# Revision history

<table>
<thead>
<tr>
<th>Manual version</th>
<th>FW version</th>
<th>HW version</th>
<th>Notes</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1.0.0</td>
<td>1.0</td>
<td>• Initial version</td>
<td>February 2022</td>
</tr>
<tr>
<td>1.1</td>
<td>1.0.0</td>
<td>1.0</td>
<td>• Updated Important notes, meta data and document style</td>
<td>July 2023</td>
</tr>
</tbody>
</table>
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC</td>
<td>Analog to Digital Converter</td>
<td></td>
</tr>
<tr>
<td>BTMAC</td>
<td></td>
<td>Bluetooth® conform MAC address of the module used on the RF-interface.</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
<td></td>
</tr>
<tr>
<td>GAP</td>
<td>Generic Access Profile</td>
<td>The GAP provides a basic level of functionality that all Bluetooth® devices must implement.</td>
</tr>
<tr>
<td>GATT</td>
<td>Generic Attribute profile</td>
<td></td>
</tr>
<tr>
<td>GPIO</td>
<td>General Purpose Input/Output</td>
<td></td>
</tr>
<tr>
<td>I/O</td>
<td>Input/output</td>
<td>Pinout description.</td>
</tr>
<tr>
<td>I²C</td>
<td>Inter-Integrated Circuit</td>
<td></td>
</tr>
<tr>
<td>LDO</td>
<td>Low Dropout</td>
<td>Low dropout voltage regulator</td>
</tr>
<tr>
<td>Bluetooth LE</td>
<td>Bluetooth Low Energy</td>
<td></td>
</tr>
<tr>
<td>LPM</td>
<td>Low power mode</td>
<td>Mode for efficient power consumption.</td>
</tr>
<tr>
<td>MAC</td>
<td></td>
<td>MAC address of the module.</td>
</tr>
<tr>
<td>MTU</td>
<td>Maximum transmission unit</td>
<td>Maximum packet size of the Bluetooth® connection.</td>
</tr>
<tr>
<td>Payload</td>
<td></td>
<td>The intended message in a frame / package.</td>
</tr>
<tr>
<td>PDU</td>
<td>Packet Data Unit</td>
<td></td>
</tr>
<tr>
<td>RF</td>
<td>Radio frequency</td>
<td>Describes wireless transmission.</td>
</tr>
<tr>
<td>SDK</td>
<td>Software Development Kit</td>
<td></td>
</tr>
<tr>
<td>Bluetooth SIG</td>
<td>Bluetooth Special Interest Group</td>
<td></td>
</tr>
<tr>
<td>SoC</td>
<td>Sistem-on-Chip</td>
<td></td>
</tr>
<tr>
<td>Soft device</td>
<td></td>
<td>Operating system used by the nRF52 chip.</td>
</tr>
<tr>
<td>SPI</td>
<td>Serial peripheral interface</td>
<td>Allows the serial communication with the module.</td>
</tr>
<tr>
<td>SPP</td>
<td>Serial Port Profile</td>
<td></td>
</tr>
<tr>
<td><strong>UART</strong></td>
<td>Universal Asynchronous Receiver Transmitter</td>
<td>Allows the serial communication with the module.</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------------------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td><strong>UUID</strong></td>
<td>Universally Unique Identifier</td>
<td></td>
</tr>
</tbody>
</table>
Contents

