Firmware for the STEVAL-25R3916B kit

Introduction

This document describes the features of the STSW-ST25R018 firmware, developed to demonstrate the capabilities of the STEVAL-25R3916B board, which is based on the ST25R3916B device.

The ST25R3916B is a high-performance NFC universal device and EMVCo® reader that can be controlled by a microcontroller through SPI or I²C interfaces.

This reader supports all standard NFC protocols to communicate with tags, smartphones, or any other reader.

1 General information

The STM32L476 microcontrollers are based on Arm® cores.

Note: Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.

1.1 List of acronyms and notational conventions

1.1.1 Acronyms

- APB: Advanced peripheral bus
- DPO: Dynamic power output
- GUI: Graphical user interface
- IEC: International electrotechnical commission
- ISO: International organization for standardization
- MCU: Micro controller unit (microcontroller)
- NFC: Near-field communication
- RF: Radio frequency
- RFID: Radio frequency identification
- RISC: Reduced instruction set computer
- RSSI: Received signal strength information
- SPI: Serial peripheral interface
- URI: Uniform resource identifier
- URL: Uniform resource locator
- USB: Universal serial bus

1.1.2 Representation of numbers

The following conventions and notations apply in this document unless otherwise stated:

- Binary numbers are represented by strings of 0 and 1 digits shown with the most significant bit (MSB) on the left, the least significant bit (LSB) on the right, and “0b” added at the beginning. Example: 0b11110101.
- Hexadecimal numbers are represented by using numbers 0 to 9 and characters A to F and adding “0x” at the beginning. The most significant byte (MSB) is shown on the left and the least significant byte (LSB) on the right. Example: 0xF5.
- Decimal numbers are represented without any trailing character. Example: 245.

2 Hardware overview

2.1 ST25R3916B

The ST25R3916B is a high-performance NFC universal device and EMVCo reader for contactless applications.

It manages the RF communication with tags, smartphones, and other readers, supporting:

- As a Reader, all standard NFC tag communication protocols:
  - NFC Forum NFC-A, NFC-B, NFC-F and NFC-V
  - ISO14443A
  - ISO14443B
  - FeliCa™
- ISO15693
- Card emulation as an NFC Forum Type 4A or Type 3 Tag
- All NFC Forum peer-to-peer modes:
  - Initiator and target roles
  - Passive and active modes

Other features of the ST25R3916B are:

- Stream modes to implement custom protocols
- Integrated inductive sensing system for low power tag presence detection using phase or amplitude
- High output power
- User selectable and automatic gain control
- SPI up to 10 Mb/s and I2C up to 3.4 Mb/s

2.2 STM32L476

The STM32L476xx devices are ultra-low-power microcontrollers based on the high-performance Arm® Cortex®-M4 32-bit RISC core operating at a frequency of up to 80 MHz. The Cortex®-M4 core features a floating-point unit (FPU) single precision, which supports all Arm® single-precision data-processing instructions and data types. It also implements a full set of DSP instructions and a memory protection unit (MPU) that enhances application security.

The STM32L476xx devices embed high-speed memories (flash memory up to 1 Mbyte, up to 128 Kbytes of SRAM), a flexible external memory controller (FSMC) for static memories

(for devices with packages of 100 pins and more), a QuadSPI flash memory interface (available on all packages) and an extensive range of enhanced I/Os and peripherals connected to two APB buses, two AHB buses and a 32-bit multi-AHB bus matrix.

The STM32L476xx devices feature several protection mechanisms for embedded flash memory and SRAM: readout protection, write protection, proprietary code readout protection and firewall.

The devices offer up to three fast 12-bit ADCs (5 Msps), two comparators, two operational amplifiers, two DAC channels, an internal voltage reference buffer, a low-power RTC, two general-purpose 32-bit timer, two 16-bit PWM timers dedicated to motor control, seven general-purpose 16-bit timers, and two 16-bit low-power timers. The devices support four digital filters for external sigma delta modulators (DFSDM).

In addition, up to 24 capacitive sensing channels are available. The devices also embed an integrated LCD driver 8x40 or 4x44, with internal step-up converter.

