



ANR005 PROTEUS-II

ADVANCED DEVELOPER GUIDE

VERSION 1.2

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Revision history

Manual version	FW version	HW version	Notes	Date
1.0	1.0.0	2.1	<ul style="list-style-type: none"> • Initial version • New corporate design and structure • Updated chapter for custom firmware development 	November 2018
1.1	1.1.0	2.1	<ul style="list-style-type: none"> • Updated file name to new AppNote name structure. Updated important notes, legal notice & license terms chapters. 	June 2019
1.2	1.1.0	2.1	<ul style="list-style-type: none"> • Updated address of Division Wireless Connectivity & Sensors location in Trier 	October 2019

Abbreviations and abstract

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.
BLE	Bluetooth® Low Energy	According to Bluetooth® specification.
BT	Bluetooth®	According to Bluetooth® specification.
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.
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.

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1 Introduction

This document provides all the information necessary to integrate the Proteus-II BLE module into user application. The standard features available with the default firmware are described in detail. Further, key parameters of the BLE specifications necessary to ensure interoperability with Bluetooth® compliant third party devices are listed and described in detail. Besides of this, valuable hints to start an app development as well as to start a custom firmware development on base of the Proteus-II hardware are given in the subsequent chapters.

2 Prerequisites

A basic understanding of the Bluetooth® Low Energy standard as well as application development background on the desired platform is necessary to fully understand this document. The manual of Proteus-II contains basic information of the standard firmware and the software interfaces provided by the application. Please read this manual carefully and completely before using its information.

Würth Elektronik eiSos does not provide general support towards the Bluetooth® standard or smart device app development (independent of the platform).

3 Bluetooth® profiles

Bluetooth® specification uses so called "Profiles" to specify the general behavior of a Bluetooth® enabled device to communicate with other Bluetooth® devices. Profiles are built on the Bluetooth® standard to clearly define what kind of data is transmitted. The device's application determines which profiles it must support, from hands-free capabilities to heart rate sensors to alerts and more.

A device may support more than one profile. For two devices to be compatible, they must support the same BLE profile.

The Proteus-II module ships with the so called AMBER SPP-like (Serial Port Profile) profile created based on the Generic Attribute profile (GATT). This profile aims at providing a BLE based wireless replacement to a serial cable connection.

4 AMBER SPP-like profile

This section contains the key data of the AMBER SPP-like profile. Each device in the network must support this profile to communicate with an Proteus-II device with the default SPP-like firmware. Customer applications may support and/or provide other profiles, services or interfaces.

4.1 Generic Access Protocol (GAP)

The main purpose of this protocol is to describe the parameters of lower layers of the Bluetooth® stack including discovery, scanning and security capabilities. The Proteus-II GAP specifications are listed below:

- Appearance as specified in the user setting `RF_Appearance`.
- Device name as specified in the user setting `RF_DeviceName`.
- Device address (6 Byte MAC) of type "public", see user setting `FS_BTMAC` (0x0018DAxxxxxx)
- Timings:
 - See user settings `RF_ScanTiming` and `RF_ScanFlags` for scan and advertising related timing parameters like
 - * Advertising interval
 - * Scan window
 - * Scan interval
 - * Connection setup timeout
 - See user setting `RF_ConnectionTiming` for connection related timing parameters like
 - * Minimum connection interval
 - * Maximum connection interval
 - * Connection supervision timeout
 - See user setting `RF_TXPower` for TX power value.
 - See user setting `RF_SecFlags` for security settings.
 - Slave latency: 0
 - Peripheral requests for connection parameters update if central has differing connection parameters
 - * Connection parameters update (initial): 5s
 - * Connection parameters update (periodic): 10s
 - * Connection parameters update counter before connection shut down: 3

4.2 Generic Attribute Profile (GATT)



The directions RX and TX in this document are described from the perspective of a central role, see description below.

4.2.1 Data length extension

The Proteus-II supports up to 243 Byte of payload data. To use this feature the data length extension has to be requested by the central device. In this case, the GATT MTU size must be 243 Byte payload + 1 Byte AMBER header + 3 Byte NUS header, which is 247 Byte in total.

The PDU size should be 243 Byte payload + 1 Byte AMBER header + 3 Byte NUS header + 4 Byte BLE header, which is 251 Byte in total.

Check also the message charts in chapter 5 to see the MTU request in the connection setup process.

4.2.2 Company identifier

The Bluetooth® listed company identifier of Würth Elektronik eiSos (formerly Amber wireless GmbH) is 0x031A (794_{dec}).

4.2.3 UUID

The Proteus-II uses a 128Bit UUID of type "Vendor specific". The base UUID is adapted by the 16Bit UUIDs of the primary service and the corresponding characteristics.

These UUIDs are only allowed to be used when one of the two corresponding devices is a Proteus-II BLE module or contains a Proteus-II BLE module of Würth Elektronik eiSos which have installed AMBER SPP-like firmware.

Service	16Bit UUID	Full UUID
Proteus-II base		6E400000-C352-11E5-953D-0002A5D5C51B
Proteus-II primary service	0x0001	6E400001-C352-11E5-953D-0002A5D5C51B
TX_CHARACTERISTIC	0x0002	6E400002-C352-11E5-953D-0002A5D5C51B
RX_CHARACTERISTIC	0x0003	6E400003-C352-11E5-953D-0002A5D5C51B



By means of the user setting `RF_SPPBaseUUID` the base UUID can be adapted to generate a custom profile.