1 Introduction ..................................................... 5

2 Bluetooth profiles .............................................. 5

3 SPP-like profile .................................................. 6
   3.1 Generic Access Protocol (GAP) ............................. 6
   3.2 Generic Attribute Profile (GATT) ........................... 7
      3.2.1 Maximum transmission unit (MTU) .................... 7
      3.2.2 Company identifier .................................... 7
      3.2.3 UUID .................................................. 7
      3.2.4 Primary Service ....................................... 7
      3.2.4.1 Characteristics ..................................... 7
   3.3 Bluetooth LE packet content ............................... 8
      3.3.1 Payload packet format ................................ 8
      3.3.2 Advertising packet content ............................ 9
      3.3.3 Scan response packet content ......................... 9
   3.4 Remote GPIO control ....................................... 10
      3.4.1 CMD_GPIO_REMOTE_WRITECONFIG_REQ .............. 10
      3.4.1.1 Example: Configure two GPIOs of the connected remote device to output high ........................................... 12
      3.4.2 CMD_GPIO_REMOTE_READCONFIG_REQ ................ 13
      3.4.2.1 Example: Read the current GPIO configuration of the connected remote device ............................................ 13
      3.4.3 CMD_GPIO_REMOTE_WRITE_REQ ....................... 15
      3.4.3.1 Example: Set a remote output GPIO to low ........ 16
      3.4.4 CMD_GPIO_REMOTE_READ_REQ .......................... 17
      3.4.4.1 Example: Read the values of remote GPIOs .......... 18
      3.4.5 CMD_GPIO_LOCAL_WRITE_IND ......................... 18
      3.4.5.1 Example: GPIOs of the remote device have been written by its local host ............................................. 18

4 App development .................................................. 19
   4.1 Connection setup message chart ........................... 19
   4.2 Enable notifications ....................................... 20
   4.3 Bonding development hints .................................. 21

5 Custom firmware development .................................. 23
   5.1 Important information for custom firmware development .................................................. 23
      5.1.1 How to adapt Nordic Semiconductor SDK examples to run on the Proteus-e hardware? ........................................... 27
      5.1.2 Firmware development hints ............................ 29
      5.1.3 Qualifying the Proteus-e with respect to Bluetooth® ............................................. 29

6 References ......................................................... 30

7 Important notes .................................................. 31
1 Introduction

This document provides advanced information concerning the Proteus-e. On the one hand the Bluetooth® LE interface of the Proteus-e is described, that must be implemented in a smart phone app to gain compatibility with the Proteus-e (chapter 2, 3 and 4). On the other hand, valuable hints to start a custom firmware development on base of the Proteus-e hardware are given (chapter 5).

Please note that basic understanding of the Bluetooth® LE standard as well as application development background on the desired platform is necessary to fully understand this document. Please refer to the user manual of Proteus-e [4] to get basic information of the functions provided by the application firmware.

2 Bluetooth profiles

The Bluetooth® LE specification uses so called "profiles" to specify the general behaviour of a Bluetooth® LE enabled device on the radio to communicate with other Bluetooth® LE devices. Profiles are built on the Bluetooth® LE standard to clearly define what kind of data is transmitted. The device's application determines which profiles matches best, 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 Bluetooth® LE profile. The Proteus-e module ships with the so-called SPP-like profile (see section 3) created on the base of the Generic Attribute profile (GATT). This profile is a custom profile defined by Würth Elektronik eiSos and aims at providing a Bluetooth® LE based wireless replacement to a serial cable connection.
3 SPP-like profile

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

3.1 Generic Access Protocol (GAP)

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

- See user setting RF_Appearance for the appearance.
- See user setting RF_DeviceName for the device name.
- See user setting FS_BTMAC (0x0018DAXxxxxx) for the device address (6 Byte MAC) of type "public".
- Timings:
  - See user settings RF_AdvertisingInterval for advertising interval configuration.
  - See user setting RF_ConnectionInterval for minimum and maximum connection interval configuration.
  - 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
    o Connection parameters update (initial): 5s
    o Connection parameters update (periodic): 10s
    o Connection parameters update counter before connection shut down: 3
### 3.2 Generic Attribute Profile (GATT)

#### 3.2.1 Maximum transmission unit (MTU)

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

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

Check also the message charts in chapter 4 to see the MTU request in the connection setup process.

#### 3.2.2 Company identifier

The Bluetooth® listed company identifier of Würth Elektronik eiSos (formerly "Amber wireless GmbH") is 0x031A (794<sub>dec</sub>).

