depth adjustment

- for ISO14443B and ISO15693
  - ISO14443B: ASK 10% modulation index
  - ISO15693: 10-30%, 100% modulation index

- The output driver impedance is adjusted to maintain the modulation index stable
- Avoids trimming in production and allows a faster development time
- Cheaper components with higher tolerances can be used

ASK 10%
NRZ, 106kbit/s

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
</table>
No external Booster required for POS
- The ST25R3911B includes low impedance drivers capable of generating >1.4W of output power
- EMVco certification easily possible without external boosters

Maximum transferred Power
- “Slave” devices like interface tags are able to harvest far more energy for batteryless devices
- Ideal for sophisticated NextGen Gaming platforms

Ideal for Challenging Environment
- The ST25R series is able to operate in metal encapsulation like doorlocks

More Power = Higher Fieldstrength

ST25R3911B Efficiency Graph
Low Power Wakeup

- **Internal wakeup circuitry**
  - The ST25R series includes a fully programmable wakeup scheme. All relevant parameters like cycle time & sensitivity can be programmed.
  - No MCU required to run the wakeup
  - Capacitive & Inductive wakeup can be combined for sophisticated wakeup scripts

- **Capacitive wakeup**
  - ST25R series with this feature can detect capacitive changes. Eg. the approach of a hand.

- **Inductive wakeup**
  - The inductive wakeup is dedicated to detect approaching cards only
General wakeup functions

- **Timer period**
  - Time in which the IC stays in Sleep mode before checking if a card is present.
  - Can be set from 10 to 800ms in 16 steps

- **Delta (window size)**
  - Allows to set the sensitivity of the wakeup
  - Can be set from 1 to 15 steps of a difference considering the 256 steps of the 8bit ADC

- **Auto averaging**
  - Allows to make the wakeup system more noise immune or to compensate for slow environmental changes.
  - Can be set to average over the last 4/8/16/32 values

- **Automatic reference measurement**
  - Allows to measure the actual environmental influence to the capacitive sensor or the antenna
  - This value is used to calibrate the wakeup system at system start or at any required time
Inductive Wakeup

- **Sleep/Wake up Mode (10-800ms)**
  - IC will remain in low power wake up mode before checking for a card ~3.6mA

- **XTAL startup (1ms)**
  - Time for starting the external oscillator. ~5.4mA

- **Actual measurement (20µs)**
  - The inductive wakeup is dedicated to detect approaching cards only ~8.7mA + I_TX

![Diagram showing supply current in different modes](image-url)
Capacitive Wakeup

- **Sleep/Wake-up Mode (10-800ms)**
  - IC will remain in low power wake-up mode before checking for a capacitive change. ~3.6µA

- **Actual measurement (200µs)**
  - The inductive wake-up is dedicated to detect approaching cards only. 1.1mA
Very High Baud Rate (VHBR) technology allows the exchange of large amounts of data between a contactless smart card and a reader. Faster data rates create potential for new applications of NFC.

ST25R3911B allows to implement VHBR communication without additional external components required.

- **Ideal for eGovernment & Passport**
  - The AS3911 increases the maximum bitrate from 848kBit to max. 6.8Mbit
  - **8x less** transfer time benefits the waiting time at border control and allows to increase stored data on eGovernment/Healthcare cards that can carry high-quality images.
The ST25R3911B can be used for VHBR communication as defined by the ISO standard.

- **VHBR timing requirements** can be difficult to reach. If the antenna is not able to fulfill these requirements, the maximum data rate will be impossible to achieve.
- Increasing the communication data rate implies reducing the rise and fall times to respect PCD ASK modulation (defined in ISO14443-2:2016). If the antenna bandwidth and quality factor (Q-factor) are not compliant with VHBR requirement, the high data rates will be impossible to reach.
  - **The quality factor of the antenna must be low**
  - **On an antenna with a high quality factor, the rising and falling times are too long to reach the required duration of the VHBR rising and falling edges**
By reducing the Q factor and therefore increasing the bandwidth, the falling and rising edges will be faster.

