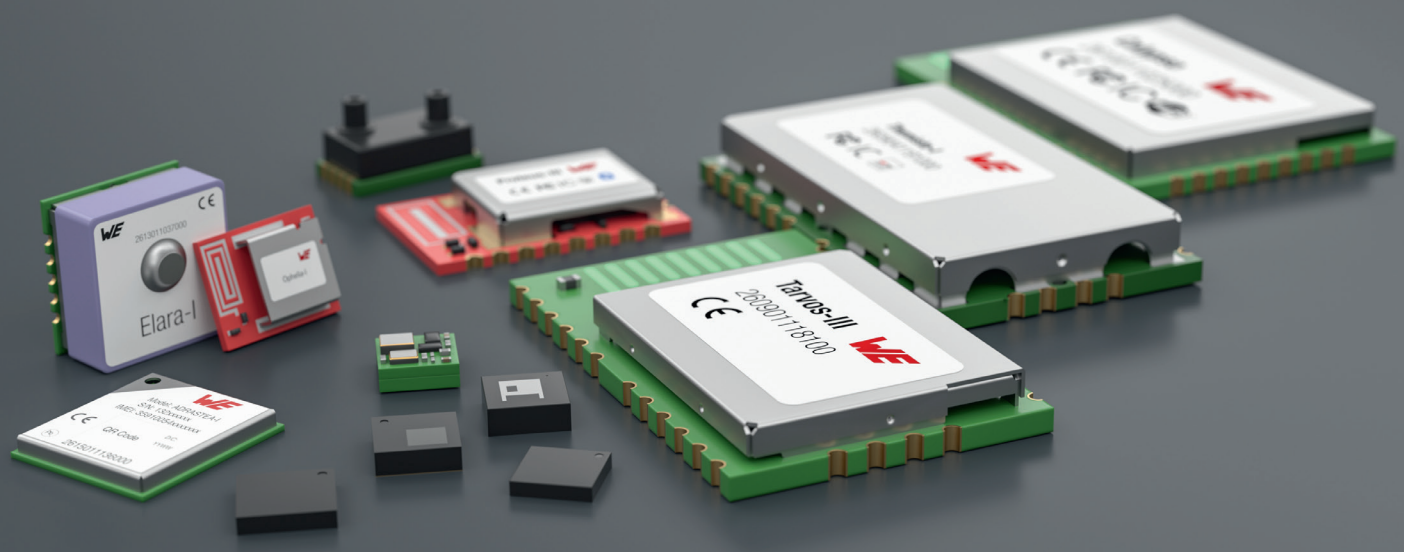


# User manual

## Proteus-I

2608011024000 / 2608011124000

Version 3.16

January 13, 2026

**Würth Elektronik** more than you expect

**********

# MUST READ

## Check for firmware updates

Before using the product, make sure you use the most recent firmware version, data sheet, and user manual. This is especially important for Wireless Connectivity products that were not purchased directly from Würth Elektronik eiSos. A firmware update on these respective products may be required.

We strongly recommend including the possibility of a firmware update in the customer system design.

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# Overview of helpful application notes

### Application note ANR002 - Proteus-I Advanced developer guide

*http://www.we-online.com/ANR002*
This advanced developer guide covers the details on the Proteus-I radio module that are required to implement compatible App for smart devices. It covers the documentation on the SPP-like Bluetooth® LE profile, the used protocols and data coding for arbitrary user payload. In addition all information required to develop a custom firmware on the Proteus module hardware platform are provided within.

### Application note ANR003 - Proteus-I Low power application with periodic wake-up

*http://www.we-online.com/ANR003*
This application note describes the steps to create a custom firmware and adapt a Nordic nRF5 SDK example to provide a low power focused application. The considered application performs a periodic wake up using the real time clock (RTC) on the Proteus-I hardware.

### Application note ANR004 - Peripheral only mode

*http://www.we-online.com/ANR004*
The Bluetooth® LE modules Proteus-I,-II,-III provide the so called ¨peripheral only mode¨, that supports a serial cable replacement by offering a transparent UART bridge functionality. This document explains how to set the module into the corresponding operation mode and how to establish a Bluetooth® LE connection to a Bluetooth® LE enabled central device.

### Application note ANR008 - Wireless Connectivity Software Development Kit

*http://www.we-online.com/ANR008*
To ease the integration of the Würth Elektronik eiSos radio modules into an application, Würth Elektronik eiSos offers the corresponding Software Development Kit (SDK) for most commonly used host processors. This SDK contains drivers and examples in C-code to communicate with the corresponding radio module. This application note shows which SDKs are available and describes how to download and use them.

### Application note ANR010 - Range estimation

*http://www.we-online.com/ANR010*
This application note presents the two most used mathematical range estimation models, Friis and two ray ground reflection, and its implementation in the range estimation tool of the RED-EXPERT.

### Application note ANR014 - Proteus-I,-II,-III Quickstart

*http://www.we-online.com/ANR014*
This application note describes how to set up a Bluetooth® LE connection between one of a

Proteus-I,-II,-III and a Bluetooth® LE enabled device, like a smart phone. Furthermore the data transmission via Bluetooth® LE is presented.

### Application note ANR026 - Proteus beacons

*http://www.we-online.com/ANR026*
Besides the standard Bluetooth® LE connection based data transmission, it is possible to transmit data via Bluetooth® LE without an active connection in a broadcast message, called ¨Beacon¨. This application note describes what beacons are and how to they can be used.

### Application note ANR027 - Bluetooth qualification guide

*http://www.we-online.com/ANR027*
Every product containing Bluetooth® technology needs to be qualified at the Bluetooth® SIG (special interest group). This application note explains the steps to be done to gain a Bluetooth® qualification for the end product using a Würth Elektronik eiSos Bluetooth® LE radio module.

### Application note ANR030 - nRF Connect

*http://www.we-online.com/ANR030*
This application note gives a short overview about the options to create a custom firmware for Würth Elektronik eiSos radio modules by using the hardware platform and the embedded nRF5x system on chip. It presents options on firmware development environments and accessories (like SDKs) for the use within the nRF5 ecosystem. The reader is informed on how to access to a multitude of radio standards (like Bluetooth® LE, Bluetooth® MESH, Bluetooth® LE Audio, Matter, Zigbee, Thread, Wirepas) for custom firmware developments whilst the hardware platform can stay the same.

### Application note ANR031 - Certification of custom modules

*http://www.we-online.com/ANR031*
This application note explains how certifications of a standard product can be used to gain the certification of a customized product. This is done for firmware, which has been adapted by Würth Elektronik eiSos, as well as for firmware written by customer.

### Ground plane effects on radio module antennas

*http://www.we-online.com/ANR033*
The ground plane plays a critical role in the performance of radio module antennas, affecting parameters such as radiation pattern, gain, and efficiency. This application note provides practical insights into how ground plane size, shape, and placement influence antenna behavior, offering guidance for optimal integration in real-world designs. Simulation results and measurement data are included to illustrate key effects and support design decisions.

# 1. Revision history

| Manual version | FW version | HW version | Notes | Date |
|---|---|---|---|---|
| 1.2 | 1.0.0 - 1.1.0 | 2.0 | • Added more detailed electrical specifications | August 2016 |
| 2.1 | 2.0.0 - 2.1.0 | 2.1 | • Better description of device states | November 2016 |
| 2.6 | 3.0.0 | 2.1 | • Adapted certification chapters | July 2017 |
| 2.10 | 3.3.0 - 3.3.6 | 2.1 | • Adapted footprint and antenna free area and measured TX power | March 2018 |
| 2.17 | 3.4.0 | 2.1 | • New corporate design and structure<br>• Added description of new features of firmware version 3.4.0 and more information about certification and Bluetooth® declaration | June 2018 |
| 2.20 | 3.4.0 | 2.1 | • Added TELEC certification details and labeling information | September 2018 |
| 3.0 | 3.4.0 | 2.1 | • Updated name from AMB2621 to Proteus-I | November 2018 |
| 3.1 | 3.4.0 | 2.1 | • Corrected `CMD_SET_CNF` message in chapter `10`<br>• Updated description of firmware update using the OTA bootloader | January 2019 |
| 3.2 | 3.4.0 | 2.1 | • Added chapter `Reference design` and `Information for explosion protection`<br>• Updated decription of chapter `Peripheral only mode` | March 2019 |
| 3.3 | 3.5.0 | 2.1 | • Added information concerning firmware version 3.5.0 in chapter `Firmware history`<br>• Updated chapter `Important notes` | May 2019 |

| | | | | |
|---|---|---|---|---|
| 3.4 | 3.5.0 | 2.1 | • Update references to new AppNote name structure. | June 2019 |
| 3.5 | 3.5.0 | 2.1 | • Corrected information on brownout and maximum TX power in chapter `Electrical specifications`<br>• Updated label in chapter `General labeling information`<br>• Corrected example of DTM RX test in chapter `CMD_DTM_REQ`<br>• Updated address of Division Wireless Connectivity & Sensors location | October 2019 |
| 3.6 | 3.5.0 | 2.1 | • Removed -30dBm as valid `RF_TXPower` value | December 2019 |
| 3.7 | 3.5.0 | 2.1 | • Correction of Value amount of inductivity for explosion protection | February 2020 |
| 3.8 | 3.5.0 | 2.1 | • Limitation of the `RF_DeviceName` to a maximum of 31 bytes<br>• Added Annex `Additional CRC8 Information` and `Example code for host integration` | June 2020 |
| 3.9 | 3.5.0 | 2.1 | • Updated Declaration of EU conformity to latest Version of EN 300 328 after successfully passing corresponding delta test in chapter `Regulatory compliance information`.<br>• Added package name in chapter `Footprint WE-FP-4`. | October 2020 |
| 3.10 | 3.5.0 | 2.1 | • Updated Declaration of EU conformity `Regulatory compliance information`. | December 2020 |

| | | | | |
|---|---|---|---|---|
| 3.11 | 3.6.0 | 2.2 | • Removed 2608011024009 and 2608011124009 `Ordering information` as there are no longer pre-cuts available. The modules are available in all quantities as cut tape.<br>• Added information concerning firmware version 3.6.0, see chapter `Firmware history`.<br>• Added overview of helpful application notes<br>• Updated document style | July 2022 |
| 3.12 | 3.6.0 | 2.2 | • Added chapter `Internal antenna radiation characteristics`<br>• Updated chapter `Firmware update steps using the nRF Device Firmware Update app`<br>• Updated meta data | May 2023 |
| 3.13 | 3.6.0 | 2.2 | • Added certificates in addition to the required compliance statements in chapter `Regulatory compliance information`. | June 2023 |
| 3.14 | 3.6.0 | 2.2 | • Added chapter `Known issues` and known issue KI-006<br>• Added chapter `Product testing`<br>• Added chapter `Important notice UKCA`<br>• Renamed Bluetooth® listing to Bluetooth® qualification<br>• Update module action byte description in `CMD_GETSTATE_CNF`<br>• Updated chapter `General labeling information` | October 2024 |
| 3.15 | 3.6.0 | 2.2 | • Added chapter `Certification of the end device` and `Hardware history` | October 2025 |

| | | | | |
|---|---|---|---|---|
| 3.16 | 3.6.0 | 2.2 | • Update CE declaration in chapter `Regulatory compliance information`. | January 2026 |

⋆ For firmware history see chapter `Firmware history`

# 2. Abbreviations

| Abbreviation | Name | Description |
|---|---|---|
| BTMAC | | Bluetooth® conform MAC address of the module used on the RF-interface |
| CS | Checksum | Byte wise XOR combination of the preceding fields |
| DTM | Direct test mode | Mode to test Bluetooth® specific RF settings |
| GAP | Generic Access Profile | The GAP provides a basic level of functionality that all Bluetooth® devices must implement |
| I/O | Input/Output | Pinout description |
| LPM | Low power mode | Mode for efficient power consumption |
| MAC | | MAC address of the module |
| MTU | Maximum transmission unit | Maximum packet size of the Bluetooth® connection |
| Payload | | The intended message in a frame / package |
| RF | Radio frequency | Describes wireless transmission |
| RSSI | Receive Signal Strength Indicator | The RSSI indicates the strength of the RF signal. Its value is always printed in two's complement notation |
| Soft device | | Operating system used by the nRF52 chip |
| | User settings | Settings to configure the module. Any relation to a specific entry in the user settings is marked in a special font and can be found in chapter 10 |
| UART | Universal Asynchronous Receiver Transmitter | Allows the serial communication with the module |
| [HEX] 0xhh | Hexadecimal | All numbers beginning with 0x are hexadecimal numbers. All other numbers are decimal, unless stated otherwise |

# 3. Introduction

This manual is valid for following Proteus-I variants:

- 2608011024000
- 2608011124000

## 3.1. Operational description

The Proteus-I exists in two variants, one variant with integrated PCB-antenna, and the other variant with 50 Ω connection to an external antenna. For the general functionality there is no difference between the variants.
The Proteus-I module is a radio sub module/device for wireless communication between devices such as control systems, remote controls, sensors etc. . On the basis of Bluetooth® LE 4.2 [1] it offers a fast and secure data transmission of data packages between two or more parties (point to point topology). A serial interface (UART) is available for communication with the host system.
The Proteus-I uses the Bluetooth® LE standard to provide general data transmission between several devices. The standard itself offers a wide range of configurations and possibilities to suit and optimize sophisticated customer applications. To fulfill the needs and specifications of such applications a tailored firmware can be developed on the basis of the Proteus-I hardware. This includes the connection and communication to custom sensors, custom Bluetooth® LE profiles, timing configurations, security configuration as well as power consumption optimizations.

### 3.1.1. Key features

The Proteus-I offers the following key features that are described in the manual in more detail:

**SPP-like connection-based secured data transmission:** The Proteus-I firmware implements an SPP-like Bluetooth® LE profile that allows the bidirectional data transmission between several Proteus-I and/or to other Bluetooth® LE devices implementing the AMBER SPP profile. Any module in the network can initiate connection setup. Secured connections allow the transmission of encrypted data (user-defined key or pairing).

**Fast sensor data transmission via Beacons:** The Proteus-I supports the transmission and reception of Beacons. Beacons are fast broadcast messages that allow the energy-efficient unidirectional transmission of data. Especially in sensor networks, this feature is suitable for the frequent transmission of measurement data as it removes the need for connection-based communication and therefore is more energy efficient.

**Advanced customization capabilities:** The configurable Device Information Service (DIS), the UUID and the appearance of the Bluetooth® LE profile, enable to personalize the Proteus-I to fuse with the user's end product.

**Low power position sensing solutions:** The current TX power of any Proteus-I is always transmitted with each advertising packet when the module is in command mode. With this, distance estimation and position sensing solutions can be realized conveniently by performing a passive scan.

**Fast serial interface:** The Proteus-I offers a UART-interface to communicate with a host using a user-defined baud rate and a simple command interface.

**Latest microprocessor generation provided by Nordic Semiconductor nRF52 series:** The heart of the Proteus-I is a Bluetooth® LE chip of the nRF52 series offering high performance values combined with low power consumption. It is a 32 Bit ARM Cortex-M4F CPU with 512 kB flash + 64 kB RAM and up to 4dBm output power.

**Bluetooth® 4.2 stack:** The Bluetooth® 4.2 stack enables fast and energy efficient data transmission using state-of-the-art technology of Nordic Semiconductors.

**All Bluetooth® LE roles supported:** The integrated Bluetooth® LE stack supports all Bluetooth® LE roles. Depending on the current state of operation the Proteus-I firmware automatically switches its role to execute the user's instructions.

**Flexible wired interfacing:** If custom hardware does not support UART communication or in case of a host less implementation, the Proteus-I is equipped with extra pins suited for custom device/sensor connection. With help of these, a tailored firmware can be developed which is optimized to the customer's needs. The pins can be configured to various functions such as UART, SPI, I2C, ADC, PWM, NFC and GPIO.

**OTA firmware update:** The Proteus-I firmware provides over the air firmware update capabilities. Firmware updates can be applied using the Nordic Apps for cell phones.

**Peripheral only mode:** The Proteus-I firmware provides the "peripheral only" operation mode (see chapter 12), that allows the easy adaption of already existing custom hardware with the Bluetooth® LE interface. By default, this mode offers the static passkey pairing method with bonding and a transparent UART interface. With this, custom hardware can be accessed by mobile Bluetooth® LE devices (like smart phones including a custom App) using an authenticated and encrypted Bluetooth® LE link without the need of configuring the module.

### 3.1.2. Connectivity

The Bluetooth® LE standard allows to setup a network with various Bluetooth® LE devices from different manufacturers. To be able to communicate with Proteus-I devices, the WE SPP-like profile must be known and implemented by all network participants. Thus arbitrary Bluetooth® LE devices (like iOS or Android devices) must implement this profile, too. To do so, the Proteus-I application note ANR002 [2] contains the design data of the WE SPP-like profile.

## 3.2. Block diagram

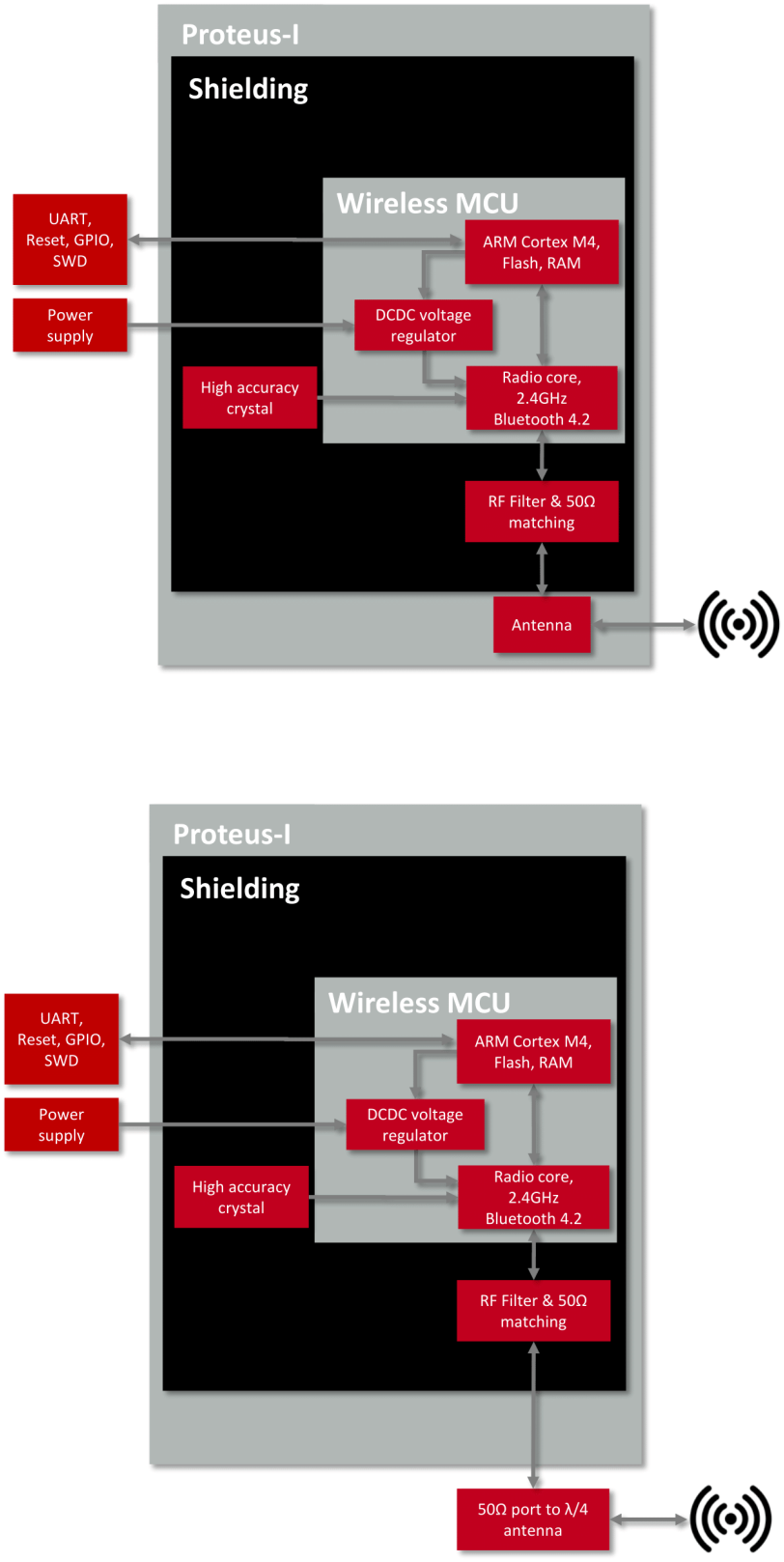



Figure 1: Block diagram of the module with internal PCB antenna and antenna pad

## 3.3. Ordering information

| WE order code | Former order code | Description |
|---|---|---|
| 2608011024000 | AMB2621-TR | Bluetooth® Low Energy radio module Tape & Reel |
| 2608011124000 | AMB2621-1-TR | Bluetooth® Low Energy radio module Tape & Reel |
| 2608019024001 | AMB2621-EV | Bluetooth® Low Energy EV-Board with AMB2621 |
| 2608019324001 | AMB2621-1-EV | Bluetooth® Low Energy EV-Board with AMB2621-1 |

Table 3: Ordering information

# 4. Electrical specifications

As not otherwise stated measured on the EV-Board Proteus-I-EV with T = 25 ℃, VDDS =3 V, f = 2.44GHz, internal DC-DC converter in use.

## 4.1. Operating conditions

| Description | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|
| Ambient temperature | -40 | 25 | 85 | ℃ |
| Supply voltage (VDDS) | 1.8 | 3 | 3.6 | V |
| Supply rise time (0V to $\geq$ 1.7V) | | | 60 | ms |

Table 4: Operating conditions

The on-chip power-on reset circuitry may not function properly for rise times longer than the specified maximum.

A step in supply voltage of 300 mV or more, with rise time of 300 ms or less, within the valid supply range, may result in a system reset.

An instable supply voltage may significantly decrease the radio performance and stability.

## 4.2. Absolute maximum ratings

| Description | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|
| Supply voltage (VDD) | -0.3 | | +3.9 | V |
| Voltage on any digital pin, VDD$\leq$3.6 V | -0.3 | | VDD+0.3 | V |
| Voltage on any digital pin, VDD$\geq$3.6 V | -0.3 | | 3.9 | V |
| Input RF level | | | 10 | dBm |
| Flash endurance | 10 000 | | | Write/erase cycles |

Table 5: Absolute maximum ratings

## 4.3. Power consumption

### 4.3.1. Static

| Continuous test mode | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|
| TX current consumption at +4 dBm | | 7.5[1] | | mA |
| TX current consumption at 0 dBm | | 5.3[1] | | mA |
| RX current consumption | | 5.4[1] | | mA |
| Sleep (system off mode) | | 0.4 | | µA |
| TX current consumption at +4 dBm | | 11[2] | | mA |
| TX current consumption at 0 dBm | | 8[2] | | mA |
| RX current consumption | | 8[2] | | mA |

Table 6: Power consumption for 100% transmission/reception

Due to the Bluetooth® LE time slot operation, the real operating currents are reduced significantly and depend on the user selectable advertising and connection interval settings.

[1] Transmitter only with DC/DC converter from nRF52 data sheet.
[2] Full module power consumption.

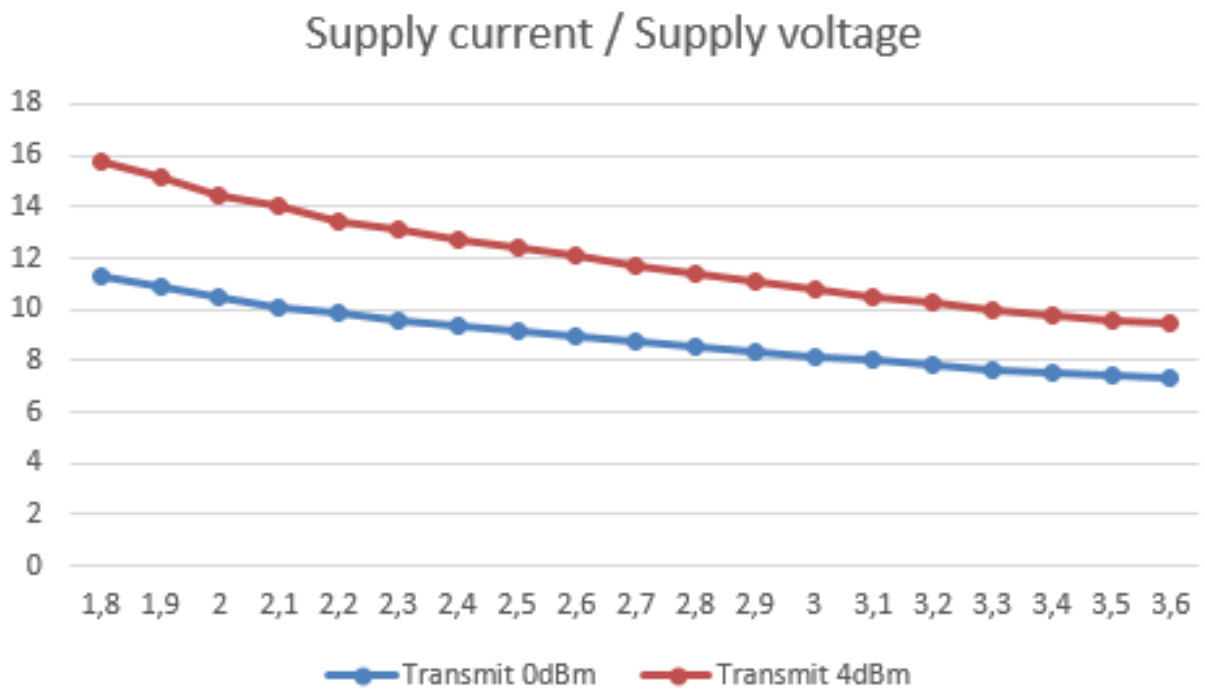
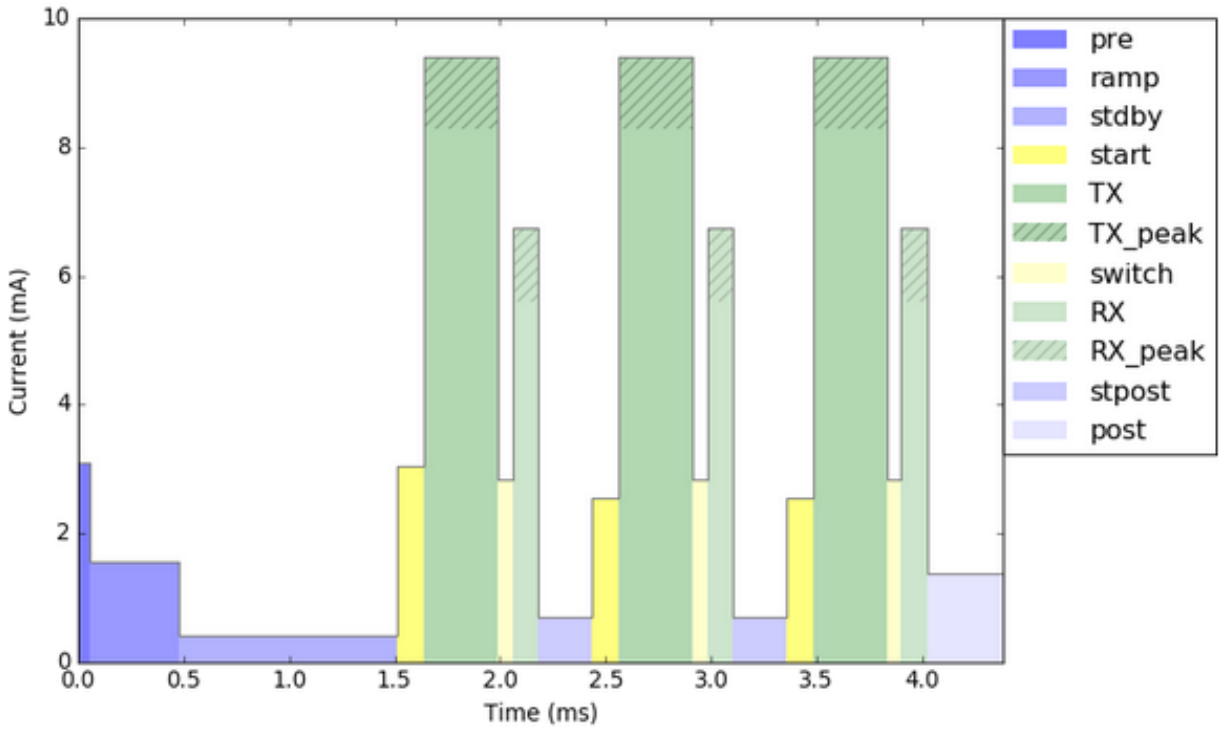



Figure 2: TX Current consumption vs. VCC

### 4.3.2. Dynamic

Besides the static TX, RX, idle and sleep current the average current is of interest. Here an example for a typical behavior of a peripheral device in advertising mode (see Figure 3 and Figure 4). Currents and state durations are dependent on the configuration of the module. In this state the module transmits the advertising packets on the 3 advertising channels.