4.2.4 Primary Service

4.2.4.1 Characteristics

- The first characteristic of the Proteus-II primary service is TX_CHARACTERISTIC:
 - The data is sent from central/client to peripheral/server using a write command.
 - Server:
 - * Has to allow a write command as well as a write without response command.
 - Client:
 - * Use write command to send data to the server.
- The second characteristic of the Proteus-II primary service is RX_CHARACTERISTIC:
 - The data is sent from peripheral/server to central/client using a notification.
 - Server:
 - * Has to allow/enable notifications. Notify client/central when sending data.
 - * When the notification enable bit is written in the CCCD (Client Characteristic Configuration Descriptor) by the central, the peripheral prints a CMD_CHANNELOPEN_RSP on the UART to signalize that the peripheral can send data to the central now. The central can only write this bit, when the configured security level of the peripheral has been met.
 - Client:
 - * Has to enable notifications.

The permissions to access the characteristics is determined by the security mode of the module.

Proteus-II security mode	CCCD read	CCCD write, RX attribute read/write, TX attribute read/write
No security	no protection, open link	no protection, open link
Just works	no protection, open link	require encryption, but no MITM protection (Mode 1, Level 2)
Static pass key	no protection, open link	require encryption and MITM protection (Mode 1, Level 3)

4.3 BLE packet content

4.3.1 RF-Packet format

To identify the type of data transmitted via BLE, we introduced a 1 Byte packet header. Thus, the standard BLE payload has to match the following format to be understood by the Proteus-II:

BLE Payload	
AMBER Header	Payload
1 Byte	Φ_{ST} Bytes

Table 1: RF-packet format

The maximum payload size Φ_{ST} is 243 Bytes.

The AMBER Header has to be one of the following types:

0x01: RF_HEADER_TYPE_DATA: The following bytes contain the user payload data.

Other: Other headers are reserved for future use and packets with this header are currently discarded.

4.3.2 Advertising packet content

The standard Proteus-II advertising packet contains the following data:

- Advertising data flags
- The UUID (128 Bit Proteus-II primary service UUID) of the AMBER SPP-like profile
- TXPower level (1 Byte in two's complement notation, only in command mode)
- Proteus-II device name as Shortened Local Name (up to 5 Bytes in command mode, up to 8 Bytes in peripheral only mode)

4.3.3 Scan response packet content

The scan response packet is requested during scan if active scanning is enabled. The standard Proteus-II scan response packet contains the following data:

- Manufacturer data (up to 20 Bytes) in RF-packet format (see Table 1) using the company identifier. This manufacturer data is used to realize the Beacon feature.

5 App development

The definition of the AMBER SPP-like profile (see section 4) in combination with the message charts of chapter 5 are sufficient to develop custom apps for mobile devices. To implement this profile from scratch fundamental knowledge of app development as well as of the BLE standard is required.

5.1 Connection setup message charts

The following message charts show which steps are run during the connection setup process between two Proteus-II modules. To implement the central role in an app to connect to the Proteus-II peripheral the steps of the central device shown below have to be reproduced. More detailed information can be found in the message chart chapter of Nordic Semiconductor's documentation of the Softdevice S132 V6.0.0.

5.1.1 No security and authentication

If the Proteus-II peripheral does not use any security settings, we just have to connect to it. After connecting a MTU request is necessary to allow a higher payload size. After the discovery of the characteristics, the notification of the RX characteristic has to be enabled.