#### 3.2.3 UUID

The Proteus-e uses a 128 Bit UUID of type "Vendor specific". The base UUID is adapted by the 16 Bit UUIDs of the primary service and the corresponding characteristics. The use of these UUID is restricted to Proteus-e modules that come with a pre-installed firmware, or devices that communicate with them.

<table>
<thead>
<tr>
<th>Service</th>
<th>16 Bit UUID</th>
<th>Full UUID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proteus-e base</td>
<td>-</td>
<td>6E400000-C352-11E5-953D-0002A5D5C51B</td>
</tr>
<tr>
<td>Proteus-e primary service</td>
<td>0x0001</td>
<td>6E4000001-C352-11E5-953D-0002A5D5C51B</td>
</tr>
<tr>
<td>RX_CHARACTERISTIC</td>
<td>0x0002</td>
<td>6E4000002-C352-11E5-953D-0002A5D5C51B</td>
</tr>
<tr>
<td>TXCharacteristic</td>
<td>0x0003</td>
<td>6E4000003-C352-11E5-953D-0002A5D5C51B</td>
</tr>
</tbody>
</table>

The UUID can be adapted by means of the user settings `RF_SPPBaseUUID`, `RF_SPPServiceUUID`, `RF_SPPTXUUID` and `RF_SPPRXUUID` to generate a custom profile.

#### 3.2.4 Primary Service

##### 3.2.4.1 Characteristics

- The first characteristic of the Proteus-e primary service is `RX_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-e primary service is TX_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.

<table>
<thead>
<tr>
<th>Proteus-e security mode</th>
<th>CCCD read</th>
<th>CCCD write, RX attribute read/write, TX attribute read/write</th>
</tr>
</thead>
<tbody>
<tr>
<td>No security</td>
<td>no protection, open link</td>
<td>no protection, open link</td>
</tr>
<tr>
<td>Just works</td>
<td>no protection, open link</td>
<td>requires encryption, but no MITM protection (Mode 1, Level 2)</td>
</tr>
<tr>
<td>Static pass key</td>
<td>no protection, open link</td>
<td>requires encryption and MITM protection (Mode 1, Level 3)</td>
</tr>
</tbody>
</table>

### 3.3 Bluetooth LE packet content

#### 3.3.1 Payload packet format

To identify the type of data transmitted via Bluetooth® LE, the data protocol on the radio contains a packet header. Thus, the standard Bluetooth® LE payload has to match the following format to be understood by the Proteus-e. Other Bluetooth® LE frames will be discarded:
### Table 1: RF-packet format to transmit data

<table>
<thead>
<tr>
<th>Bluetooth® LE Payload</th>
<th>Header</th>
<th>Payload data</th>
<th>0x01</th>
<th>ΦST Bytes</th>
</tr>
</thead>
</table>

Table 1: RF-packet format to transmit data

<table>
<thead>
<tr>
<th>Bluetooth® LE Payload</th>
<th>Header</th>
<th>Command data</th>
<th>0x02</th>
<th>ΦST Bytes</th>
</tr>
</thead>
</table>

Table 2: RF-packet format to transmit commands, like remote GPIO commands (see chapter 3.4)

The value ΦST is 243 Bytes.

#### 3.3.2 Advertising packet content

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

- Advertising data flags
- Proteus-e device name as Full or Shortened Local Name (up to 26 Bytes)

#### 3.3.3 Scan response packet content

The scan response packet is requested during scan if active scanning is enabled on the central device (i.e. smart phone). The standard Proteus-e scan response packet contains the following data:

- The UUID (128 Bit Proteus-e primary service UUID) of the SPP-like profile
- TX power level (1 Byte in two’s complement notation)
### 3.4 Remote GPIO control

The Proteus-e contains a feature to control its free GPIOs via the Bluetooth® LE interface. To do so a connected remote device must send remote commands via the Bluetooth® LE interface to the Proteus-e.