Nordic Semiconductor provides an online tool calculating the average current of a Bluetooth® connection. It can be accessed at *https://devzone.nordicsemi.com/power/* .




| Stage | Description | Time (ms) | Length (us) | Avg. current (mA) | Peak current (mA) |
|---|---|---|---|---|---|
| pre | Pre-processing | 0.0 | 56 | 3.1 | |
| ramp | Standby + HFXO ramp | 0.1 | 420 | 1.6 | |
| stdby | Standby | 0.5 | 1034 | 0.4 | |
| start | Radio startup + CPU | 1.5 | 128 | 3.1 | |
| TX | Radio TX | 1.6 | 353 | 8.3 | 9.4 |
| switch | Radio switch | 2.0 | 67 | 2.8 | |
| RX | Radio RX | 2.1 | 123 | 5.6 | 6.7 |
| stpost | Standby + Post-processing | 2.2 | 256 | 0.7 | |
| start | Radio startup | 2.4 | 123 | 2.6 | |
| TX | Radio TX | 2.6 | 353 | 8.3 | 9.4 |
| switch | Radio switch | 2.9 | 67 | 2.8 | |
| RX | Radio RX | 3.0 | 123 | 5.6 | 6.7 |
| stpost | Standby + Post-processing | 3.1 | 256 | 0.7 | |
| start | Radio startup | 3.4 | 123 | 2.6 | |
| TX | Radio TX | 3.5 | 353 | 8.3 | 9.4 |
| switch | Radio switch | 3.8 | 67 | 2.8 | |
| RX | Radio RX | 3.9 | 123 | 5.6 | 6.7 |
| post | Post-processing | 4.0 | 358 | 1.4 | |
| | System On IDLE | 4.4 | 40.6 ms | 1.9 uA | |
| Total | | | 45.0 ms | 325 uA | |

Figure 3: Current consumption calculation in advertising mode with 40 ms advertising interval, UART disabled

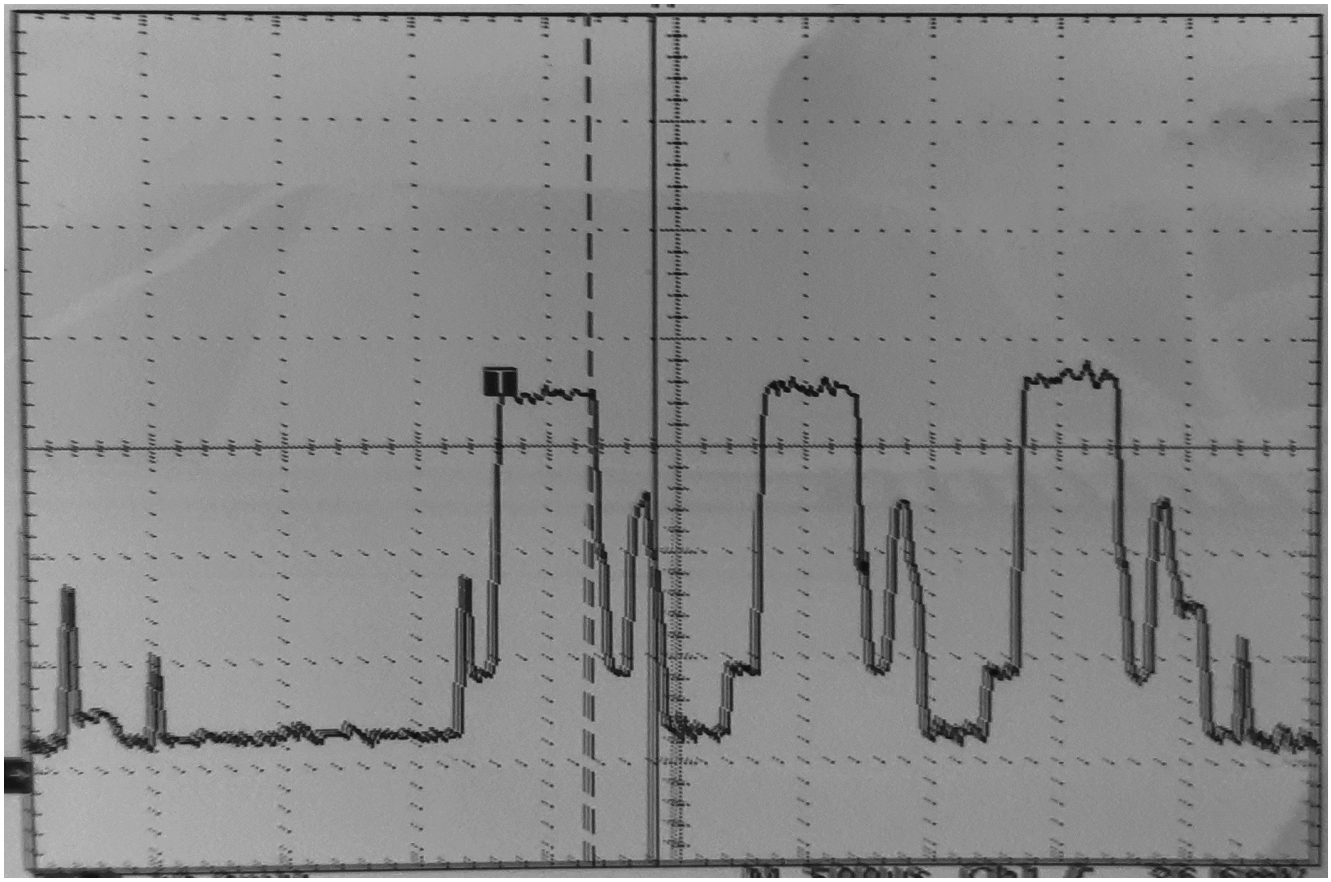


Figure 4: Measured Proteus-I transient current consumption in advertising mode with 40 ms advertising interval, excerpt of 5ms

## 4.4. Radio characteristics

50 Ω conducted measurements from nRF52 data sheet

| Description | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|
| Output power | -40 | +3 | +4 | dBm |
| Input sensitivity ($\leq$ 37 Bytes, BER=1E-3) | | -92[1] | | dBm |
| RSSI accuracy valid range (±2dB) | -90 | | -20 | dBm |
| Enable TX or RX delay | | 140 | | µs |
| Enable TX or RX delay (fast mode) | | 40 | | µs |
| Disable TX delay | | 6 | | µs |
| Disable RX delay | | 0 | | µs |

Table 7: Radio parameters

| Output power `RF_TXPower` = 4 | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|
| Proteus-I external antenna (50 Ω conducted) | | 3 | 4 | dBm |
| Proteus-I integrated pcb antenna (e.i.r.p.) | | -2 | 0 | dBm |

Table 8: Output power

[1] nRF52832 Rev.1, with build code CIAA-B00, CSP package, in DC/DC Mode

## 4.5. Pin characteristics

When configured as digital pin output "standard drive" is used in the Proteus-I firmware.

| Description | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|
| Input high voltage | 0.7 ×VCC | | VCC | V |
| Input low voltage | VSS | | 0.3 ×VCC | V |
| Current at VSS+0.4 V, output set low, **standard drive**, VDD ≥1.7V | 1 | 2 | 4 | mA |
| Current at VSS+0.4 V, output set low, high drive, VDD ≥ 2.7 V | 6 | 10 | 15 | mA |
| Current at VSS+0.4 V, output set low, high drive, VDD ≥ 1.7 V | 3 | | | mA |
| Current at VDD-0.4 V, output set high, **standard drive**, VCC ≥1.7V | 1 | 2 | 4 | mA |
| Current at VDD-0.4 V, output set high, high drive, VDD ≥ 2.7 V | 6 | 9 | 14 | mA |
| Current at VDD-0.4 V, output set high, high drive, VDD ≥ 1.7 V | 3 | | | mA |
| Internal pull-up resistance | | 13 | | kΩ |
| Internal pull-down resistance | | 13 | | kΩ |

Table 9: Pin characteristics

# 5. Pinout

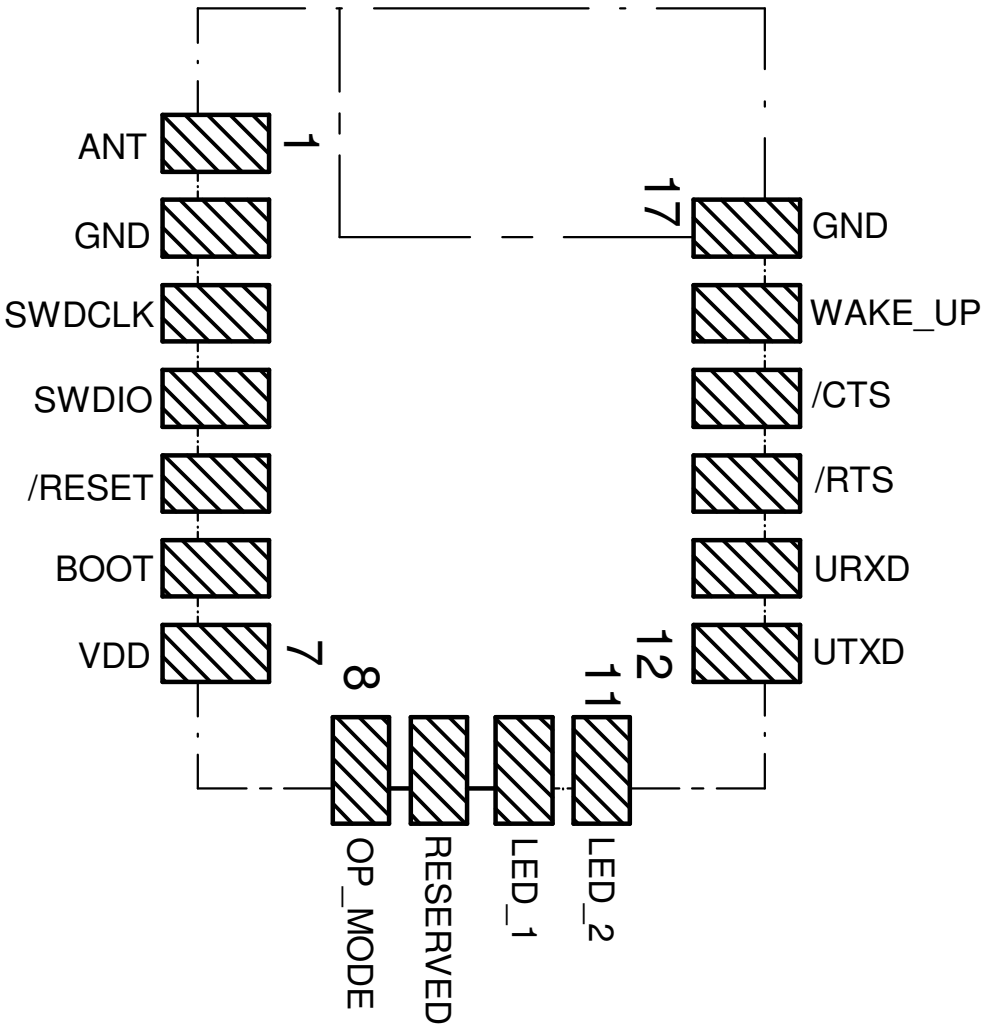



Figure 5: Pinout (top view)

| No | µC Pin | Designation | I/O | Description |
|---|---|---|---|---|
| 1 | | *ANT* | RF | Antenna connection in case of module variant with external antenna. In case of module with integrated antenna, do not connect. |
| 2 | | *GND* | Supply | Ground |
| 3 | | *SWDCLK* | Input | Serial wire clock. Uses internal pull down resistor. Do not connect if not needed. |

| | | | | |
|---|---|---|---|---|
| 4 | | *SWDIO* | Input | Serial wire input/output. Uses internal pull up resistor. Do not connect if not needed. |
| 5 | P0.21 | */RESET* | Input | Reset pin. A low signal resets the module. Uses internal pull up resistor. |
| 6 | P0.05/AIN3 | *BOOT* | Input | Boot pin with internal pull up resistor[1] during start-up. A low signal during and short after reset starts the module in OTA bootloader mode. Do not connect if not needed. |
| 7 | | *VDD* | Supply | Supply voltage |
| 8 | P0.10/NFC2[2] | *OP_MODE* | Input | Operation mode pin with internal pull down resistor[1] during start-up. Low level or open: Normal Mode. High level: Peripheral only Mode. Do not connect if not needed. |
| 9 | P0.09/NFC1[2] | RESERVED | I/O | Do not connect. |
| 10 | P0.00/XL1[2] | *LED_1* | Output | Indicates the module state (active high). Do not connect if not needed. |
| 11 | P0.01/XL2[2] | *LED_2* | Output | Indicates the module state (active high). Do not connect if not needed. |
| 12 | P0.02/AIN0 | *UTXD* | Output | UART (Transmission), if UART is enabled[3]. |
| 13 | P0.03/AIN1 | *URXD* | Input | UART (Reception) with internal pull up resistor[1], if UART is enabled[3]. |
| 14 | P0.04/AIN2 | */RTS* | Output | /RTS signal if UART[3] and flow control is enabled. Input floating otherwise. Do not connect if not needed. |
| 15 | P0.28/AIN4 | */CTS* | Input | /CTS signal if UART[3] and flow control is enabled. Input floating otherwise. Do not connect if not needed. |
| 16 | P0.29/AIN5 | *WAKE_UP* | Input | Wake-up will allow leaving the system-off mode or re-enabling the UART. Uses internal pull up resistor[4]. Do not connect if not needed. |
| 17 | | *GND* | Supply | Ground |

Table 10: Pinout

[1] Internal pull ups or pull downs are configured at start-up by the firmware installed in the SoC.
[2] Pins for NFC and external crystal are only available in custom firmware.
[3] If UART is disabled, this pin is input floating. UART can be disabled using the `CMD_UARTDISABLE_REQ` command in command mode, or closing the Bluetooth® LE connection in peripheral only mode.
[4] Internal pull ups or pull downs are configured at start-up by the firmware installed in the SoC.

# 6. Quick start

## 6.1. Minimal pin configuration

In factory state the modules are immediately ready for operation; the following pins are required in the minimal configuration:
*VDD*, *GND*, *UTXD*, *URXD*, */RESET*

If the flow control is enabled additionally the pins */RTS* and */CTS* shall be connected.

We recommend to additionally have the pins *SWDIO* and *SWDCLK* accessible in order to support a fail-safe firmware update. A standard socket on the customer's PCB for connecting a flash adapter can be useful for debugging purposes (e.g. a JTAG 2*10 pin header with 2.54mm pin-to-pin distance).

Implementing the fail-safe firmware update method using the SWD interface is recommended. Without having the SWD interface available a fail-safe firmware update on a customer PCB cannot be guaranteed.

If the module has to be connected to a PC, a converter (TTL to RS-232 or TTL to USB) has to be used. See chapter 5 for details on all pins. Please refer to the Proteus-I-EV schemes for a reference design.

The logic level of the module is based on 3V. A 5 V logic level must not be connected directly to the module.

## 6.2. Power up

After powering the module the */RESET* pin shall be hold for another $\Delta$t of 1 ms after the *VDD* is stable to ensure a safe start-up. The module will send a `CMD_GETSTATE_CNF` to indicate "ready for operation" after the */RESET* pin was released.

Applying a reset (e.g. a host temporarily pulling the */RESET* pin down for at least 1 ms and releasing it again) after the VCC is stable will also be sufficient.

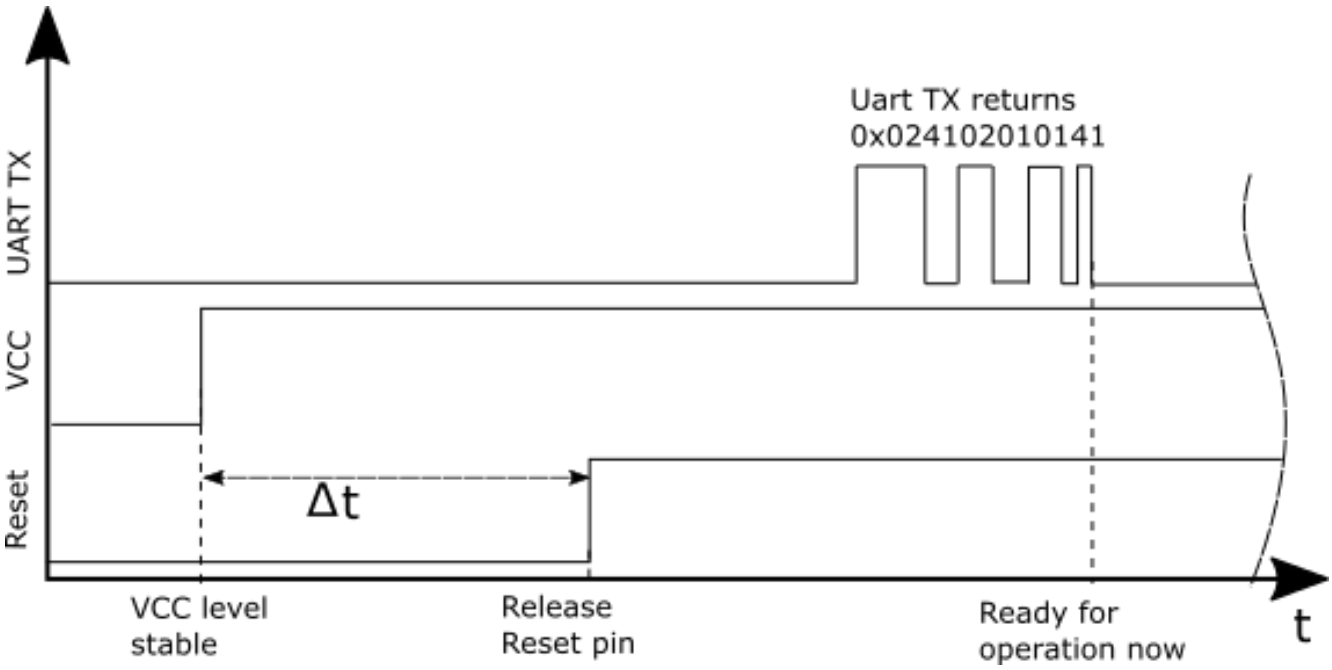



Figure 6: Power up

## 6.3. Quickstart example

This section describes how to quick start the data transmission between two Proteus-I modules. The goal is to setup a connection between module A and module B, transmit some data and close the connection again.
In this section, all packet data from or to the modules is given in **hexadecimal notation**. For quick testing, a pair of Proteus-I-EV is recommended.
Connect the two devices (modules, EV-Boards or USB dongles) to a PC. A terminal program, for example *hterm*, is used to perform the communication via COM ports. The two corresponding COM ports have to be selected and opened with a default configuration of 115200 Baud, 8 data Bits, 1 stop Bit and parity set to none (8n1).

To reproduce the following sequence, note that, the `FS_BTMAC` of every module is different, thus it has to be replaced it in the commands below. In addition, the checksum has to be adjusted, when adapting any command. The command structure and checksum calculation is described in chapter `10`.

Note that the module goes to `ACTION_SLEEP` mode if no connection is setup after `RF_AdvertisingTimeout` seconds. The module will indicate this using a `CMD_SLEEP_CNF`. In addition, the UART is disabled in `ACTION_SLEEP` mode. The default value is 0s, which means that it will run forever.

### Connection setup and first data transmission

1. Power-up the modules and make their UARTs accessible by the host(s) (115200 Baud, 8n1). After the power-up or after reset the following sequence is sent from the module.

| Info | Module A | Module B |
|---|---|---|
| ⇐ Response `CMD_GETSTATE_CNF`: Module A started in `ACTION_IDLE` mode. | 02 41 02 00 01 01 41 | |
| ⇐ Response `CMD_GETSTATE_CNF`: Module B started in `ACTION_IDLE` mode. | | 02 41 02 00 01 01 41 |

2. Request the `FS_BTMAC` of both modules.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request `CMD_GET_REQ` with settings index 4 | 02 10 01 00 04 17 | |
| ⇐ Response `CMD_GET_CNF`: `FS_BTMAC` of module A is 0x55 0x00 0x00 0xDA 0x18 0x00 | 02 50 07 00 00 55 00 00 DA 18 00 C2 | |
| ⇒ Request `CMD_GET_REQ` with settings index 4 | | 02 10 01 00 04 17 |
| ⇐ Response `CMD_GET_CNF`: `FS_BTMAC` of module B is 0x11 0x00 0x00 0xDA 0x18 0x00 | | 02 50 07 00 00 11 00 00 DA 18 00 86 |

3. Connect module A to module B via Bluetooth®.

This example is taken from an older firmware. Using newer firmwares with the optional Bluetooth® 4.2 feature "LE Packet Length Extension", the maximum supported payload per packet may be higher than 0x13.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request `CMD_CONNECT_REQ` with `FS_BTMAC` of module B | 02 06 06 00 11 00 00 DA 18 00 D1 | |
| ⇐ Response `CMD_CONNECT_CNF`: Request understood, try to connect now | 02 46 01 00 00 45 | |
| ⇐ Indication `CMD_CONNECT_IND`: Physical connection established successfully to module with `FS_BTMAC` 0x11 0x00 0x00 0xDA 0x18 0x00 | 02 86 07 00 00 11 00 00 DA 18 00 50 | |

| | | |
|---|---|---|
| ⇐ Indication CMD_CONNECT_IND: Physical connection established successfully to module with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 | | 02 86 07 00 00 55 00 00 DA 18 00 14 |
| ⇐ Indication CMD_CHANNELOPEN_RSP: Channel opened successfully to module with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0x13 (19 Bytes) per packet | 02 C6 08 00 00 11 00 00 DA 18 00 13 C3 | |
| ⇐ Indication CMD_CHANNELOPEN_RSP: Channel opened successfully to module with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0x13 (19 Bytes) per packet | | 02 C6 08 00 00 55 00 00 DA 18 00 13 87 |

4. Once the connection is active, data can be sent in each direction. Let us send a string "ABCD" from module B to module A.

The RSSI values will be different in your tests.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_DATA_REQ: Send "ABCD" to module A | | 02 04 04 00 41 42 43 44 06 |
| ⇐ Response CMD_DATA_CNF: Request received, send data now | | 02 44 01 00 00 47 |
| ⇐ Indication CMD_DATA_IND: Received string "ABCD" from FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 with RSSI of 0xCA (-54dBm) | 02 84 0B 00 11 00 00 DA 18 00 CA 41 42 43 44 90 | |
| ⇐ Response CMD_TXCOMPLETE_RSP: Data transmitted successfully | | 02 C4 01 00 00 C7 |

5. Reply with "EFGH" to module B.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_DATA_REQ: Send "EFGH" to module B | 02 04 04 00 45 46 47 48 0E | |
| ⇐ Response CMD_DATA_CNF: Request received, send data now | 02 44 01 00 00 47 | |

| | | |
|---|---|---|
| ⇐ Indication CMD_DATA_IND: Received string "EFGH" from FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 with RSSI of 0xC1 (-63dBm) | | 02 84 0B 00 55 00 00 DA 18 00 C1 45 46 47 48 D7 |
| ⇐ Response CMD_TXCOMPLETE_RSP: Data transmitted successfully | 02 C4 01 00 00 C7 | |

6. Now module A closes the connection, so both modules will get a disconnect indication.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_DISCONNECT_REQ: Disconnect | 02 07 00 00 05 | |
| ⇐ Response CMD_DISCONNECT_CNF: Request received, disconnect now | 02 47 01 00 00 44 | |
| ⇐ Indication CMD_DISCONNECT_IND: Connection closed | 02 87 01 00 16 92 | |
| ⇐ Indication CMD_DISCONNECT_IND: Connection closed | | 02 87 01 00 13 97 |

# 7. Functional description

## 7.1. Operation modes

The Proteus-I module acts as a slave and can be fully controlled by an external host. The Proteus-I supports the following operating modes:

- The **command mode**, where the Proteus-I can be controlled by the host controller via commands. The command mode allows to use all central and peripheral function of the radio module. The functions of the radio module, like data transmission or configuration tasks, can be triggered by predefined commands (see chapter 9) that are sent as telegrams over the UART interface.
- The **peripheral only mode** (see chapter 12) provides a transparent UART interface and supports only the peripheral functions of the radio module. Data transmission can be done by the host without using any commands.

## 7.2. Radio module states

The Proteus-I can operate in different states. Depending on the active state several commands of the command interface (see chapter9) are permitted to modify the state, configure the module or transmit data over the radio interface. An overview of the different states and the corresponding allowed commands can be found in Figure 7.
When the Proteus-I is powered up, it starts in ACTION_IDLE state. In this state the module advertises (Bluetooth® LE role "peripheral"), such that other devices in range (Bluetooth® LE role "central" or "observer") can detect it and connect to it. If no connection was setup after RF_AdvertisingTimeout seconds, the module goes to ACTION_SLEEP state which will stop advertising.
The ACTION_IDLE state also allows to switch to ACTION_SCANNING state, where the module stops advertising and scans for other advertising modules in range (Bluetooth® LE role "central").
When leaving the ACTION_SCANNING state with the corresponding command, the module is in ACTION_IDLE state and starts advertising again.
The ACTION_CONNECTED state can be entered either by getting a connection request from another module (Bluetooth® LE role "peripheral") or by setting up a connection itself (Bluetooth® LE role "central"). In this case it stops advertising and data can be transmitted and received to/from the connected module. This state remains active as long as the module does not disconnect itself (e.g. due to a timeout), no disconnection request from the connected device is received. When disconnecting, the module goes to ACTION_IDLE state and starts advertising again.

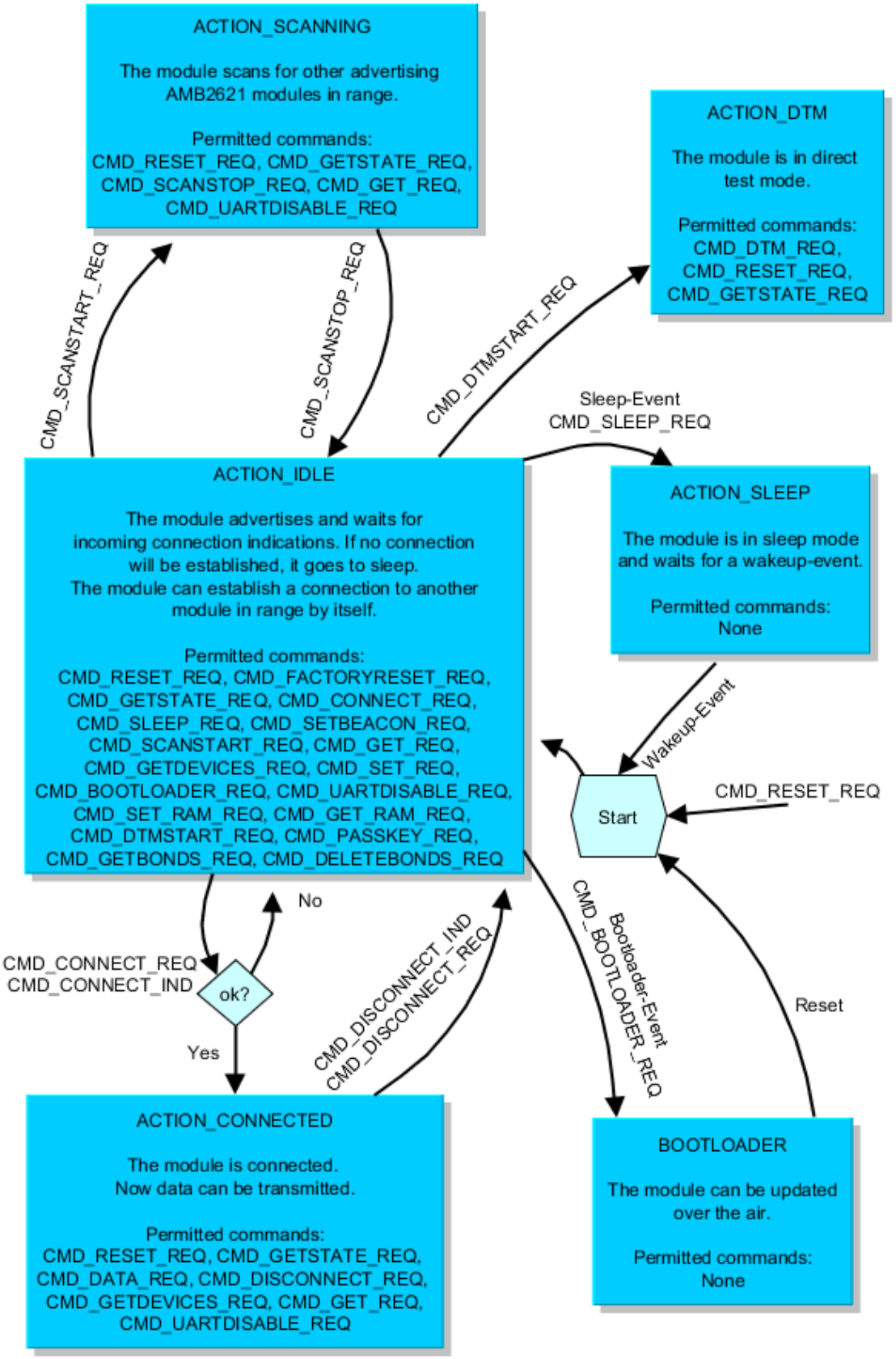



Figure 7: State overview

## 7.3. State indication using the LED pins

The pins *LED_1* and *LED_2* of the Proteus-I can be used to determine the module state. The states described in Figure 7 result in the following pin behavior. The pins on the Proteus-I are active high.

| State | *LED_1* | *LED_2* |
|---|---|---|
| ACTION_IDLE | Blinking (On for 200 ms, Off for 2800 ms) | Off |
| ACTION_SCANNING | Blinking (On for 1000 ms, Off for 1000 ms) | Off |
| ACTION_CONNECTED | On | Off, On (as soon as the channel was opened successfully, see CMD_CHANNELOPEN_RSP) |
| ACTION_SLEEP | Off | Off |
| ACTION_DTM | Off | Off |
| BOOTLOADER waiting for connection | On | Off |
| BOOTLOADER connected, firmware update running | Off | On |

Table 17: LED behavior of the Proteus-I

## 7.4. Sleep mode

Especially for battery-powered devices the ACTION_SLEEP mode (system-off mode) supports very low power consumption (<1µA). It can be entered by sending the command CMD_SLEEP_REQ to the module. If allowed (due to the current operating state) the module will then send a CMD_SLEEP_CNF and then enter the ACTION_SLEEP mode.
In ACTION_SLEEP mode the UART is disabled, so the module will not receive or transmit any data. To prevent leakage current, the host shall not pull the *UART_RX* to LOW level (as the module has an internal pull-up resistor enabled on this pin).
To leave the ACTION_SLEEP mode and enter ACTION_IDLE state again, the module has to be woken up by applying a low signal to the *WAKE_UP* pin for at least 5ms before releasing the signal back to high. The module then restarts completely, so that all volatile settings are set to default. A CMD_GETSTATE_CNF will be sent when the module is ready for operation.

Please note that the *WAKE_UP* pin has a second function. If the module is not in ACTION_SLEEP mode and the UART was disabled using the CMD_UARTDISABLE_REQ, the UART can be re-enabled by applying falling edge, holding the line low for at least 10 ms before applying a rising edge and holding it high for at least 10 ms. In this case the module answers with a CMD_UARTENABLE_IND message.

## 7.5. Identification of a Proteus-I device on the radio

The Proteus-I can be identified on the radio interface by its FS_BTMAC. This FS_BTMAC is a Bluetooth®-conform MAC address, which is part of the data package sent during advertising in ACTION_IDLE mode. A FS_BTMAC has the size of 6 Bytes.
In ACTION_SCANNING state a module listens to the data packets of all advertising modules in range and stores their FS_BTMAC to an internal data base. With help of a FS_BTMAC a connection to the corresponding device can then be established using the CMD_CONNECT_REQ command.
To simplify the identification of Proteus-I devices on the RF-interface a short user-defined name (see RF_DeviceName) can be given to the module, which is also part of the advertising packet.

The FS_BTMAC consists of the Würth Elektronik eiSos MAC ID 0x0018DA followed by the FS_SerialNumber of the module.

## 7.6. Connection based data transmission, with or without security

In the Bluetooth® LE standard the transmission of data typically is connection based. A connection between two devices can be secured (with or without key exchange) or unsecured (default setting). In any case, each data packet transmitted is acknowledged on the link layer, such that it is resent as long as a packet is lost. The following lines describe how to run the connection setup and data transmission using the Proteus-I.
If module A is supposed to setup a connection with module B, module A can use the command CMD_CONNECT_REQ including the FS_BTMAC of module B. If the FS_BTMAC of module B is unknown, a scan can be run before by module A to discover all available modules in range.
After sending the command CMD_CONNECT_REQ, the module answers with a CMD_CONNECT_CNF to signal that the request has been understood and the module now tries to establish the connection.
If module B cannot be found on the air within a timeout, module A outputs a CMD_CONNECT_IND with "failed" as status. Otherwise, as soon as the physical connection has been set up successfully, module A and B print a CMD_CONNECT_IND with the status of the successful connection and *LED_1* turns on.
Next some security and authentication messages will follow, like CMD_SECURITY_IND, if security is enabled.
After the physical connection has been setup successfully the modules exchange their services. As soon as this has finished successfully, a CMD_CHANNELOPEN_RSP is given out to the UART indicating that the connection is ready for data transmission. Furthermore, *LED_2* turns on.
Now data can be transmitted in both directions using the command CMD_DATA_REQ. It is confirmed by a CMD_DATA_CNF (data will be processed) and a CMD_TXCOMPLETE_RSP (data transmitted successfully).
Each time data has been received a CMD_DATA_IND will be output containing the transmitted data.
As soon as one module closes the connection using a CMD_DISCONNECT_REQ, both modules will inform their host by a CMD_DISCONNECT_IND message that the connection is no longer open.

If one module is no longer within range, the CMD_DISCONNECT_IND message is triggered by a timeout.
For an example on setting up an unsecured connection, see chapter 6.3. See also the Proteus-I application note ANR002 to get detailed information about the connection setup with foreign devices.
For an example on setting up an unsecured connection, see chapter 6.3. See also the application note ANR002 [2] to get detailed information about the connection setup with foreign devices.

### 7.6.1. Further information for a secure connection setup

The RF_SecFlags parameter of the module determines the security mode. If a certain security mode of a Proteus-I peripheral device is set, its security level has to be met by the connecting central device to be able to exchange data. As soon as the defined security level is not met by the central device, no access to the peripheral's profiles will be granted.

When connecting from a Proteus-I to a Proteus-I, you shall not use different security modes.

To get further information about the secured connection setup, when using a foreign device (i.e. mobile phone with a custom APP), please refer to the Application Note "advanced user guide" (Proteus-I: ANR002, Proteus-II: ANR005).

#### 7.6.1.1. Just works mode

In case of the "Just works" mode, each time a connection is established, a new random key is exchanged in advance to be used for data encryption. Since no authentication will be performed, also devices without input and output capabilities (like keyboard or display) are able to connect to each other.

**Example: Secured connection with LE Legacy security method "Just Works" without bonding**

1. Power-up the modules and make their UARTs accessible by the host(s) (115200 Baud, 8n1). After the power-up or after reset the following sequence is sent from the module

| Info | Module A | Module B |
|---|---|---|
| ⇐ Response CMD_GETSTATE_CNF: Module A started in ACTION_IDLE mode. | 02 41 02 00 01 01 41 | |
| ⇐ Response CMD_GETSTATE_CNF: Module B started in ACTION_IDLE mode. | | 02 41 02 00 01 01 41 |

2. Request the FS_BTMAC of both modules.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_GET_REQ with settings index 4 | 02 10 01 00 04 17 | |
| ⇐ Response CMD_GET_CNF: FS_BTMAC of module A is 0x55 0x00 0x00 0xDA 0x18 0x00 | 02 50 07 00 00 55 00 00 DA 18 00 C2 | |
| ⇒ Request CMD_GET_REQ with settings index 4 | | 02 10 01 00 04 17 |
| ⇐ Response CMD_GET_CNF: FS_BTMAC of module B is 0x11 0x00 0x00 0xDA 0x18 0x00 | | 02 50 07 00 00 11 00 00 DA 18 00 86 |

3. Configure the parameter RF_SecFlags to use "Just Works" pairing method for Bluetooth® security.

| Info | Module A | Module B |
|---|---|---|
| ⇒Perform CMD_SET_REQ with settings index 12 and value 0x02 on module A | 02 11 02 00 0C 02 1F | |
| ⇐ Response CMD_SET_CNF (Module will restart to adopt the new value) | 02 51 01 00 00 52 | |
| ⇐ Response CMD_GETSTATE_CNF | 02 41 02 00 01 01 41 | |
| ⇒Perform CMD_SET_REQ with settings index 12 and value 0x02 on module B | | 02 11 02 00 0C 02 1F |
| ⇐ Response CMD_SET_CNF (Module will restart to adopt the new value) | | 02 51 01 00 00 52 |
| ⇐ Response CMD_GETSTATE_CNF | | 02 41 02 00 01 01 41 |

4. Connect module A to module B via Bluetooth®.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_CONNECT_REQ with FS_BTMAC of module B | 02 06 06 00 11 00 00 DA 18 00 D1 | |
| ⇐ Response CMD_CONNECT_CNF: Request understood, try to connect now | 02 46 01 00 00 45 | |
| ⇐ Indication CMD_CONNECT_IND: Physical connection established successfully to module with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 | 02 86 07 00 00 11 00 00 DA 18 00 50 | |

| | | |
|---|---|---|
| ⇐ Indication CMD_CONNECT_IND: Physical connection established successfully to module with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 | | 02 86 07 00 00 55 00 00 DA 18 00 14 |
| ⇐ Indication CMD_SECURITY_IND, status 0x02 (encrypted link, pairing, no bonding), with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 | 02 88 07 00 02 11 00 00 DA 18 00 5C | |
| ⇐ Indication CMD_SECURITY_IND, status 0x02 (encrypted link, pairing, no bonding), with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 | | 02 88 07 00 02 55 00 00 DA 18 00 18 |

| Info | Module A | Module B |
|---|---|---|
| ⇐ Indication CMD_CHANNELOPEN_RSP: Channel opened successfully to module with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0xF3 (243 Bytes) per packet | 02 C6 08 00 00 11 00 00 DA 18 00 F3 EC | |
| ⇐ Indication CMD_CHANNELOPEN_RSP: Channel opened successfully to module with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0xF3 (243 Bytes) per packet | | 02 C6 08 00 00 55 00 00 DA 18 00 F3 A8 |

5. Once the connection is active, data can be sent in each direction. Let us send a string "ABCD" from module B to module A.