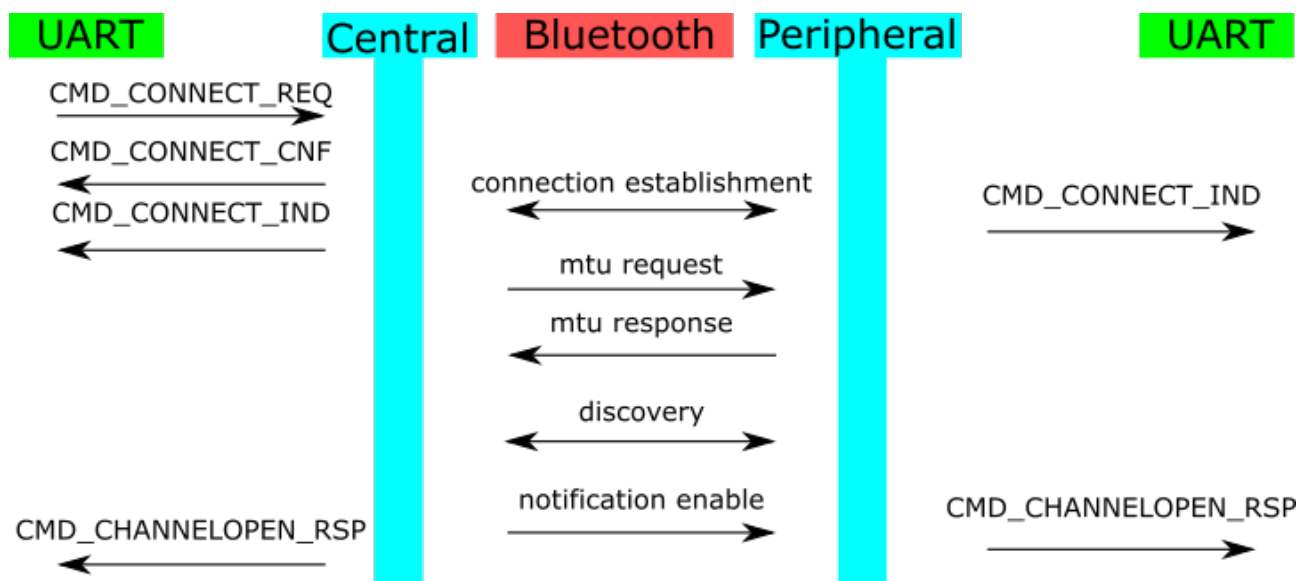


Figure 1: No security enabled

5.1.2 Just works pairing

If the Proteus-II peripheral needs the just works pairing security level, we just have to place a just works pairing request (no in/out capabilities, no mitm) after the connection step was run. Here a MTU request is necessary again to allow a higher payload size. After the discovery of the characteristics, the notification of the RX characteristic has to be enabled.

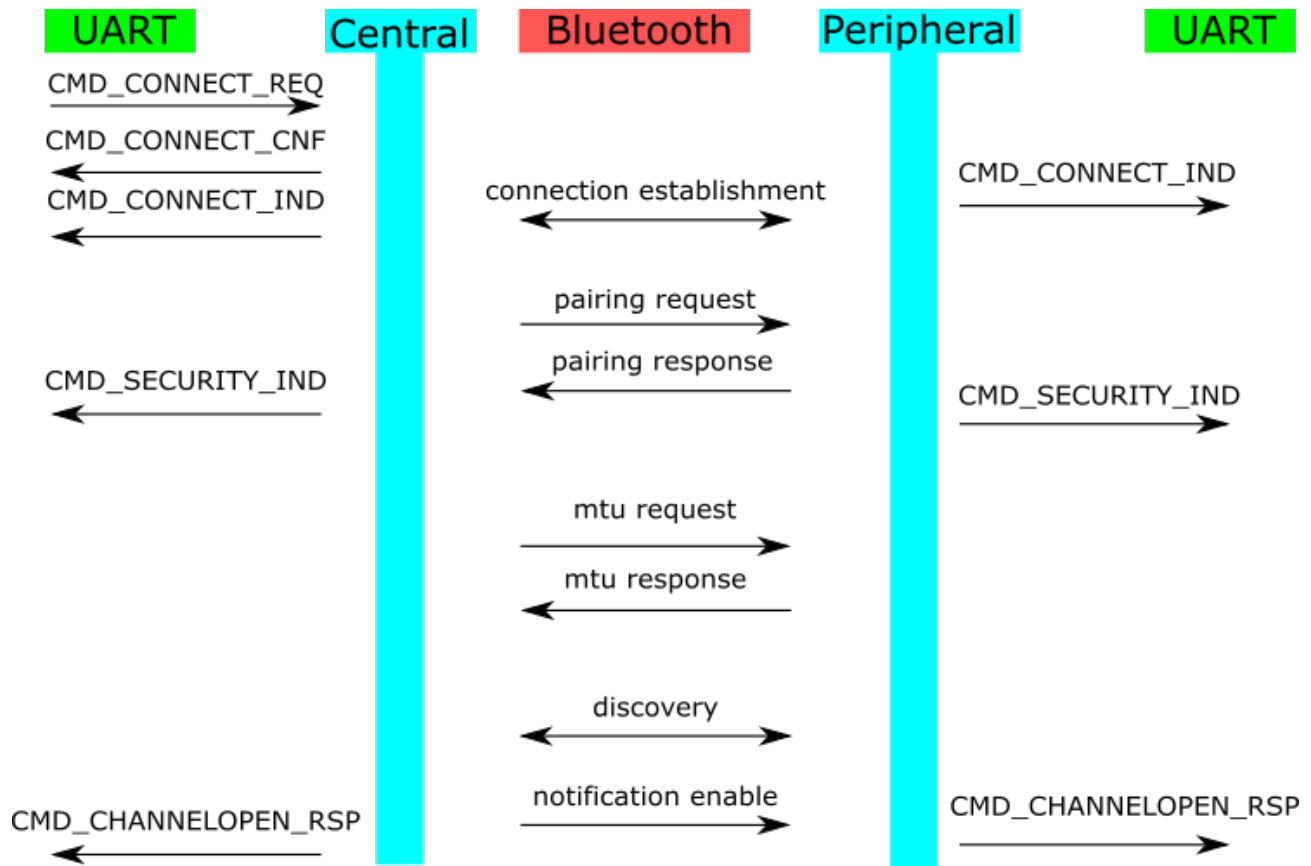


Figure 2: Just works pairing enabled

5.1.3 Static pass key pairing

If the Proteus-II peripheral needs the static pass key pairing security level, we just have to place a pairing request (keyboard only, mitm) after the connection step was run. The Proteus-II sends a pass key request, such that the static pass key of the Proteus-II peripheral has to be entered on the central side (app).

Afterwards a MTU request is necessary again to allow a higher payload size. After the discovery of the characteristics, the notification of the RX characteristic has to be enabled.