In case the GPIOs of interest have not been configured by the locally connected host via UART commands, it must be configured first by the remote device via Bluetooth® LE using the CMD_GPIO_REMOTE_WRITECONFIG_REQ and CMD_GPIO_REMOTE_READCONFIG_REQ commands.

If this has been done, the GPIOs can be used as input and/or output pins (CMD_GPIO_REMOTE_WRITE_REQ / CMD_GPIO_REMOTE_READ_REQ).

The remote commands to be sent have the following structure (see the following chapters):

<table>
<thead>
<tr>
<th>Bluetooth® LE Payload</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Header</td>
<td>Command Payload</td>
</tr>
<tr>
<td>0x02</td>
<td>x Bytes</td>
</tr>
</tbody>
</table>

#### Table 3: Packet command format

### 3.4.1 CMD_GPIO_REMOTE_WRITECONFIG_REQ

This command can be used to configure the free GPIOs of the remote device.

Remote configuration can be blocked by writing the corresponding bit of the user setting CFG_Flags via UART commands.

**Format:**

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block₁</th>
<th>...</th>
<th>Blockₙ</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x28</td>
<td>x Bytes</td>
<td></td>
<td>x Bytes</td>
</tr>
</tbody>
</table>

Response (CMD_GPIO_REMOTE_WRITECONFIG_CNF):

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block₁</th>
<th>...</th>
<th>Blockₙ</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x68</td>
<td>x Bytes</td>
<td></td>
<td>x Bytes</td>
</tr>
</tbody>
</table>

**CMD_GPIO_REMOTE_WRITECONFIG_REQ block structure**

Each **Block** has the following format:
**Length**: Length of the subsequent bytes in this block

**GPIO_ID**: ID of the GPIO, see Proteus-e manual

**Function**:

0x00: GPIO disconnected
0x01: GPIO works as input
0x02: GPIO works as output

**Value**:

- if **Function** is disconnected:
  0x00: value field must use 0x00
- if **Function** is input:
  0x00: GPIO has no pull resistor
  0x01: GPIO has pull down resistor
  0x02: GPIO has pull up resistor
- if **Function** is output:
  0x00: GPIO is output low
  0x01: GPIO is output high

**CMD_GPIO_REMOTE_WRITECONFIG_CNF block structure**

Each **Block** has the following format:

<table>
<thead>
<tr>
<th>Length</th>
<th>GPIO_ID</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>1 Byte</td>
<td>1 Byte</td>
</tr>
</tbody>
</table>

**Length**: Length of the subsequent bytes in this block

**GPIO_ID**: ID of the GPIO, see Proteus-e manual

**Status**:

0x00: Success
0x01: Failed
0xFF: Remote configuration not allowed (blocked by the user setting CFG_Flags of the remote device)
3.4.1.1 Example: Configure two GPIOs of the connected remote device to output high

Configure the GPIOs with ID 0x01 and 0x02 to output high:

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block₁</th>
<th>Block₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x28</td>
<td>0x03 0x01 0x02 0x01</td>
<td>0x03 0x02 0x02 0x01</td>
</tr>
</tbody>
</table>

Response:

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block₁</th>
<th>Block₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x68</td>
<td>0x02 0x01 0x00</td>
<td>0x02 0x02 0x00</td>
</tr>
</tbody>
</table>

Configured both GPIOs with success.
3.4.2 CMD_GPIO_REMOTE_READCONFIG_REQ

This command can be used to read the configuration of the free GPIOs of the remote device. Format:

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x2C</td>
</tr>
</tbody>
</table>

Response (CMD_GPIO_REMOTE_READCONFIG_CNF):

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block₁</th>
<th>...</th>
<th>Blockₙ</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x6C</td>
<td>x Bytes</td>
<td></td>
<td>x Bytes</td>
</tr>
</tbody>
</table>