The RSSI values will be different in your tests.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_DATA_REQ: Send "ABCD" to module A | | 02 04 04 00 41 42 43 44 06 |
| ⇐ Response CMD_DATA_CNF: Request received, send data now | | 02 44 01 00 00 47 |
| ⇐ Indication CMD_DATA_IND: Received string "ABCD" from FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 with RSSI of 0xCA (-54dBm) | 02 84 0B 00 11 00 00 DA 18 00 CA 41 42 43 44 90 | |

| | | |
|---|---|---|
| ⇐ Response CMD_TXCOMPLETE_RSP: Data transmitted successfully | | 02 C4 01 00 00 C7 |

6. Reply with "EFGH" to module B.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_DATA_REQ: Send "EFGH" to module B | 02 04 04 00 45 46 47 48 0E | |
| ⇐ Response CMD_DATA_CNF: Request received, send data now | 02 44 01 00 00 47 | |
| ⇐ Indication CMD_DATA_IND: Received string "EFGH" from FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 with RSSI of 0xC1 (-63dBm) | | 02 84 0B 00 55 00 00 DA 18 00 C1 45 46 47 48 D7 |
| ⇐ Response CMD_TXCOMPLETE_RSP: Data transmitted successfully | 02 C4 01 00 00 C7 | |

7. Now module A closes the connection, so both modules will get a disconnect indication.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_DISCONNECT_REQ: Disconnect | 02 07 00 00 05 | |
| ⇐ Response CMD_DISCONNECT_CNF: Request received, disconnect now | 02 47 01 00 00 44 | |
| ⇐ Indication CMD_DISCONNECT_IND: Connection closed | 02 87 01 00 16 92 | |
| ⇐ Indication CMD_DISCONNECT_IND: Connection closed | | 02 87 01 00 13 97 |

8. You may want to perform a CMD_FACTORYRESET_REQ to restore default settings.

#### 7.6.1.2. StaticPasskey mode

In case of the "StaticPasskey" mode, a pass key has to be entered at the central side that has to match the pass key of the peripheral. Here the Proteus-I uses a static pass key in the peripheral role that is stored in the parameter RF_StaticPasskey. When using this method, the central device requests its host to enter the correct pass key (see CMD_PASSKEY_IND). In this case the pass key of the peripheral has to be entered on central side using the CMD_PASSKEY_REQ command. If the entered pass key is correct, the channel will be opened for data transmission. Otherwise, the connection will be rejected.

### Example: Secured connection with security method "StaticPasskey"

1. Power-up the modules and make their UARTs accessible by the host(s) (115200 Baud, 8n1). After the power-up or after reset the following sequence is sent from the module

| Info | Module A | Module B |
|---|---|---|
| ⇐ Response CMD_GETSTATE_CNF: Module A started in ACTION_IDLE mode. | 02 41 02 00 01 01 41 | |
| ⇐ Response CMD_GETSTATE_CNF: Module B started in ACTION_IDLE mode. | | 02 41 02 00 01 01 41 |

2. Request the FS_BTMAC of both modules.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_GET_REQ with settings index 4 | 02 10 01 00 04 17 | |
| ⇐ Response CMD_GET_CNF: FS_BTMAC of module A is 0x55 0x00 0x00 0xDA 0x18 0x00 | 02 50 07 00 00 55 00 00 DA 18 00 C2 | |
| ⇒ Request CMD_GET_REQ with settings index 4 | | 02 10 01 00 04 17 |
| ⇐ Response CMD_GET_CNF: FS_BTMAC of module B is 0x11 0x00 0x00 0xDA 0x18 0x00 | | 02 50 07 00 00 11 00 00 DA 18 00 86 |

3. Configure the parameter RF_SecFlags to use "StaticPasskey" pairing method for Bluetooth® security.

| Info | Module A | Module B |
|---|---|---|
| ⇒Perform CMD_SET_REQ with settings index 12 and value 0x03 on module A | 02 11 02 00 0C 03 1E | |
| ⇐ Response CMD_SET_CNF (Module will restart to adopt the new value) | 02 51 01 00 00 52 | |
| ⇐ Response CMD_GETSTATE_CNF | 02 41 02 00 01 01 41 | |
| ⇒Perform CMD_SET_REQ with settings index 12 and value 0x03 on module B | | 02 11 02 00 0C 03 1E |
| ⇐ Response CMD_SET_CNF (Module will restart to adopt the new value) | | 02 51 01 00 00 52 |
| ⇐ Response CMD_GETSTATE_CNF | | 02 41 02 00 01 01 41 |

4. Connect module A to module B via Bluetooth®.

| Info | Module A | Module B |
|---|---|---|

| | | |
|---|---|---|
| ⇒ Request CMD_CONNECT_REQ with FS_BTMAC of module B | 02 06 06 00 11 00 00 DA 18 00 D1 | |
| ⇐ Response CMD_CONNECT_CNF: Request understood, try to connect now | 02 46 01 00 00 45 | |
| ⇐ Indication CMD_CONNECT_IND: Physical connection established successfully to module with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 | 02 86 07 00 00 11 00 00 DA 18 00 50 | |
| ⇐ Indication CMD_CONNECT_IND: Physical connection established successfully to module with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 | | 02 86 07 00 00 55 00 00 DA 18 00 14 |
| ⇐ Indication CMD_PASSKEY_IND to ask for the pass key | 02 8D 07 00 00 11 00 00 DA 18 00 5B | |
| ⇒ Answer with the CMD_PASSKEY_REQ and the pass key "123123" | 02 0D 06 00 31 32 33 31 32 33 09 | |
| ⇐ Response CMD_PASSKEY_CNF: Pass key ok | 02 4D 01 00 00 4E | |
| ⇐ Indication CMD_SECURITY_IND, status 0x02 (encrypted link, pairing, no bonding), with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 | 02 88 07 00 02 11 00 00 DA 18 00 5C | |
| ⇐ Indication CMD_SECURITY_IND, status 0x02 (encrypted link, pairing, no bonding), with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 | | 02 88 07 00 02 55 00 00 DA 18 00 18 |
| ⇐ Indication CMD_CHANNELOPEN_RSP: Channel opened successfully to module with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0xF3 (243 Bytes) per packet | 02 C6 08 00 00 11 00 00 DA 18 00 F3 EC | |
| ⇐ Indication CMD_CHANNELOPEN_RSP: Channel opened successfully to module with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0xF3 (243 Bytes) per packet | | 02 C6 08 00 00 55 00 00 DA 18 00 F3 A8 |

5. Once the connection is active, data can be sent in each direction. Let us send a string "ABCD" from module B to module A.

The RSSI values will be different in your tests.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_DATA_REQ: Send "ABCD" to module A | | 02 04 04 00 41 42 43 44 06 |
| ⇐ Response CMD_DATA_CNF: Request received, send data now | | 02 44 01 00 00 47 |
| ⇐ Indication CMD_DATA_IND: Received string "ABCD" from FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 with RSSI of 0xCA (-54dBm) | 02 84 0B 00 11 00 00 DA 18 00 CA 41 42 43 44 90 | |
| ⇐ Response CMD_TXCOMPLETE_RSP: Data transmitted successfully | | 02 C4 01 00 00 C7 |

6. Reply with "EFGH" to module B.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_DATA_REQ: Send "EFGH" to module B | 02 04 04 00 45 46 47 48 0E | |
| ⇐ Response CMD_DATA_CNF: Request received, send data now | 02 44 01 00 00 47 | |
| ⇐ Indication CMD_DATA_IND: Received string "EFGH" from FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 with RSSI of 0xC1 (-63dBm) | | 02 84 0B 00 55 00 00 DA 18 00 C1 45 46 47 48 D7 |
| ⇐ Response CMD_TXCOMPLETE_RSP: Data transmitted successfully | 02 C4 01 00 00 C7 | |

7. Now module A closes the connection, so both modules will get a disconnect indication.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_DISCONNECT_REQ: Disconnect | 02 07 00 00 05 | |
| ⇐ Response CMD_DISCONNECT_CNF: Request received, disconnect now | 02 47 01 00 00 44 | |
| ⇐ Indication CMD_DISCONNECT_IND: Connection closed | 02 87 01 00 16 92 | |
| ⇐ Indication CMD_DISCONNECT_IND: Connection closed | | 02 87 01 00 13 97 |

8. You may want to perform a CMD_FACTORYRESET_REQ to restore default settings.

#### 7.6.1.3. Bonding

The SECFLAGS_BONDING_ENABLE flag in the RF_SecFlags user setting allows enabling the bonding feature. This feature stores the keys that are exchanged during the pairing phase in a

connection setup. With this, subsequent connections to bonded devices can be established without renegotiation. Bonding data of up to 32 devices will be stored in the flash.
The commands CMD_GETBONDS_REQ and CMD_DELETEBONDS_REQ allow to display and remove certain or all entries of the list of bonded devices.

**Example: Secured connection with LE Legacy security method "Just Works" using bonding**

1. Power-up the modules and make their UARTs accessible by the host(s) (115200 Baud, 8n1). After the power-up or after reset the following sequence is sent from the module

| Info | Module A | Module B |
|---|---|---|
| ⇐ Response CMD_GETSTATE_CNF: Module A started in ACTION_IDLE mode. | 02 41 02 00 01 01 41 | |
| ⇐ Response CMD_GETSTATE_CNF: Module B started in ACTION_IDLE mode. | | 02 41 02 00 01 01 41 |

2. Request the FS_BTMAC of both modules.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_GET_REQ with settings index 4 | 02 10 01 00 04 17 | |
| ⇐ Response CMD_GET_CNF: FS_BTMAC of module A is 0x55 0x00 0x00 0xDA 0x18 0x00 | 02 50 07 00 00 55 00 00 DA 18 00 C2 | |
| ⇒ Request CMD_GET_REQ with settings index 4 | | 02 10 01 00 04 17 |
| ⇐ Response CMD_GET_CNF: FS_BTMAC of module B is 0x11 0x00 0x00 0xDA 0x18 0x00 | | 02 50 07 00 00 11 00 00 DA 18 00 86 |

3. Configure the parameter RF_SecFlags to use "Just Works with bonding" pairing method for Bluetooth® security.

| Info | Module A | Module B |
|---|---|---|
| ⇒Perform CMD_SET_REQ with settings index 12 and value 0x0A (Just works with SECFLAGS_BONDING_ENABLE flag set) on module A | 02 11 02 00 0C 0A 17 | |
| ⇐ Response CMD_SET_CNF (Module will restart to adopt the new value) | 02 51 01 00 00 52 | |
| ⇐ Response CMD_GETSTATE_CNF | 02 41 02 00 01 01 41 | |

| | | |
|---|---|---|
| ⇒Perform CMD_SET_REQ with settings index 12 and value 0x0A (Just works with SECFLAGS_BONDING_ENABLE flag set) on module B | | 02 11 02 00 0C 0A 17 |
| ⇐ Response CMD_SET_CNF (Module will restart to adopt the new value) | | 02 51 01 00 00 52 |
| ⇐ Response CMD_GETSTATE_CNF | | 02 41 02 00 01 01 41 |

4. Connect module A to module B via Bluetooth®.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_CONNECT_REQ with FS_BTMAC of module B | 02 06 06 00 11 00 00 DA 18 00 D1 | |
| ⇐ Response CMD_CONNECT_CNF: Request understood, try to connect now | 02 46 01 00 00 45 | |
| ⇐ Indication CMD_CONNECT_IND: Physical connection established successfully to module with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 | 02 86 07 00 00 11 00 00 DA 18 00 50 | |
| ⇐ Indication CMD_CONNECT_IND: Physical connection established successfully to module with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 | | 02 86 07 00 00 55 00 00 DA 18 00 14 |
| ⇐ Indication CMD_SECURITY_IND, status 0x01 (encrypted link, bonding established), with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 | 02 88 07 00 01 11 00 00 DA 18 00 5F | |
| ⇐ Indication CMD_SECURITY_IND, status 0x01 (encrypted link, bonding established), with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 | | 02 88 07 00 01 55 00 00 DA 18 00 1B |
| ⇐ Indication CMD_CHANNELOPEN_RSP: Channel opened successfully to module with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0xF3 (243 Bytes) per packet | 02 C6 08 00 00 11 00 00 DA 18 00 F3 EC | |
| ⇐ Indication CMD_CHANNELOPEN_RSP: Channel opened successfully to module with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0xF3 (243 Bytes) per packet | | 02 C6 08 00 00 55 00 00 DA 18 00 F3 A8 |

5. Now module A closes the connection, so both modules will get a disconnect indication.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_DISCONNECT_REQ: Disconnect | 02 07 00 00 05 | |
| ⇐ Response CMD_DISCONNECT_CNF: Request received, disconnect now | 02 47 01 00 00 44 | |
| ⇐ Indication CMD_DISCONNECT_IND: Connection closed | 02 87 01 00 16 92 | |
| ⇐ Indication CMD_DISCONNECT_IND: Connection closed | | 02 87 01 00 13 97 |

6. Connect module A to module B a second time. Now, since both devices have been bonded before, the exchanged keys are reused.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_CONNECT_REQ with FS_BTMAC of module B | 02 06 06 00 11 00 00 DA 18 00 D1 | |
| ⇐ Response CMD_CONNECT_CNF: Request understood, try to connect now | 02 46 01 00 00 45 | |
| ⇐ Indication CMD_CONNECT_IND: Physical connection established successfully to module with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 | 02 86 07 00 00 11 00 00 DA 18 00 50 | |
| ⇐ Indication CMD_CONNECT_IND: Physical connection established successfully to module with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 | | 02 86 07 00 00 55 00 00 DA 18 00 14 |
| ⇐ Indication CMD_SECURITY_IND, status 0x00 (encrypted link to bonded device), with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 | 02 88 07 00 00 11 00 00 DA 18 00 5E | |
| ⇐ Indication CMD_SECURITY_IND, status 0x00 (encrypted link to bonded device), with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 | | 02 88 07 00 00 55 00 00 DA 18 00 1A |
| ⇐ Indication CMD_CHANNELOPEN_RSP: Channel opened successfully to module with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0xF3 (243 Bytes) per packet | 02 C6 08 00 00 11 00 00 DA 18 00 F3 EC | |

| | | |
|---|---|---|
| ⇐ Indication `CMD_CHANNELOPEN_RSP`: Channel opened successfully to module with `FS_BTMAC` 0x55 0x00 0x00 0xDA 0x18 0x00 and maximum payload size of 0xF3 (243 Bytes) per packet | | 02 C6 08 00 00 55 00 00 DA 18 00 F3 A8 |

7. You may want to perform a `CMD_FACTORYRESET_REQ` to restore default settings.

## 7.7. Unidirectional connectionless data transmission using Beacons

Besides the connection-based type of data transmission described in the previous section, there exists a second method that uses so called Beacons. In this case, up to 19 bytes of user data can be placed in the Bluetooth® LE scan response packet, which is broadcasted frequently without acknowledgement and without security during advertising.
If a Proteus-I is supposed to broadcast some user data the command `CMD_SETBEACON_REQ` places the payload data, that is marked as "manufacturer data" combined with the Würth Elektronik eiSos company identifier 0x031A, in the scan response packet.
If a second Proteus-I, which has its Beacon-function enabled (see `RF_BeaconFlags`), is in the operating state `ACTION_SCANNING`, the scan response packet and the containing beacon data is received. Filtering the beacon messages can be enabled or disabled using the user setting `RF_BeaconFlags`.
After the reception of the beacon data, it is output to the connected host using a `CMD_BEACON_IND` message.
To set the module into `ACTION_SCANNING` mode the command `CMD_SCANSTART_REQ` has to be used. Enable the Beacon-function before by setting the corresponding value in the `RF_BeaconFlags` parameter.

This method is very suitable for sensor networks, which frequently send their data to data collectors. Especially when using a slow `RF_ScanTiming` mode, data can be transmitted in very energy efficient way.

Please check the settings `RF_AdvertisingTimeout` and the advertising interval in `RF_ScanTiming` to configure the frequency and interval of transmissions which will have an influence on the current consumption of the module.

| Info | Module A | Module B |
|---|---|---|
| ⇐ Reset both modules using */RESET* pin, `CMD_GETSTATE_CNF` | 02 41 02 00 01 01 41 | 02 41 02 00 01 01 41 |
| ⇒ Configure `RF_BeaconFlags` using `CMD_SET_REQ` to "beacon rx enabled, no filter" | | 02 11 02 00 0E 01 1E |
| ⇐ `CMD_SET_CNF` from module B | | 02 51 01 00 00 52 |
| ⇐ Module B reset such that the change in the user setting takes effect (`CMD_GETSTATE_CNF`) | | 02 41 02 00 01 01 41 |
| ⇒ Activate scanning on module B | | 02 09 00 00 0B |
| ⇐ Response `CMD_SCANSTART_CNF` | | 02 49 01 00 00 4A |
| ⇒ `CMD_SETBEACON_REQ`, content "Hallo" | 02 0C 05 00 48 61 6C 6C 6F 4D | |
| ⇐ `CMD_SETBEACON_CNF` | 02 4C 01 00 00 4F | |

| | | |
|---|---|---|
| ⇐ Receiving multiple CMD_BEACON_IND | | 02 8C 0C 00 02 00 00 DA 18 00 B5 48 61 6C 6C 6F B1 02 8C 0C 00 02 00 00 DA 18 00 B1 48 61 6C 6C 6F B5 |
| ⋮ | ⋮ | ⋮ |
| ⇒ Deactivate scanning on module B, CMD_SCANSTOP_REQ | | 02 0A 00 00 08 |
| ⇐ Response CMD_SCANSTOP_CNF | | 02 4A 01 00 00 49 |
| ⇒ Reset module A (disable sending beacons), CMD_RESET_REQ | 02 00 00 00 02 | |
| ⇐ Response CMD_RESET_CNF | 02 40 01 00 00 43 | |
| ⇐ Response CMD_GETSTATE_CNF | 02 41 02 00 01 01 41 | |

## 7.8. Energy-efficient distance estimation solutions

The Proteus-I advertising packet contains the TX power value of the transmitting device. This value in combination with the RSSI value of the received advertising packet can be used to estimate the distance between the modules. Using a suitable triangulation algorithm and multiple receivers or transmitters, a position can be approximated.
The advertising packets can be received by performing a passive scan that will not request the scan response. Thus only one frame, instead of three frames, is transmitted per advertising interval.
Besides the FS_BTMAC of the sending module, the RSSI value and the TX power is output in format of a CMD_RSSI_IND message via UART when an advertising packet of another Proteus-I has been received.
To enable this function, the corresponding Bit in the RF_BeaconFlags has to be set.

## 7.9. Configure the module for low power consumption

Depending on the application environment of the Proteus-I, the goal is to find the optimal trade-off between the module's performance and its power consumption. Therefore, the main settings and operation modes that affect the current consumption are listed below:

- CMD_SLEEP_REQ: This command puts the module into ACTION_SLEEP mode, where it consumes the lowest current (<1µA). In this case, both the UART and the Bluetooth® LE interface are shut down.
- CMD_UARTDISABLE_REQ: This command disables the UART interface. It is enabled again as soon as the module is reset/woken or when the module outputs a message e.g. when a connection request has been received or the *WAKE_UP* pin of the module was used.
- RF_TXPower: This setting can be used to configure the output power of the module. Reducing the output power saves energy.

- `RF_ScanTiming` and `RF_ScanFactor`: These settings define the timing behavior of the module, when advertising or scanning. The less often the module sends advertising packets or scans, the less current is consumed.
- `RF_ConnectionTiming`: This setting defines the timing behavior of the module during connection setup and an established connection. The less often the connected modules communicate with each other, the less current is consumed.
- The on-board nRF52 SoC is running in debug mode. This will not occur if the pins are connected as described in this manual.

For optimum energy efficiency a user and application specific firmware may be required.

## 7.10. Start the direct test mode (DTM)

The direct test mode (DTM) enables the test functions described in Bluetooth® Specification. The purpose of DTM is to test the operation of the radio at the physical level, such as transmission power and receiver sensitivity, frequency offset and drift, modulation characteristics, packet error rate and inter modulation performance.

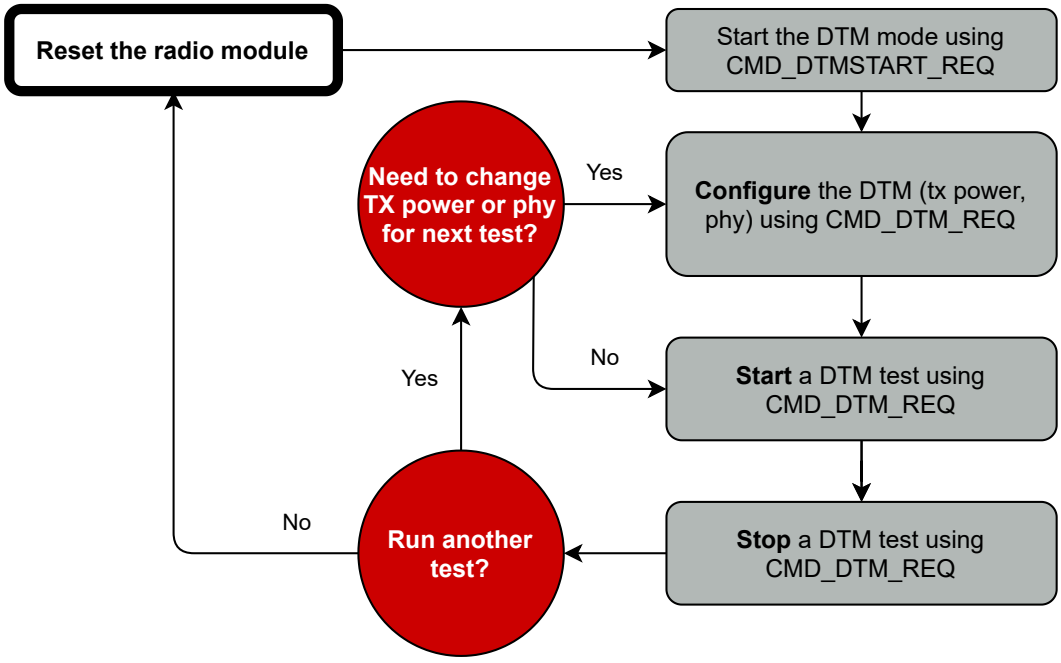



Figure 8: DTM flow chart

Conformance tests of the nRF52 with the DTM application are carried out by dedicated test equipment. To get access to the test functions the `CMD_DTMSTART_REQ`[1] shall be used first. This

[1]Please note that the WE UART Terminal [3] PC tool in version 1.3.1.0 or newer supports the DTM function.

command restarts the module in direct test mode. A CMD_GETSTATE_CNF message confirms that the DTM has been started successfully.
Now the CMD_DTM_REQ can be used to configure output power and phy of the subsequent tests. Next, to start and stop the test functions, please use again the CMD_DTM_REQ command. After a test has been started, it has to be stopped before a next test can be run.

**Example: Transmission test on channel 0 with Bit pattern 0x0F**
The goal of this example is to show how the DTM, and in specific the transmission/reception test, can be run. Here fore we need to connect two modules, start the transmission test on one module and start the reception test on the second module. In this section, all packet data from or to the modules is given in **hexadecimal notation**.
All steps are described in the following:

- First, restart the modules in DTM mode.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_DTMSTART_REQ to enable the DTM on module A | 02 1D 00 00 1F | |
| ⇐ Response CMD_DTMSTART_CNF: Request understood, try to start DTM now | 02 5D 01 00 00 5E | |
| ⇐ Indication CMD_GETSTATE_CNF: Restarted module with DTM enabled | 02 41 02 00 10 05 54 | |
| ⇒ Request CMD_DTMSTART_REQ to enable the DTM on module B | | 02 1D 00 00 1F |
| ⇐ Response CMD_DTMSTART_CNF: Request understood, try to start DTM now | | 02 5D 01 00 00 5E |
| ⇐ Indication CMD_GETSTATE_CNF: Restarted module with DTM enabled | | 02 41 02 00 10 05 54 |

- Now both modules are ready for the DTM configuration and operation.
- Set the output power to 4 dBm (default setting after start-up is 0 dBm).

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request CMD_DTM_REQ to set module A to 8 dBm output power | 02 1E 04 00 02 04 02 03 1F | |
| ⇐ Response CMD_DTM_CNF: Success | 02 5E 03 00 00 00 00 5F | |
| ⇒ Request CMD_DTM_REQ to set module B to 8 dBm output power | | 02 1E 04 00 02 04 02 03 1F |
| ⇐ Response CMD_DTM_CNF: Success | | 02 5E 03 00 00 00 00 5F |

- After configuration the tests can start. First start the transmission test.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request `CMD_DTM_REQ` to start the transmission test on module A with channel 0 and Bit pattern 16 times 0x0F | 02 1E 04 00 02 00 10 01 0B | |
| ⇐ Response `CMD_DTM_CNF`: Started test successfully | 02 5E 03 00 00 00 00 5F | |

- Start the reception test.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request `CMD_DTM_REQ` to start the reception test on module B with channel 0 | | 02 1E 04 00 01 00 00 00 19 |
| ⇐ Response `CMD_DTM_CNF`: Started test successfully | | 02 5E 03 00 00 00 00 5F |

- Stop both tests again.

| Info | Module A | Module B |
|---|---|---|
| ⇒ Request `CMD_DTM_REQ` to stop the transmission test | 02 1E 04 00 03 00 00 01 1A | |
| ⇐ Response `CMD_DTM_CNF`: Stopped test successfully | 02 5E 03 00 00 80 00 DF | |
| ⇒ Request `CMD_DTM_REQ` to stop the reception test | | 02 1E 04 00 03 00 00 01 1A |
| ⇐ Response `CMD_DTM_CNF`: Stopped test successfully, received 0x14FE ($5374_{dec}$) packets | | 02 5E 03 00 00 94 FE 35 |

During the time the reception and transmission tests were running 5374 data packets have been received by module B, which were transmitted by module A.

# 8. Host connection

## 8.1. Serial interface: UART

The configuration in factory state of the UART is 115200 Baud without flow control and with data format of 8 data Bits, no parity and 1 stop Bit ("8n1"). The baud rate of the UART can be configured by means of the user setting `UART_BaudrateIndex`. The data format is fixed to 8n1. The flow control can be enabled by means of the user setting `UART_Flags`.
The output of characters on the serial interface runs with secondary priority. For this reason, short interruptions may occur between the outputs of individual successive Bytes. The host must not implement too strict timeouts between two Bytes to be able to receive packets that have interruptions in between.

# 9. The command interface

The module acts as a slave and can be fully controlled by an external host. The configuration as well as the operation of the module can be managed by predefined commands that are sent as telegrams over the UART interface of the module.
The commands of the command interface can be divided into 3 groups:

- Requests: The host requests the module to trigger any action, e.g. in case of the request `CMD_RESET_REQ` the host asks the module to perform a reset.
- Confirmations: On each request, the module answers with a confirmation message to give a feedback on the requested operation status. In case of a `CMD_RESET_REQ`, the module answers with a `CMD_RESET_CNF` to tell the host whether the reset will be performed or not.
- Indications and Responses: The module indicates spontaneously when a special event has occurred. The `CMD_CONNECT_IND` indicates for example that a connection has been established.

| Start signal | Command | Length | Payload | CS |
|---|---|---|---|---|
| 0x02 | 1 Byte | 2 Byte, LSB first | Length Bytes | 1 Byte |

**Start signal:** 0x02 (1 Byte)

**Command:** One of the predefined commands (1 Byte).

**Length:** Specifies the length of the data that follows. Length is a 16 Bit field with LSB first.

**Payload:** Variable number (defined by the length field) of data or parameters.

**Checksum:** Byte wise XOR combination of all preceding Bytes including the start signal, i.e. 0x02 ^ Command ^ Length ^ Payload = CS

Host integration example codes for checksum calculation and command frame structure can be found in annex `A` and `B`, as well as in the *Wireless Connectivity SDK*.

If the transmission of the UART command has not finished within the packet transmission duration (depending on the currently selected UART Baud rate + 5ms after having received the start signal), the module will discard the received Bytes and wait for a new command. This means that the delay between 2 successive Bytes in a frame must be kept as low as possible.

Please note that the different commands are only valid in specific module states (see Figure 7). If a command is not permitted in the current state, the command confirmation returns "Operation not permitted" as a response.

## 9.1. Scan for other modules in range

### 9.1.1. CMD_SCANSTART_REQ

This command starts the scan operation to find other Proteus-I in range. All found devices that fit the Proteus-I specification (i.e. devices that support WE SPP-like service UUID) are saved in an internal data base. Before outputting the data base content using the command `CMD_GETDEVICES_REQ`, the scan has to be stopped using `CMD_SCANSTOP_REQ`.
Format:

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x09 | 0x00 0x00 | 0x0B |

Response (`CMD_SCANSTART_CNF`):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x49 | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Request received, will start scan now

**0x01:** Operation failed

**0xFF:** Operation not permitted

### 9.1.2. CMD_SCANSTOP_REQ

This command stops the scan operation that was started using `CMD_SCANSTART_REQ`. It stores the detected Proteus-I `FS_BTMAC` addresses in an internal database, which can be output using the `CMD_GETDEVICES_REQ`.
Format:

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x0A | 0x00 0x00 | 0x08 |

Response (`CMD_SCANSTOP_CNF`):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x4A | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Request received, will stop scan now

**0x01:** Operation failed

**0xFF:** Operation not permitted

### 9.1.3. CMD_GETDEVICES_REQ

This command returns the information about the devices found during the last scan operation. `#Devices` determines the number of devices that have been detected. The corresponding information will be output one after the other in the field behind `#Devices` in the `CMD_GETDEVICES_CNF` response. The RSSI and TXPower values are transmitted in the two's complement notation.
Format:

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x0B | 0x00 0x00 | 0x09 |

Response (`CMD_GETDEVICES_CNF`):

| Start signal | Command \| 0x40 | Length | Status | `#Devices` | Payload | CS |
|---|---|---|---|---|---|---|
| 0x02 | 0x4B | 2 Bytes | 1 Byte | 1 Byte | (Length - 2) Bytes | 1 Byte |

The Payload sequentially lists the data of the detected `#Devices` devices. It consists of `#Devices` times the following telegram (see example below).

| BTMAC | RSSI | TXPower | Device name length | Device name |
|---|---|---|---|---|
| 6 Bytes | 1 Byte | 1 Byte | 1 Byte | Device name length Bytes |

Status:

**0x00:** Request received

**0x01:** Operation failed

**0xFF:** Operation not permitted

If there are too many devices found to be output, the response of the `CMD_GETDEVICES_REQ` is split into several `CMD_GETDEVICES_CNF` messages.

The detected device name is the content of the device name field of the received advertising packet. Thus, in case of the "Complete Local Name" is too long to fit into the device name field of the advertising packet, this could be the "Shortened Local Name" of the device.

If RSSI = 0x80, there is no value available.

If TXPower = 0x80, there is no value available.

If Device name length = 0, then there is no device name available.

#### 9.1.3.1. Example 1

Request for the FS_BTMAC of the devices found during the last scan.

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x0B | 0x00 0x00 | 0x09 |

Response:

| Start signal | Command \| 0x40 | Length | Status | #Devices | Payload | CS |
|---|---|---|---|---|---|---|
| 0x02 | 0x4B | 0x1E 0x00 | 0x00 | 0x02 | 0x11 0x00 0x00 0xDA 0x18 0x00 0xE2 0x04 0x05 0x4D 0x4F 0x44 0x20 0x31 0x55 0x00 0x00 0xDA 0x18 0x00 0xE5 0x00 0x05 0x4D 0x4F 0x44 0x20 0x32 | 0x11 |

During the last scan two devices have been detected:

- Device 1 with FS_BTMAC 0x11 0x00 0x00 0xDA 0x18 0x00, RSSI value of 0xE2 (-30 dBm), TXPower of 0x04 (=+4 dBm) and device name of length 5 with the value of 0x4D4F442031 ("MOD 1").
- Device 2 with FS_BTMAC 0x55 0x00 0x00 0xDA 0x18 0x00 and RSSI value of 0xE5 (-27 dBm), TXPower of 0x00 (0 dBm) and device name 0x4D4F442032 ("MOD 2") of length 5.