They also feature standard and advanced communication interfaces:

- three I2Cs
- three SPIs
- three USARTs, two UARTs and one low-power UART
- two SAIs (serial audio interfaces)
- one SDMMC
- one CAN
- one USB OTG full speed
- one SWPMI (single-wire protocol master interface)

2.3 STEVAL-25R3916B kit

The STEVAL-25R3916B is a kit designed to evaluate the performance of the ST25R3916B reader. This kit is composed of two boards:

- ST25 Evaluation motherboard, with the firmware (STSW-ST25R018) already flashed in.
- ST25R3916B Evaluation antenna daughter board

The STEVAL-25R3916B kit also provides two tags.

2.3.1 ST25 evaluation motherboard

The ST25 evaluation motherboard is powered through one of the USB buses (micro and mini connectors), no external power supply is required.

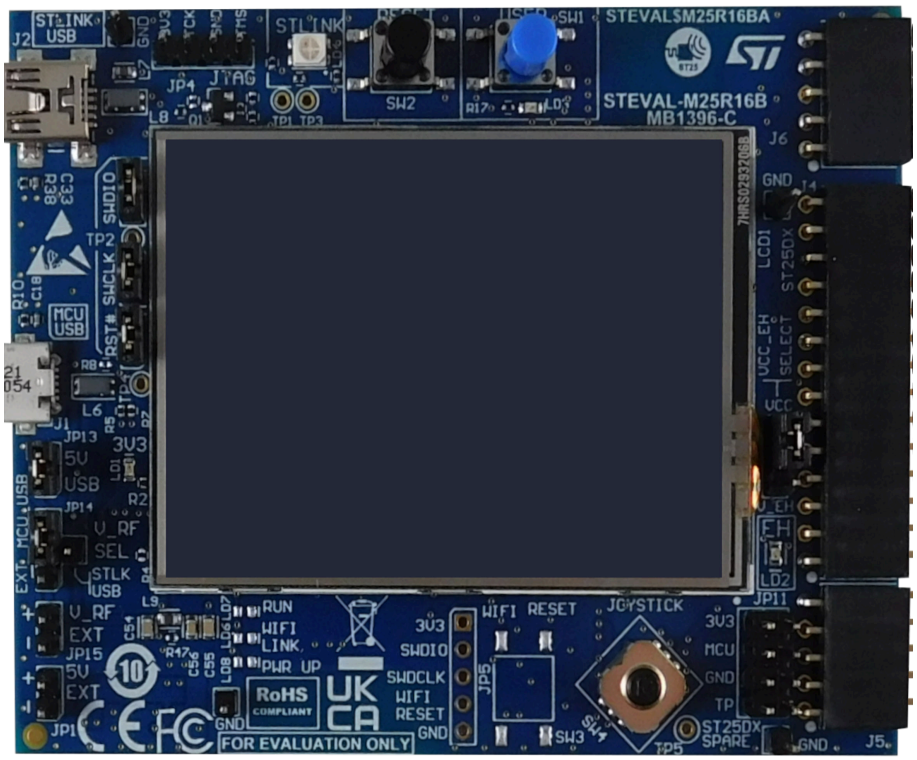
Note: The default setup of the STEVAL-25R3916B kit requires to power the ST25 evaluation motherboard through the USB-Micro port.

This motherboard embeds the STM32L476VG microcontroller and different peripherals:

- LCD display.
- USB connectors to connect to a PC (mini-USB for the ST-LINK debugger and micro-USB available for the user application).
- Optional modules: Wi-Fi® and Bluetooth® Low Energy (BLE) to connect with a smartphone.

The connector on the right side of the board is dedicated to daughter boards based on ST25 NFC devices.