For a High-Q antenna, it means the bandwidth is lower. It allows reliable communication at low data rates:

- Better signal quality
- Better noise immunity
- Less energy required to generate

On Low-Q antenna, a higher bandwidth is achieved:

- A Q around 8 is a good compromise for speed/read range, as such an antenna will be able to communicate using data rates from 106kbits/s to 3.4Mbits/s. A Q of 4 would work up to 6.8Mbit.
- Such Low-Q tuning like on the ST25R3911B-DISCO allows to read VHBR cards with a read range performance decrease of only 10%.
The St25R series allows to drive two single ended antennas or one fully differential antenna. Address 00h is used for configuration.

For single ended antennas bit 7 must be 1. Bit 6 then allows to switch between the antenna ports.

- Driving two independent antennas
- Less field strength than a differential antenna

On fully differential antennas bit 7 must be 0. Bit 6 is a “don’t care”.

- Achieve the maximum field strength possible
- Less sensitive to noise, eg GND bounce.
Takeaway

- **Best performing reader on the market**
  - No external power amplifier required to achieve high field strength
  - Automatic antenna tuning
  - Lowest power wakeup
  - Excellent P2P compatibility (phone compatibility)

- **Fastest time to market**
  - reduced time to market at our customers significantly

- **Proven solution**
  - The ST25R family is a market proven solution used in the consumer and automotive space.
  - Ensures best customer experience

- **Full integration into the STM32 library**
**Transmitter**

- The transmitter incorporates drivers that drive external antenna through pins RFO1 and RFO2. Single sided and differential driving is possible. The transmitter block additionally contains a sub-block that modulates transmitted signal (OOK or configurable AM modulation).
- The ST25R3911B transmitter is intended to directly drive antennas (without 50Ω cable, usually antenna is on the same PCB). Operation with 50Ω cable is also possible, but in that case some of the advanced features are not available.

**Receiver**

- The receiver detects transponder modulation superimposed on the 13.56 MHz carrier signal. The receiver contains two receive chains (one for AM and another for PM demodulation) composed of a peak detector followed by two gain and filtering stages and a final digitizer stage.
- The filter characteristics are adjusted to optimize performance for each mode and bit rate (with sub-carrier frequencies up to 6.8 MHz).
- The receiver chain inputs are the RFI1 and RFI2 pins. The receiver chain incorporates several features that enable reliable operation in challenging phase and noise conditions.
Phase and amplitude detector

The phase detector is observing the phase difference between the transmitter output signals (RFO1 and RFO2) and the receiver input signals (RFI1 and RFI2). The amplitude detector is observing the amplitude of the receiver input signals (RFI1 and RFI2) via self-mixing. The amplitude of the receiver input signals (RFI1 and RFI2) is directly proportional to the amplitude of the antenna LC tank signal.

The phase detector and the amplitude detector can be used for the following purposes:

- Doing PM demodulation by observing RFI1 and RFI2 phase variation
- Checking average phase difference between RFOx pins and RFIx pins and optimize antenna tuning
- Measure amplitude of signal present on RFI1 and RFI2 pins is used to check and optimize antenna tuning.
A/D converter

- The ST25R3911B contains a built in Analog to Digital (A/D) converter. Its input can be multiplexed from different sources and is used in several applications (measurement of RF amplitude and phase, calibration of modulation depth...). The result of the A/D conversion is stored in the A/D Converter Output Register and can be read via SPI.

Capacitive Sensor

- The capacitive sensor is used to implement low power detection of transponder presence, it measures the capacitance between two copper patches connected to the CSI and CSO pins. The capacitance changes with the presence of an object (card, hand). During calibration the reference capacitance (representing parasitic capacitance of the environment) is stored. In normal operation the capacitance is periodically measured and compared to the stored reference value, if the measured capacitance differs from the stored reference value by more than a register defined threshold, then an interrupt is sent to the external controller.
External field detector

- The External field detector is a low power block used in NFC mode to detect the presence of an external RF field. It supports two different detection thresholds, Peer Detection Threshold and Collision Avoidance Threshold. The Peer Detection Threshold is used in the NFCIP-1 target mode to detect the presence of an initiator field, and is also used in active communication initiator mode to detect the activation of the target field. The Collision Avoidance Threshold is used to detect the presence of an RF field during the NFCIP-1 RF Collision Avoidance procedure.