### 9.1.4. CMD_RSSI_IND

This telegram indicates the reception of an advertising packet sent by another Proteus-I module. It can be used to realize a position sensing application. This data can only be received, when the module is in ACTION_SCANNING mode (passive scan is sufficient) and the corresponding Bit in the RF_BeaconFlags is set.
Besides the FS_BTMAC, the RSSI value of the advertising packet and the transmission power of

the sending device are output. Both, the RSSI value and the TX power are in two's complement notation.
The accuracy is ±2dB when inside the RSSI range of -90 to -20 dBm.
The value of the parameter TX power is read from the content of the received advertise packet.
Format:

| Start signal | Command | Length | BTMAC | RSSI | TX Power | CS |
|---|---|---|---|---|---|---|
| 0x02 | 0x8B | 2 Bytes | 6 Byte | 1 Byte | 1 Byte | 1 Byte |

## 9.2. Setup connections

### 9.2.1. CMD_CONNECT_REQ

This command tries to setup a connection to the Proteus-I, which is identified by the FS_BTMAC used in the command. After the module prints a CMD_CONNECT_CNF to confirm that the request was received, the indication message CMD_CONNECT_IND follows which determines whether the connection request was accepted by the other device.
In case of enabled security features (see the setting RF_SecFlags) a CMD_SECURITY_IND is output in addition.
As soon as the connection setup has been completed and all services have been discovered successfully a CMD_CHANNELOPEN_RSP is printed by the UART. Now data may be sent using the CMD_DATA_REQ.
Format:

| Start signal | Command | Length | BTMAC | CS |
|---|---|---|---|---|
| 0x02 | 0x06 | 0x06 0x00 | 6 Bytes | 1 Byte |

Response (CMD_CONNECT_CNF):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x46 | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Request received, try to connect to the device with the FS_BTMAC

**0x01:** Operation failed

**0xFF:** Operation not permitted

### 9.2.2. CMD_CONNECT_IND

This telegram indicates the connection status and the FS_BTMAC of the connected device. This indication message is the result of a connection request (CMD_CONNECT_REQ).
Format:

| Start signal | Command | Length | Status | BTMAC | CS |
|---|---|---|---|---|---|
| 0x02 | 0x86 | 0x07 0x00 | 1 Byte | 6 Bytes | 1 Byte |

Status:

**0x00:** Physical connection established successfully

**0x01:** Connection failed, e.g. due to a timeout (as defined by RF_ScanTiming)

### 9.2.3. CMD_SECURITY_IND

This telegram indicates the security status and the FS_BTMAC of the connected device. This indication message is the result of a connection request (CMD_CONNECT_REQ).
Format:

| Start signal | Command | Length | Status | BTMAC | CS |
|---|---|---|---|---|---|
| 0x02 | 0x88 | 0x07 0x00 | 1 Byte | 6 Bytes | 1 Byte |

Status:

**0x00:** Encrypted link to previously bonded device established

**0x01:** Bonding successful, encrypted link established

**0x02:** No bonding, pairing successful, encrypted link established

### 9.2.4. CMD_CHANNELOPEN_RSP

This command is printed on the UART as soon as connection setup and service discovery has been completed successfully. Now data can be transmitted using the `CMD_DATA_REQ`. Next to the `FS_BTMAC` of the connected device, the maximum payload size that is supported by the link is part of this telegram. This indication message is the result of a connection request (`CMD_CONNECT_REQ`).
Format:

| Start signal | Command | Length | Status | BTMAC | Max payload | CS |
|---|---|---|---|---|---|---|
| 0x02 | 0xC6 | 0x08 0x00 | 1 Byte | 6 Bytes | 1 Byte | 1 Byte |

Status:

**0x00:** Success

### 9.2.5. CMD_DISCONNECT_REQ

This command shuts down the existing connection. Thereafter the module prints a `CMD_DISCONNECT_CNF` to confirm that the request has been received, the indication message `CMD_DISCONNECT_IND` follows which determines whether the disconnection operation has been performed successfully or not.
Format:

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x07 | 0x00 0x00 | 0x05 |

Response (`CMD_DISCONNECT_CNF`):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x47 | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Request received, try to disconnect

**0x01:** Operation failed

**0xFF:** Operation not permitted

### 9.2.6. CMD_DISCONNECT_IND

This telegram indicates that the connection has shut down successfully. This indication message is the result of a disconnection request (`CMD_DISCONNECT_REQ`).
Format:

| Start signal | Command | Length | Reason | CS |
|---|---|---|---|---|
| 0x02 | 0x87 | 0x01 0x00 | 1 Byte | 1 Byte |

Reason:

**0x08:** Connection timeout

**0x13:** User terminated connection

**0x16:** Host terminated connection

**0x3B:** Connection interval unacceptable

**0x3D:** Connection terminated due to MIC failure (Not able to connect due to bad link quality, or connection request ignored due to wrong key)

**0x3E:** Connection setup failed

### 9.2.7. CMD_PASSKEY_REQ

When receiving a `CMD_PASSKEY_IND` during connection setup, the peripheral requests for a pass key to authenticate the connecting device. To answer this request the `CMD_PASSKEY_REQ` message has to be sent to the Proteus-I central including the passkey of the peripheral. The permissible characters of the passkey are ranging from 0x30 to 0x39 (both included) which are ASCII numbers (0-9).
Format:

| Start signal | Command | Length | Pass key | CS |
|---|---|---|---|---|
| 0x02 | 0x0D | 0x06 0x00 | 6 Bytes | 1 Byte |

Response (`CMD_PASSKEY_CNF`):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x4D | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Pass key accepted and pass key request answered

**0x01:** Operation failed, due to invalid pass key

**0xFF:** Operation not permitted

### 9.2.8. CMD_PASSKEY_IND

Depending on the security settings of the peripheral, a passkey has to be entered on the central side to authenticate the central device. When such a pass key authentication request is received on the central side this `CMD_PASSKEY_IND` message is sent to the host. In this case, the passkey has to be entered using the `CMD_PASSKEY_REQ` to successfully finish the connection procedure.
Format:

| Start signal | Command | Length | Status | BTMAC | CS |
|---|---|---|---|---|---|
| 0x02 | 0x8D | 0x07 0x00 | 1 Byte | 6 Bytes | 1 Byte |

Status:

**0x00:** Success

### 9.2.9. CMD_GETBONDS_REQ

This command requests the MAC addresses of all bonded devices.
Format:

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x0F | 0x00 0x00 | 0x0D |

Response (`CMD_GETBONDS_CNF`):

| Start signal | Command \| 0x40 | Length | Status | `#Devices` | Payload | CS |
|---|---|---|---|---|---|---|
| 0x02 | 0x4F | 2 Bytes | 1 Byte | 1 Byte | (Length - 2) Bytes | 1 Byte |

The Payload sequentially lists the data of the bonded `#Devices` devices. It consists of `#Devices` times the following telegram (see example below).

| Bond_ID | BTMAC |
|---|---|
| 2 Bytes | 6 Bytes |

Status:

**0x00:** Request successfully processed

**0x01:** Operation failed

**0xFF:** Operation not permitted

If there are too many devices, the response of the CMD_GETBONDS_REQ is split into several CMD_GETBONDS_CNF messages.

#### 9.2.9.1. Example 1

Request for the bonding data of the devices in database.

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x0F | 0x00 0x00 | 0x0D |

Response:

| Start signal | Command \| 0x40 | Length | Status | #Devices | Payload | CS |
|---|---|---|---|---|---|---|
| 0x02 | 0x4F | 0x12 0x00 | 0x00 | 0x02 | 0x00 0x00 0x82 0x5C 0xA7 0xE2 0x87 0xD0 0x01 0x00 0x01 0x00 0x00 0xDA 0x18 0x00 | 0x53 |

Two devices have been bonded before:

- Device 1 (Bond_ID 0x0000) with FS_BTMAC 0x82 0x5C 0xA7 0xE2 0x87 0xD0
- Device 2 (Bond_ID 0x0001) with FS_BTMAC 0x01 0x00 0x00 0xDA 0x18 0x00

### 9.2.10. CMD_DELETEBONDS_REQ

This command removes the bonding information of all or single bonded devices. Enter Bond_ID to remove the bonding data of a certain Bond_ID. To remove all bonding data, choose Length equals 0 and leave Bond_ID empty.
Format:

| Start signal | Command | Length | Bond_ID | CS |
|---|---|---|---|---|
| 0x02 | 0x0E | 2 Bytes | 0 or 2 Bytes | 1 Byte |

Response (CMD_DELETEBONDS_CNF):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x4E | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Request successfully processed

**0x01:** Operation failed (e.g. Bond_ID not found)

**0xFF:** Operation not permitted

#### 9.2.10.1. Example 1

Request to remove all bonding data.

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x0E | 0x00 0x00 | 0x0C |

Response:

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x4E | 0x01 0x00 | 0x00 | 0x4D |

Successfully removed all bonding information.

#### 9.2.10.2. Example 2

Request to remove the bonding of the device corresponding to Bond_ID 0.

| Start signal | Command | Length | Bond_ID | CS |
|---|---|---|---|---|
| 0x02 | 0x0E | 0x02 0x00 | 0x00 0x00 | 0x0E |

Response:

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x4E | 0x01 0x00 | 0x00 | 0x4D |

Successfully removed the bonding information.

## 9.3. Transmit and receive data

### 9.3.1. CMD_DATA_REQ

This command provides the simple data transfer between two connected modules. Transmission takes place to the previously connected device(s). This command is suitable for transmission for a point-to-point connection. The number of payload data Bytes is negotiated during the connection phase. It can be maximal 243 Bytes, but at least 19 Bytes.
When the data is processed by the module a `CMD_DATA_CNF` is output by the UART. Additionally a `CMD_TXCOMPLETE_RSP` will follow as soon as the data has been sent.
The receiving Proteus-I will get a `CMD_DATA_IND` message containing the transmitted payload data.
Format:

| Start signal | Command | Length | Payload | CS |
|---|---|---|---|---|
| 0x02 | 0x04 | 2 Bytes | Length Bytes | 1 Byte |

Response (`CMD_DATA_CNF`):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x44 | 2 Bytes | Length Bytes | 1 Byte |

Status:

**0x00:** Request received, will send data now

**0x01 + 0xXX:** Operation failed + 0xXX maximum payload size (if it was exceeded)

**0xFF:** Operation not permitted

### 9.3.2. CMD_TXCOMPLETE_RSP

This command is output to the UART as soon as the data, which was requested by a `CMD_DATA_REQ` has been transmitted successfully.
Format:

| Start signal | Command | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0xC4 | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Data transmitted successfully

**0x01:** Data transmission failed

### 9.3.3. CMD_DATA_IND

This telegram indicates the reception of data sent by the previously connected device. This indication message is the result of a data request (CMD_DATA_REQ) sent to the associated device within a connection.
The CMD_DATA_IND returns the FS_BTMAC of the sending device, the RSSI value of the received data packet and the data received via the RF-interface, which can be found in the payload. The RSSI value is printed in two's complement notation.
Format:

| Start signal | Command | Length | BTMAC | RSSI | Payload | CS |
|---|---|---|---|---|---|---|
| 0x02 | 0x84 | 2 Bytes | 6 Bytes | 1 Byte | (Length - 7) Bytes | 1 Byte |

### 9.3.4. CMD_SETBEACON_REQ

This command is used to place user data in the scan response packet. The data is broadcasted frequently without acknowledgement and security. No connection is needed for this mode of operation.
It can be received by any scanning Proteus-I with Beacon-function enabled (see RF_BeaconFlags). The receiving module will output a CMD_BEACON_IND indication message containing the transmitted data. See chapter 7.7 for more information.
Choosing 0x00 as Length and leaving the Payload field empty will remove the data from the scan response packet. The number of payload data Bytes is limited to 19.
Format:

| Start signal | Command | Length | Payload | CS |
|---|---|---|---|---|
| 0x02 | 0x0C | 2 Bytes | Length Bytes | 1 Byte |

Response (CMD_SETBEACON_CNF):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x4C | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Request received, will place data now

**0x01:** Operation failed

**0xFF:** Operation not permitted

### 9.3.5. CMD_BEACON_IND

This telegram indicates the reception of data Bytes that have been transmitted in a beacon-packet. This data can only be received, when the module is in ACTION_SCANNING mode and the beacon-function is enabled (see RF_BeaconFlags).
The data received via the RF-interface can be found in the payload of the CMD_BEACON_IND

telegram. Besides this, the `FS_BTMAC` of the sending device and the RSSI value of the data packet are output as well. The RSSI value is output in two's complement notation.
Format:

| Start signal | Command | Length | BTMAC | RSSI | Payload | CS |
|---|---|---|---|---|---|---|
| 0x02 | 0x8C | 2 Bytes | 6 Bytes | 1 Byte | (Length - 7) Bytes | 1 Byte |

## 9.4. Configuring the module and modifying the device settings


It is strongly recommended to have identical settings on all devices, which have to open a connection with each other or are to be used in Beacon mode.

The module's parameters are stored in flash, but have a local copy in RAM. The flash parameters can be modified by the CMD_SET_REQ, read by the CMD_GET_REQ and retain their content even when resetting the module.

### 9.4.1. CMD_SET_REQ

This command enables direct manipulation of the parameters in the module's settings in flash. The respective parameters are accessed by means of the corresponding settings index, which can be found in Table 53.
Parameters of 2 or more Bytes have to be transferred with the LSB first unless noted differently in the corresponding description.

The modified parameters only take effect after a restart of the module. This may be done by a CMD_RESET_REQ if the module does not restart automatically.

The flash memory used to store these settings has a limited count of write cycles. Try to avoid performing periodic CMD_SET_REQ as each command will use one write cycle.


The validity of the specified parameters is not verified. Incorrect values can result in device malfunction!


To save the parameters in the flash memory of the module, the particular memory segment must first be flushed entirely and then restored from RAM. If a reset occurs during this procedure, the entire memory area may be corrupted (e.g. due to supply voltage fluctuations).
Recommendation: First, verify the configuration of the module with CMD_GET_REQ and only then apply a CMD_SET_REQ if required to avoid unnecessary flash cycles.

Format:

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 2 Bytes | 1 Byte | (Length - 1) Bytes | 1 Byte |

Response (`CMD_SET_CNF`):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Request received, settings set successfully

**0x01:** Operation failed due to invalid parameter

**0x04:** Serious error, when writing flash. Try to factory reset or re-flash the device

**0xFF:** Operation not permitted

#### 9.4.1.1. Example 1

Setting the advertising time `RF_AdvertisingTimeout` to 180 seconds.

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x03 0x00 | 0x07 | 0xB4 0x00 | 0xA3 |

Response:

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

Setting was set successfully.

#### 9.4.1.2. Example 2

Setting the static pass key `RF_StaticPasskey` to "123456".

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x07 0x00 | 0x12 | 0x31 0x32 0x33<br>0x34 0x35 0x36 | 0x01 |

Response:

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

Setting was set successfully.

### 9.4.2. CMD_GET_REQ

This command can be used to query individual setting parameters in flash. The respective parameters are accessed by means of the corresponding settings index, which can be found in Table 53.
Parameters of 2 or more Bytes have to be transferred with the LSB first unless noted differently in the corresponding description.
Read access to the memory area outside the setting is blocked.
Format:

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 1 Byte | 1 Byte |

Response (CMD_GET_CNF):

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 2 Bytes | 1 Byte | (Length - 1) Bytes | 1 Byte |

Status:

**0x00:** Request received, read out of setting successful

**0x01:** Operation failed

**0xFF:** Operation not permitted

#### 9.4.2.1. Example 1

Request the current static pass key RF_StaticPasskey.

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x12 | 0x01 |

Response: The current RF_StaticPasskey in flash is "123123" (0x31 0x32 0x33 0x31 0x32 0x33).

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x07 0x00 | 0x00 | 0x31 0x32 0x33<br>0x31 0x32 0x33 | 0x55 |

Setting was read successfully.

## 9.5. Manage the device state

### 9.5.1. CMD_GETSTATE_REQ

This command returns the current state of the module.

Please refer to chapter 7 for details on the states of the module.

Format:

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x01 | 0x00 0x00 | 0x03 |

Response (CMD_GETSTATE_CNF):

| Start signal | Command \| 0x40 | Length | Module role | Module action | More info | CS |
|---|---|---|---|---|---|---|
| 0x02 | 0x41 | 2 Bytes | 1 Byte | 1 Byte | (Length - 2) Bytes | 1 Byte |

Module role:

**0x00:** No role

**0x01:** Peripheral

**0x02:** Central

**0x10:** Direct test mode (DTM)

**Other:** Reserved

Module action:

**0x00:** No action

**0x01:** Idle (advertising)

**0x02:** Scanning

**0x03:** Connected (More info is the 6 Bytes FS_BTMAC address of the connected device)

**0x04:** Sleep (system-off mode)

**0x05:** Direct test mode

**0x06:** Connected, but link is still closed (central must enable notifications first)

#### 9.5.1.1. Example 1

Get the current state of the module.

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x01 | 0x00 0x00 | 0x03 |

Response:

| Start signal | Command \| 0x40 | Length | Module role | Module actions | More info | CS |
|---|---|---|---|---|---|---|
| 0x02 | 0x41 | 0x08 0x00 | 0x02 | 0x03 | 0x11 0x00 0x00 0xDA 0x18 0x00 | 0x99 |

The module is connected to another module with `FS_BTMAC` 0x11 0x00 0x00 0xDA 0x18 0x00.

### 9.5.2. CMD_RESET_REQ

This command triggers a software reset of the module.
Format:

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x00 | 0x00 0x00 | 0x02 |

Response (`CMD_RESET_CNF`):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x40 | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Request received, will perform reset now

**0x01:** Operation failed

**0xFF:** Operation not permitted

### 9.5.3. CMD_SLEEP_REQ

This command is used to start the system-off mode (`ACTION_SLEEP`). After entering this mode, the module has to be woken up using the *WAKE_UP* pin (apply a low signal at this for at least 5ms and release it to high again) before any other action can be performed. The UART interface as well as the Bluetooth® LE interface are shut down in this mode. For more details, please see also chapter `7.4`.
Format:

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x02 | 0x00 0x00 | 0x00 |

Response (`CMD_SLEEP_CNF`):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x42 | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Request received, will go to sleep now

**0x01:** Operation failed

**0xFF:** Operation not permitted

Please note that the *WAKE_UP* pin has a second function. If the module is not in `ACTION_SLEEP` mode and the UART was disabled using the `CMD_UARTDISABLE_REQ`, the UART can be re-enabled by applying falling edge, holding the line low for at least 10 ms before applying a rising edge and holding it high for at least 10 ms. In this case the module answers with a `CMD_UARTENABLE_IND` message.

### 9.5.4. CMD_SLEEP_IND

This indication is sent by the module when the `RF_AdvertisingTimeout` has expired without a connection to the module.
Format:

| Start signal | Command | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x82 | 0x01 0x00 | 0x00 | 1 Byte |

Status:

**0x00:** Advertising timeout detected, will go to sleep now

### 9.5.5. CMD_FACTORYRESET_REQ

This command triggers a factory reset of the module. First, the default user settings are restored, then the module is reset.
Format:

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x1C | 0x00 0x00 | 0x1E |

Response (`CMD_FACTORYRESET_CNF`):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x5C | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Request received, will perform factory reset now

**0x01:** Operation failed

**0xFF:** Operation not permitted


To save the parameters in the flash memory of the module, the particular memory segment must first be flushed entirely and then restored from RAM. If a reset occurs during this procedure (e.g. due to supply voltage fluctuations), the entire memory area may be destroyed.

During start-up of the device, the user settings memory is checked for consistency. In case of inconsistency (e.g. the memory was erased) the device will perform a factory reset.

This command also removes all bonding data.

### 9.5.6. CMD_UARTDISABLE_REQ

This command disables the UART of the module. It will be re-enabled when the module has to send data to the host (e.g. data was received via RF or a state is indicated) or if the *WAKE_UP* pin is used (apply a falling edge, hold low for at least 10 ms before applying a rising edge and hold high for at least 10 ms). In this case, either the received data or a `CMD_UARTENABLE_IND` is transmitted by the module. Afterwards the UART will stay active until another `CMD_UARTDISABLE_REQ` or `CMD_SLEEP_REQ` or a timer triggered sleep event occurs.
Format:

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x1B | 0x00 0x00 | 0x19 |

Response (`CMD_UARTDISABLE_CNF`):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x5B | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Request received, will disable UART now

**0x01:** Operation failed

**0xFF:** Operation not permitted

We insistently recommend disabling the UART using this command only, if it is foreseeable that there will be no UART communication for several seconds! Use cases could be during advertising phase to wait for connecting Bluetooth® LE devices or when broadcasting data via Beacons.

Disabling the UART peripheral of the module results in a reduction of current consumption of about 1.15mA.

Please note that the *WAKE_UP* pin has a second function. If the module is in `ACTION_SLEEP` mode, this pin wakes up the module by applying a low signal at this for at least 5ms and releasing it to high. In this case, the module answers with a `CMD_GETSTATE_CNF`.

### 9.5.7. CMD_UARTENABLE_IND

This indication is shown when the UART of the module is re-enabled (after performing a `CMD_UARTDISABLE_REQ` followed by using the *WAKE_UP* pin). After receiving this message the UART can be used for any operation again.
Format:

| Start signal | Command | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x9B | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** UART has been re-enabled successfully

### 9.5.8. CMD_BOOTLOADER_REQ

This command resets the module and starts the OTA bootloader.

Please refer to chapter `15` on how to use the bootloader for a firmware update.

Please note that you can only exit the bootloader mode by performing a hardware reset using the respective pin.

The bootloader mode will also be enabled if the firmware image is marked "invalid" or if the *BOOT* pin logic level (set by the host) is set to start the bootloader during start-up of the module.

Format:

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x1F | 0x00 0x00 | 0x1D |

Response (`CMD_BOOTLOADER_CNF`):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x5F | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Request received, will start bootloader now

**0x01:** Operation failed

**0xFF:** Operation not permitted

## 9.6. Run the Bluetooth test modes

The test modes "DTM" as specified by the Bluetooth® SIG are defined in the Bluetooth® Core specification.

### 9.6.1. CMD_DTMSTART_REQ

This command restarts the module in direct test mode (DTM). When starting in DTM mode, a `CMD_GETSTATE_CNF` message follows which indicates that the test mode has been enabled successfully. Now the `CMD_DTM_REQ` can be used to start and stop various test modes.
As soon as the module is reset, the DTM will be left again and normal operations can be performed.
Performing a reset will leave the DTM and restart the module in the `ACTION_IDLE` state.
Format:

| Start signal | Command | Length | CS |
|---|---|---|---|
| 0x02 | 0x1D | 0x00 0x00 | 0x1F |

Response (`CMD_DTMSTART_CNF`):

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x5D | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x00:** Request received, will enable the direct test mode now

**0x01:** Operation failed

**0xFF:** Operation not permitted

### 9.6.2. CMD_DTM_REQ

This command starts and stops various test modes. To be able to run these test modes, the DTM has to be enabled first using the `CMD_DTMSTART_REQ`. After a test has been started, it has to be stopped first before a next test can be run.
The default TX power value is 0 dBm, the allowed range is from -40 up to +4 dBm in steps of 4 dB (see chapter `10.17`).
The valid range for channel (or Vendor option in case of Vendor Command = Carrier Test) is 0. . . 39.

Configuring the phy and TX power can be only done, when the test is stopped (no TX or RX test ongoing).

Format:

| Start signal | Command | Length | Command code | Channel / Vendor option | Length / Vendor command | Payload | CS |
|---|---|---|---|---|---|---|---|
| 0x02 | 0x1E | 0x04 0x00 | 1 Byte | 1 Byte | 1 Byte | 1 Byte | 1 Byte |

Command code:

**0x00:** DTM reset (note: this command does not perform a module reset.

**0x01:** Start RX test

**0x02:** Start TX test

**0x03:** Stop last test

Payload:

**0x00:** Bit pattern PRBS9

**0x01:** Bit pattern 0x0F

**0x02:** Bit pattern 0x55

**0x03:** Vendor specific

| Payload ≠ Vendor specific (0x00, 0x01 or 0x02) | Payload = Vendor specific (0x03) |
|---|---|
| Length / Vendor Command:<br>Length of the packet to send | Length / Vendor Command:<br>0x00: Carrier test<br>0x02: Set transmission power |
| Channel:<br>Frequency = (2402 + Channel * 2) MHz to be used for RX/TX | Vendor option:<br>(dependent on used "Vendor command")<br>Frequency = (2402 + [Vendor option] * 2) MHz<br>or<br>[Vendor option] := TXPower (in two's complement notation) in steps of 4 dB |

Response (`CMD_DTM_CNF`):

| Start signal | Command \| 0x40 | Length | Status | Result | CS |
|---|---|---|---|---|---|
| 0x02 | 0x5E | 2 Bytes | 1 Byte | 0-2 Bytes | 1 Byte |

Status:

**0x00:** Request received

**0x01:** Operation failed

**0x03:** Busy

**0xFF:** Operation not permitted

Result:

**0x0000:** Test success

**0x0001:** Test failed

**0x8000 + n:** Received n packets during RX test

See also the example in chapter 7.10.

#### 9.6.2.1. Example: Transmission, 16 times 0x0F, channel 0

Start the transmission test on channel 0 (2402 MHz). The packets consist of 16 times 0x0F:

| Start signal | Command | Length | Command code | Channel / Vendor option | Length / Vendor command | Payload | CS |
|---|---|---|---|---|---|---|---|
| 0x02 | 0x1E | 0x04 0x00 | 0x02 | 0x00 | 0x10 | 0x01 | 0x0B |

Response:

| Start signal | Command \| 0x40 | Length | Status | Result | CS |
|---|---|---|---|---|---|
| 0x02 | 0x5E | 0x03 0x00 | 0x00 | 0x00 0x00 | 0x5F |

Test started successfully. Now stop the test again.

| Start signal | Command | Length | Command code | Channel / Vendor option | Length / Vendor command | Payload | CS |
|---|---|---|---|---|---|---|---|
| 0x02 | 0x1E | 0x04 0x00 | 0x03 | 0x00 | 0x00 | 0x01 | 0x0B |

Response:

| Start signal | Command \| 0x40 | Length | Status | Result | CS |
|---|---|---|---|---|---|
| 0x02 | 0x5E | 0x03 0x00 | 0x00 | 0x80 0x00 | 0xDF |

Test stopped successfully and received 0 packets.

#### 9.6.2.2. Example: Receiver, channel 0

Start the reception test on channel 0 (2402 MHz) with Bit pattern 0x0F:

| Start signal | Command | Length | Command code | Channel / Vendor option | Length / Vendor command | Payload | CS |
|---|---|---|---|---|---|---|---|
| 0x02 | 0x1E | 0x04 0x00 | 0x01 | 0x00 | 0x00 | 0x00 | 0x19 |

Response:

| Start signal | Command \| 0x40 | Length | Status | Result | CS |
|---|---|---|---|---|---|
| 0x02 | 0x5E | 0x03 0x00 | 0x00 | 0x00 0x00 | 0x5F |

Test started successfully. In between we started the transmission test on a second module. When we stop RX test now, we can count the received packets from the transmitting module.

| Start signal | Command | Length | Command code | Channel / Vendor option | Length / Vendor command | Payload | CS |
|---|---|---|---|---|---|---|---|
| 0x02 | 0x1E | 0x04 0x00 | 0x03 | 0x00 | 0x00 | 0x01 | 0x1A |

Response:

| Start signal | Command \| 0x40 | Length | Status | Result | CS |
|---|---|---|---|---|---|
| 0x02 | 0x5E | 0x03 0x00 | 0x00 | 0x8E 0x67 | 0xB6 |

Test stopped successfully and received 0x0E67 (3687) packets.

#### 9.6.2.3. Example: Transmission, carrier test, channel 0

Start the carrier test on channel 0 (2402 MHz). We need to use a vendor specific command:

| Start signal | Command | Length | Command code | Channel / Vendor option | Length / Vendor command | Payload | CS |
|---|---|---|---|---|---|---|---|
| 0x02 | 0x1E | 0x04 0x00 | 0x02 | 0x00 | 0x00 | 0x03 | 0x19 |

Response:

| Start signal | Command \| 0x40 | Length | Status | Result | CS |
|---|---|---|---|---|---|
| 0x02 | 0x5E | 0x03 0x00 | 0x00 | 0x00 0x00 | 0x5F |

See the previous example to stop the test again.

#### 9.6.2.4. Example: Set TX power to -4 dBm

Set the TX power to -4 dBm (0xFC in two's complement notation):

| Start signal | Command | Length | Command code | Channel / Vendor option | Length / Vendor command | Payload | CS |
|---|---|---|---|---|---|---|---|
| 0x02 | 0x1E | 0x04 0x00 | 0x02 | 0xFC | 0x02 | 0x03 | 0xE7 |

Response:

| Start signal | Command \| 0x40 | Length | Status | Result | CS |
|---|---|---|---|---|---|
| 0x02 | 0x5E | 0x03 0x00 | 0x00 | 0x00 0x00 | 0x5F |

See the previous example to stop the test again.

## 9.7. Other messages

### 9.7.1. CMD_ERROR_IND

This indication is shown when the module entered an error state.
Format:

| Start signal | Command | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0xA2 | 0x01 0x00 | 1 Byte | 1 Byte |

Status:

**0x01: UART_COMMUNICATION_ERROR** The UART had a buffer overflow. Thus, UART TX and RX was aborted and UART has restarted. Please restart module if UART is still malfunctioning.

## 9.8. Message overview

| Start signal | CMD | Message name | Short description | Chapter |
|---|---|---|---|---|
| 0x02 | 0x00 | CMD_RESET_REQ | Reset the module | 9.5.2 |
| 0x02 | 0x01 | CMD_GETSTATE_REQ | Request the current module state | 9.5.1 |
| 0x02 | 0x02 | CMD_SLEEP_REQ | Go to sleep | 9.5.3 |
| 0x02 | 0x04 | CMD_DATA_REQ | Send data to the connected device | 9.3.1 |
| 0x02 | 0x06 | CMD_CONNECT_REQ | Setup a connection with another device | 9.2.1 |
| 0x02 | 0x07 | CMD_DISCONNECT_REQ | Close the connection | 9.2.5 |
| 0x02 | 0x09 | CMD_SCANSTART_REQ | Start scan | 9.1.1 |
| 0x02 | 0x0A | CMD_SCANSTOP_REQ | Stop scan | 9.1.2 |
| 0x02 | 0x0B | CMD_GETDEVICES_REQ | Request the scanned/detected devices | 9.1.3 |
| 0x02 | 0x0C | CMD_SETBEACON_REQ | Place data in scan response packet | 9.3.4 |
| 0x02 | 0x0D | CMD_PASSKEY_REQ | Respond to a pass key request | 9.2.7 |
| 0x02 | 0x0E | CMD_DELETEBONDS_REQ | Delete bonding information | 9.2.10 |
| 0x02 | 0x0F | CMD_GETBONDS_REQ | Read the MACs of bonded devices | 9.2.9 |
| 0x02 | 0x10 | CMD_GET_REQ | Read the module settings in flash | 9.4.2 |
| 0x02 | 0x11 | CMD_SET_REQ | Modify the module settings in flash | 9.4.1 |
| 0x02 | 0x1B | CMD_UARTDISABLE_REQ | Disable the UART | 9.5.6 |
| 0x02 | 0x1C | CMD_FACTORYRESET_REQ | Perform a factory reset | 9.5.5 |
| 0x02 | 0x1D | CMD_DTMSTART_REQ | Enable the direct test mode | 9.6.1 |
| 0x02 | 0x1E | CMD_DTM_REQ | Start/stop a test of the direct test mode | 9.6.2 |
| 0x02 | 0x1F | CMD_BOOTLOADER_REQ | Switch to the bootloader | 9.5.8 |

Table 45: Message overview: Requests

| Start signal | CMD | Message name | Short description | Chapter |
|---|---|---|---|---|
| 0x02 | 0x40 | CMD_RESET_CNF | Reset request received | 9.5.2 |
| 0x02 | 0x41 | CMD_GETSTATE_CNF | Return the current module state | 9.5.1 |
| 0x02 | 0x42 | CMD_SLEEP_CNF | Sleep request received | 9.5.3 |
| 0x02 | 0x44 | CMD_DATA_CNF | Data transmission request received | 9.3.1 |
| 0x02 | 0x46 | CMD_CONNECT_CNF | Connection setup request received | 9.2.1 |
| 0x02 | 0x47 | CMD_DISCONNECT_CNF | Disconnection request received | 9.2.5 |
| 0x02 | 0x49 | CMD_SCANSTART_CNF | Scan started | 9.1.1 |

| | | | | |
|---|---|---|---|---|
| 0x02 | 0x4A | CMD_SCANSTOP_CNF | Scan stopped | 9.1.2 |
| 0x02 | 0x4B | CMD_GETDEVICES_CNF | Output the scanned/detected devices | 9.1.3 |
| 0x02 | 0x4C | CMD_SETBEACON_CNF | Data is placed in scan response packet | 9.3.4 |
| 0x02 | 0x4D | CMD_PASSKEY_CNF | Received the pass key | 9.2.7 |
| 0x02 | 0x4E | CMD_DELETEBONDS_CNF | Deleted bonding information | 9.2.10 |
| 0x02 | 0x4F | CMD_GETBONDS_CNF | Return the MAC of all bonded devices | 9.2.9 |
| 0x02 | 0x50 | CMD_GET_CNF | Return the requested module flash settings | 9.4.2 |
| 0x02 | 0x51 | CMD_SET_CNF | Module flash settings have been modified | 9.4.1 |
| 0x02 | 0x5B | CMD_UARTDISABLE_CNF | Disable UART request received | 9.5.6 |
| 0x02 | 0x5C | CMD_FACTORYRESET_CNF | Factory reset request received | 9.5.5 |
| 0x02 | 0x5D | CMD_DTMSTART_CNF | Enable the direct test mode now | 9.6.1 |
| 0x02 | 0x5E | CMD_DTM_CNF | Test of direct test mode started/stopped | 9.6.2 |
| 0x02 | 0x5F | CMD_BOOTLOADER_CNF | Will switch to bootloader now | 9.5.8 |

Table 46: Message overview: Confirmations

| Start signal | CMD | Message name | Short description | Chapter |
|---|---|---|---|---|
| 0x02 | 0x82 | CMD_SLEEP_IND | State will be changed to ACTION_SLEEP | 9.5.4 |
| 0x02 | 0x84 | CMD_DATA_IND | Data has been received | 9.3.3 |
| 0x02 | 0x86 | CMD_CONNECT_IND | Connection established | 9.2.2 |
| 0x02 | 0x87 | CMD_DISCONNECT_IND | Disconnected | 9.2.6 |
| 0x02 | 0x88 | CMD_SECURITY_IND | Secured connection established | 9.2.3 |
| 0x02 | 0x8B | CMD_RSSI_IND | Advertising package detected | 9.1.4 |
| 0x02 | 0x8C | CMD_BEACON_IND | Received Beacon data | 9.3.5 |
| 0x02 | 0x8D | CMD_PASSKEY_IND | Received a pass key request | 9.2.8 |
| 0x02 | 0x9B | CMD_UARTENABLE_IND | UART was re-enabled | 9.5.7 |
| 0x02 | 0xA2 | CMD_ERROR_IND | Entered error state | 9.7.1 |
| 0x02 | 0xC4 | CMD_TXCOMPLETE_RSP | Data has been sent | 9.3.2 |
| 0x02 | 0xC6 | CMD_CHANNELOPEN_RSP | Channel open, data transmission possible | 9.2.4 |

Table 47: Message overview: Indications

# 10. User settings - Module configuration values

The settings described in this chapter are stored permanently in the module's flash memory. Depending on their corresponding permissions, their current values can be read out by the `CMD_GET_REQ` command or modified by the `CMD_SET_REQ` command. To do so the corresponding settings index is used, which can be found in the primary table of each setting description.
These settings cannot be accessed (read, write) from the Peripheral only mode introduced in a follow-up chapter.