Figure 1. STEVAL-M25R16B evaluation motherboard (top view)



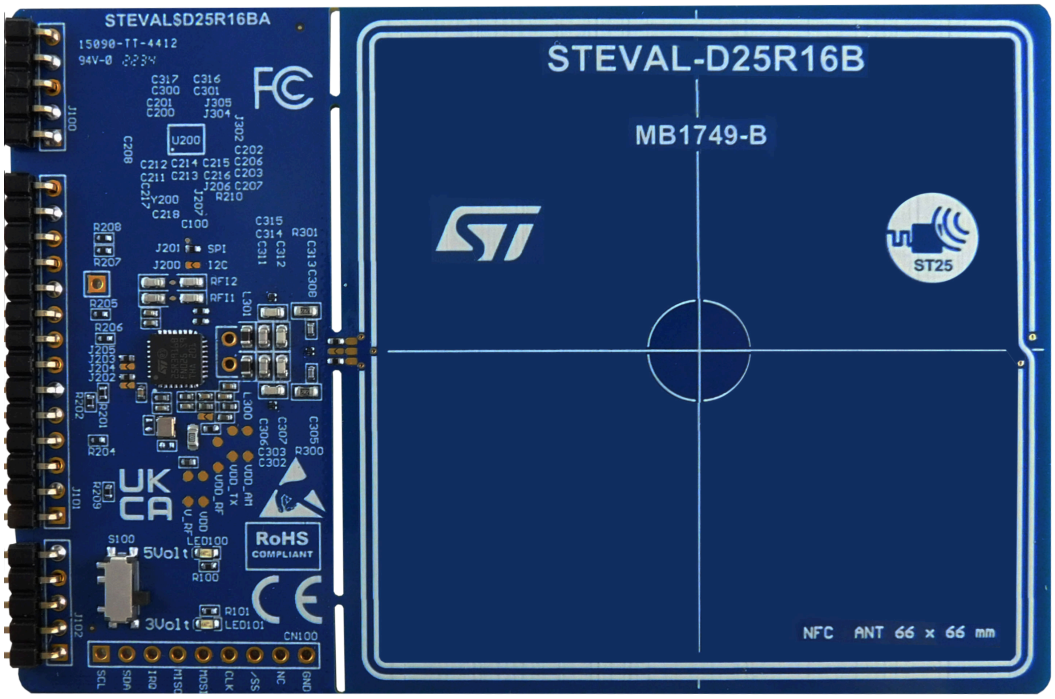
2.3.2 STEVAL-D25R16B evaluation antenna daughter board

This board embeds the ST25R3916B NFC reader device and a 67 x 67 mm2, 13.56 MHz single layer copper etched antenna.

The ST25R3916B can communicate with the STM32L476VG 32-bit MCU via the SPI or I2C bus.

The board also features a switch to select the RF voltage (3.3 V or 5 V).

Figure 2. STEVAL-D25R16B evaluation antenna daughter board (top view)



3 STEVAL-25R3916B demonstrations

3.1 Prerequisite

To run the demonstrations described below it is required to have the following hardware:

- STEVAL-25R3916B kit (motherboard + antenna daughter board)
- Make sure that the JP14 jumper on the ST25 evaluation motherboard is positioned as shown here

.

- A cable micro USB to connect to a PC, required for two purposes:
  - Power supply
  - Control of the demonstrations from a PC when in USB mode, see Section 3.8: USB mode.
- Optionally USB mini cable to connect to a PC in order to make use of the ST-LINK to flash the program memory of the STM32L476 MCU.
- The Reader / Writer demonstration requires to have NFC tags, like the ones provided with the STEVAL-25R3916B kit.

Some demonstrations (card emulation, peer-to-peer) require another reader, such as:

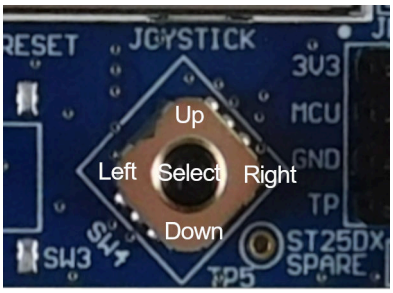
- a smartphone with NFC feature
- a second STEVAL-25R3916B kit

On the software side, the following packages can be downloaded from www.st.com:

- STSW-ST25R018: firmware for the STEVAL-25R3916B kit (binary and source code available)
- STSW-ST25R010: PC installer for the ST25R3916B Evaluation GUI, used for USB mode

3.2 Navigation with the joystick

Figure 3. STEVAL-25R3916B buttons view



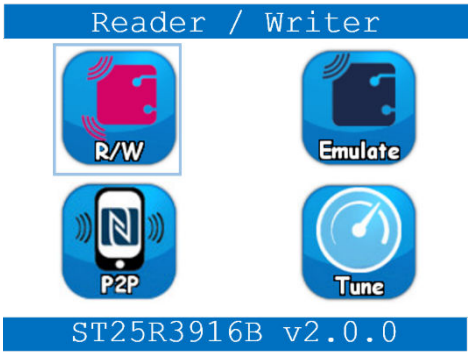
Joystick buttons are used to navigate through the menu using left, right, up and down buttons. To validate the selection, press the select button.

To exit the menu and go back to previous screen, you need to press the blue user button. The demo is displaying an information message to inform when this is available (message example “PB Blue to exit”).

3.3 Main menu

The main menu is composed of four icons, intended to access the submenus.

Figure 4. Main menu display



Each item allows the user to start the corresponding demonstration, as indicated below.

Table 1. Available demonstrations

Demonstration	Icon	Reference
Reader / Writer		Section 3.4: Reader / Writer demonstration
Card emulation		Section 3.5: Card emulation demonstration
Peer to peer		Section 3.6: Peer to peer demonstration
Automatic antenna tuning		Section 3.7: Automatic antenna tuning demonstration

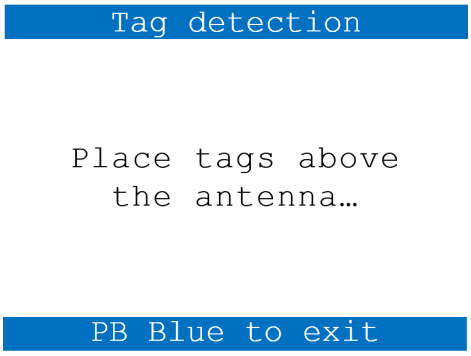
To start a demonstration, select the desired icon with the joystick. Press the select button to start this demo.
In any demonstration it is possible to go back to the previous screen by pressing the blue user button.

3.4 Reader / Writer demonstration

3.4.1 Tag detection screen

As shown in Figure 5, this demonstration starts with the Tag detection screen, it waits for the user to approach a tag on the antenna:

Figure 5. Tag detection screen



3.4.2 Tag inventory screen

When the demonstration is in the tag detection screen, any tag placed above the antenna is inventoried and displayed on the screen with basic information (Figure 5. Tag detection screen):

- The NFC protocol supported by the tag
- The first 4 bytes of the tag UID

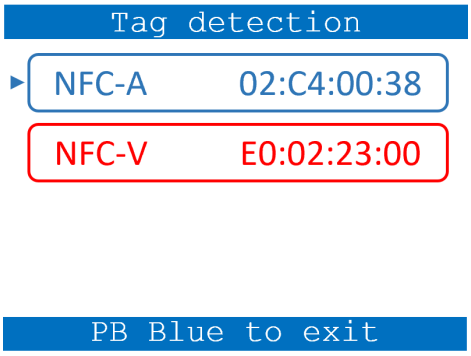
Up to four tags can be displayed on the LCD.

Different colors are used to display the tag, depending on the supported communication protocol:

- Blue for NFC-A
- Green for NFC-B
- Brown for NFC-F
- Red for NFC-V

The user can continue the demonstration by pressing the up, or the down button to select tag to display information about. A small arrow informs which tag is currently selected. Pressing the select button on the joystick opens the information screen for this selected tag.

Figure 6. Tag inventory screen



3.4.3 Tag information screen

The tag information screen displays more information on the selected tag (see Figure 7):

- The type of the tag.
- Its complete UID.
- The communication speed for reception/transmission.
- The RSSI displayed as a bar, which enlarges as the signal strength increase. RSSI is measured by regularly reading data from the tag.
- The DPO profile, displayed in the top-right box. Only two DPO profiles are defined for this demonstration:
  - Full power: maximum RF power delivered when the tag is far from the antenna
  - Low power: RF power is divided by approximately 4, when the tag is near the antenna.