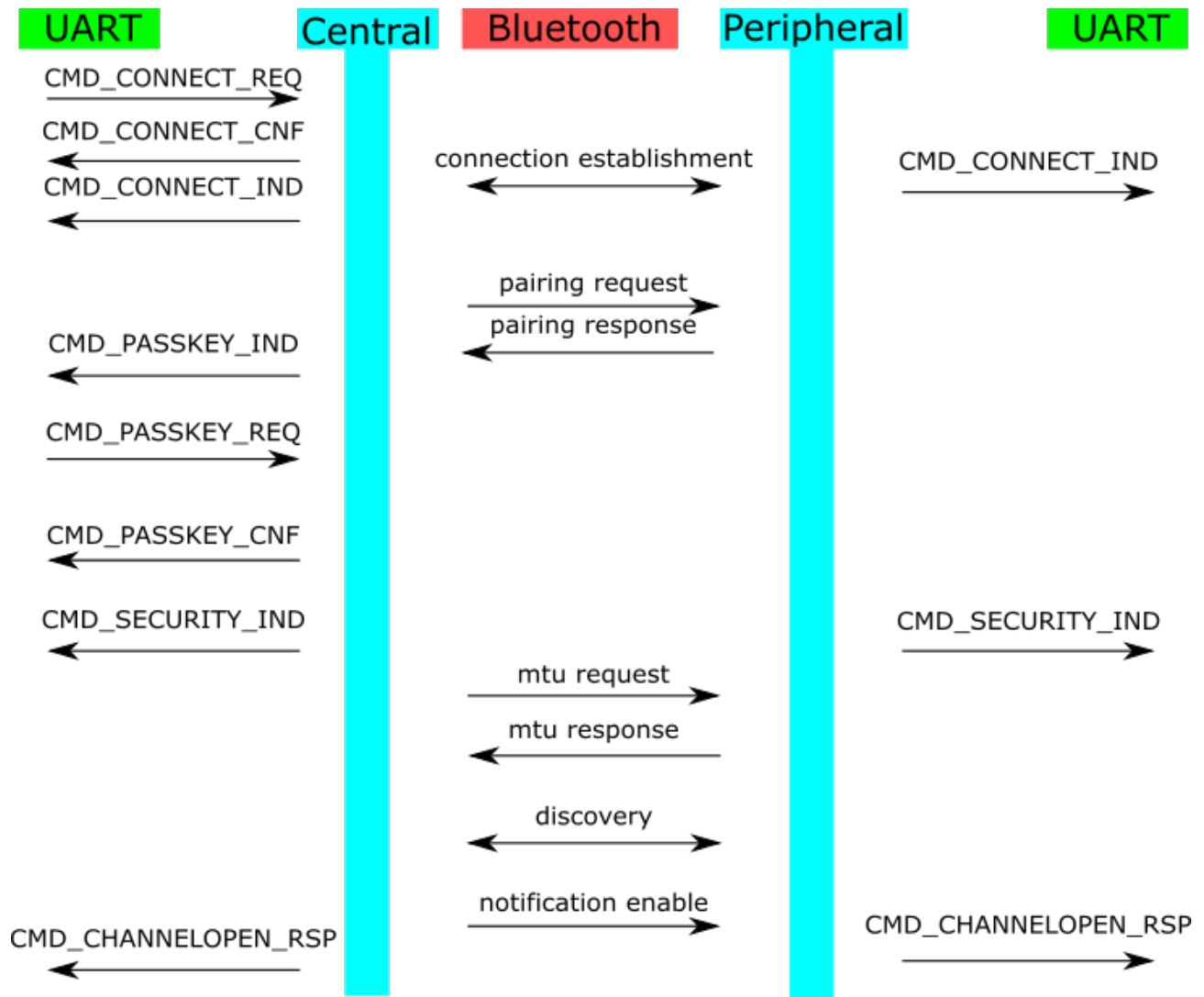


Figure 3: Static pass key pairing enabled

5.2 Bonding development hints

The firmware of the Proteus-II provides the bonding feature that allows to re-pair without repeating the authentication step (e.g. entering the static passkey). Thus, in the initial connection all bonding data is stored in the devices' flash to be used during the setup of subsequent connections.

The function `CMD_DELETEBONDS_REQ` of the Proteus-II allows to remove not needed bonding data from the module's flash. Thus in case of missing bonding data on one of the two connection partners, a re-bonding has to be initiated by the central device! Otherwise, the security level is not met to send the "notification enable" and thus the channel for data transmission cannot be opened.



Please note that iOS devices do not run the re-bonding step by default, if bonding data is missing on one of the two connection partners. In certain cases, the bonding data on the iOS device has to be cleared first, such that iOS starts the re-bonding step.

5.3 Nordic BLE UART example app as base

Nordic Semiconductor provides source code to develop Android, iOS and Windows applications. To implement the AMBER SPP-like profile for your own app, these source codes can be taken as a base for your own app development.



Please note that this app does not implement any authentication and security features. Thus, the Proteus-II to connect to must have no security enabled when using this provided example. Furthermore, the request for data length extension is not part of the provided source code.