The validity of the specified parameters is not verified. Incorrect values can result in device malfunction.


After the modification of the non-volatile parameters, a reset will be necessary for the changes to be applied.

## 10.1. FS_DeviceInfo: Read the chip type and OS version

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 15 | `FS_DeviceInfo` | - | - | read | 12 |

This setting contains information about the chip type and the OS version. The value of `FS_DeviceInfo` is composed of the following 4 sub parameters (ordered by appearance in the response):

| OS version | Build code | Package variant | Chip ID |
|---|---|---|---|
| 2 Bytes | 4 Bytes | 2 Bytes | 4 Bytes |

OS version:

**0x0081 :** Softdevice S132 2.0.0

**0x0088 :** Softdevice S132 2.0.1

**0x008C :** Softdevice S132 3.0.0

**0x0091 :** Softdevice S132 3.1.0

Build code:

- ASCII coded (see the following table 48)

Package variant:

**0x2000:** QFN

**0x2002:** CI

Chip ID:

**0x00052832 :** nRF52832

| Packet variant | Build code | Package | Flash size | RAM size |
|---|---|---|---|---|
| QF | AAB0 | QFN48 | 512 kB | 64 kB |
| QF | ABB0 | QFN48 | 256 kB | 32 kB |
| CI | AABA, AAB0, AAB1, AAE0, AAE1 | WLCSP | 512 kB | 64 kB |

Table 48: nRF52832 IC revision overview

### 10.1.1. Example 1

Request the device info of the module using `CMD_GET_REQ` with settings index 15

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x0F | 0x1C |

Response `CMD_GET_CNF`: Successfully read out the device info (with Byte order changed to MSB first):
OS version = 0x0088 (Softdevice S132 2.0.1)
Build code = 0x41414241 (AABA)
Package variant = 0x2002 (CI)
Chip ID = 0x00052832
Please note that LSB is transmitted first in case of parameters with more than 1 Byte length.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x0D 0x00 | 0x00 | 0x88 0x00 0x41 0x42<br>0x41 0x41 0x02 0x20<br>0x32 0x28 0x05 0x00 | 0xE9 |

## 10.2. FS_FWVersion: Read the firmware version

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 1 | FS_FWVersion | - | - | read | 3 |

This setting contains the firmware version of the module.

### 10.2.1. Example 1

Request the firmware version of the module using CMD_GET_REQ with settings index 1

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x01 | 0x12 |

Response CMD_GET_CNF: Successfully read out the firmware version, for this example it is 0x000001 so "1.0.0" (with the parameter reverted to MSB first).

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x04 0x00 | 0x00 | 0x00 0x00 0x01 | 0x57 |

## 10.3. FS_MAC: Read the MAC address

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 3 | FS_MAC | - | - | read | 6 |

This setting contains the unique MAC address of the module.

### 10.3.1. Example 1

Request the MAC address of the module using CMD_GET_REQ with settings index 3

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x03 | 0x10 |

Response CMD_GET_CNF: Successfully read out the MAC address 0x55 0x93 0x19 0x6E 0x5B 0x87

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x07 0x00 | 0x00 | 0x55 0x93 0x19 0x6E 0x5B 0x87 | 0x38 |

## 10.4. FS_BTMAC: Read the Bluetooth conform MAC address

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 4 | FS_BTMAC | - | - | read | 6 |

This setting contains the Bluetooth® LE conform MAC address of the module. The FS_BTMAC is introduced and used to find the respective device on the RF-interface. It consists of the Würth Elektronik eiSos MAC ID 0x0018DA followed by the FS_SerialNumber of the module. Please note that LSB is transmitted first in all commands.

### 10.4.1. Example 1

Request the Bluetooth®-conform MAC address of the module using CMD_GET_REQ with settings index 4

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x04 | 0x17 |

Response CMD_GET_CNF: Successfully read out the Bluetooth® LE conform MAC address 0x11 0x00 0x00 0xDA 0x18 0x00.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x07 0x00 | 0x00 | 0x11 0x00 0x00 0xDA 0x18 0x00 | 0x86 |

## 10.5. FS_SerialNumber: Read the serial number of the module

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 16 | FS_SerialNumber | - | - | read | 3 |

This setting contains the serial number of the module.

### 10.5.1. Example 1

Request the serial number of the module using CMD_GET_REQ with settings index 16

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x10 | 0x03 |

Response CMD_GET_CNF: Successfully read out the serial number, it is 0.0.11

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x04 0x00 | 0x00 | 0x11 0x00 0x00 | 0x57 |

## 10.6. RF_DeviceName: Modify the device name

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 2 | RF_DeviceName | See description | "A2621" | read/write | 1-31 |

This parameter is using MSB first notation.

This parameter determines the name of the module, which is used in the advertising packets as well as in the Generic Access Profile (GAP). The permissible characters are in the range of 0x20 - 0x7E which are special characters (see ASCII table), alphabetic characters (a-z and A-Z), numbers (0-9) and whitespace.

The maximum size of the device name that fits into an advertising packet is 5 Bytes in default configuration. With help of the user setting RF_AdvertisingFlags it can be extended to 8 Bytes. Longer device names will be shortened and declared as "Shortened Local Name" in the advertising packet. The full device name is included in the GAP.

### 10.6.1. Example 1

Set the device name of the module to 0x4D 0x4F 0x44 0x20 0x31 = "MOD 1" using CMD_SET_REQ with settings index 2.

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x06 0x00 | 0x02 | 0x4D 0x4F 0x44 0x20 0x31 | 0x40 |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.6.2. Example 2

Request the device name of the module using CMD_GET_REQ with settings index 2:

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x02 | 0x11 |

Response `CMD_GET_CNF`: Successfully read out the module as 0x41 0x32 0x36 0x32 0x31 = "A2621".

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x06 0x00 | 0x00 | 0x41 0x32 0x36 0x32 0x31 | 0x12 |

## 10.7. RF_StaticPasskey: Modify the static passkey

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 18 | RF_StaticPasskey | See description | "123123" | read/write | 6 |

This setting determines the static pass key of the peripheral device used for authentication. If the static pass key security mode is enabled by the peripheral, this key must be entered in the central device. In case of a Proteus-I central, the command to enter this pass key during connection setup is the CMD_PASSKEY_REQ.
The permissible characters are ranging from 0x30 to 0x39 (both included) which are ASCII numbers (0-9). This is due to the fact that mobile phones prefer numbers only for the passkey.

### 10.7.1. Example 1

Set the static pass key of the module to 0x31 0x32 0x33 0x34 0x35 0x36 = "123456" using CMD_SET_REQ with settings index 18

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x07 0x00 | 0x12 | 0x31 0x32 0x33 0x34 0x35 0x36 | 0x01 |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.7.2. Example 2

Request the static pass key of the module using CMD_GET_REQ with settings index 18

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x12 | 0x01 |

Response CMD_GET_CNF:Successfully read out the key as 0x31 0x32 0x33 0x34 0x35 0x36 = "123456"

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x07 0x00 | 0x00 | 0x31 0x32 0x33 0x34 0x35 0x36 | 0x52 |

## 10.8. RF_SecFlags: Modify the security settings

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 12 | RF_SecFlags | See description | 0 | read/write | 1 |

This 8-Bit field configures security settings of the module. Chapter 7.6 contains further information about secure connections.

When connecting from a Proteus-I to another Proteus-I, be sure that the same security mode is used.

When connecting from a foreign device to a Proteus-I, the peripheral (Proteus-I) determines the minimum security level needed for communication. So configure the RF_SecFlags of the peripheral to set the desired security level.

When updating this user setting (like enabling bonding or changing the security mode) please remove all existing bonding data using the command CMD_DELETEBONDS_REQ.

<table>
<tr><th>Bit no.</th><th>Description</th></tr>
<tr><td>2 : 0</td><td>Security mode configuration. Depending on its value, different modes are chosen when setting up a secure connection. In firmware version 2.1.0 and newer the peripheral decides which is the minimum security level to access its data.
<table>
<tr><td>0x0</td><td>No security</td><td>Data is transmitted without authentication and encryption.</td></tr>
<tr><td>0x2</td><td>Just works level 1.2</td><td>Each time a connection is established, new random keys are exchanged in advance to use them for data encryption. This mode uses the "just works" method.</td></tr>
<tr><td>0x3</td><td>Static pass key level 1.3</td><td>For authentication, the <code>RF_StaticPasskey</code> is used. If the peripheral uses this method, the central device must enter the correct passkey to finalize the connection.</td></tr>
<tr><td>others</td><td></td><td>Reserved</td></tr>
</table></td></tr>
<tr><td>3</td><td><code>SECFLAGS_BONDING_ENABLE</code>: If this Bit is set, bonding is enabled when using one of the pairing methods. Bonding data of up to 32 devices will be stored in the flash. If bonding storage is full, the bonding information that has not been used for the longest period will be removed.</td></tr>
<tr><td>7 : 4</td><td>Reserved</td></tr>
</table>

Table 49: Security configuration flags

### 10.8.1. Example 1

Set the security flags to 0x0B, to use the static passkey pairing and with bonding enabled, using `CMD_SET_REQ` with settings index 12

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x02 0x00 | 0x0C | 0x0B | 0x16 |

Response `CMD_SET_CNF`: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.8.2. Example 2

Request the security flags of the module using `CMD_GET_REQ` with settings index 12

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x0C | 0x1F |

Response `CMD_GET_CNF`: Successfully read out the value 2, which means that the just works pairing mode is enabled.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x02 0x00 | 0x00 | 0x02 | 0x52 |

## 10.9. RF_SecFlagsPerOnly: Modify the security settings (Peripheral only mode)

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 44 | RF_SecFlagsPerOnly | See description | 11 | read/write | 1 |

Please refer to the setting RF_SecFlags for more details.

### 10.9.1. Example 1

Set the security flags to 0x02 to use the just works pairing, using CMD_SET_REQ with settings index 44

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x02 0x00 | 0x2C | 0x02 | 0x3F |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.9.2. Example 2

Request the security flags of the module using CMD_GET_REQ with settings index 44

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x2C | 0x3F |

Response CMD_GET_CNF: Successfully read out the value 2, which means that the just works pairing mode is enabled.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x02 0x00 | 0x00 | 0x02 | 0x52 |

## 10.10. RF_ScanFlags: Modify the scan behavior

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 13 | RF_ScanFlags | See description | 0 | read/write | 1 |

This 8-Bit field configures the scan behavior of the module. To use multiple settings, add the Bit numbers and choose the result as value for RF_ScanFlags.

| Bit no. | Description |
|---|---|
| 0 | If this Bit is set, an active scan is performed when using CMD_SCANSTART_REQ. In this case, after receiving an advertising packet a scan request is sent to the advertising module that returns a scan response containing additional information. For the communication of Proteus-I modules, active scanning is only needed when using Beacons. In this case, it is enabled automatically by the firmware. Please note that active scanning increases the current consumption. |
| 15 : 1 | Reserved |

Table 50: Scan configuration flags

### 10.10.1. Example 1

Set the scan flags to 0x01 to enable active scanning using CMD_SET_REQ with settings index 13

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x02 0x00 | 0x0D | 0x01 | 0x1D |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.10.2. Example 2

Request the scan flags of the module using CMD_GET_REQ with settings index 13

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x0D | 0x1E |

Response CMD_GET_CNF: Successfully read out the value 0, which means that active scan is disabled.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x02 0x00 | 0x00 | 0x00 | 0x50 |

## 10.11. RF_BeaconFlags: Interprete the advertising data

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 14 | RF_BeaconFlags | See description | 0 | read/write | 1 |

This 8-Bit field enables/disables the reception of Beacons. To use multiple settings, add the Bit numbers and choose the result as value for RF_BeaconFlags.

| Bit no. | Description |
|---|---|
| 1 : 0 | Enable/disable the reception of Beacons. To avoid too much traffic on the UART, we recommend to use the filtered version.<br>0x0: Reception of Beacons disabled.<br>0x1: Receive all Beacons from Proteus-I devices in range. Each received packet is interpreted and output by the UART. In this case, active scanning is performed which increases the current consumption. To decrease the work load of the receiving module, use a sufficiently high UART baud rate at the receiving device and slow advertising intervals at the sending devices.<br>0x3: Same as '0x1' plus additional filter. This filter discards redundant packets that contain the same content.<br>others: Reserved. |
| 2 | If this Bit is set, a CMD_RSSI_IND message is output each time when an advertising packet with WE SPP-like UUID is received. This feature can be used to realize a position sensing application, since the CMD_RSSI_IND contains the current TX power level and the current RSSI value besides the FS_BTMAC of the sending device. To decrease the work load of the receiving module, please use a sufficiently high UART baud rate at the receiving device and slow advertising intervals at the sending devices. |
| 15 : 3 | Reserved. |

Table 51: Beacon configuration flags

The internal database of the module may host the advertising data of 25 different devices. If the data base is full, the oldest entry is removed.

To avoid too much traffic the usage of slow advertising intervals is recommended.

### 10.11.1. Example 1

Set the Beacon flags to 0x04 using `CMD_SET_REQ` with settings index 14. Thus when an advertising packet with WE SPP-like UUID is received, a `CMD_RSSI_IND` message is printed.

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x02 0x00 | 0x0E | 0x04 | 0x1B |

Response `CMD_SET_CNF`: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.11.2. Example 2

Request the Beacon flags of the module using `CMD_GET_REQ` with settings index 14

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x0E | 0x1D |

Response `CMD_GET_CNF`: Successfully read out the value 3, which means that the reception of Beacons is enabled and double packets are filtered by the module.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x02 0x00 | 0x00 | 0x03 | 0x53 |

## 10.12. RF_AdvertisingTimeout: Modify the advertising timeout

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 7 | RF_AdvertisingTimeout | 0 (infinite),1 - 650 | 0 | read/write | 2 |

This parameter defines the time in seconds after which the advertising of the module stops. If no peer connects before this timeout, advertising stops and the module goes to system-off mode. If the RF_AdvertisingTimeout is set to 0, the module advertises infinitely.

To ensure that the module sends a sufficient amount of advertising packets per RF_AdvertisingTimeout, please also check the RF_ScanTiming parameter, which defines the frequency of advertising packets.

### 10.12.1. Example 1

Set the advertising timeout parameter to 0x00 0xB4 (180s) using CMD_SET_REQ with settings index 7.

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x03 0x00 | 0x07 | 0xB4 0x00 | 0xA3 |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.12.2. Example 2

Request the advertising timeout of the module using CMD_GET_REQ with settings index 7

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x07 | 0x14 |

Response CMD_GET_CNF: Successfully read out the value 0x00 0x00 = 0s, which indicates indefinite advertising.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x03 0x00 | 0x00 | 0x00 0x00 | 0x51 |

## 10.13. RF_AdvertisingFlags: Configure the advertising packet

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 29 | RF_AdvertisingFlags | 0,1 | 0 | read/write | 1 |

The user setting RF_AdvertisingFlags specifies the content of the advertising packet.

| Bit no. | Description | |
|---|---|---|
| 0 | Define the content of the advertising packet | |
| | 0x0 | Command mode: Advertising packet contains 5 bytes device name RF_DeviceName and the TX power |
| | | PeripheralOnly mode: Advertising packet contains only 8 bytes device name generated by the FS_BTMAC (A-123456 in case the FS_BTMAC is 0x0018DA123456) |
| | 0x1 | All modes: Advertising packet contains only 8 bytes device name RF_DeviceName |
| | others | Reserved. |
| 7 : 1 | Reserved. | |

Table 52: Advertising packet configuration flags


To use the beacon feature (see chapter 7.7) the TX power must be included in the advertising packet.

### 10.13.1. Example 1

Set the advertising flags to 1 such that command mode and PeripheralOnly mode use the same advertising packet content using the CMD_SET_REQ with settings index 29

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x02 0x00 | 0x1D | 0x01 | 0x0D |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.13.2. Example 2

Request the RF_AdvertisingFlags using CMD_GET_REQ with settings index 29:

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x1D | 0x0E |

Response `CMD_GET_CNF`: Successfully read out the value 0x00.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x02 0x00 | 0x00 | 0x00 | 0x50 |

## 10.14. RF_ScanFactor: Modify the scan factor

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 10 | RF_ScanFactor | 1 - 10 | 2 | read/write | 1 |

This parameter defines the factor between the scan window and the scan interval. See RF_ScanTiming for more information.

Example: Let's assume that the scan window is 50 ms, the RF_ScanFactor is 3, then the module scans for 50 ms on a fixed channel, enters a suspend mode (system-on mode) for 100 ms (3×50 ms - 50 ms), switches the channel, again scans for 50 ms and so on. The larger the RF_ScanFactor, the less time the module scans and thus the less power is consumed, but also the more difficult it is to detect other Bluetooth® LE devices on air.

### 10.14.1. Example 1

Set the scan factor to 0x03 using CMD_SET_REQ with settings index 10.

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x02 0x00 | 0x0A | 0x03 | 0x18 |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.14.2. Example 2

Request the scan factor of the module using CMD_GET_REQ with settings index 10

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x0A | 0x19 |

Response CMD_GET_CNF: Successfully read out the value 2.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x02 0x00 | 0x00 | 0x02 | 0x52 |

## 10.15. RF_ScanTiming: Modify the scan timing

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 9 | RF_ScanTiming | 0 - 5 | 1 | read/write | 1 |

The RF_ScanTiming enables the possibility to configure the timing behavior of the module's RF interface during advertising and scanning state. Using this parameter several predefined configurations can be chosen, which include timing parameters, such as the frequency of advertising packets and the length of a scan window.
The choice of the RF_ScanTiming primarily affects the latency of device detection on air as well as the current consumption. The lower the RF_ScanTiming, the faster the modules can find each other for communication, but also the more power will be consumed.

| RF_ScanTiming | 0 | 1 | 2 | 3[1] | 4[1] | 5[1] |
|---|---|---|---|---|---|---|
| Advertising interval [ms] | 20 | 40 | 250 | 1000 | 5000 | 10240 |
| Scan window [ms] | 25 | 50 | 312 | 1250 | 6250 | 10240 |
| Scan interval [ms] | Defined by the RF_ScanFactor. | | | | | |
| Connection setup timeout [s] | 1 | 2 | 2 | 5 | 20 | 35 |
| Current consumption | High | ... | | | | Low |

Further information:

- In ACTION_SCANNING mode, the scan interval defines the time after which the module switches channel to detect other Bluetooth® LE devices in range. See also RF_ScanFactor.
- In ACTION_SCANNING mode, the scan window defines the section of the scan interval, where the module is scanning. During the remaining time, the module enters a suspend mode (system-on mode). See also RF_ScanFactor.
- In ACTION_IDLE mode, the advertising interval defines the time after which the module periodically sends its advertising packet. In between, the module enters a suspend mode (system-on mode).
- The connection setup timeout defines the time after which a connection request has to be answered by the peripheral.

Please ensure that all members of a network support the same advertising and scan timing parameters.

[1] Mainly suitable for transmitting data using Beacons without consuming much energy.

To ensure that the module is allowed to send a sufficient amount of advertising packets, please also check the `RF_AdvertisingTimeout` parameter.

### 10.15.1. Example 1

Set the scan timing parameter to 0x00 using `CMD_SET_REQ`with settings index 9.

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x02 0x00 | 0x09 | 0x00 | 0x18 |

Response `CMD_SET_CNF`: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.15.2. Example 2

Request the scan timing parameter of the module using `CMD_GET_REQ` with settings index 9

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x09 | 0x1A |

Response `CMD_GET_CNF`: Successfully read out the value 4.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x02 0x00 | 0x00 | 0x04 | 0x54 |

## 10.16. RF_ConnectionTiming: Modify the connection timing

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 8 | RF_ConnectionTiming | 0 - 10 | 1 | read/write | 1 |

The RF_ConnectionTiming enables the possibility to configure the timing behavior of the module's RF interface during an established connection. Using this parameter several predefined configurations can be chosen, which include the minimum and maximum connection interval, as well as the connection supervision timeout.
The choice of the RF_ConnectionTiming primarily determines how rapidly the connection is established and data is transmitted. The lower the RF_ConnectionTiming, the more frequently the connected devices communicate with each other and thus, the more power is consumed.

| RF_ConnectionTiming | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Minimum connection interval [ms] | 7.5 | 15 | 45 | 195 | 750 | 2000 | 7.5 |
| Maximum connection interval [ms] | 30 | 75 | 250 | 1000 | 1995 | 4000 | 7.5 |
| Connection supervision timeout [s] | 4 | 4 | 4 | 6 | 6 | 25 | 4 |

| RF_ConnectionTiming | 7 | 8 | 9 | 10 |
|---|---|---|---|---|
| Minimum connection interval [ms] | 7.5 | 11.25 | 15 | 15 |
| Maximum connection interval [ms] | 11.25 | 20 | 15 | 30 |
| Connection supervision timeout [s] | 4 | 4 | 4 | 4 |

Please note that the smallest minimum connection interval supported by Android is 11.25 ms. Thus profile 6 cannot be used by Android devices. Further note that iOS supports only profiles, where its minimum connection interval is 15 ms or a multiple of it.

Further information:

- The minimum and maximum connection interval parameters specify the borders of the connection interval as determined in the negotiation procedure between the central and the peripheral during connection setup. The connection interval defines the frequency of communication during connection setup and data transmission. If a Proteus-I module A (central) connects to a Proteus-I module B (peripheral), the connection interval settings

of the central are used for connection setup. If both modules have different connection interval settings the peripheral requests the central to accept the peripheral's settings after 5s. The central accepts these settings, and thus the peripheral's connection interval is used.
If now another Bluetooth® LE device (e.g. a smart phone) connects as central to a Proteus-I module (peripheral) and the connection interval settings do not coincide, the Proteus-I requests the smart phone to accept its settings after 5s. If the cell phone does not accept the settings, it will be requested a further 3 times with a delay of 10s. If the peripheral's settings request have been rejected in all cases the connection will be shut down. If the smart phone itself requests to update the connection interval of the Proteus-I, the module accepts the request. Reversely, if a Proteus-I (central) connects to another Bluetooth® LE device (peripheral) and the connection interval settings do not coincide, the Proteus-I accepts all requests of the peripheral to update the connection parameter settings.

- The connection supervision timeout defines the time after which an already established connection is considered as lost, when no further communication has occurred.


Please ensure that all members (Proteus-I, cell phones and other Bluetooth® LE devices) of a network use the same connection timing parameters to avoid connection problems and changes of the connection interval during an opened connection.


Please check the minimum connection interval that is supported by iOS. Former iOS devices do not support connection intervals shorter than 30 ms!

### 10.16.1. Example 1

Set the connection timing parameter to 0x00 using `CMD_SET_REQ` with settings index 8.

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x02 0x00 | 0x08 | 0x00 | 0x19 |

Response `CMD_SET_CNF`: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.16.2. Example 2

Request the connection timing parameter of the module using `CMD_GET_REQ` with settings index 8

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x08 | 0x1B |

Response `CMD_GET_CNF`: Successfully read out the value 1.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x02 0x00 | 0x00 | 0x01 | 0x51 |

## 10.17. RF_TXPower: Modify the output power

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 17 | RF_TXPower | See description | 4 | read/write | 1 |

This setting determines the output power in dBm of the module. The value has to be entered in hexadecimal and as two's complement. The permissible values are listed in the following table.

| Permissible values | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Decimal [dBm] | -40 | -20 | -16 | -12 | -8 | -4 | 0 | +4 |
| Two's complement, hexadecimal | 0xD8 | 0xEC | 0xF0 | 0xF4 | 0xF8 | 0xFC | 0x00 | 0x04 |

### 10.17.1. Example 1

Set the output power of the module to -8 dBm, which is 0xF8 in two's complement notation, using CMD_SET_REQ with settings index 17

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x02 0x00 | 0x11 | 0xF8 | 0xF8 |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.17.2. Example 2

Request the output power of the module using CMD_GET_REQ with settings index 17

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x11 | 0x02 |

Response CMD_GET_CNF: Successfully read out the value 0x04 = 4dBm

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x02 0x00 | 0x00 | 0x04 | 0x54 |

## 10.18. RF_SPPBaseUUID: Configure the SPP base UUID

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 26 | RF_SPPBaseUUID | See description | 0x6E400000C352 11E5953D0002 A5D5C51B | read/write | 16 |

The WE SPP-like profile consists of the 16 Bytes base UUID 0x6E40xxxx-C352-11E5-953D-0002A5D5C51B plus the 2 Bytes UUIDs for the underlying characteristics:

| Characteristic | 2 Bytes UUID |
|---|---|
| Primary service | 0x0001 |
| TX_CHARACTERISTIC | 0x0002 |
| RX_CHARACTERISTIC | 0x0003 |

With this the TX characteristic can be identified by the resulting 16 Bytes UUID 0x6E400002-C352-11E5-953D-0002A5D5C51B on the radio. With help of the RF_SPPBaseUUID parameter we have to possibility to update the 16Byte base UUID of the WE SPP-like profile.


Please note that the UUID 0xFB349B5F8000008000100000xxxx0000 (0000xxxx-0000-1000-8000-00805f9b34fb) is reserved for 16 Bit UUIDs and must not be used here.

### 10.18.1. Example 1

Set the base UUID to 0xEFEEEDEC-EBEA-E9E8-E7E6-E5E4E3E2E1E0 using CMD_SET_REQ with settings index 26

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x11 0x00 | 0x1A | 0xE0 0xE1 0xE2 0xE3 0xE4 0xE5 0xE6 0xE7 0xE8 0xE9 0xEA 0xEB 0xEC 0xED 0xEE 0xEF | 0x18 |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.18.2. Example 2

Request the base UUID of the module using CMD_GET_REQ:

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x1A | 0x09 |

Response `CMD_GET_CNF`: Successfully read out the value 0x6E400000-C352-11E5-953D-0002A5D5C51B.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x11 0x00 | 0x00 | 0x1B 0xC5 0xD5 0xA5<br>0x02 0x00 0x3D 0x95<br>0xE5 0x11 0x52 0xC3<br>0x00 0x00 0x40 0x6E | 0x0C |

## 10.19. RF_Appearance: Configure the appearance of the device

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 25 | RF_Appearance | 0-65535 | 0 | read/write | 2 |

The user setting RF_Appearance specifies the appearance of the Bluetooth® devices. It's a 2 Bytes field defined by the Bluetooth® SIG. Please check the Bluetooth® Core Specification:Core Specification Supplement, Part A, section 1.12 for permissible values.

### 10.19.1. Example 1

Set the appearance to "Generic computer" (0x0080) using CMD_SET_REQ with settings index 25

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x03 0x00 | 0x19 | 0x80 0x00 | 0x89 |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.19.2. Example 2

Request the RF_Appearance using CMD_GET_REQ:

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x19 | 0x0A |

Response CMD_GET_CNF: Successfully read out the value 0x0000, meaning that the appearance is unknown.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x03 0x00 | 0x00 | 0x00 0x00 | 0x51 |

## 10.20. UART_BaudrateIndex: Modify the UART speed

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 11 | UART_BaudrateIndex | See description | 3 | read/write | 1 |

This parameter defines the baud rate used by the module's UART. The permissible values are listed in the following table.

| Permissible values | | | | | | | |
|---|---|---|---|---|---|---|---|
| UART_BaudrateIndex | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Rate [Baud] | 9600 | 19200 | 38400 | 115200 | 230400 | 460800 | 921600 |

The flow control pins */RTS* and */CTS* can be enabled using the user setting UART_Flags. For UART_BaudrateIndex 5 and 6 the flow control pins are enabled independent of the UART_Flags.

Please note that due to the HF-activity of the chip, single Bytes on the UART can get lost, when using a very fast UART data rate. To avoid loosing single bytes, please enable the UART flow control.

STOP

For baud rates faster than 230400 Baud, the flow control pins */RTS* and */CTS* are enabled.
The EV-Board Proteus-I-EV version 2.0 does not provide the connection between the flow control pins of the module and the EV-Board's USB port. Thus in this version of the Proteus-I-EV the flow control can be only used, if the onboard UART is disconnected (remove respective jumpers on JP2) and all UART lines (*URXD*,*UTXD*,*/RTS* and */CTS*) are connected to an external FTDI cable.

After changing the baud rate using the CMD_SET_REQ the module restarts using the new baud rate. Therefore don't forget to update the baud rate of the connected host to be able to further use the module's UART.

### 10.20.1. Example 1

Set the baud rate index to 0x04 (230400 Baud) using CMD_SET_REQ with settings index 11

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x02 0x00 | 0x0B | 0x04 | 0x1E |

Response `CMD_SET_CNF`: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.20.2. Example 2

Request the baud rate index of the module using `CMD_GET_REQ` with settings index 11

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x0B | 0x18 |

Response `CMD_GET_CNF`: Successfully read out the value 0x03, which equals 115200 Baud.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x02 0x00 | 0x00 | 0x03 | 0x53 |

## 10.21. UART_Flags: Configure the UART

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 27 | UART_Flags | 0,1 | 0 | read/write | 1 |

The user setting UART_Flags specifies whether the UART uses flow control or not.

| Bit no. | Description |
|---|---|
| 0 | Set this Bit to 1 to enable the flow control pins */RTS* and */CTS*. |
| 1-7 | Reserved. |


For baud rates faster than 230400 Baud, the flow control pins */RTS* and */CTS* are enabled.
The EV-Board Proteus-I-EV version 2.0 does not provide the connection between the flow control pins of the module and the EV-Board's USB port. Thus in this version of the Proteus-I-EV the flow control can be only used, if the on-board UART is disconnected (remove respective jumpers on JP2) and all UART lines (*URXD*,*UTXD*,*/RTS* and */CTS*) are connected to an external FTDI cable.

### 10.21.1. Example 1

Enable the flow control using CMD_SET_REQ with settings index 27

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x02 0x00 | 0x1B | 0x01 | 0x0B |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.21.2. Example 2

Request the UART_Flags using CMD_GET_REQ with settings index 27:

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x1B | 0x08 |

Response CMD_GET_CNF: Successfully read out the value 0x00, meaning that the flow control is disabled.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x02 0x00 | 0x00 | 0x00 | 0x50 |

## 10.22. DIS_ManufacturerName: Configure the manufacturer name

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 20 | DIS_ManufacturerName | See description | "Default" | read/write | 1-64 |

The user setting DIS_ManufacturerName specifies the content of the manufacturer name field of the Device Information Service. The permissible characters are in the range of 0x20 - 0x7E which are special characters (see ASCII table), alphabetic characters (a-z and A-Z), numbers (0-9) and whitespace.

To add the content of the DIS_ManufacturerName to the DIS profile, please set the corresponding Bit in the DIS_Flags.

### 10.22.1. Example 1

Set the manufacturer name to "Manufacturer1" using CMD_SET_REQ with settings index 20

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x0E 0x00 | 0x14 | 0x4D 0x61 0x6E 0x75 0x66 0x61 0x63 0x74 0x75 0x72 0x65 0x72 0x31 | 0x0F |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.22.2. Example 2

Request the manufacturer name of the DIS profile using CMD_GET_REQ:

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x14 | 0x07 |

Response CMD_GET_CNF: Successfully read out the value "Default".

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x08 0x00 | 0x00 | 0x44 0x65 0x66 0x61<br>0x75 0x6C 0x74 | 0x11 |

## 10.23. DIS_ModelNumber: Configure the model number

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 21 | DIS_ModelNumber | See description | "Default" | read/write | 1-64 |

The user setting DIS_ModelNumber specifies the content of the model number field of the Device Information Service. The permissible characters are in the range of 0x20 - 0x7E which are special characters (see ASCII table), alphabetic characters (a-z and A-Z), numbers (0-9) and whitespace.

To add the content of the DIS_ModelNumber to the DIS profile, please set the corresponding Bit in the DIS_Flags.

### 10.23.1. Example 1

Set the model number to "Model1" using CMD_SET_REQ with settings index 21

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x07 0x00 | 0x15 | 0x4D 0x6F 0x64 0x65 0x6C 0x31 | 0x7F |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.23.2. Example 2

Request the model number of the DIS profile using CMD_GET_REQ:

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x15 | 0x06 |

Response CMD_GET_CNF: Successfully read out the value "Default".

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x08 0x00 | 0x00 | 0x44 0x65 0x66 0x61<br>0x75 0x6C 0x74 | 0x11 |

## 10.24. DIS_SerialNumber: Configure the serial number

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 22 | DIS_SerialNumber | See description | "Default" | read/write | 1-64 |

The user setting DIS_SerialNumber specifies the content of the serial number field of the Device Information Service. The permissible characters are in the range of 0x20 - 0x7E which are special characters (see ASCII table), alphabetic characters (a-z and A-Z), numbers (0-9) and whitespace.

To add the content of the DIS_SerialNumber to the DIS profile, please set the corresponding Bit in the DIS_Flags.

### 10.24.1. Example 1

Set the serial number to "1.2.3" using CMD_SET_REQ with settings index 22

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x06 0x00 | 0x16 | 0x31 0x2E 0x32 0x2E 0x33 | 0x33 |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.24.2. Example 2

Request the serial number of the DIS profile using CMD_GET_REQ:

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x16 | 0x05 |

Response CMD_GET_CNF: Successfully read out the value "Default".

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x08 0x00 | 0x00 | 0x44 0x65 0x66 0x61<br>0x75 0x6C 0x74 | 0x11 |

## 10.25. DIS_HWVersion: Configure the HW version

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 23 | DIS_HWVersion | See description | "Default" | read/write | 1-16 |

The user setting DIS_HWVersion specifies the content of the hardware version field of the Device Information Service. The permissible characters are in the range of 0x20 - 0x7E which are special characters (see ASCII table), alphabetic characters (a-z and A-Z), numbers (0-9) and whitespace.

To add the content of the DIS_HWVersion to the DIS profile, please set the corresponding Bit in the DIS_Flags.