The DPO profile is automatically selected depending upon the distance between the tag and the reader.

If the selected tag has a valid TruST25 signature (making it possible to authenticate a tag), the valid icon is also displayed on the screen (see Figure 8).

Note: TruST25Link™ is a proprietary protocol, which allows the user to verify the authenticity of the device, thanks to a unique digital signature. Contact your local STMicroelectronics sales office for more details on how to use this feature.

The display is regularly refreshed to show the measured RSSI and resulting DPO values. For this reason, moving the tag in front of the antenna is reflected immediately on the display.

Note: Some tags advertise a very long transmission timeout to the reader. Consequently, if the tag goes out of the field, the GUI may seem to freeze waiting for the tag response timeout. In this situation it is possible to interrupt the running transfer by touching the screen (either the exit area, or any other area if the tag is back in the field).

Figure 7. Tag information screen

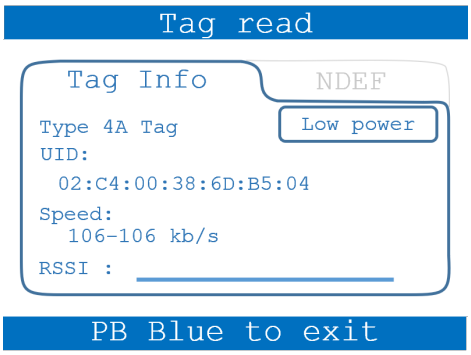
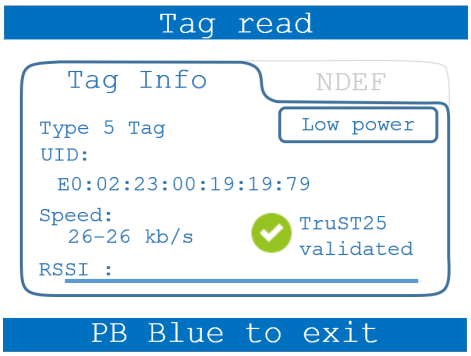


Figure 8. Tag information with TruST25 signature



3.4.4 NDEF screen

By pressing the right button on the joystick, the user enters the NDEF demonstration screen. This demonstration makes it possible to read and write NDEF messages from / to the selected tag.

This demonstration first reads the data in the tag, and if this data is an NDEF message, displays it such as in Figure 9 for an URI or Figure 10 for a vCard.

If the data is not an NDEF messages, only the first bytes of raw data are displayed (see Figure 11).

The NDEF message write icon  is present only if the selected tag supports NDEF. Press the DOWN button to write an NDEF URI message to the tag memory (http://www.st.com/st25r).