Quartz crystal oscillator

- The quartz crystal oscillator can operate with 13.56 MHz and 27.12 MHz crystals. At start-up the trans conductance of the oscillator is increased to achieve a fast start-up. The start-up time varies with crystal type, temperature and other parameters, hence the oscillator amplitude is observed and an interrupt is sent when stable oscillator operation is reached.
- The use of a 27.12 MHz crystal is mandatory for VHBR operation.
The ST25R3911B is a slave device and the external microcontroller initiates all communication. Communication is performed by a 4-wire Serial Peripheral Interface (SPI).

- The ST25R3911B sends an interrupt request (pin IRQ) to the microcontroller, which can use clock signal available on pin MCU_CLK when the oscillator is running.

### Communication with external MCU

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min (ns)</th>
<th>Typ (ns)</th>
<th>Max (ns)</th>
<th>Unit</th>
<th>Comments</th>
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<tr>
<td>T_SCLK</td>
<td>SCLK period</td>
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<td>T_SCLKV</td>
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<td>T_SCLKH</td>
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</table>

### SPI general timing

![SPI general timing diagram](image)
Communication with external MCU

Writing data to addressable registers (Write mode)

- After the SPI operation mode bits, the address of register to be written is provided.
- Then one or more data bytes are transferred from the SPI, always from the MSB to the LSB. The data byte is written in register on falling edge of its last clock.

Reading data from addressable registers (Read mode)

- After the SPI operation mode bits the address of register to be read has to be provided from the MSB to the LSB.
- Then one or more data bytes are transferred to MISO output, always from the MSB to the LSB. As in case of the write mode also the read mode supports auto-incrementing address.
- MOSI is sampled at the falling edge of SCLK (like shown in the following diagrams), data to be read from the ST25R3911B internal register is driven to MISO pin on rising edge of SCLK and is sampled by the master at the falling edge of SCLK.
ST25R – Support material
ST25R support eco-system

- Documentation
- e2e community
- PC SW tools
- MCU drivers (FW)
- Antenna Design & Application Notes
- Eval Board
- Schematic, BOM, Gerber

PC SW tools include ST25R development tools for design and development.

Documentation includes detailed guides and user manuals for the ST25R.

E2e community provides a platform for discussions and support.

Antenna Design & Application Notes provide insights into the design and application of antennas.

 Eval Board is a physical unit that demonstrates the functionality of the ST25R.

Schematic, BOM, Gerber include technical drawings and instructions for the ST25R board.

ST25 is the core component of the eco-system.
The ST25R3911B-DISCO consists of the ST25R3911B high performance reader frontend controlled by a STM32L476 ultra-low-power ARM Cortex-M4 MCU with 512Kbytes flash. It connects via USB to a Windows PC and can be controlled via the ST25R3911B GUI.

Features:

- Onboard 105 mm x 52 mm, two turns, 13.56 MHz inductive antenna and possibility for external antenna.
- Reader/Writer modes supported
- RF communication
  - ISO14443 (A&B) including VHBR
  - ISO15693
  - ISO18092 (P2P, NFCIP-1)
  - MIFARE® Classic compatible, Felica
- Free comprehensive development library and schematics/Gerber files available
- FCC/CE certified

Available July 2017
X-NUCLEO-NFC05A1

The X-NUCLEO-NFC05A1 is a shield addon consisting of the ST25R3911B high performance reader frontend. It connects to the STM32 Nucleo platform.

Features:

- Onboard 47mm x 34mm, four turns, 13.56 MHz inductive antenna and possibility for external antenna.
- Reader/Writer modes supported
- RF communication
  - ISO14443 (A&B) including VHBR
  - ISO15693
  - ISO18092 (P2P, NFCIP-1)
  - MIFARE® Classic compatible, Felica
- Free comprehensive development library available as source and schematics/Gerber files available [here](#).
- FCC/CE certified

Available July 2017
Thank You!