### 10.25.1. Example 1

Set the hardware version to "1.2.3" using CMD_SET_REQ with settings index 23

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x06 0x00 | 0x17 | 0x31 0x2E 0x32 0x2E 0x33 | 0x32 |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.25.2. Example 2

Request the hardware version of the DIS profile using CMD_GET_REQ:

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x17 | 0x04 |

Response CMD_GET_CNF: Successfully read out the value "Default".

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x08 0x00 | 0x00 | 0x44 0x65 0x66 0x61<br>0x75 0x6C 0x74 | 0x11 |

## 10.26. DIS_SWVersion: Configure the SW version

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 24 | DIS_SWVersion | See description | "Default" | read/write | 1-16 |

The user setting DIS_SWVersion specifies the content of the software version field of the Device Information Service. The permissible characters are in the range of 0x20 - 0x7E which are special characters (see ASCII table), alphabetic characters (a-z and A-Z), numbers (0-9) and whitespace.

To add the content of the DIS_SWVersion to the DIS profile, please set the corresponding Bit in the DIS_Flags.

### 10.26.1. Example 1

Set the software version to "1.2.3" using CMD_SET_REQ with settings index 24

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x06 0x00 | 0x18 | 0x31 0x2E 0x32 0x2E 0x33 | 0x3D |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.26.2. Example 2

Request the software version of the DIS profile using CMD_GET_REQ:

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x18 | 0x0B |

Response CMD_GET_CNF: Successfully read out the value "Default".

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x08 0x00 | 0x00 | 0x44 0x65 0x66 0x61<br>0x75 0x6C 0x74 | 0x11 |

## 10.27. DIS_Flags: Configure the device information service

| Settings index | Designation | Permissible values | Default value | Permissions | Number of Bytes |
|---|---|---|---|---|---|
| 19 | DIS_Flags | 0-255 | 0 | read/write | 1 |

The user setting DIS_Flags specifies the content of the Device Information Service. To add a specific field, like DIS_ModelNumber to the Device Information Service, the corresponding Bit has to be set in the DIS_Flags.

| Bit no. | Description |
|---|---|
| 0 | Set this Bit to 1 to add the DIS_ManufacturerName to the Device Information Service. |
| 1 | Set this Bit to 1 to add the DIS_ModelNumber to the Device Information Service. |
| 2 | Set this Bit to 1 to add the DIS_SerialNumber to the Device Information Service. |
| 3 | Set this Bit to 1 to add the DIS_HWVersion to the Device Information Service. |
| 4 | Set this Bit to 1 to add the DIS_SWVersion to the Device Information Service. |
| 5-7 | Reserved. |

### 10.27.1. Example 1

Add the manufacturer name and model number (Bit0|Bit1 = 0x03) to the Device Information Service using CMD_SET_REQ with settings index 19

| Start signal | Command | Length | Settings index | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x11 | 0x02 0x00 | 0x13 | 0x03 | 0x01 |

Response CMD_SET_CNF: Successfully modified the setting.

| Start signal | Command \| 0x40 | Length | Status | CS |
|---|---|---|---|---|
| 0x02 | 0x51 | 0x01 0x00 | 0x00 | 0x52 |

### 10.27.2. Example 2

Request the DIS_Flags using CMD_GET_REQ:

| Start signal | Command | Length | Settings index | CS |
|---|---|---|---|---|
| 0x02 | 0x10 | 0x01 0x00 | 0x13 | 0x00 |

Response CMD_GET_CNF: Successfully read out the value 0x00, meaning that the Device Information Service is disabled, since no field was added.

| Start signal | Command \| 0x40 | Length | Status | Parameter | CS |
|---|---|---|---|---|---|
| 0x02 | 0x50 | 0x02 0x00 | 0x00 | 0x00 | 0x50 |

| Settings index | Designation | Summary | Permissible values | Default value | Permis-sions | Number of Bytes |
|---|---|---|---|---|---|---|
| 1 | FS_FWVersion | Version of the firmware | - | - | read | 3 |
| 2 | RF_DeviceName | Name of the module | See description | "A2621" | read / write | 1-31 |
| 3 | FS_MAC | MAC address of the module | - | - | read | 6 |
| 4 | FS_BTMAC | Bluetooth® LE conform MAC address of the module | - | - | read | 6 |
| 7 | RF_ AdvertisingTimeout | Time [s] after advertising stops. LSB first | 0 (infinite), 1 - 65535 | 0 | read / write | 2 |
| 8 | RF_ConnectionTiming | Module connection timing configuration | 0 - 10 | 1 | read / write | 1 |
| 9 | RF_ScanTiming | Module advertising and scanning timing configuration | 0 - 5 | 1 | read / write | 1 |
| 10 | RF_ScanFactor | Factor between scan interval and scan window | 1 - 10 | 2 | read / write | 1 |
| 11 | UART_BaudrateIndex | Baud rate of the UART | See description | 3 | read / write | 1 |
| 12 | RF_SecFlags | Security settings of the module | See description | 0 | read / write | 1 |
| 13 | RF_ScanFlags | Scan settings of the module | See description | 0 | read / write | 1 |
| 14 | RF_BeaconFlags | Beacon settings of the module | See description | 0 | read / write | 1 |
| 15 | FS_DeviceInfo | Information about the chip | - | - | read | 12 |
| 16 | FS_SerialNumber | Serial number of the module | - | - | read | 3 |
| 17 | RF_TXPower | Output power [dBm] Two's complement | See description | 4 | read / write | 1 |
| 18 | RF_StaticPasskey | 6 digit pass key | See description | "123123" | read / write | 6 |
| 19 | DIS_Flags | Flags for the DIS | 0 - 255 | 0 | read / write | 1 |
| 20 | DIS_ManufacturerName | Manufacturer name field of the DIS | See description | "Default" | read / write | 1-64 |
| 21 | DIS_ModelNumber | Model number field of the DIS | See description | "Default" | read / write | 1-64 |
| 22 | DIS_SerialNumber | Serial number field of the DIS | See description | "Default" | read / write | 1-64 |
| 23 | DIS_HWVersion | HW version field of the DIS | See description | "Default" | read / write | 1-16 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 24 | DIS_SWVersion | SW version field of the DIS | See description | "Default" | read / write | 1-16 |
| 25 | RF_Appearance | Appearance | 0-65535 | 0 | read / write | 2 |
| 26 | RF_SPPBaseUUID | Base UUID of the WE SPP-like profile | See description | See description | read / write | 16 |
| 27 | UART_Flags | UART Flags | 0,1 | 0 | read / write | 1 |
| 29 | RF_AdvertisingFlags | Advertising Flags | 0,1 | 0 | read / write | 1 |
| 44 | RF_SecFlagsPerOnly | Security settings of the module (peripheral only mode only) | See description | 11 | read / write | 1 |

Table 53: Table of settings

# 11. Timing parameters

## 11.1. Reset and sleep

After power-up, resetting the module or waking the module from sleep a `CMD_GETSTATE_CNF` is sent to the serial interface as soon as the module is ready for operation.

| Description | Typ. | Unit |
|---|---|---|
| Ready after reset/sleep | 4 | ms |

## 11.2. Bluetooth LE timing parameters

The timing parameters for sending advertising packets or scanning are determined by the user settings `RF_ScanTiming`, `RF_ScanFactor` and `RF_AdvertisingTimeout`. Using these settings, the advertising interval, the advertising timeout, the scan interval and the scan window can be configured. Furthermore, the user setting `RF_ConnectionTiming` allows to configure the timing parameters used during connection setup and connection retention, as well as the connection interval and the connection supervision timeout.

## 11.3. Connection establishment

The time needed to establish a connection sums up as the time needed to detect the selected peripheral on air and the time needed for connection parameter negotiation and service discovery.

1. Peripheral detection To establish a connection, the initiating device (central) waits for an advertising packet, which was sent by the peripheral to which it wants to connect to. As soon as such an advertising packet has been received, the central sends a connection request to the chosen peripheral. The time needed to receive this advertising packet strongly depends on the advertising interval of the peripheral as well as on the scan interval and scan window of the central (see `RF_ScanTiming`).

2. Connection parameter negotiation After the connection request has been sent the central and peripheral negotiate the timing and security parameters of the connection. To finish this procedure and discover the services of the peripheral several messages have to be sent, whereby only one is sent per connection interval (see `RF_ConnectionTiming`).

| Connection type | Estimated number of exchanged messages | Negotiation time for a connection interval of 50 ms |
|---|---|---|
| Unsecured connection | 12-14 | 600-700 ms |
| Secured connection using the pairing method | 22-24 | 1100-1200 ms |
| Secured connection to already bonded device | 19-20 | 950-1000 ms |

Knowing the connection interval and the number of messages that will be sent, the time necessary to setup a connection can be estimated by multiplying the number of messages with the connection interval.

In case the Device Information Service is enabled, the number of messages and thus the timing of the connection setup may be increased.

## 11.4. Connection based data transmission

After setting up a connection, data can be transmitted using the `CMD_DATA_REQ`. It buffers the data in the module and sends it with the next connection interval event. As soon as the data has been transmitted successfully, a `CMD_TXCOMPLETE_RSP` is returned by the UART. The time needed for this coincides with the connection interval that was negotiated during connection setup. The `RF_ConnectionTiming` parameter defines the minimum and maximum connection interval, which is supported by the module.

# 12. Peripheral only mode

The Proteus-I implements a new feature that allows the easy integration of the Proteus-I Bluetooth® LE module to an already existing host. The peripheral only mode offers a plug and play installation without previous configuration of the Proteus-I. It is tailored for easy communication with mobile Bluetooth® LE devices like smart phones.
The peripheral only mode is a special operation mode, that uses the user settings and the peripheral functions of the normal mode described in the previous chapters. It has to be enabled during the module start-up and contains the following key features:

- Peripheral only functions: The Proteus-I only contains the functions of a peripheral. Thus, it is advertising until another Bluetooth® LE device connects to it. In this case, the UART of the Proteus-I is enabled, the *LED_2* pin shows that the channel is open and bidirectional data transmission can start. As soon as the connection is closed, the UART is disabled again to save power. Since all central functions are no longer valid, the module cannot initiate any connection or run scans.
- Transparent UART interface: The serial interface of the Proteus-I is no longer driven by commands. This means, when the UART of the module is enabled (i.e. only when a channel is open, indicated by both LEDs active), data sent to the UART is transmitted by the Proteus-I to the connected Bluetooth® LE device. On the other hand, all data received by RF is sent from the Proteus-I to the connected host without additional header Bytes. The UART is only running, when a channel is open. Thus, power is saved during the advertising period. Depending on the configured connection interval, only one packet per interval is allowed to be transmitted. Since the commands of the command interface are no longer valid, a Proteus-I cannot be configured when running in peripheral only mode.
- Pairing: The default security mode is the static passkey pairing method (see `RF_SecFlagsPerOnly`), with the default key "123123". The bonding feature is enabled by default.

## 12.1. Reasons to use the peripheral only mode

The Proteus-I peripheral only mode equips custom applications with a Bluetooth® LE interface (to be accessible by other Bluetooth® LE devices) without installation effort.
To setup a connection to the Proteus-I in peripheral only mode the central device has to insert the Proteus-I's static passkey. As soon as the channel to a connected Bluetooth® LE central device is open, the *LED_2* pin switches on to signalize that data can be exchanged now. When the connection was shut down by the Bluetooth® LE central device, the *LED_2* pin switches off again.
Due to the transparent UART interface, data can be exchanged without additional headers.
Furthermore, the peripheral only mode allows an energy efficient operation of the Bluetooth® LE interface, since the UART is only enabled when it is really used.

## 12.2. How to use the peripheral only mode

The peripheral only mode is enabled, when a high signal is present on the *OP_MODE* pin during device start-up or reset.

No configuration of the module is needed for this operating mode. The module shall be set to factory settings if reconfigured before so it uses the default user settings. In this case, the UART uses 115200 Baud 8n1 and static passkey pairing is used as authentication method.

If a configuration of the module is still needed (e.g. when another UART baud rate needs to be chosen), the module has to be started in normal mode and the `CMD_SET_REQ` may be used to update the user settings.
It is permitted to modify any user setting to change the behaviour of the peripheral only mode. Nevertheless, we recommend to update only the following parameters to run the device in factory state with minimal adaptions:

- `UART_BaudrateIndex` (change the UART baud rate, default value "115200")
- `UART_Flags` (enable or disable the flow control)
- `RF_StaticPasskey` (change the default static passkey, default value "123123")
- `RF_AdvertisingFlags` and `RF_DeviceName` (determine the content of the advertising packet)

## 12.3. More information

### 12.3.1. Radio

- In peripheral only mode a new 8-digit device name is automatically generated by the `FS_BTMAC`. In case of the `FS_BTMAC` equals 0x0018DA123456 the device name is "A-123456". This is a workaround for iOS, which does not allow access to the BTMAC for received Bluetooth® frames.
- The content of the advertising packet was changed in peripheral only mode. The TX power information block was removed, as the device name was extended to 8 digits.

### 12.3.2. UART

- The maximum payload per packet supported by an open channel depends on the connected central device. The Proteus-I supports up to 243 Bytes payload (corresponding to a MTU of 247 Bytes), which may be negotiated by the central device (using a MTU request). If no MTU request is requested by the connecting central device the value of 19 Bytes payload per packet and connection interval as given by the Bluetooth® 4.0 standard is used (compatibility mode to Bluetooth® LE 4.0 devices). Data received by the Proteus-I's UART, that exceeds the maximum payload size of the open channel, is discarded. In peripheral only mode, (due to the deactivated commands) the Proteus-I cannot inform its host about the maximum payload size or of payload discarding.
- The connecting device could implement a function to inform the host behind the Proteus-I which MTU the channel is capable of. Until this message is received, the host shall assume a payload capability of up to 19 Byte.
- The data sent to the UART is buffered in the Proteus-I up to a maximum payload depending on of the current channel MTU. When no new Byte was received for 20 ms, the data will be transmitted by RF to the connected Bluetooth® LE device.

# 13. Customizing the Proteus-I

## 13.1. DIS - Device information service

Besides the WE SPP-like profile for data transmission, the Proteus-I contains the so called Device Information Service. This profile exposes manufacturer information about a device and is used to personalize the Proteus-I to fuse with the custom product. The Device Information Service is a standard Bluetooth® LE profile that is recognized by all devices with Bluetooth® capabilities. It contains the following fields, that can only be modified by updating the respective user setting using the `CMD_SET_REQ` command:

| Field name | User setting | Maximum length |
|---|---|---|
| Manufacturer Name String | `DIS_ManufacturerName` | 64 |
| Model Number String | `DIS_ModelNumber` | 64 |
| Serial Number String | `DIS_SerialNumber` | 64 |
| Hardware Revision String | `DIS_HWVersion` | 16 |
| Software Revision String | `DIS_SWVersion` | 16 |

Furthermore, the user setting `DIS_Flags` defines which of the described DIS fields are finally placed in the DIS profile. Thus after adding content to the a DIS field user setting, like `DIS_ManufacturerName`, the user setting `DIS_Flags` has to be adapted such that the content is added to the profile.

## 13.2. UUID

The UUID is a unique number identifying a Bluetooth® LE profile and thus describing its functions. The Proteus-I using its standard UUID is compatible to all devices that implement the WE SPP-like profile, whichever device it is integrated. To suspend this interoperability, the user setting `RF_SPPBaseUUID` can be used to modify the UUID of the WE SPP-like profile. With this, a new custom SPP-like profile is defined that is solely known to those that chose the new UUID. To generate a custom UUID the Bluetooth® SIG recommends to use the tool:
*http://www.uuidgenerator.net/*

## 13.3. Appearance

The appearance of the Bluetooth® device is a 2 Bytes value defined by the Bluetooth® SIG. It can be configured by adapting the parameter `RF_Appearance`.

# 14. Custom firmware and configuration

Any kind of configuration and firmware, which is provided as Intel hex file, can be programmed on the radio module at Würth Elektronik eiSos production site.

In case of interest, please contact your Business Development Manager (BDM) or *WCS@we-online.com*.

## 14.1. Custom configuration of standard firmware

The configuration of the standard firmware includes adoption of the non-volatile settings to customer requirements and creating a customized product based on the standard product.
This variant will result in a customer exclusive module with a unique ordering number. It will also freeze the firmware version to a specific and customer tested version and thus results in a customer exclusive module with a unique ordering number.
Further scheduled firmware updates of the standard firmware will not be applied to this variant automatically. Applying updates or further functions require a customer request and release procedure.

## 14.2. Customer specific firmware

A customer specific firmware may include "Custom configuration of standard firmware" plus additional options or functions and tasks that are customer specific and not part of the standard firmware.
Further scheduled firmware updates of the standard firmware will not be applied to this variant automatically. Applying updates or further functions require a customer request and release procedure.
This also results in a customer exclusive module with a unique ordering number.
An example for this level of customization are functions like host-less operation where the module will perform data generation (e.g. by reading a SPI or $I^2C$ sensor) and cyclic transmission of this data to a data collector, while sleeping or being passive most of the time.
Also replacing UART with SPI as host communication interface is classified as a custom specific option.
Certification critical changes need to be re-evaluated by an external qualified measurement laboratory. These critical changes may occur when e.g. changing radio parameters, the channel access method, the duty-cycle or in case of various other functions and options possibly used or changed by a customer specific firmware.

## 14.3. Customer firmware

A customer firmware is a firmware written and tested by the customer himself or a 3rd party as a customer representative specifically for the hardware platform provided by a module.
This customer firmware (e.g. in form of an Intel hex file) will be implemented into the module's production process at our production site.

This also results in a customer exclusive module with a unique ordering number.
The additional information needed for this type of customer firmware, such as hardware specific details and details towards the development of such firmware are not available for the public and can only be made available to qualified customers.


The qualification(s) and certification(s) of the standard module cannot be applied to this customer firmware solution without a review and verification.

# 15. Firmware updates

All products will experience maintenance, security and/or feature updates from time to time. For the standard products these are maintained via the PCN process.
Customers can request the creation of a customized product including a "firmware freeze" to ensure that they will receive their verified product even if the standard product is updated.

## 15.1. Firmware flashing using the production interface

Most Würth Elektronik eiSos wireless connectivity modules offer a production interface (e.g. JTAG, SWD, Spy-Bi-Wire) for module flash access. Depending on the product, this interface can be used by customers to erase the entire chip and install their own or special test firmware for certification tests.

Using the production interface is not intended to perform updates of Würth Elektronik eiSos standard product firmware[1].

Production firmware images and binary files for Würth Elektronik eiSos wireless connectivity modules are not publicly available.


Any certification, declaration, listing and qualification becomes invalid if the production interface is used by a customer.

Customers shall make the product specific firmware update interface available to their application. These methods will use a wired (UART, SPI, etc.) or wireless (Bluetooth® LE, WiFi, etc.) communication interface of the module to allow updating the product's firmware. Details are described in the next sections.

## 15.2. Firmware update using the Proteus-I OTA bootloader

This method offers a possibility to update the standard product firmware[1] over the air (OTA). Any other firmware (i.e. custom firmware, Bluetooth® test firmware (DTM), ...) must be flashed via the production interface (see chapter 15.1).

For the OTA firmware update, the Nordic nRF52 Bluetooth® LE DFU Secure Bootloader is integrated into the Proteus-I's firmware, which will communicate over the Bluetooth® LE interface. The OTA bootloader mode is a distinct operating mode besides the normal operating modes mentioned before. For this reason, a .zip-file can be provided, which contains all (bootloader, Softdevice, application) parts of the firmware in an encrypted and authenticated package.

Before starting any update procedure, please check whether the installed firmware can be updated to a new one:

[1] The standard product firmware is the firmware described in this user manual.

| Version of the firmware before the update | Version of the new firmware | App |
|---|---|---|
| 1.0.0 - 1.1.0 | 2.1.0 | Not supported, due to S132 update and bootloader changes |
| 2.1.0, 3.X.X | 3.X.X | nRF Device Firmware Update [4, 5] |

Table 54: Compatibility matrix

To start the bootloader, one of the following two conditions has to be satisfied:

1. Send the command `CMD_BOOTLOADER_REQ` to the module to restart in bootloader. mode
2. During a reset and while restarting, a low signal has to be present on the *BOOT* pin of the module to start it in bootloader mode. To do this on the Proteus-I EV-Board, put a jumper on JP3(1,2) and JP2(1,2) to apply GND to the *BOOT* before resetting the module via pressing the */RESET* button.

The bootloader mode has started successfully if *LED_1* has turned on. After the bootloader has started successfully, the module goes into the advertising mode using the name "DFUxxx".

iOS devices may not show the live device name "DFUxxx" that is placed in the radio packets due to internal look-up table use. It will only update the device name after a connection was successfully established. Vice versa, when re-booting the device after using the FOTA mode, iOS will still show "DFUxxx" as device name until a connection has been setup to the module again.

Now, any Bluetooth® LE device hosting an application that understands the commands of the Nordic nRF52 Bluetooth® LE DFU Bootloader can connect in order to update the Proteus-I firmware.
The DFU application of the used App (see Table 54) is such an application. For more details, please refer to chapter 15.2.1. As soon as a connection has been set up, *LED_1* turns off again and *LED_2* turns on.

The implemented Nordic nRF52 Bluetooth® LE DFU bootloader uses a dual bank method to update the firmware. Thus, the old firmware is only replaced once the new firmware has been transferred and authenticated successfully. This prevents the module from being flashed with a faulty firmware.

An OTA firmware update will take several minutes to be performed, the duration is also dependent how much of the firmware shall be updated (application only or complete update).

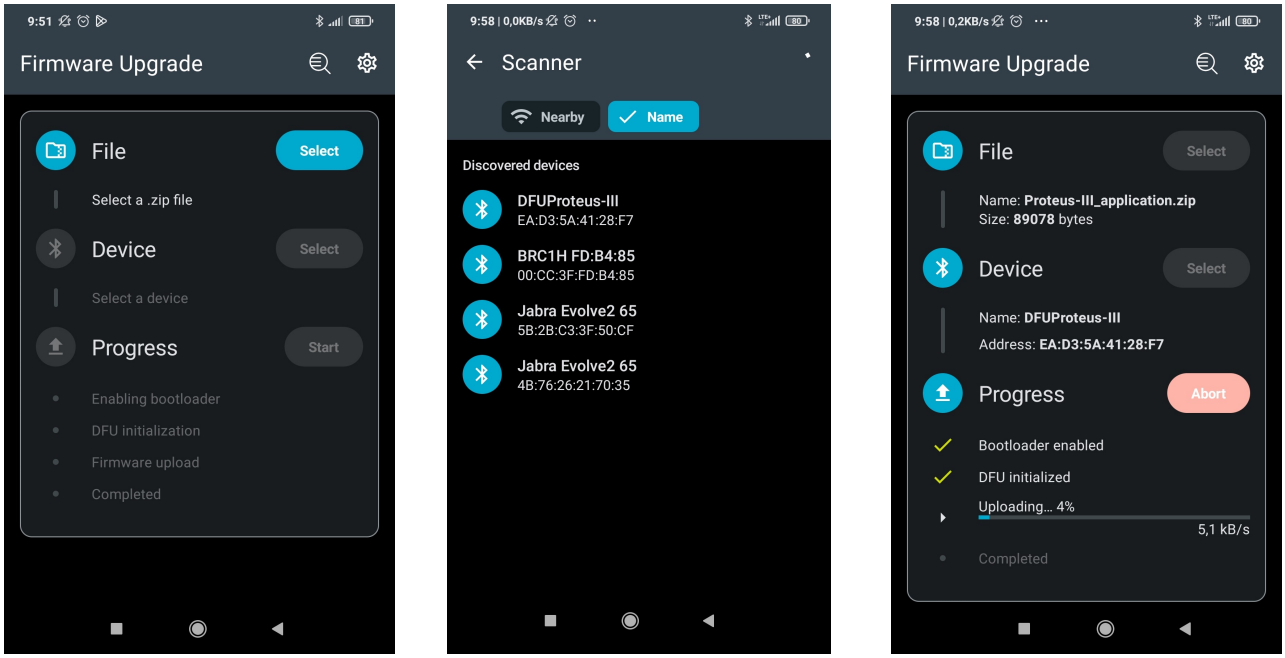
### 15.2.1. Firmware update steps using the nRF Device Firmware Update app

If the radio module Proteus-I has been set to bootloader mode, the nRF Device Firmware Update app [4, 5] can be used to perform the OTA firmware update.

- Open the app, press "Select" to choose the file. The file explorer opens where you can select the zip file that contains the FOTA image.
- Then press "Select" to choose the device to update. The app scans for available Bluetooth® LE devices. The Proteus-I in bootloader mode appears as "DFUxxxx" in the scan list. Select that.

If there is no device named "DFUxxxx" on the radio, please check whether the module has been started in bootloader mode.

- Then press "Start" to start the update process.
- Wait until it has finished.




a) Select file b) Scan list c) FOTA running

Figure 9: nRF Device Firmware Update app

# 16. Firmware history

**Version 1.0.0** "Release"

- First production release
- New command interface with 2 Bytes length field
- using Softdevice 2.0.1 + SDK 11.0
- SPP-Like Protocol

**Version 1.0.1** "Release"

- UART checks for max. buffer size

**Version 1.1.0** "Release"

- DCDC enabled for lowest power consumption

**Version 2.1.0** "Release"

- Using Softdevice 3.0.0 and SDK 12.1.0
- Remove UART baud rates faster than 230400 Baud to prevent lost Bytes
- due to DMA usage the UART current is increased (without DMA the UART data rate must be decreased further below 230400 Baud)
- Introduced `CMD_ERROR_IND` message indicating internal error states
- Introduced support for transmission of large Bluetooth® LE packets (19 Bytes payload → 128Bytes payload). This is a non-mandatory Bluetooth® LE 4.2 feature. Use `CMD_DATA_REQ` command to send long packets if it is indicated by the `CMD_CHANNELOPEN_RSP`.
- Modified the `CMD_CHANNELOPEN_RSP` indication the max. supported payload size
- `CMD_DATA_REQ` returns maximum supported payload size if it was exceeded
- Modified `RF_ConnectionTiming` profile 0 and added profile 6
- Modified the `CMD_SECURITY_IND` message
- DTM uses max packet size for TX test packets (255 Bytes)
- Parameter `RF_SecLTK` replaced by `RF_OwnLTK` and `RF_PeerLTK`
- Added commands `CMD_SET_RAM_REQ` and `CMD_GET_RAM_REQ` to set/get volatile RAM parameter values (only `RF_PeerLTK` at the moment)
- Moved the settings index of parameter `RF_TXPower`
- New OTA bootloader
- AMB2621 Toolbox App version 1.18.4 must be used to update the firmware
- `CMD_DATAEX_REQ` removed due to incompatibilities with foreign Bluetooth® LE devices
- Added new security concept. Now the peripheral decides whether the security level is sufficient.
- Added new security mode in `RF_SecFlags` (Static pass key method was added)
- New user setting `RF_StaticPasskey` added

- New commands CMD_PASSKEY_REQ and CMD_PASSKEY_IND added

**Version 3.0.0** "Release"

- Using Softdevice 3.1.0 and SDK 12.1.0
- Changed default value of user setting parameter RF_AdvertisingTimeout from 180s to 0s. This means, that in default configuration the module does not go to sleep after 180s as in the previous firmware versions.
- Function of *LED_2* has changed. Now it indicates whether a channel is open or not.
- Introduced new operation mode "Peripheral only mode" with special behavior
  - Introduced new Advertise format containing the LSBs of the MAC address (only for Peripheral only mode)
  - Introduced pin *OP_MODE* to enable the Peripheral only mode, as an internal pull-down is used the "do not connect if not needed" still applies for normal mode operation
  - Introduced a transparent UART interface (only available for this mode)
  - Introduced a new user setting RF_SecFlagsPerOnly

**Version 3.3.0** "Release"

- Using Softdevice 3.1.0 and SDK 12.3.0
- New compatible OTA bootloader
- Increased maximum payload from 128 Bytes to 243 Bytes
- Added bonding feature and new commands CMD_DELETEBONDS_REQ and CMD_GETBONDS_REQ
- Update of the user setting RF_SecFlags
  - Removed the direct LTK-encryption option
  - Added flag SECFLAGS_BONDING_ENABLE to switch on bonding
- Default value of user settings RF_SecFlagsPerOnly changed to 11 (Static pass key and bonding enabled)
- Removed user setting RF_OwnLTK and RF_PeerLTK
- Modified the message CMD_SECURITY_IND
- CMD_SETBEACON_REQ allows 0 as length

**Version 3.3.6** "Release"

- Blink interval of *LED_1* changed in mode ACTION_SCANNING, now it is 1000 ms on 1000 ms off

**Version 3.4.0** "Release"

- Added possibilities for improved customization of the Proteus-I see chapter 13.
  - Added the user setting RF_SPPBaseUUID to modify the UUID of the WE SPP-like profile to generate a customized profile.
  - Added the user setting RF_Appearance to modify the appearance of the module

  - Added the Device Information Service (DIS) as second Bluetooth® LE profile to the Proteus-I to add customer specific data to the Bluetooth® LE interface of the Proteus-I
- Increased the maximum length of the user setting `RF_DeviceName` to 32 Bytes, that defines the name of the device on radio.
- Higher throughput due to faster UART baud rates.
  - Added the flow control pins */RTS* and */CTS* to the pinout.
  - Added 460800 and 921600 Baud to the user setting `UART_BaudrateIndex` using the flow control.
  - Added the user setting `UART_Flags` to enable/disable the flow control for UART baud rates slower than 430800 Baud.
- Reduced the detection time of pin *WAKE_UP* from 50 ms to 10 ms to re-enable the UART again, when the UART was switched off using the command `CMD_UARTDISABLE_REQ`.

**Version 3.5.0** "Release"

- Integrated additional internal tests for better detection of production failures on our production sides

**Version 3.6.0** "Release"

- Updated the user setting `RF_ConnectionTiming`. The new values better support most recent Android and iOS devices.
- Introduced new user setting `RF_AdvertisingFlags` to determine the content of the advertising packet. This allows to use the `RF_DeviceName` also in the advertising packet in peripheral only mode.
- Fixed known issues of previous version: Wrong setting of `RF_DeviceName` and `RF_TXPower`

## 16.1. Known issues

| Index | Details | Affected versions |
|---|---|---|
| KI-001 | **Description:** The user setting `RF_AdvertisingTimeout` can not be modified.<br><br>**Affected functions**: User setting `RF_AdvertisingTimeout` and command `CMD_SET_REQ`.<br><br>**Workaround:** None | $\leq$ 1.0.0 |

| | | |
|---|---|---|
| KI-002 | **Description:** Limited OTA update compatibility.<br><br>**Affected functions**: The module can only be updated to firmware revisions of 1.x.x .<br><br>**Workaround:** None. | $\leq$ 1.1.0 |
| KI-003 | **Description:** Limited Bluetooth® compatibility.<br><br>**Affected functions**: The module can only connect to modules of version 3.0.0 and older, if bonding is not enabled.<br><br>**Workaround:** Do not use bonding when connecting to modules of version 3.0.0 and older. | $\geq$ 3.3.0 |
| KI-004 | **Description:** Choosing invalid value for user setting `RF_StaticPasskey` may lead to malfunction.<br><br>**Affected functions**: User setting `RF_StaticPasskey` and command `CMD_SET_REQ`.<br><br>**Workaround:** Do not use `CMD_SET_REQ` function to set the user setting `RF_StaticPasskey` to an invalid key. The device can be recovered by a FOTA (firmware over the air) update. | $\leq$ 3.3.0 |
| KI-005 | **Description:** The output power value `RF_TXPower` equals -30 dBm is invalid. The module will not start-up again.<br><br>**Affected functions**: User setting `RF_TXPower` and command `CMD_SET_REQ`.<br><br>**Workaround:** Do not use `CMD_SET_REQ` function to set the user setting `RF_TXPower` to -30 dBm. The device can be recovered by a FOTA (firmware over the air) update. | $\leq$ 3.4.0 |
| KI-006 | **Description:** Setting the Bluetooth® reserved UUID 0000xxxx-0000-1000-8000-00805f9b34fb as base UUID will result in malfunctioning. The module will not start-up again.<br><br>**Affected functions**: User setting `RF_SPPBaseUUID` and command `CMD_SET_REQ`.<br><br>**Workaround:** Do not use `CMD_SET_REQ` function to set the user setting `RF_SPPBaseUUID` to the value 0000xxxx-0000-1000-8000-00805f9b34fb. The device can be recovered by a FOTA (firmware over the air) update. | $\leq$ 3.6.0 |

# 17. Hardware history

**Version 2.2** "Release"

- Add second source for components.

# 18. Design in guide

## 18.1. Advice for schematic and layout

For users with less RF experience it is advisable to closely copy the relating EV-Board with respect to schematic and layout, as it is a proven design. The layout should be conducted with particular care, because even small deficiencies could affect the radio performance and its range or even the conformity.

The following general advice should be taken into consideration:

- A clean, stable power supply is strongly recommended. Interference, especially oscillation can severely restrain range and conformity.
- Variations in voltage level should be avoided.
- LDOs, properly designed in, usually deliver a proper regulated voltage.
- Blocking capacitors and a ferrite bead in the power supply line can be included to filter and smoothen the supply voltage when necessary.
- Elements for ESD protection should be placed on all pins that are accessible from the outside and should be placed close to the accessible area. For example, the RF-pin is accessible when using an external antenna and should be protected.
- ESD protection for the antenna connection must be chosen such as to have a minimum effect on the RF signal. For example, a protection diode with low capacitance such as the 8231606A or a 68 nH air-core coil connecting the RF-line to ground give good results.
- Placeholders for optional antenna matching or additional filtering are recommended.
- The antenna path should be kept as short as possible.
- The use of an external reset IC should be considered if one of the following points is relevant:
  - The slew rate of the power supply exceeds the electrical specifications.
  - The effect of different current consumptions on the voltage level of batteries or voltage regulators should be considered. The module draws higher currents in certain scenarios like start-up or radio transmit which may lead to a voltage drop on the supply. A restart under such circumstances should be prevented by ensuring that the supply voltage does not drop below the minimum specifications.
  - Voltage levels below the minimum recommended voltage level may lead to malfunction. The reset pin of the module shall be held on LOW logic level whenever the VDD is not stable or below the minimum operating Voltage.
  - Special care must be taken in case of battery powered systems.
- To avoid the risk of short circuits and interference there should be no routing underneath the module on the top layer of the baseboard.
- On the second layer, a ground plane is recommended, to provide good grounding and shielding to any following layers and application environment.