The following few changes have to be applied to the Nordic UART-APP-example to implement the SPP-like profile:

- Replace the implemented UUIDs by the SPP-like profile UUID.
Android example:

```
private final static UUID UART_SERVICE_UUID = UUID.fromString("6E400001-C352-11E5-953D-0002A5D5C51B");
private final static UUID UART_RX_CHARACTERISTIC_UUID = UUID.fromString("6E400002-C352-11E5-953D-0002A5D5C51B");
private final static UUID UART_TX_CHARACTERISTIC_UUID = UUID.fromString("6E400003-C352-11E5-953D-0002A5D5C51B");
```

Code 1: Update UUID

- When sending data, add the packet header in front of the payload.
Android example:

```
public void send(final String text) {
    // Are we connected?
    if (mRXCharacteristic == null)
        return;
```

```

if (!TextUtils.isEmpty(text) && mOutgoingBuffer == null) {
final char AMBER_RF_HEADER_TYPE_DATA = 0x01;
final byte[] buffer = mOutgoingBuffer = (AMBER_RF_HEADER_TYPE_DATA + text).getBytes();
mBufferOffset = 0;
...
}

```

Code 2: Add packet header on sender side

```

public void onDataSent(final String data) {
if (AMBER_RF_HEADER_TYPE_DATA == data.charAt(0)) {
Logger.a(getLogSession(), "Valid_data_sent:\"\" + data.substring(1) + "\"");
}
else {
Logger.w(getLogSession(), "Invalid_data_sent:\"\" + data + "\"");
}
...
}

```

Code 3: Check packet header in sender callback

- When receiving data, first interpret the header to detect the data type before any other action (data output or command execution) is performed.

Android Example:

```

public void onDataReceived(final String data) {
if (AMBER_RF_HEADER_TYPE_DATA == data.charAt(0)) {
Logger.a(getLogSession(), "Valid_data_received:\"\" + data.substring(1) + "\"");
}
else {
Logger.w(getLogSession(), "Invalid_data_received:\"\" + data + "\"");
}
...
}

```

Code 4: Remove packet header on receiver side

6 Custom firmware development

Using the Proteus-II hardware a custom firmware can be developed to better fit the customer's needs. Based on the Nordic Semiconductor SDK and demo examples various BLE-profiles and custom applications can be realized and flashed on the Proteus-II module. The versatile and well documented Nordic stack ensures quick and easy realization of various standard BLE-profiles. Chapter 6.2 contains the information needed to run Nordic standard examples on the Proteus-II hardware.

On the other hand, Würth Elektronik eiSos provides firmware development services for customers that are not interested in writing their own firmware stack. Here, Würth Elektronik eiSos can quickly adapt the Proteus-II standard firmware to the customer's need or completely develop a new firmware from scratch (see chapter 6.1).