CMD_GPIO_REMOTE_READCONFIG_CNF block structure

Each Block has the following format:

<table>
<thead>
<tr>
<th>Length</th>
<th>GPIO_ID</th>
<th>Function</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x03</td>
<td>1 Byte</td>
<td>1 Byte</td>
<td>1 Byte</td>
</tr>
</tbody>
</table>

Length: Length of the subsequent bytes in this block

GPIO_ID: ID of the GPIO, see Proteus-e manual

Function:

- **0x00**: GPIO is not configured yet (Length is 0x02 and Value is empty)
- **0x01**: GPIO works as input
- **0x02**: GPIO works as output

Value:

- if Function is input:
  - **0x00**: GPIO has no pull resistor
  - **0x01**: GPIO has pull down resistor
  - **0x02**: GPIO has pull up resistor
- if Function is output:
  - **0x00**: GPIO is output low
  - **0x01**: GPIO is output high

3.4.2.1 Example: Read the current GPIO configuration of the connected remote device

Read the current GPIO configuration of the connected remote device:
**Response:**

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x6C</td>
<td>0x03, 0x01, 0x02, 0x01, 0x03, 0x02, 0x02, 0x01, 0x02, 0x03, 0x00, 0x02, 0x04, 0x00, 0x02, 0x05, 0x00, 0x02, 0x06, 0x00</td>
</tr>
</tbody>
</table>

The GPIOs with GPIO_ID **0x01** and **0x02** are output high. The remaining GPIOs with GPIO_ID **0x03**, **0x04**, **0x05** and **0x06** are not configured.
3.4.3 CMD_GPIO_REMOTE_WRITE_REQ

This command can be used to write the free GPIOs of the remote device. This command can be only run successfully if the respective pins of the remote device are configured as output pins.

Perform a CMD_GPIO_REMOTE_READCONFIG_REQ before using the CMD_GPIO_REMOTE_WRITE_REQ command to ensure the pins are setup correctly.

Format:

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block1</th>
<th>...</th>
<th>Blockn</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x29</td>
<td>x Bytes</td>
<td></td>
<td>x Bytes</td>
</tr>
</tbody>
</table>

Response (CMD_GPIO_REMOTE_WRITE_CNF):

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block1</th>
<th>...</th>
<th>Blockn</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x69</td>
<td>x Bytes</td>
<td></td>
<td>x Bytes</td>
</tr>
</tbody>
</table>

CMD_GPIO_REMOTE_WRITE_REQ block structure

Each Block has the following format:

<table>
<thead>
<tr>
<th>Length</th>
<th>GPIO_ID</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>1 Byte</td>
<td>1 Byte</td>
</tr>
</tbody>
</table>

Length: Length of the subsequent bytes in this block

GPIO_ID: ID of the GPIO, see Proteus-e manual

Value:

- **0x00**: Set GPIO to low
- **0x01**: Set GPIO to high

CMD_GPIO_REMOTE_WRITE_CNF block structure

Each Block has the following format:

<table>
<thead>
<tr>
<th>Length</th>
<th>GPIO_ID</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>1 Byte</td>
<td>1 Byte</td>
</tr>
</tbody>
</table>
Length: Length of the subsequent bytes in this block

GPIO_ID: ID of the GPIO, see Proteus-e manual

Status:

0x00: Success
0x01: Failed

3.4.3.1 Example: Set a remote output GPIO to low

Set the output GPIO (GPIO_ID 0x01) of the connected remote device to low:

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x29</td>
<td>0x02 0x01 0x00</td>
</tr>
</tbody>
</table>

Response:

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x69</td>
<td>0x02 0x01 0x00</td>
</tr>
</tbody>
</table>

Successfully set GPIO with GPIO_ID 0x01 to low.
3.4.4 CMD_GPIO_REMOTE_READ_REQ

This command can be used to read the free GPIOs of the remote device. This command can be only run successfully if the respective pins of the remote device are configured.