Figure 9. NDEF URI read

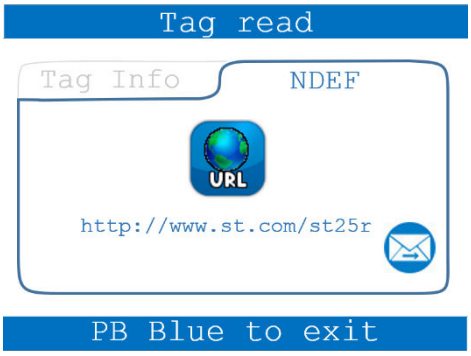


Figure 10. NDEF vCard read

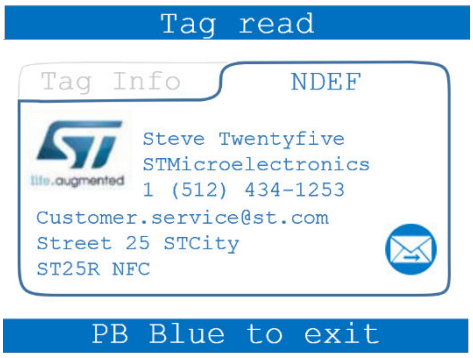
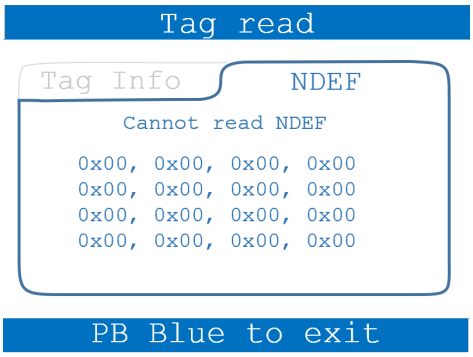


Figure 11. No NDEF present



3.5 Card emulation demonstration

This demonstration configures the ST25R3916B to act as an NFC Forum Type 4A card.

Note: More card emulation options are available by using the STSW-ST25R010 PC software.

As shown below, the screen displays the message: “CE mode running”, and the three icons below:

	When selected the ST25R3916B emulates an NDEF URI message.
	When selected the ST25R3916B emulates an NDEF vCard message (~ 8 Kbytes, including a picture).
	Enabled (colored) after the emulated card has received data from a smartphone or reader. When enabled, select it with the joystick button and press select to see the received data. Inactive (gray) before any data is received.

For this demonstration, the user can bring a smartphone with NFC enabled or a reader above the ST25R3916B antenna. An Android® smartphone natively reads the emulated card content and opens the corresponding application (a web browser for the URL, a Contact app for the vCard).

An iOS® smartphone (iPhone Xs/Xr or newer), natively reads the emulated URI and opens a web browser (Safari), other ones may require an NFC application like the ST25 NFCTap (to be downloaded from the application store).

To write the emulated card with an Android® smartphone, the user has to install an application such as the ST25 NFCTap (available on the Play Store, referred to as STSW-ST25001 on www.st.com). In this demonstration, the maximum size of an NDEF to be written is set to 3 Kbytes.

Any reader supporting the NFC Forum Type 4 tag protocol can be used to write data to the card emulated by the ST25R3916B. For instance, it is possible to use a second STEVAL-25R3916B kit in Reader/Writer mode to write an URI (see Section 3.4.4: NDEF screen).

Figure 12. Card emulation demonstration

3.6 Peer to peer demonstration

This demonstration configures the ST25R3916B in the different NFC Forum peer to peer modes:

- Initiator and target roles
- Active and passive modes

The ST25R3916B searches for a peer device before moving to the next mode.

As shown below, the screen displays the message: “Wait connection…”, and three icons:

	When selected, the ST25R3916B sends an NDEF URI message to the peer device.
	When selected, the ST25R3916B sends an NDEF vCard message to the peer device (~ 8 Kbytes, including a picture).
	Enabled (colored) after the ST25R3916B has received data from a peer device (smartphone or reader). When enabled, select it with the joystick button and press select to see the received data. Inactive (gray) before any data is received.

Put an Android® smartphone above the STEVAL-25R3916B kit antenna to connect natively in peer-to-peer mode.

The role and mode of the ST25R3916B is shown in Figure 14. The mode can be one among the following ones:

Initiator

Target (P): for the passive target (waiting for the field)

Target (A): for the active target (enabling its RF field for communication)

Once connected to a peer device, the selected NDEF message is automatically sent.

If the peer device is an Android smartphone, it natively opens the corresponding application (a web browser for the URI, or a contact app for the vCard).

Alternatively, another reader, with NFC Forum peer to peer support, can be used as peer device. For instance, a second STEVAL-25R3916B kit, with peer-to-peer demonstration started, can be used for that purpose.

Note: This demonstration only implements a limited support of the peer-to-peer mode, for a full support it is recommended to use the STEVAL-25R3916B PC GUI (see Section 3.8: USB mode).

Note: If the peer device is in passive target mode, when it goes out of the field, the GUI may seem to freeze waiting for the peer device response timeout. In this situation it is possible to interrupt the running transfer by pressing the blue user button.