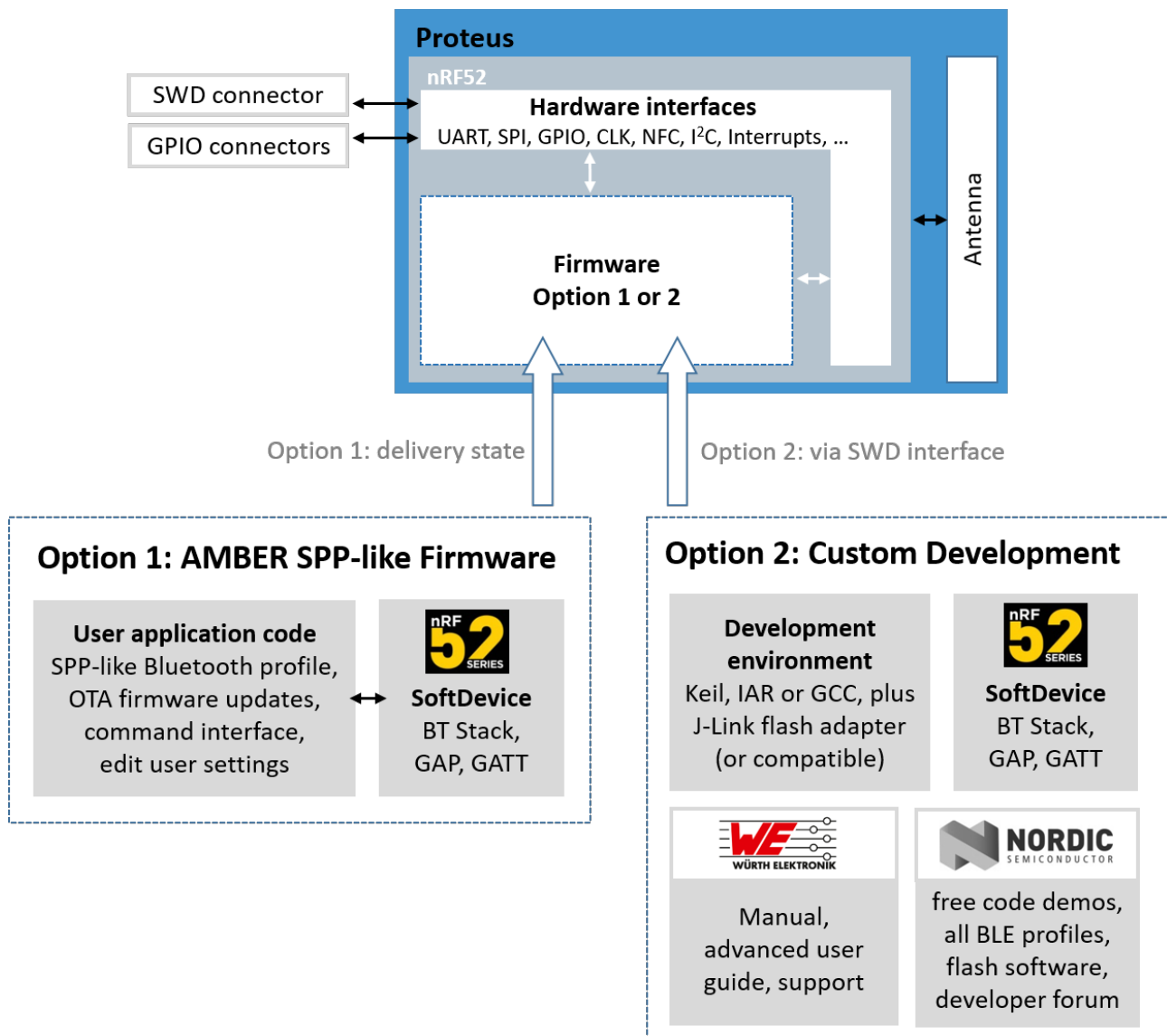


Figure 4: Options for running the Proteus-II with standard or custom firmware

6.1 Custom firmware services of Würth Elektronik eiSos

The Proteus-II firmware as described in the Proteus-II manual includes the Softdevice, a dual-bank bootloader and the application hosting the SPP-like protocol for RF communication. After flashing this firmware onto the chip, there are up to 128kB free memory for custom applications that can be included into the firmware on request.

If more memory is needed, the dual-bank bootloader can be replaced by a single-bank bootloader or even completely removed. In this case, more than 300kB of memory can be reserved for custom application code. As an alternative external Flash/EEPROM IC(s) can be connected to the module (e.g. using SPI or I2C interface) on the customer PCB.



Source codes for the Proteus-II SPP-like firmware are property of Würth Elektronik eiSos and will not be provided to customers. Nonetheless, Würth Elektronik eiSos may consider different license models or exceptions for individual customers.

Besides of this, Würth Elektronik eiSos also provides custom firmware developments from scratch. Please contact your local field sales engineer (FSE) or wireless-sales@we-online.com to discuss further details.

6.2 Important information for custom firmware development

To start a custom firmware development on top of the Proteus-II hardware, the following information must be considered:

- **Chip**
The Proteus-II contains the Nordic Semiconductor nRF52832-CHAA SoC. The CPU is a 64MHz ARM Cortex-M4F.
- **Pinout**
The Proteus-II provides the following pins of the Nordic SoC with its pads. Only the *RF*, *GND*, *VDD*, *Reset*, *SWDCLK* and *SWDIO* pins are fixed. All other pins can be used for custom firmware development. For special functions like near field communication (NFC), external low frequency quartz crystal XL or analog input (AIN) the respective pins have to be used.

No.	Pad Name	No.	Pad Name
1	RF	9	P0.09/NFC1
2, 17	GND	10	P0.00/XL1
3	SWDCLK	11	P0.01/XL2
4	SWDIO	12	P0.02/AIN0
5	P0.21/Reset	13	P0.03/AIN1
6	P0.05/AIN3	14	P0.04/AIN2
7	VDD	15	P0.28/AIN4
8	P0.10/NFC2	16	P0.29/AIN5

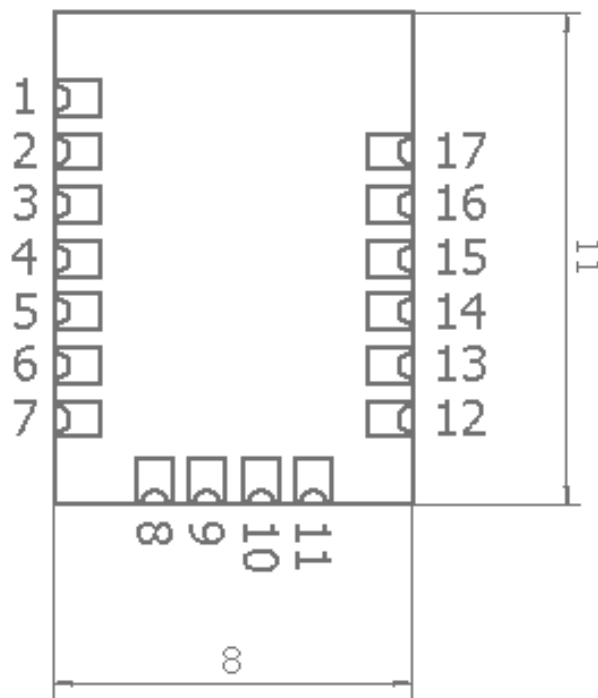


Figure 5: Pinout

- **Hardware for development & debugging**
Using Segger J-Link flasher and the SWD interface is required for firmware development and debugging. Checkout the Proteus-II-EV board. It provides the easiest way to develop software based on Proteus-II module or apps for the SPP-like profile.
- **Software development environment**
Nordic Semiconductor provides software packages for several compilers (KEIL, IAR, GCC, Segger Embedded).
For example, the Keil SDK includes the required BLE stack ("Softdevice"), many demo examples for BLE profiles and services to conveniently develop a custom firmware on basis of the Nordic SoC. Further library's for hardware peripheral (such as ADC, I2C, SPI, UART etc.) are also include in the SDK and examples. More information and details about the chip and the operating system is bundled on the Nordic Semiconductor Infocenter:
<http://infocenter.nordicsemi.com/>

Please check the tab "nRF52 Series" to access the newest information about the nRF52 radio chip and the software environment.
If available, use the examples for the Nordic evaluation platform (like PCA10040 or PCA10056) as a starting point. See also chapter 6.2.1 for more information how to run Nordic standard examples on top of the Proteus-II.
- **Clock sources**
The Proteus-II module contains a dedicated RF clock (HFCLK). The Proteus-II does not contain a dedicated low frequency clock (LFCLK). Thus custom firmware must use the internal RC-oscillator as long as no external clock crystal is connected to the

respective pins (*XL1*, *XL2*) on the customer PCB.