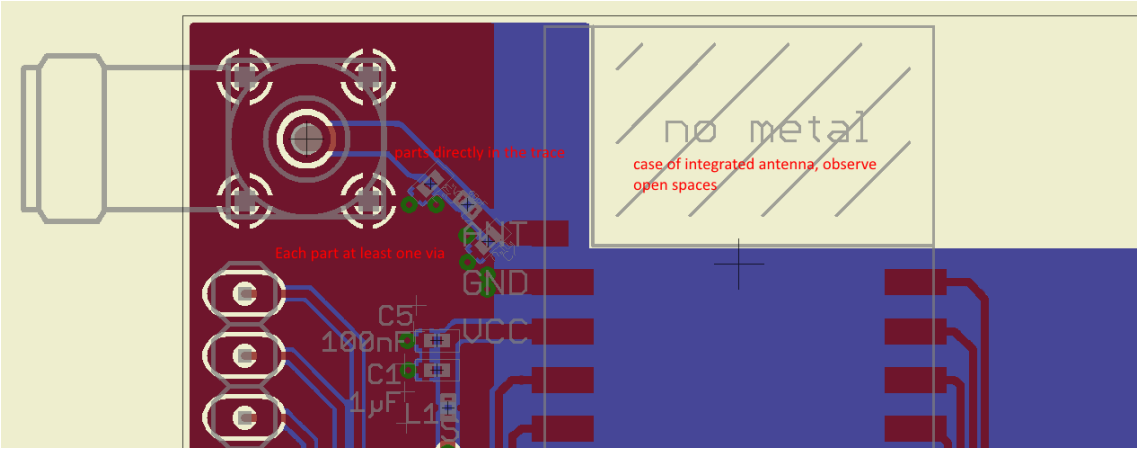



Figure 10: Layout

- In case of integrated antennas it is required to have areas free from ground. This area should be copied from the EV-Board.
- The area with the integrated antenna must overlap with the carrier board and should not protrude, as it is matched to sitting directly on top of a PCB.
- Modules with integrated antennas should be placed with the antenna at the edge of the main board. It should not be placed in the middle of the main board or far away from the edge. This is to avoid tracks beside the antenna.
- Filter and blocking capacitors should be placed directly in the tracks without stubs, to achieve the best effect.
- Antenna matching elements should be placed close to the antenna / connector, blocking capacitors close to the module.
- Ground connections for the module and the capacitors should be kept as short as possible and with at least one separate through hole connection to the ground layer.
- ESD protection elements should be placed as close as possible to the exposed areas.

Fixed values can not be recommended, as these depend on the circumstances of the application (main power source, interferences etc.).

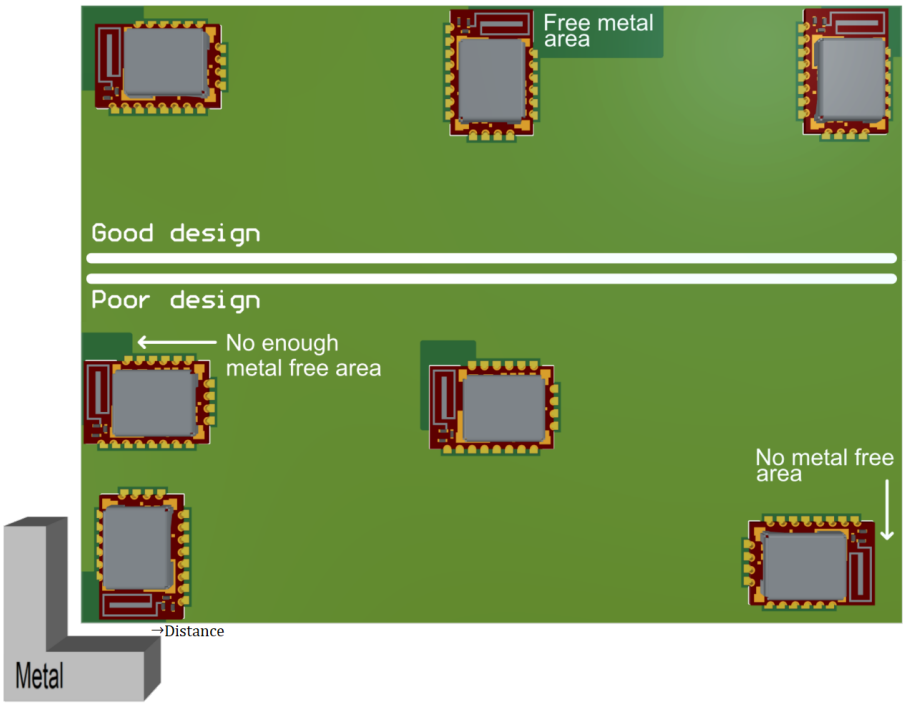



Figure 11: Placement of the module with integrated antenna

## 18.2. Designing the antenna connection

The antenna should be connected with a 50 Ω line. This is needed to obtain impedance matching to the module and avoids reflections. Here we show as an example how to calculate the dimensions of a 50 Ω line in form of a micro strip above ground, as this is easiest to calculate. Other connections like coplanar or strip line are more complicated to calculate but can offer more robustness to EMC. There are free calculation tools available in the internet.

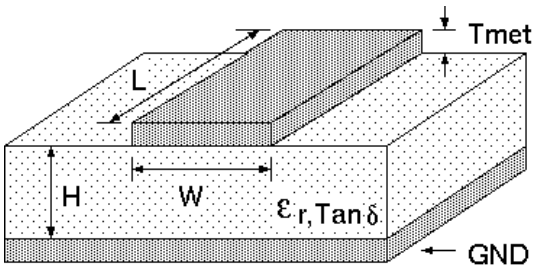



Figure 12: Dimensioning the antenna connection as micro strip

The width W for a micro strip can be calculated using the following equation:

$$W = 1.25 \times \left( \frac{5.98 \times H}{e^{\frac{50 \times \sqrt{\epsilon_r} + 1.41}{87}}} - T_{met} \right)$$

Example:
A FR4 material with $\varepsilon_r$ = 4.3, a height H = 1000 µm and a copper thickness of $T_{met}$ = 18 µm will lead to a trace width of W ~ 1.9 mm. To ease the calculation of the micro strip line (or e.g. a

coplanar) many calculators can be found in the internet.

- As rule of thumb a distance of about 3×W should be observed between the micro strip and other traces / ground.
- The micro strip refers to ground, therefore there has to be the ground plane underneath the trace.
- Keep the feeding line as short as possible.

## 18.3. Antenna solutions

There exist several kinds of antennas, which are optimized for different needs. Chip antennas are optimized for minimal size requirements but at the expense of range, PCB antennas are optimized for minimal costs, and are generally a compromise between size and range. Both usually fit inside a housing.
Range optimization in general is at the expense of space. Antennas that are bigger in size, so that they would probably not fit in a small housing, are usually equipped with a RF connector. A benefit of this connector may be to use it to lead the RF signal through a metal plate (e.g. metal housing, cabinet).
As a rule of thumb a minimum distance of λ /10 (which is 3.5 cm @ 868 MHz and 1.2 cm @ 2.44 GHz) from the antenna to any other metal should be kept. Metal placed further away will not directly influence the behavior of the antenna, but will anyway produce shadowing.

Keep the antenna as far as possible from large metal objects to avoid electromagnetic field blocking.

In the following chapters, some special types of antenna are described.

### 18.3.1. Wire antenna

An effective antenna is a λ /4 radiator with a suiting ground plane. The simplest realization is a piece of wire. It's length is depending on the used radio frequency, so for example 8.6 cm 868.0 MHz and 3.1 cm for 2.440 GHz as frequency. This radiator needs a ground plane at its feeding point. Ideally, it is placed vertically in the middle of the ground plane. As this is often not possible because of space requirements, a suitable compromise is to bend the wire away from the PCB respective to the ground plane. The λ/4 radiator has approximately 40 Ω input impedance. Therefore, matching is not required.

### 18.3.2. Chip antenna

There are many chip antennas from various manufacturers. The benefit of a chip antenna is obviously the minimal space required and reasonable costs. However, this is often at the expense of range. For the chip antennas, reference designs should be followed as closely as possible, because only in this constellation can the stated performance be achieved.

### 18.3.3. PCB antenna

PCB antenna designs can be very different. The special attention can be on the miniaturization or on the performance. The benefits of the PCB antenna are their small / not existing (if PCB space is available) costs, however the EV of a PCB antenna holds more risk of failure than the use of a finished antenna. Most PCB antenna designs are a compromise of range and space between chip antennas and connector antennas.

### 18.3.4. Antennas provided by Würth Elektronik eiSos

Besides the radio modules Würth Elektronik eiSos provides various antennas tailored for the different frequency bands. The recommended single external antennas are shown in the subsequent chapters.

In case integrated multilayer chip antennas are needed because of space limitations, please refer to *https://www.we-online.com/en/components/products/WE-MCA*.

#### 18.3.4.1. 2600130021 - Himalia dipole antenna

Figure 13: Himalia dipole antenna

Due to the fact that the antenna has dipole topology, there is no need for an additional ground plane. Nevertheless, the specification was measured edge mounted and 90 ° bent on a 100 x 100 mm ground plane.

| Specification | Value |
|---|---|
| Frequency range [GHz] | 2.4 – 2.5 |
| Impedance [Ω] | 50 |
| VSWR | $\leq$ 2:1 |
| Polarization | Linear |
| Radiation | Omni-Directional |
| Peak Gain [dBi] | 2.8 |
| Average Gain [dBi] | -0.6 |
| Efficiency | 85 % |
| Dimensions (L x d) [mm] | 83.1 x 10 |
| Weight [g] | 7.4 |
| Connector | SMA plug |
| Operating temp. [°C] | -40 – +80 |

Special care must be taken for FCC certification when using this external antenna to fulfill the requirement of permanently attached antenna or unique coupling, for example by using the certified dipole antenna in a closed housing, so that it is possible to remove it only through professional installation.

# 19. Reference design

Proteus-I was tested and certified on the corresponding Proteus-I EV-Board. For the compliance with the EU directive 2014/53/EU Annex I, the EV-Board serves as reference design. This is no discrepancy due to the fact that the EV-Board itself does not fall within the scope of the EU directive 2014/53/EU Annex I as the module is tested on the EV-Board, which is also the recommended use.

Further information concerning the use of the EV-Board can be found in the manual of the Proteus-I EV-Board.

## 19.1. Schematic

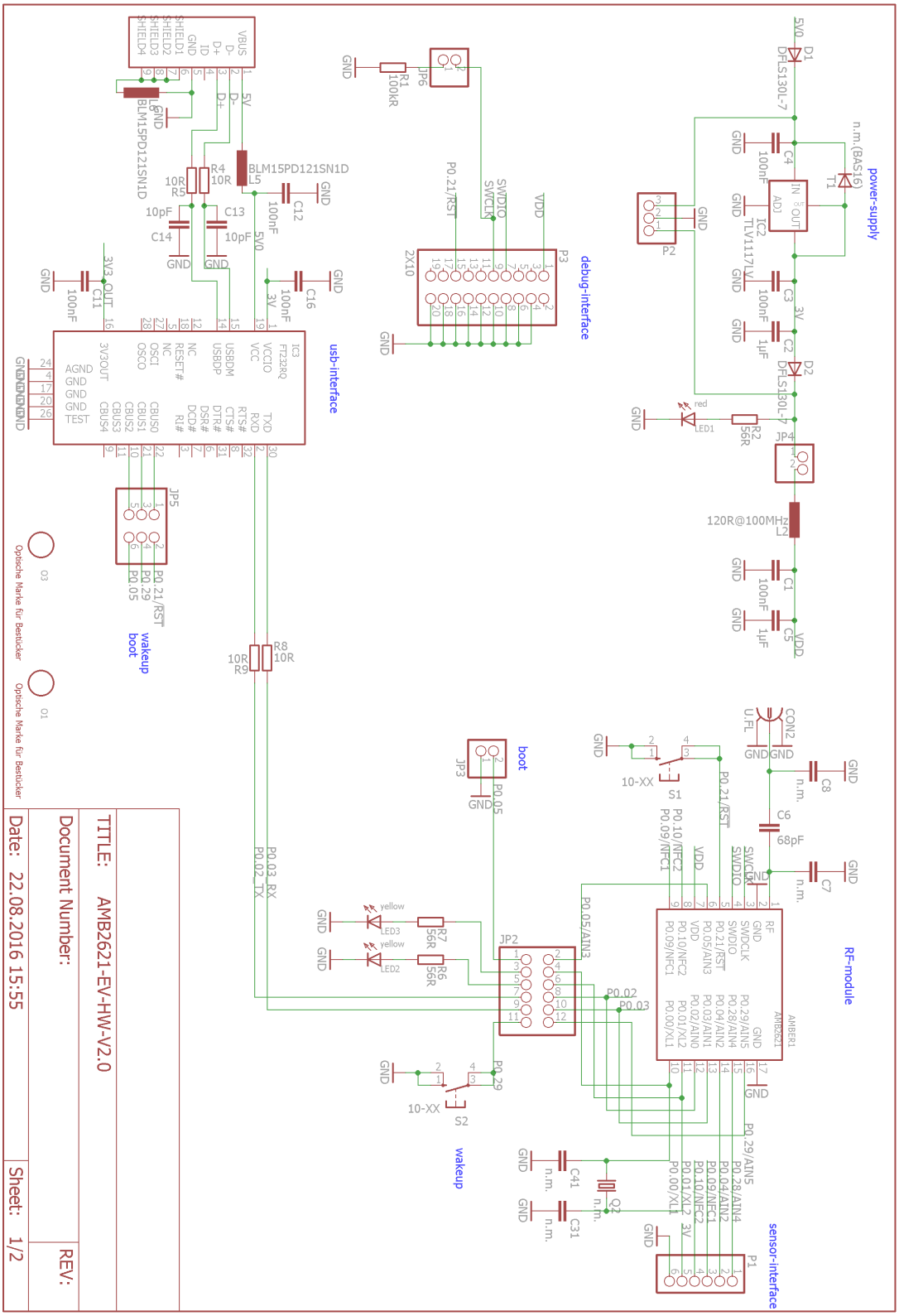



Figure 14: Circuit diagram

## 19.2. Layout

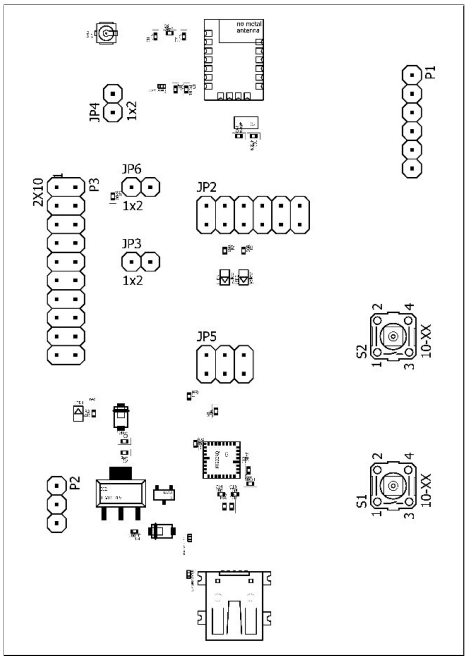



Figure 15: Assembly diagram

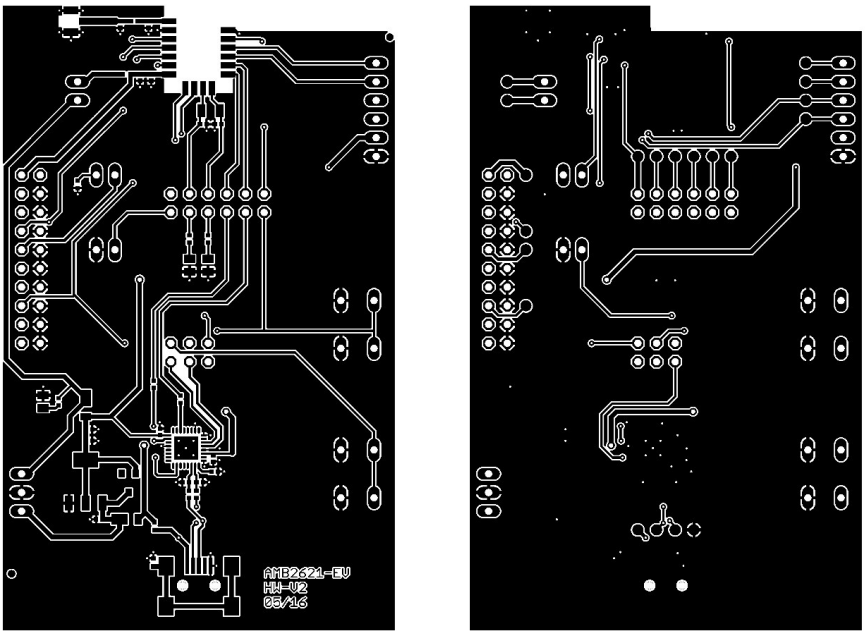



Figure 16: Top & bottom Layer

## 19.3. Internal antenna radiation characteristics

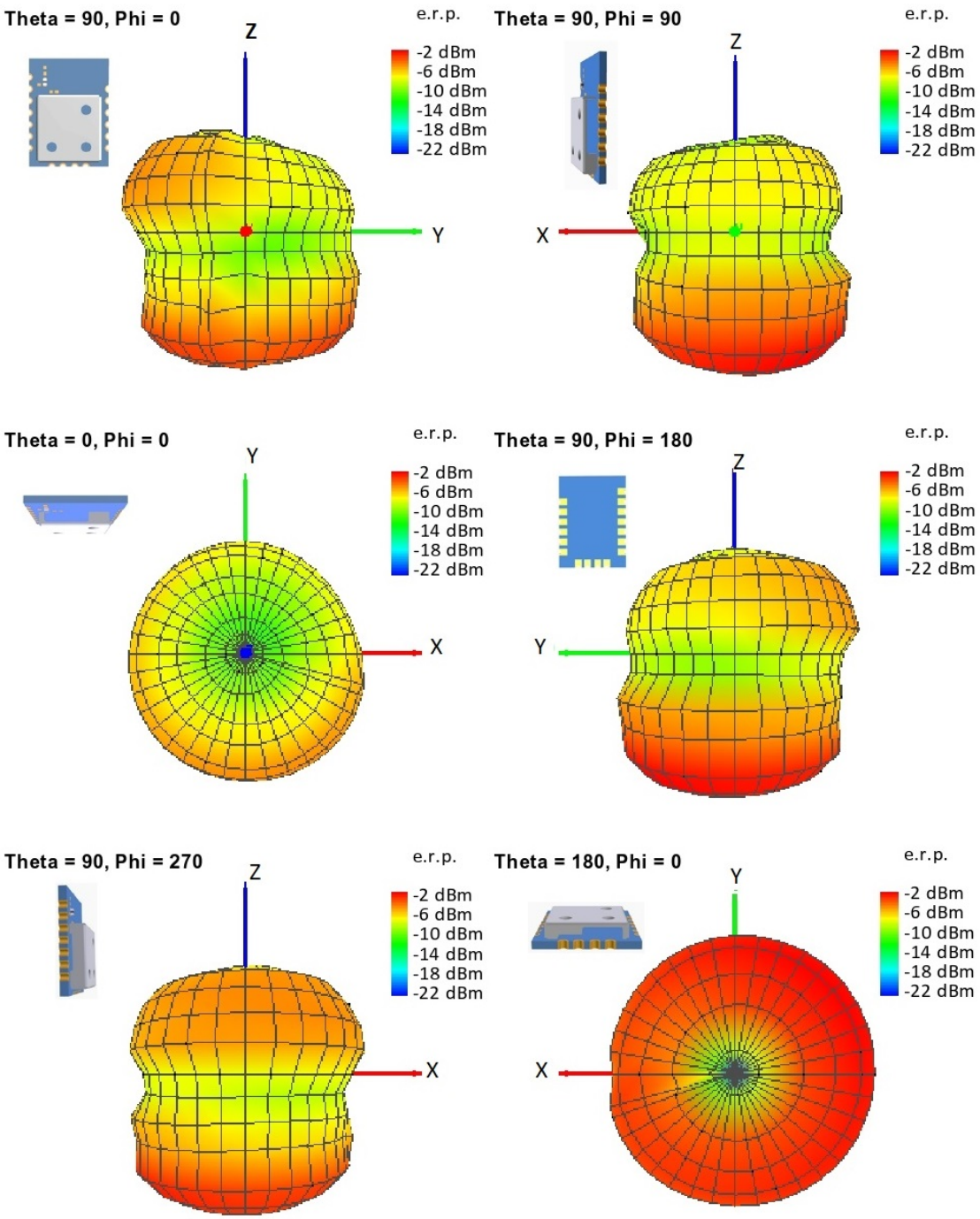



Figure 17: Antenna characteristic from integrated antenna measured on official EV-Board*

[1] Radiation characteristic shown is valid for the module on the EV-Board. It is important to be aware that size of groundplane and placement of module has influence on the radiation pattern.

# 20. Manufacturing information

## 20.1. Moisture sensitivity level

This wireless connectivity product is categorized as JEDEC Moisture Sensitivity Level 3 (MSL3), which requires special handling.
More information regarding the MSL requirements can be found in the IPC/JEDEC J-STD-020 standard on *www.jedec.org*.
More information about the handling, picking, shipping and the usage of moisture/reflow and/or process sensitive products can be found in the IPC/JEDEC J-STD-033 standard on *www.jedec.org*.

## 20.2. Soldering

### 20.2.1. Reflow soldering

Attention must be paid on the thickness of the solder resist between the host PCB top side and the modules bottom side. Only lead-free assembly is recommended according to JEDEC J-STD020.

| Profile feature | | Value |
|---|---|---|
| Preheat temperature, min | $T_{S\ Min}$ | 150 °C |
| Preheat temperature, max | $T_{S\ Max}$ | 200 °C |
| Preheat time from $T_{S\ Min}$ to $T_{S\ Max}$ | $t_S$ | 60 - 120 s |
| Ramp-up rate ($T_L$ to $T_P$) | | 3 °C/s max. |
| Liquidous temperature | $T_L$ | 217 °C |
| Time $t_L$ maintained above $T_L$ | $t_L$ | 60 - 150 s |
| Peak package body temperature | $T_P$ | 260 °C |
| Time within 5 °C of actual peak temperature | $t_P$ | 20 - 30 s |
| Ramp-down rate ($T_P$ to $T_L$) | | 6 °C/s max. |
| Time 20 °C to $T_P$ | | 8 min max. |

Table 56: Classification reflow soldering profile, Note: refer to IPC/JEDEC J-STD-020E

It is recommended to solder this module on the last reflow cycle of the PCB. For solder paste use a LFM-48W or Indium based SAC 305 alloy (Sn 96.5 / Ag 3.0 / Cu 0.5 / Indium 8.9HF / Type 3 / 89 %) type 3 or higher.

The reflow profile must be adjusted based on the thermal mass of the entire populated PCB, heat transfer efficiency of the reflow oven and the specific type of solder paste used. Based on the specific process and PCB layout the optimal soldering profile must be adjusted and verified. Other soldering methods (e.g. vapor phase) have not been verified and have to be validated by the customer at their own risk. Rework is not recommended.

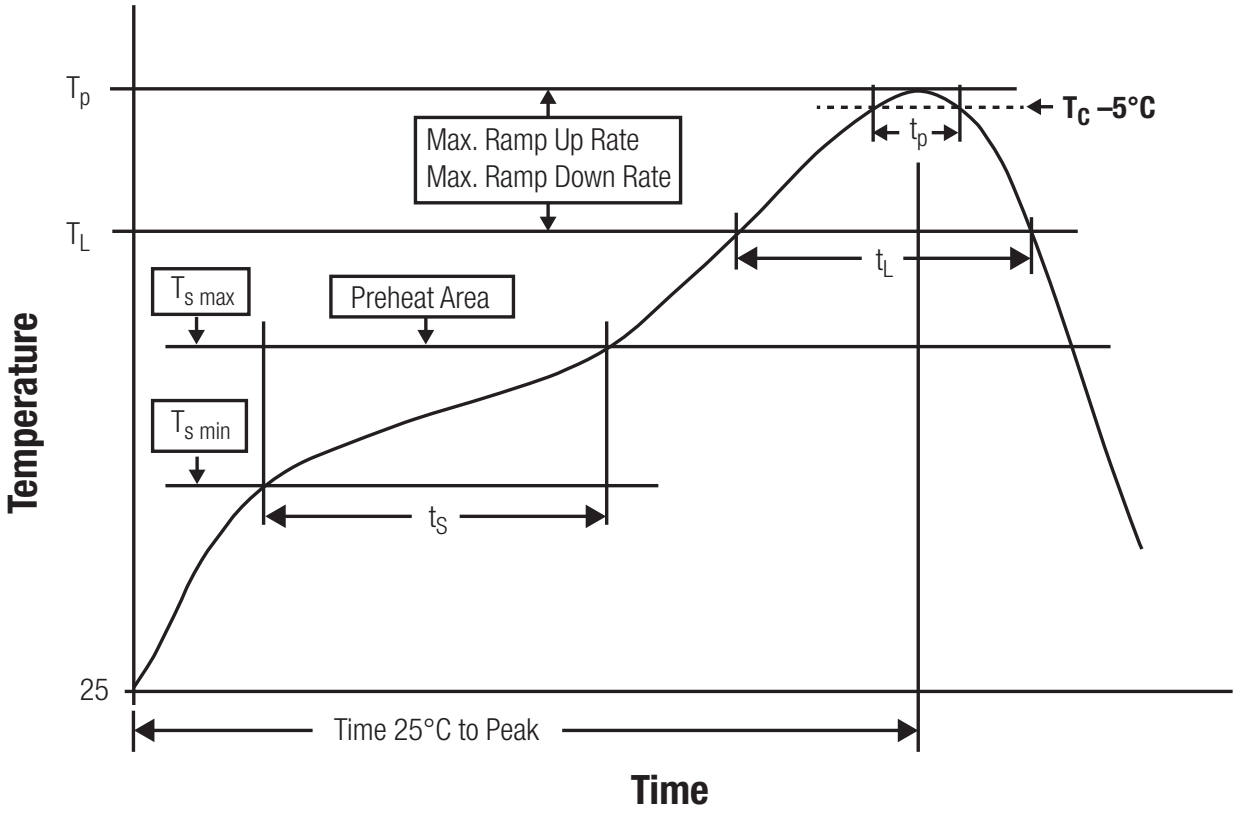



Figure 18: Reflow soldering profile

After reflow soldering, visually inspect the board to confirm proper alignment.

### 20.2.2. Cleaning

Do not clean the product. Any residue cannot be easily removed by washing. Use a "no clean" soldering paste and do not clean the board after soldering.

- Do not clean the product with water. Capillary effects can draw water into the gap between the host PCB and the module, absorbing water underneath it. If water is trapped inside, it may short-circuit adjoining pads. The water may also destroy the label and ink-jet printed text on it.
- Cleaning processes using alcohol or other organic solvents may draw solder flux residues into the housing, which won't be detected in a post-wash inspection. The solvent may also destroy the label and ink-jet printed text on it.
- Do not use ultrasonic cleaning as it will permanently damage the part, particularly the crystal oscillators.

### 20.2.3. Potting and coating

- If the product is potted in the customer application, the potting material might shrink or expand during and after hardening. Shrinking could lead to an incomplete seal, allowing contaminants into the component. Expansion could damage components. We recommend a manual inspection after potting to avoid these effects.
- Conformal coating or potting results in loss of warranty.
- The RF shield will not protect the part from low-viscosity coatings and potting. An undefined amount of coating and potting will enter inside the shielding.
- Conformal coating and potting will influence the parts of the radio front end and consequently influence the radio performance.
- Potting will influence the temperature behavior of the device. This might be critical for components with high power.

### 20.2.4. Other notations

- Do not attempt to improve the grounding by forming metal strips directly to the EMI covers or soldering on ground cables, as it may damage the part and will void the warranty.
- Always solder every pad to the host PCB even if some are unused, to improve the mechanical strength of the module.
- The part is sensitive to ultrasonic waves, as such do not use ultrasonic cleaning, welding or other processing. Any ultrasonic processing will void the warranty.

## 20.3. ESD handling

This product is highly sensitive to electrostatic discharge (ESD). As such, always use proper ESD precautions when handling. Make sure to handle the part properly throughout all stages of production, including on the host PCB where the module is installed. For ESD ratings, refer to the module series' maximum ESD section. For more information, refer to the relevant chapter 4. Failing to follow the aforementioned recommendations can result in severe damage to the part.

- The first contact point when handling the PCB is always between the local GND and the host PCB GND, unless there is a galvanic coupling between the local GND (for example work table) and the host PCB GND.
- Before assembling an antenna patch, connect the grounds.
- While handling the RF pin, avoid contact with any charged capacitors and be careful when contacting any materials that can develop charges (for example coaxial cable with around 50-80 pF/m, patch antenna with around 10 pF, soldering iron etc.)
- Do not touch any exposed area of the antenna to avoid electrostatic discharge. Do not let the antenna area be touched in a non ESD-safe manner.
- When soldering, use an ESD-safe soldering iron.

## 20.4. Safety recommendations

It is your duty to ensure that the product is allowed to be used in the destination country and within the required environment. Usage of the product can be dangerous and must be tested and verified by the end user. Be especially careful of:

- Use in areas with risk of explosion (for example oil refineries, gas stations).
- Use in areas such as airports, aircraft, hospitals, etc., where the product may interfere with other electronic components.

It is the customer's responsibility to ensure compliance with all applicable legal, regulatory and safety-related requirements as well as applicable environmental regulations. Disassembling the product is not allowed. Evidence of tampering will void the warranty.

- Compliance with the instructions in the product manual is recommended for correct product set-up.
- The product must be provided with a consolidated voltage source. The wiring must meet all applicable fire and security prevention standards.
- Handle with care. Avoid touching the pins as there could be ESD damage.

Be careful when working with any external components. When in doubt consult the technical documentation and relevant standards. Always use an antenna with the proper characteristics.

Würth Elektronik eiSos radio modules with high output power of up to 500 mW generate a large amount of heat while transmitting. The manufacturer of the end device must take care of potentially necessary actions for his application.

# 21. Product testing

## 21.1. Würth Elektronik eiSos in-house production tests

To achieve a high quality standard, Würth Elektronik eiSos follows a philosophy of supplying fully tested radio modules. At the end of the production process, every unit undergoes an optical inspection. Here the quality of soldering, edge castellation and edge milling is monitored.

If this has been passed, the radio modules are handed over to the automatic test equipment for the electrical characterization. This includes:

- Voltage and current tests to ensure proper electrical performance
- RF characteristics (frequency, spectrum, TX power) measurement and calibration
- Radio communication tests
- Firmware and serial number programming
- Host interface communication tests

The automated testing process is logged for internal quality control. The gained measurement data of each unit is analysed to detect defective parts and investigate the corresponding root cause. Defective radio modules are discarded, in order to guarantee a 100% failure-free delivery to customers.

## 21.2. EMS production tests

The rigorous in-series production testing ensures that EMS don't need to duplicate firmware tests or measurements. This streamlines the process and eliminates the need for additional testing over analogue and digital interfaces during device production. When it comes to device testing, the ideal focus should be on module assembly quality:

- All module pins are soldered properly on the base PCB
- There are no short circuits
- The mounting process did not damage the module
- The communication between host and radio module is working
- The antenna is connected properly

Simple "Go/No go" tests, like checking the RSSI value, give already a hint if the power supply and antenna have been connected properly.

In addition to such standard testing procedures, radio module integrators have the flexibility to perform additional dedicated tests to thoroughly evaluate the device. Specific tests they can consider are:

- Measure module current consumption in a specified operating state. Deviations from expected results (compared to a "Golden Device") can signal potential issues.

- Perform functional tests, including communication checks with the host controller and verification of interfaces.
- Assess fundamental RF characteristics (modulation accuracy, power levels, spectrum). Verify that the device meets expected performance standards.