Figure 13. Peer to peer demonstration

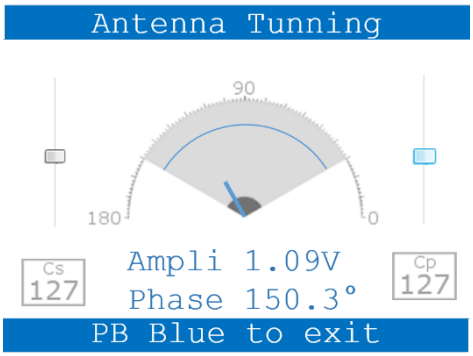
Figure 14. **Peer to peer connected as initiator**

3.7 Automatic antenna tuning demonstration

The ST25R3916B allows the user to control variable capacitances to fine-tune the antenna and achieve the best setup in any environment. For the tuning, three variable capacitances are used, two (Cs) connected serially, the third one (Cp) in parallel to the antenna.

When entering the demonstration, the capacitances are set to their default values, and the corresponding antenna measurements (amplitude and phase) are displayed both by a needle on a gauge and numerically on the screen (see Figure 15).

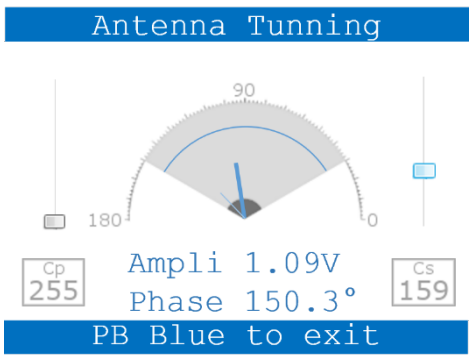
Figure 15. **Default antenna tuning**



Press the SELECT button on the joystick during 2 seconds to run the automatic antenna tuning, thus improving its performance. New capacitances are displayed along with the updated antenna measurement.

The needle corresponding to the previous values (before tuning) is now displayed in gray, while the new antenna metrics are displayed by the blue needle and the message on the screen (see Figure 16).

Figure 16. **Automatic antenna tuning done**



Push the SELECT button of the joystick on the ST25 evaluation motherboard to reset the capacitances to their default values.

The user can also manually explore the result of different capacitance settings by pressing the left or right button to select the slide bar (cursor turns blue for the selected one). By pressing the up or down button to change the value of the selected capacitance. The display is then immediately refreshed with new antenna measurements.

3.8 USB mode

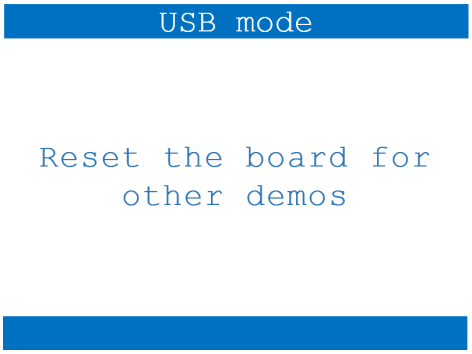
To enter USB mode, the user must reset the motherboard while keeping the user button (blue) pushed. The screen must be as shown in Figure 17. To leave this mode, another reset is required, while leaving the user button not pushed.

The USB mode is used to allow a PC to control the STEVAL-25R3916B kit through the USB-micro connector present on the motherboard.

The user must first download and install the STSW-ST25R010 software (available on www.st.com) on a PC, and then connect the ST25 evaluation board to it with the micro USB port. Then, it must ensure that the jumper JP14 on the ST25 evaluation motherboard is positioned on MCU_USB, as indicated in Section 3.1: Prerequisite.

In this mode, the ST25R3916B evaluation GUI PC software has full control over the STEVAL-25R3916B kit. Refer to the STEVAL-25R3916B reference graphical user interface user manual to learn about the demonstrations available with the ST25R3916B evaluation GUI.

Figure 17. USB mode



Revision history

Table 2. **Document revision history**

Date	Revision	Changes
23-Jan-2023	1	Initial release.
14-Nov-2024	2	Added note in Section 3.4.3: Tag information screen.

Contents

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