Example for enabling the internal RC oscillator for Softdevice S132 V3.1.0 and SDK 12.3.0:

```
nrf_clock_lf_cfg_t clock_lf_cfg = {
    .source = NRF_CLOCK_LF_SRC_RC,\
    .rc_ctiv = 16,\
    .rc_temp_ctiv = 2,\
};

SOFTDEVICE_HANDLER_INIT(&clock_lf_cfg, NULL);
```



Code may differ when using different Softdevice and/or SDK version.

- Voltage regulator

As internal voltage regulator, we recommend to use the DCDC instead of the LDO. The DCDC has to be switched on explicitly in application code. Example for Softdevice S132 V3.1.0 and SDK 12.3.0:

```
sd_power_dcdc_mode_set(NRF_POWER_DCDC_ENABLE);
```



Code may differ when using different Softdevice and/or SDK version.

Changing from LDO to DCDC reduces the current consumption of the module to meet lowest power specifications.

- Certification

Custom firmware may require additional certification. Please contact your BT certified testing laboratory regarding this questions.

- BT-Listing

Any (end-)device containing Bluetooth® IP must be listed by the BT SIG which requires membership and qualification. Please contact the BT SIG or your preferred BT certification laboratory for question. Further information are available in the Proteus-II manual.

- Serial number

The unique serial number (used for tracing and the generation of the Proteus-II BT-MAC) is placed in the user information configuration register (UICR->Customer[0]) and will be removed by flashing a customer firmware onto the SoC.

6.2.1 How to adapt Nordic Semiconductor SDK examples to run on the Proteus-II hardware?



The following description is based on the SDK 12.3.0. Code may differ when using a different Softdevice and/or SDK version.

Please perform the following steps to run a Nordic standard example on the Proteus-II:

1. Open the example project of interest and compile.
2. In case of success¹, enable the DCDC by adding the following line at the end of the stack init function.

```
static void ble_stack_init(void){
.
.
.
// Enable DCDC
err_code = sd_power_dcdc_mode_set(NRF_POWER_DCDC_ENABLE);
APP_ERROR_CHECK(err_code);
}
```

3. Go to the file board.h and add the include for the Proteus-II.h board file.

```
#if defined(BOARD_PCA10040)
#include "pca10040.h"
#elif defined(BOARD_PROTEUSI)
#include "ProteusI.h"
#elif defined(BOARD_PROTEUSII)
#include "ProteusII.h"
#elif defined(BOARD_PROTEUSIII)
#include "ProteusIII.h"
#else
#error "Board_is_not_defined"

#endif
```

¹ If you have a Nordic evaluation board available, please check that the original example without modifications runs successfully on the evaluation board.

4. Then create the Proteus-II board file. To do so, please copy the board file of the Nordic evaluation board (like PCA10040 or PCA10056) and add the pinout, led button numbering, button numbering and clock definition of the Proteus-II:

```
#ifndef PROTEUSII_H
#define PROTEUSII_H

/* PINS of the nRF52:
 * The pins are named w.r.t their function in the PROTEUSII standard firmware
 */

#define NRF_PIN_LED_1 0
#define NRF_PIN_LED_2 1
#define NRF_PIN_UARTTX 2
#define NRF_PIN_UARTRX 3
#define NRF_PIN_UARTRTS 4
#define NRF_PIN_BOOT 5
#define NRF_PIN_6 6
#define NRF_PIN_7 7
#define NRF_PIN_8 8
#define NRF_PIN_CUSTOM_9 9 /* corresponds to PROTEUSII_PIN_9 */
#define NRF_PIN_OPERATIONMODE 10 /* corresponds to PROTEUSII_PIN_8 */
#define NRF_PIN_11 11
#define NRF_PIN_12 12
#define NRF_PIN_13 13
#define NRF_PIN_14 14
#define NRF_PIN_15 15
#define NRF_PIN_16 16
#define NRF_PIN_17 17
#define NRF_PIN_18 18
#define NRF_PIN_19 19
#define NRF_PIN_20 20
#define NRF_PIN_RESET 21
#define NRF_PIN_22 22
#define NRF_PIN_23 23
#define NRF_PIN_24 24
#define NRF_PIN_25 25
#define NRF_PIN_26 26
#define NRF_PIN_27 27
#define NRF_PIN_UARTCTS 28
#define NRF_PIN_SLEEP 29
#define NRF_PIN_30 30
#define NRF_PIN_31 31

// LEDs definitions for PROTEUSII
#define LEDS_NUMBER 2
#define LEDS_LIST {NRF_PIN_LED_1, NRF_PIN_LED_2}
#define BSP_LED_0 NRF_PIN_LED_1
#define BSP_LED_1 NRF_PIN_LED_2
/* all LEDs are lit when GPIO is low */
#define LEDS_ACTIVE_STATE 1
#define LEDS_INV_MASK LEDS_MASK

// Buttons definitions for PROTEUSII
#define BUTTONS_NUMBER 1
#define BUTTONS_LIST {NRF_PIN_SLEEP}
#define BSP_BUTTON_0 NRF_PIN_SLEEP
#define BUTTON_PULL NRF_GPIO_PIN_PULLUP
```

```
#define BUTTONS_ACTIVE_STATE 0

// UART definitions for PROTEUSII
#define RX_PIN_NUMBER NRF_PIN_UARTRX
#define TX_PIN_NUMBER NRF_PIN_UARTTX
#define RTS_PIN_NUMBER NRF_PIN_UARTRTS
#define CTS_PIN_NUMBER NRF_PIN_UARTCTS

// Low frequency clock source to be used by the SoftDevice
#define NRF_CLOCK_LFCLKSRC {
    .source = NRF_CLOCK_LF_SRC_RC,\
    .rc_ctiv = 16,\
    .rc_temp_ctiv = 2,\
}

#endif // PROTEUSII_H
```