# 22. Physical specifications

## 22.1. Dimensions

| Dimensions |
| --- |
| 11 x 8 x 2 mm |

Table 57: Dimensions

## 22.2. Weight

| Weight |
| --- |
| < 1 g |

Table 58: Weight

## 22.3. Module drawing

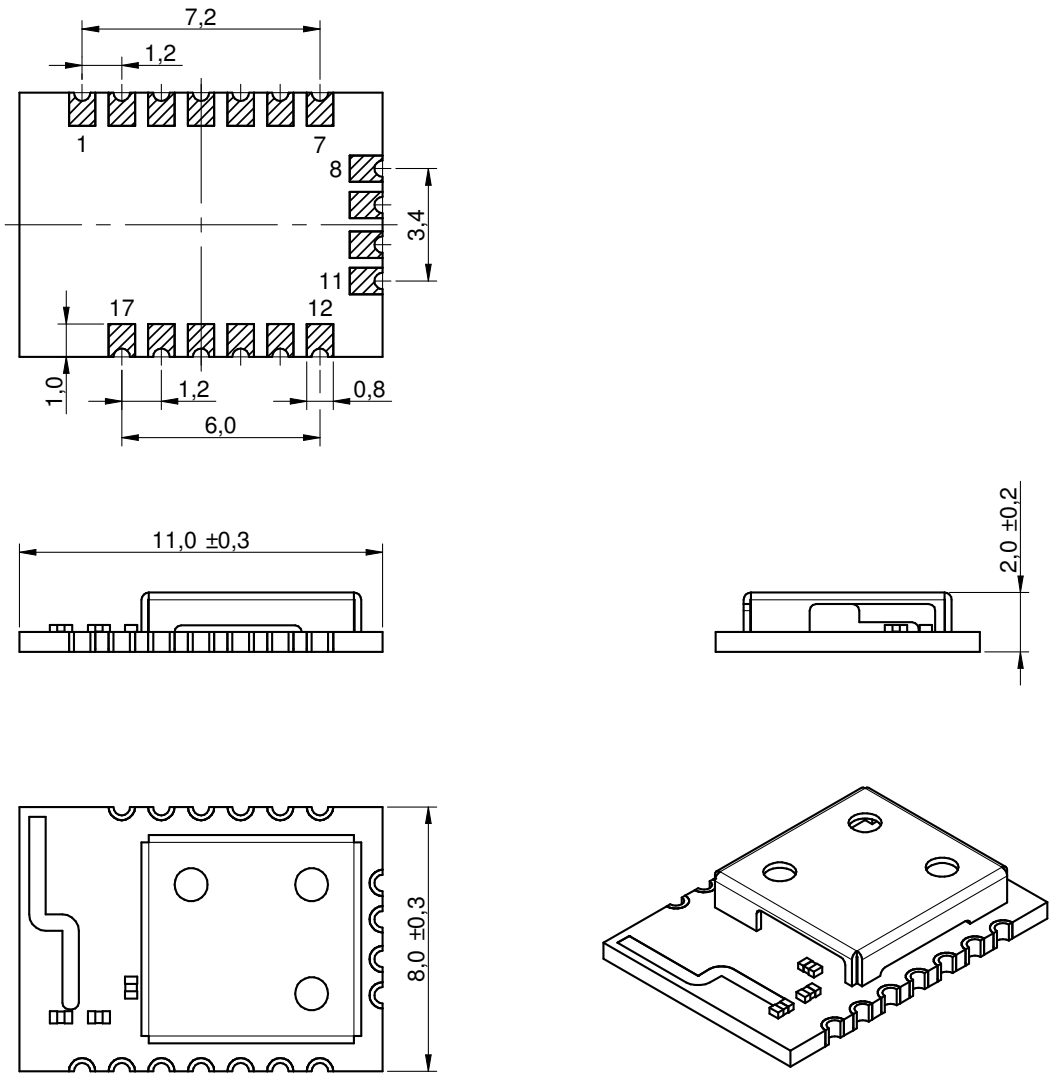



Figure 19: Module dimensions [mm]

## 22.4. Footprint WE-FP-4

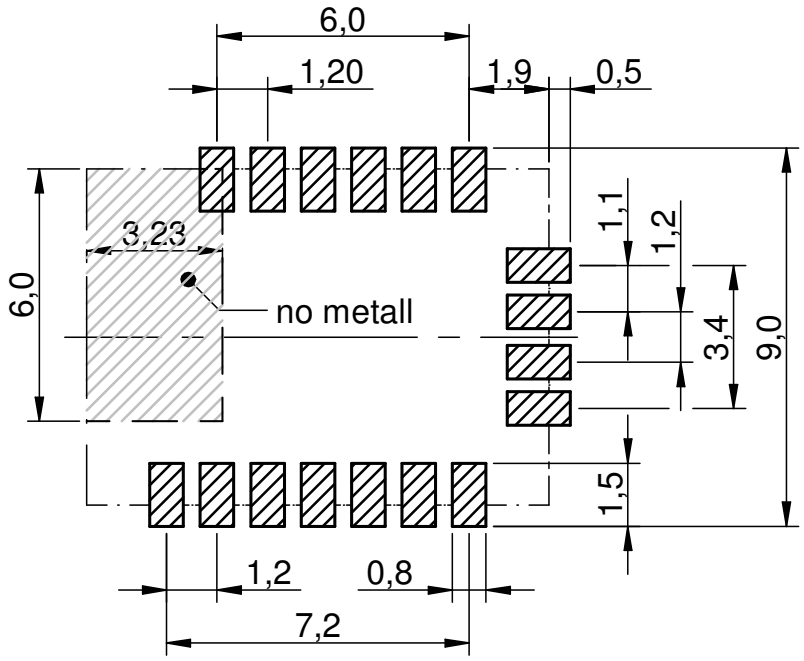



Figure 20: Footprint WE-FP-4 [mm]

## 22.5. Antenna free area

To avoid influence and mismatching of the antenna the recommended free area around the antenna should be maintained. As rule of thumb a minimum distance of metal parts to the antenna of λ/10 should be kept (see figure 20). Even though metal parts would influence the characteristic of the antenna, but the direct influence and matching keep an acceptable level.

# 23. Marking

## 23.1. Lot number

The 15 digit lot number is printed in numerical digits as well as in form of a machine readable bar code. It is divided into 5 blocks as shown in the following picture and can be translated according to the following table.

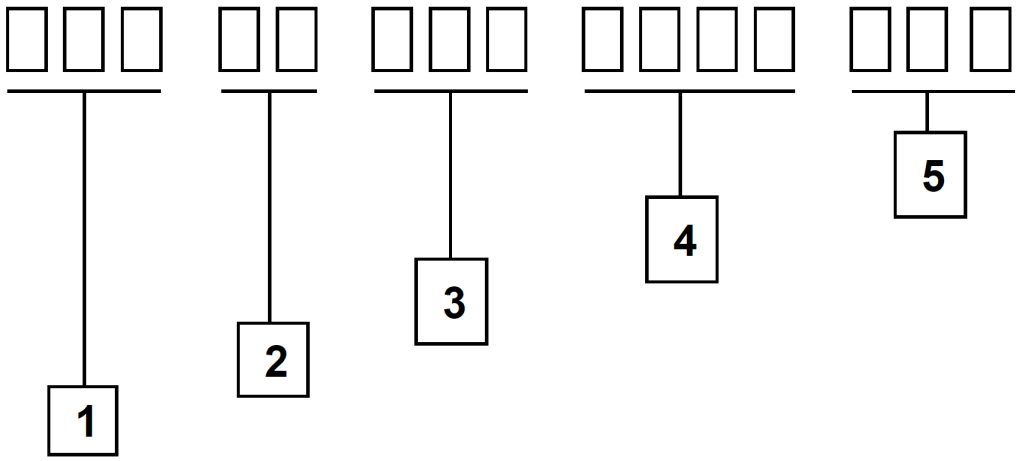



Figure 21: Lot number structure

| Block | Information | Example(s) |
|---|---|---|
| 1 | eiSos internal, 3 digits | 438 |
| 2 | eiSos internal, 2 digits | 01 |
| 3 | Radio module hardware version, 3 digits | V2.4 = 024, V12.2 = 122 |
| 4 | Date code, 4 digits | 1703 = week 03 in year 2017, 1816 = week 16 in year 2018 |
| 5 | Radio module firmware version, 3 digits | V3.2 = 302, V5.13 = 513 |

Table 59: Lot number details

As the user can perform a firmware update the printed lot number only shows the factory delivery state. The currently installed firmware can be requested from the module using the corresponding product specific command. The firmware version as well as the hardware version are restricted to show only major and minor version not the patch identifier. Block 5 is not applicable for products without firmware.

## 23.2. General labeling information

Labels of Würth Elektronik eiSos radio modules include several fields. Besides the manufacturer identification, the product's *WE* order code, serial number and certification information are placed on the label. In case of small labels, additional certification marks are placed on the label of the reel.
The information on the label are fixed. Only the serial number changes with each entity of the radio module. For Proteus-I the label is as follows:

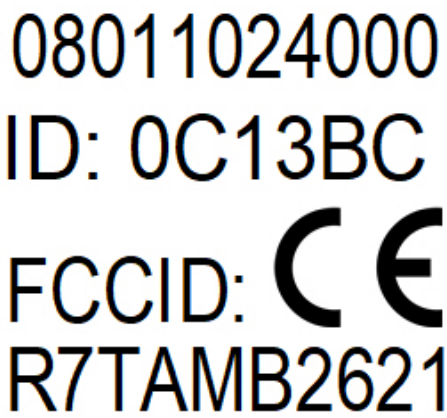



Figure 22: Label of the Proteus-I

# 24. Information for explosion protection

In case the end product should be used in Explosion protection areas the following information can be used:

- The module itself is unfused.
- The maximum output power of the module is 5 dBm for external antenna and 0 dBm for internal antenna.
- The total amount of capacitance of all capacitors is 5.9 µF.
- The total amount of inductance of all inductors is 10.025 µH.
- A DC/DC regulator is included in the chipset and used to obtain low power functionality.

# 25. Bluetooth SIG listing/qualification

| Type | Data |
|---|---|
| Design name | AMB2621 |
| Declaration ID | D033500 |
| QDID | 90212 |
| Specification name | 4.2 |
| Project type | End product |

Each product containing intellectual property of the Bluetooth® Special Interest Group (SIG) must be qualified by the SIG to obtain the corresponding Declaration ID.
Due to the qualification of the Proteus-I as end product no further Bluetooth® tests are required. The only arising expenses are those for purchasing a Bluetooth® Declaration ID.
To obtain the Bluetooth® listing of the end device, please refer to the application note ANR027 [6].

# 26. Regulatory compliance information

## 26.1. Important notice EU

The use of RF frequencies is limited by national regulations. The Proteus-I has been designed to comply with the RED directive 2014/53/EU of the European Union (EU).
The Proteus-I can be operated without notification and free of charge in the area of the European Union. However, according to the RED directive, restrictions (e.g. in terms of duty cycle or maximum allowed RF power) may apply.

Modifications (2014/53/EU article 3 (i))
Caution: Changes or modifications for this equipment not expressly approved by Würth Elektronik eiSos may void the CE conformity to operate this equipment.

## 26.2. Important notice UKCA

The UK's government has laid legislation to continue recognition of current EU requirements for a range of product regulations, including the CE marking. The Radio Equipment Regulation 2017/1206 is within the scope of this announcement, among others.
Consequently, the Proteus-I can be sold and utilized in the UK with the CE marking, without the need of UKCA declaration of conformity or UKCA marking.

Source: *https://www.gov.uk/guidance/ce-marking*

## 26.3. Important notice FCC

The use of RF frequencies is limited by national regulations. The Proteus-I has been designed to comply with the FCC Part 15.
The Proteus-I can be operated without notification and free of charge in the area of the United States of America. However, according to the FCC Part 15, restrictions (e.g. in terms of maximum allowed RF power and antenna) may apply.

## 26.4. Conformity assessment of the final product

The Proteus-I is a subassembly. It is designed to be embedded into other products (products incorporating the Proteus-I are henceforward referred to as "final products").
It is the responsibility of the manufacturer of the final product to ensure that the final product is in compliance with the essential requirements of the underlying national radio regulations.
The conformity assessment of the subassembly Proteus-I carried out by Würth Elektronik eiSos does not replace the required conformity assessment of the final product.

## 26.5. Exemption clause

Relevant regulation requirements are subject to change. Würth Elektronik eiSos does not guarantee the accuracy of the before mentioned information. Directives, technical standards, procedural descriptions and the like may be interpreted differently by the national authorities.

Equally, the national laws and restrictions may vary with the country. In case of doubt or uncertainty, we recommend that you consult with the authorities or official certification organizations of the relevant countries. Würth Elektronik eiSos is exempt from any responsibilities or liabilities related to regulatory compliance.

Notwithstanding the above, Würth Elektronik eiSos makes no representations and warranties of any kind related to their accuracy, correctness, completeness and/or usability for customer applications. No responsibility is assumed for inaccuracies or incompleteness.

## 26.6. EU Declaration of conformity

CE

**EU DECLARATION OF CONFORMITY**

**Radio equipment:** **2608011024000 & 2608011124000**

**The manufacturer:** Würth Elektronik eiSos GmbH & Co. KG
Max-Eyth-Straße 1
74638 Waldenburg

This declaration of conformity is issued under the sole responsibility of the manufacturer.

**Object of the declaration: 2608011024000 & 2608011124000**

The object of the declaration described above is in conformity with the relevant Union harmonisation legislation Directive 2014/53/EU. Following harmonised norms or technical specifications have been applied:

EN 300 328 V2.2.2 (2019-07)
EN 301 489-1 V2.2.3 (2019-11)
EN 301 489-17 V3.3.1 (2024-09)
EN 62479 : 2010
EN 62368-1:2014 + AC:2015
2011/65/EU with its amending Annex II EU 2015/863

i.A. G. Erdrich

Trier, 12th of January 2026
Place and date of issue

## 26.7. RED-DA Cybersecurity statement

Cybersecurity as per articles 3.3d, 3.3e and 3.3f of the Radio Equipment Directive Delegated Act. The RED-DA mandates to comply to the EN 18031-1, 18031-2 and 18031-3 in order to fulfill the requirements of the cybersecurity chapters (d, e and f).

- EN 18031-1: Common security requirements for radio equipment - Part 1: Internet connected radio equipment
- EN 18031-2: Common security requirements for radio equipment - Part 2: Radio equipment processing data, namely internet connected radio equipment, childcare radio equipment, toys radio equipment and wearable radio equipment
- EN 18031-3: Common security requirements for radio equipment - Part 3: Internet connected radio equipment processing virtual money or monetary value

| Requirements | Statement and conditions |
|---|---|
| (d) Radio equipment does not harm the network or its functioning nor misuses network resources, thereby causing an unacceptable degradation of service | "Not applicable":<br>The product is not capable itself to communicate over the internet. The product is only able to communicate via the following protocols and interfaces. None of the protocols contained in the product are "internet-connectable".<br><br>Radio communication protocols:<br>This Bluetooth (2.1, 4.x, 5.x, 6.x) product does not support or include the "Internet Protocol Support Profile". Bluetooth is a set of radio standards (e.g. Bluetooth Classic, Bluetooth Low Energy, Bluetooth MESH, Bluetooth LE Audio, ...) maintained by the Bluetooth SIG.<br><br>Host Interface, wired:<br>The host interface of the product does not support internet connectivity.<br>UART is used as a wired communication and control channel towards the customers host. |
| (e) Radio equipment incorporates safeguards to ensure that the personal data and privacy of the user and of the subscriber are protected | "Not applicable":<br>The product is not internet connected.<br>The product does not pose a risk to the users or subscribers privacy, as it does not store or process any personal data. |
| (f) Radio equipment supports certain features ensuring protection from fraud | "Not applicable":<br>The product is not internet connected.<br>The product does not pose a risk of fraud because it does not store or process financial data or enables financial transactions. |

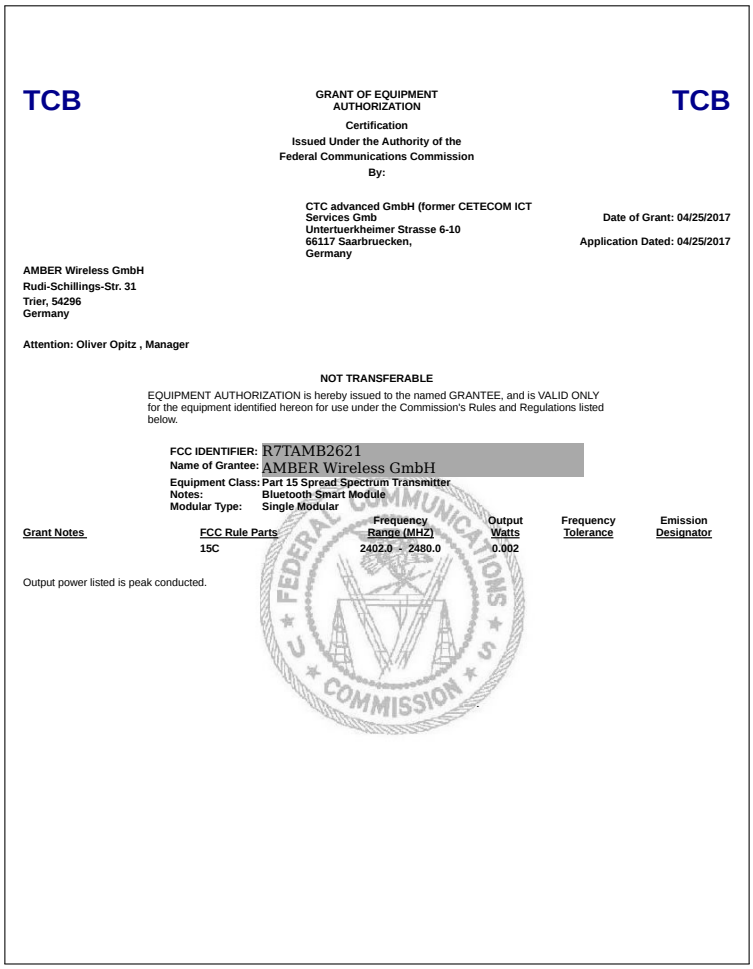
## 26.8. FCC Compliance Statement (US)

FCC ID: R7TAMB2621

This device complies with Part 15 of the FCC Rules.
Operation is subject to the following two conditions:
(1) this device may not cause harmful interference, and
(2) this device must accept any interference received, including interference that may cause undesired operation.
(FCC 15.19)

Modifications (FCC 15.21)
Caution: Changes or modifications for this equipment not expressly approved by Würth Elektronik eiSos may void the FCC authorization to operate this equipment.

### 26.8.1. FCC certificate



TCB

GRANT OF EQUIPMENT AUTHORIZATION

Certification

Issued Under the Authority of the Federal Communications Commission By:

TCB

CTC advanced GmbH (former CETECOM ICT Services Gmb
Untertuerkheimer Strasse 6-10
66117 Saarbruecken,
Germany

Date of Grant: 04/25/2017

Application Dated: 04/25/2017

AMBER Wireless GmbH
Rudi-Schillings-Str. 31
Trier, 54296
Germany

Attention: Oliver Opitz , Manager

NOT TRANSFERABLE

EQUIPMENT AUTHORIZATION is hereby issued to the named GRANTEE, and is VALID ONLY for the equipment identified hereon for use under the Commission's Rules and Regulations listed below.

FCC IDENTIFIER: R7TAMB2621
Name of Grantee: AMBER Wireless GmbH
Equipment Class: Part 15 Spread Spectrum Transmitter
Notes: Bluetooth Smart Module
Modular Type: Single Modular

| Grant Notes | FCC Rule Parts | Frequency Range (MHZ) | Output Watts | Frequency Tolerance | Emission Designator |
|---|---|---|---|---|---|
| | 15C | 2402.0 - 2480.0 | 0.002 | | |

Output power listed is peak conducted.

Figure 23: FCC certificate

## 26.9. IC Compliance Statement (Canada)

Certification Number: 5136A-AMB2621
HVIN: AMB2621
This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.
Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

### 26.9.1. IC certificate


TECHNICAL ACCEPTANCE CERTIFICATE
Canada

CETECOM ICT Services is now
CTC advanced
member of RWTÜV group

CTC advanced GmbH
CAB Identification Number DE0009
Authorized by the German Government to act as CAB (Conformity Assessment Body) in accordance with the MRA EU-Canada of 1st November 1998.
Bundesnetzagentur
BNetzA-CAB-03/22-51

| | |
|---|---|
| Certificate Holder | AMBER WIRELESS GmbH<br>Rudi-Schillings-Strasse 31<br>54296 Trier<br>Germany |
| IC Certification Number | 5136A-AMB2621 |
| Product Description | Bluetooth Smart Module |
| CTC Registration No. | 1626 |
| OATS Facility | CTC advanced GmbH<br>Untertuerkheimer Str. 6 -10<br>66117 Saarbruecken<br>Germany<br>Phone: +49 681 598-0<br>Fax: +49 681 598-8775<br>Email: |
| OATS Facility ID | 3462C-1 |

*Certification of equipment means only that the equipment has met the requirements of the above-noted specification. License applications, where applicable to use certified equipment, are acted on accordingly by the ISED issuing office and will depend on the existing radio environment, service and location of operation. This certificate is issued on condition that the holder complies and will continue to comply with the requirements and procedures issued by ISED. The equipment for which this certificate is issued shall not be manufactured, imported, distributed, leased, offered for sale or sold unless the equipment complies with the applicable technical specifications and procedures issued by ISED.*

*La certification du matériel signifie seulement que le matériel a satisfait aux exigences de la norme indiquée ci-dessus. Les demandes de licences nécessaires pour l'utilisation du matériel certifié sont traitées en conséquence par le bureau de délivrance d'ISED et dépendent des conditions radio ambiantes, du service et de l'emplacement d'exploitation. Le présent certificat est délivré à la condition que le titulaire satisfasse et continue de satisfaire aux exigences et aux procédures d'ISED. Le matériel à l'égard duquel le présent certificat est délivré ne doit pas être fabriqué, importé, distribué, loué, mis en vente ou vendu à moins d'être conforme aux procédures et aux spécifications techniques applicables publiées par ISED.*

*I hereby attest that the subject equipment was tested and found in compliance with the above-noted specification.*
*J'atteste par la présente que le matériel a fait l'objet d'essai et jugé conforme à la spécification ci-dessus.*

Place, date of issue
**Saarbrücken, 04/27/2017**

**CTC advanced GmbH**

FOREIGN CERTIFICATION BODY
FOREIGN CERTIFICATION BODY

Telecommunication Certification Body

*This certificate becomes valid when published in REL at :*
*Le présent certificat n'entre en vigueur qu'après être publié en REL sur :*
*https://sms-sgs.ic.gc.ca/equipmentSearch/searchRadioEquipments*

CTC advanced GmbH - Untertuerkheimer Str. 6-10
DE 66117 Saarbruecken - TCB@ctcadvanced.com - www.ctcadvanced.com

Figure 24: IC certificate

## 26.10. TELEC radio law approval (Japan)

Japanese Radio Law Compliance

This device has passed the Radio Law approval for Japan through the registered certification body TELEC. The corresponding ARIB (Association of Radio Industries and Businesses) standard has been applied. Accordingly, the market approval is given by the MIC (Ministry of Internal Affairs and Communications).

This device should not be modified (otherwise the granted designation number will become invalid)

| | |
|---|---|
| ID-Code (Interference provision) | The MAC address of the radio device maintains the format 00:18:DA:xx:xx:xx. The latter part xx:xx:xx of the MAC address coincides with the serial number of the device. |

### 26.10.1. Label

Due to the size of the Proteus-I (AMB2621) label, the certification label of the Proteus-I is not placed onto the module label.

| | |
|---|---|
| 260801102400x (AMB2621): |  R 202-LSG026 |
| 260801112400x (AMB2621-1): |  R 202-LSG029 |

After integration of the Proteus-I (AMB2621, AMB2621-1) in the end device, the corresponding certification label must be recognized from the outside. Otherwise this information must be referenced on the housing as well as in the user manual. E labeling is allowed.

### 26.10.2. Certified antennas

The Proteus-I is pre-certified with the following antennas.

| Product | Certified antennas |
|---|---|
| Proteus-I (2608011024000, AMB2621) | PCB antenna included in the Proteus-I |
| Proteus-I (2608011124000, AMB2621-1) | 260013021 (AMB1926) - 2.4 GHz dipole antenna[1] as specified in chapter 18.3.4.1 |

### 26.10.3. TELEC certificate

CTC advanced GmbH
Untertürkheimer Strasse 6-10, D-66117 Saarbrücken, Germany

*Conformity Assessment Body*
*Registered Certification Body for Japan*

認証書 TYPE - BASED CERTIFICATE

| | |
|---|---|
| Approval Holder<br>認証を受けた者 | Würth Elektronik eiSos GmbH & Co KG<br>Max-Eyth-Str. 1<br>74638 Waldenburg<br>Germany |
| Manufacturer Name<br>製造者名 | Würth Elektronik eiSos GmbH & Co KG<br>Max-Eyth-Str. 1<br>74638 Waldenburg<br>Germany |
| Model Name<br>型式又は名称 | AMB2621, 2608011024000, 2608011024010 |
| Classification of Specified Radio equipment<br>特定無線設備の種類 | Ordinance concerning Technical Regulations Conformity Certification etc. of Specified Radio Equipment<br>特定無線設備の技術基準適合証明等に関する規則<br>第 2 条第 1 項第 19 号に掲げる無線設備<br>Low power data communications system in the 2.4GHz band |
| Type of Emissions, Frequency and Antenna Power<br>電波の形式、周波数<br>及び空中線電力 | F1D 2402 ~ 2480MHz (2MHz separation, 40 channels) 0.0012W |
| Certified Number<br>認証番号 | 202-LSG026 |
| Certified Date<br>認証年月日 | 2020-05-28 |

上記のとおり、電波法第 38 条の 24 第 1 項の規定に基づく認証を行ったものであることを証する。
This is to certify that the above-mentioned certification by type has been granted in accordance with the provisions of Article 38-24, Paragraph 1 of the Radio Law.

Recognized by
The Ministry of Internal Affairs and Communications (MIC)
via
Bundesnetzagentur
BNetzA-CAB-03/25-51

CTC advanced GmbH
Stefan Mann
*Signature*

Page 1of 1

Figure 25: TELEC certificate (internal antenna)

[1] Additional, not yet certified, antennas must be re-certified without retesting. Only antenna gain and antenna characteristic diagrams must be specified. Please contact your Business Development Engineer (BDM) to get support in certifying your own antenna.

CTC advanced GmbH
Untertürkheimer Strasse 6-10, D-66117 Saarbrücken, Germany

*Conformity Assessment Body*
*Registered Certification Body for Japan*

認証書 TYPE - BASED CERTIFICATE

| | |
|---|---|
| **Approval Holder**<br>認証を受けた者 | **Würth Elektronik eiSos GmbH & Co KG**<br>**Max-Eyth-Str. 1**<br>**74638 Waldenburg**<br>**Germany** |
| **Manufacturer Name**<br>製造者名 | **Würth Elektronik eiSos GmbH & Co KG**<br>**Max-Eyth-Str. 1**<br>**74638 Waldenburg**<br>**Germany** |
| **Model Name**<br>型式又は名称 | **AMB2621-1, 2608011124000, 2608011124010** |
| **Classification of Specified Radio equipment**<br>特定無線設備の種類 | **Ordinance concerning Technical Regulations Conformity Certification etc. of Specified Radio Equipment**<br>**特定無線設備の技術基準適合証明等に関する規則**<br>**第 2 条第 1 項第 19 号に掲げる無線設備**<br>Low power data communications system in the 2.4GHz band |
| **Type of Emissions, Frequency and Antenna Power**<br>電波の形式、周波数<br>及び空中線電力 | **F1D 2402 ~ 2480MHz (2MHz separation, 40 channels) 0.0012W** |
| **Certified Number**<br>認証番号 | **202-LSG029** |
| **Certified Date**<br>認証年月日 | **2020-05-28** |

**上記のとおり、電波法第 38 条の 24 第 1 項の規定に基づく認証を行ったものであることを証する。**
This is to certify that the above-mentioned certification by type has been granted in accordance with the provisions of Article 38-24, Paragraph 1 of the Radio Law.

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via

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**CTC advanced GmbH**
**Stefan Mann**

*Signature*

Page 1of 1

Figure 26: TELEC certificate (external antenna)

## 26.11. Certification of the end device

For the certification of the end device, which integrates the Proteus-I, it is necessary to run the Bluetooth® direct test modes (DTM) on the Proteus-I and check its radio behavior.

To do that, the Proteus-I standard firmware provides already the required direct test mode commands (see chapter 9.6). These commands follow the radio module's command interface, and must be sent via UART to the Proteus-I.

For running the certification tests, the radio module's UART pins must be exposed to externally control the DTM functions.

In case the test house requires to use a Bluetooth® tester[2], the radio module must support the 2-wire DTM protocol on the UART. In this scenario it is necessary to flash the radio module with a 2-wire DTM firmware using the production flash interface mentioned in chapter 15.1.

In case it is required to flash the 2-wire DTM firmware, the SWD pins be exposed as well to use the production programming interface.

The 2-wire DTM firmware is provided on request, as well as the DTM GUI PC tool. This tool is used to send the DTM test commands to the radio module. It supports both protocols, the standard firmware DTM as well as the 2-wire DTM.

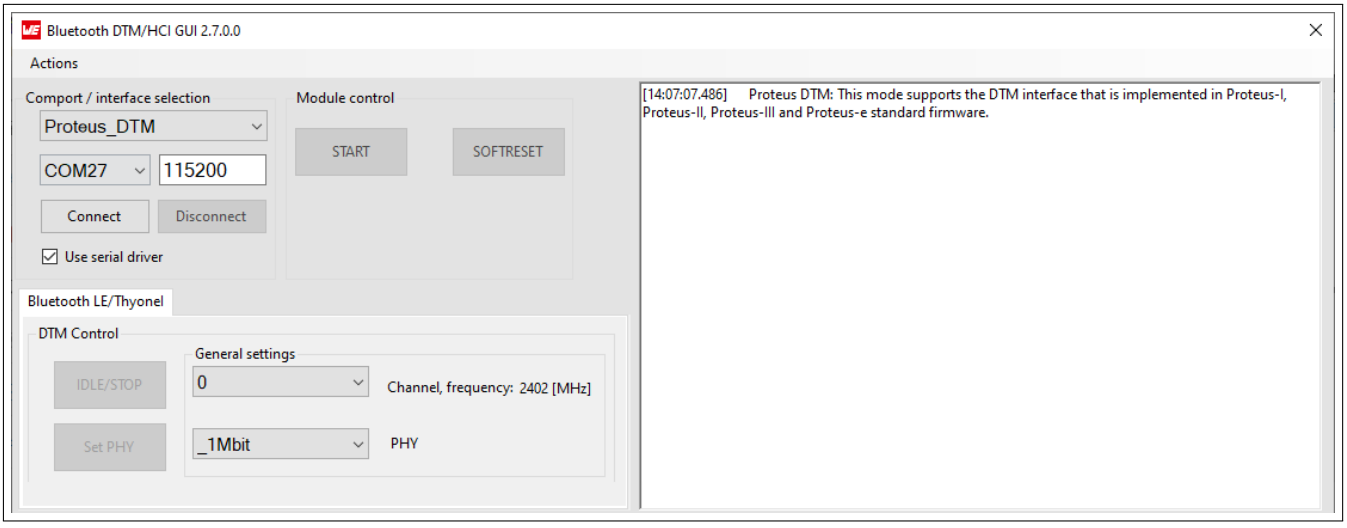


Figure 27: Bluetooth® DTM GUI PC tool

[2] A Bluetooth® tester is a certified device running automated tests on a connected Bluetooth® enabled device.

# 27. References

[1] Bluetooth®. Bluetooth® Core Specification, version 4.2. https://www.bluetooth.com/specifications/specs/core-specification-4-2/.

[2] Würth Elektronik. Application note 2 - Proteus-I advanced developer guide. http://www.we-online.com/ANR002.

[3] Würth Elektronik. WE UART Terminal PC tool (Smart Commander). https://www.we-online.de/wcs-software.

[4] Nordic Semiconductor. nRF Device Firmware Update app for Android. https://play.google.com/store/apps/details?id=no.nordicsemi.android.dfu.

[5] Nordic Semiconductor. nRF Device Firmware Update app for iOS. https://apps.apple.com/us/app/device-firmware-update/id1624454660.

[6] Würth Elektronik. Application note 27 - Bluetooth listing guide. http://www.we-online.com/ANR027.

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# A. Additional CRC8 Information

This Annex gives an example CRC8 implementation and test vectors.

## A.1. Example CRC8 Implementation

```
#include <stdint.h>

uint8_t Get_CRC8(uint8_t * bufP, uint16_t len)
{
    uint8_t crc = 0x00;
    for (uint16_t i = 0; i < len; i++)
    {
        crc ^= bufP[i];
    }
    return crc;
}
```

Code 1: Example CRC8 Implementation

## A.2. CRC8 Test Vectors

| Input data | Data length | Resulting CRC8 |
|---|---|---|
| Null | 0 | 0x00 |
| 0x02 0x01 0x00 0x00 | 4 | 0x03 |
| 0x02 0x87 0x01 0x00 0x16 | 5 | 0x92 |
| 0x02 0x04 0x04 0x00 0x41 0x42 0x43 0x44 | 8 | 0x06 |
| 0x02 0x88 0x07 0x00 0x00 0x55 0x00 0x00 0xDA 0x18 0x00 | 11 | 0x1A |

Table 61: CRC8 Test Vectors

# B. Example code for host integration

The following code is an example implementation of a function to transmit data using a 2 byte length field in the command frame. For demonstration reasons, the Proteus-III has been taken. The full function codes of all radio modules are available in the Wireless Connectivity SDK (*www.we-online.com/wco-SDK*).

```
#define CMD_PAYLOAD_MAX 964
typedef struct {
    uint8_t Stx;
    uint8_t Cmd;
    uint16_t Length;                /* LSB first */
    uint8_t Data[CMD_PAYLOAD_MAX+1]; /* +1 for CRC8 */
} CMD_Frame_t;
#define CMD_OFFSET_TO_DATAFIELD 4
#define CMD_OVERHEAD (CMD_OFFSET_TO_DATAFIELD+1)

bool ProteusIII_Transmit(uint8_t *PayloadP, uint16_t length)
{
    /* fill request message with STX, command byte and length field */
    CMD_Frame_t CMD_Frame;
    CMD_Frame.Stx = CMD_STX; /* 0x02 */
    CMD_Frame.Cmd = ProteusIII_CMD_DATA_REQ; /* 0x04 */
    CMD_Frame.Length = length;

    /* fill request message with user payload */
    memcpy(CMD_Frame.Data, PayloadP, length);

    /* fill request message with CRC8 */
    CMD_Frame.Data[CMD_Frame.Length] = Get_CRC8(&CMD_Frame, CMD_Frame.Length +
        CMD_OFFSET_TO_DATAFIELD);

    /* transmit full message via UART to radio module */
    UART_SendBytes(&CMD_Frame, (CMD_Frame.Length + CMD_OVERHEAD));

    /* wait for response message from radio module */
    return UART_Wait_for_Response(CMD_WAIT_TIME, ProteusIII_CMD_TXCOMPLETE_RSP,
        CMD_Status_Success, true);
}
```

Code 2: Example function implementation for radio modules with 2 byte length field

**Contact**
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