Code 5: Content of the ProteusII.h

5. Then check that the Proteus-II hardware is used instead the Nordic evaluation board hardware. This can be done by adding/removing the respective macros in the precompiler options of the project.
6. Then check that the correct pins of the Proteus-II.h are used. Probably peripheral pins (UART, SPI,...), LED pins and/or button pins have to be adapted to fit the pin definition of the Proteus-II.h .



Please make sure that the selected pin number and its function matches the underlying hardware (e.g. evaluation board Proteus-II-EV).

7. Now all necessary changes have been done. Thus recompile the whole project and check for errors.
8. In case of success, erase the whole chip and flash ONLY the Softdevice onto the chip. The J-Flash tool can be used to do so.
9. After this, flash the compiled project code onto the chip using Keil (or the IDE of your choice) without erasing the flash area of the Softdevice.
10. Now, the whole code was flashed. Thus testing can start.

6.2.2 Firmware development hints

When creating a custom firmware the following hints may be useful during development:

- In standard Nordic examples, the *Reset* pin is hard coded. We recommend using the pin definition of the board-file to guarantee that changes in the layout take effect.
- After the chip was flashed or when a clock signal was applied to the *SWCLK* pin, the chip is in debug mode. In this case, all chip states are simulated. Please repower the chip to be in normal mode to test modes like the system off mode (especially when you want to measure currents of a low power mode).

- Reviewing the pin settings (direction, pull-up/-down resistors) of the firmware is the first option when experiencing leakage current.
- The *UART RX* pin is quite sensitive towards wrong levels during UART start-up. A floating *UART RX* pin of the SoC may result in unwanted behavior. In this case, an internal or external pull-up resistor can be installed to prevent floating. Be aware that this resistor will lead to leakage current.
- The *NFC* pins are optimized for NFC function and can lead to leakage current when not used properly in GPIO mode.
- Checkout the errata sheet of the nRF52 SoC to have an overview of known issues with the nRF52 SoC and possible software workarounds.

7 Important notes

The following conditions apply to all goods within the wireless connectivity product range of Würth Elektronik eiSos GmbH & Co. KG:

7.1 General customer responsibility

Some goods within the product range of Würth Elektronik eiSos GmbH & Co. KG contain statements regarding general suitability for certain application areas. These statements about suitability are based on our knowledge and experience of typical requirements concerning the areas, serve as general guidance and cannot be estimated as binding statements about the suitability for a customer application. The responsibility for the applicability and use in a particular customer design is always solely within the authority of the customer. Due to this fact, it is up to the customer to evaluate, where appropriate to investigate and to decide whether the device with the specific product characteristics described in the product specification is valid and suitable for the respective customer application or not. Accordingly, the customer is cautioned to verify that the documentation is current before placing orders.

7.2 Customer responsibility related to specific, in particular safety-relevant applications

It has to be clearly pointed out that the possibility of a malfunction of electronic components or failure before the end of the usual lifetime cannot be completely eliminated in the current state of the art, even if the products are operated within the range of the specifications. The same statement is valid for all software sourcecode and firmware parts contained in or used with or for products in the wireless connectivity and sensor product range of Würth Elektronik eiSos GmbH & Co. KG. In certain customer applications requiring a high level of safety and especially in customer applications in which the malfunction or failure of an electronic component could endanger human life or health, it must be ensured by most advanced technological aid of suitable design of the customer application that no injury or damage is caused to third parties in the event of malfunction or failure of an electronic component.

7.3 Best care and attention

Any product-specific data sheets, manuals, application notes, PCN's, warnings and cautions must be strictly observed in the most recent versions and matching to the products firmware revisions. This documents can be downloaded from the product specific sections on the wireless connectivity homepage.

7.4 Customer support for product specifications

Some products within the product range may contain substances, which are subject to restrictions in certain jurisdictions in order to serve specific technical requirements. Necessary information is available on request. In this case, the field sales engineer or the internal sales person in charge should be contacted who will be happy to support in this matter.

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Due to constant product improvement, product specifications may change from time to time. As a standard reporting procedure of the Product Change Notification (PCN) according to the JEDEC-Standard, we inform about major changes. In case of further queries regarding the PCN, the field sales engineer, the internal sales person or the technical support team in charge should be contacted. The basic responsibility of the customer as per section 7.1 and 7.2 remains unaffected. All wireless connectivity module driver software "wireless connectivity SDK" and its source codes as well as all PC software tools are not subject to the Product Change Notification information process.

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