Perform a CMD_GPIO_REMOTE_READ_CONFIG_REQ before using the CMD_GPIO_REMOTE_READ_REQ command to ensure the pins are setup correctly.

Format:

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block₁</th>
<th>...</th>
<th>Blockₙ</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x2A</td>
<td>x Bytes</td>
<td>x Bytes</td>
<td></td>
</tr>
</tbody>
</table>

Response (CMD_GPIO_REMOTE_READ_CNF)

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block₁</th>
<th>...</th>
<th>Blockₙ</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x6A</td>
<td>x Bytes</td>
<td>x Bytes</td>
<td></td>
</tr>
</tbody>
</table>

CMD_GPIO_REMOTE_READ_REQ block structure

Each Block has the following format:

<table>
<thead>
<tr>
<th>Length</th>
<th>GPIO_ID₁</th>
<th>...</th>
<th>GPIO_IDₙ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Bytes</td>
<td>1 Byte</td>
<td>1 Byte</td>
<td></td>
</tr>
</tbody>
</table>

Length: Length of the subsequent bytes in this block

GPIO_ID: ID of the GPIO, see Proteus-e manual

CMD_GPIO_REMOTE_READ_CNF block structure

Each Block has the following format:

<table>
<thead>
<tr>
<th>Length</th>
<th>GPIO_ID</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>1 Byte</td>
<td>1 Byte</td>
</tr>
</tbody>
</table>

Length: Length of the subsequent bytes in this block

GPIO_ID: ID of the GPIO, see Proteus-e manual

Value:

- 0x00: The remote GPIO is low.
- 0x01: The remote GPIO is high.
- 0xFF: Failed reading remote GPIO value.
3.4.4.1 Example: Read the values of remote GPIOs

Read the value of the GPIOs with GPIO_ID 0x01 and 0x02 of the connected remote device:

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x2A</td>
<td>0x02</td>
</tr>
</tbody>
</table>

Response:

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block1</th>
<th>Block2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0x6A</td>
<td>0x02</td>
<td>0x01</td>
</tr>
</tbody>
</table>

Successfully read the values of the remote GPIOs with GPIO_ID 0x01 (GPIO is low) and 0x02 (GPIO is high).

3.4.5 CMD_GPIO_LOCAL_WRITE_IND

This message informs the connected remote device, that the radio module's local host has written the GPIOs.

Please note that only the GPIOs that have been successfully updated are part of this message. Failed attempts of GPIO updates will not be indicated by this message.

Format:

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block1</th>
<th>...</th>
<th>Blockn</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0xA8</td>
<td>x Bytes</td>
<td></td>
<td>x Bytes</td>
</tr>
</tbody>
</table>

Each Block has the format of CMD_GPIO_REMOTE_READ_CNF block structure.

3.4.5.1 Example: GPIOs of the remote device have been written by its local host

<table>
<thead>
<tr>
<th>Header</th>
<th>Command</th>
<th>Block1</th>
<th>Block2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>0xA6</td>
<td>0x02</td>
<td>0x01</td>
</tr>
</tbody>
</table>

The GPIOs with GPIO_ID 0x01 (GPIO is low) and 0x02 (GPIO is high) of the remote device have been written by its local host.
4 App development

The definition of the SPP-like profile (see section 3) in combination with the message chart of chapter 4.1 is sufficient to develop custom apps for mobile devices. To implement this profile from scratch fundamental knowledge of app development as well as of the Bluetooth® LE standard is required. To make life easy Würth Elektronik eiSos published the source code of the compatible "Proteus Connect App" for iOS [6] and Android [5] on GitHub. This app can be used as starting point for own app developments.

4.1 Connection setup message chart

The following message chart shows which steps are run during the connection setup process between a mobile phone and a Proteus-e radio module. To implement the central role in a mobile device app to connect to the Proteus-e peripheral the steps of the central device shown below have to be reproduced.

1. First of all, the central device must place a connection request to setup the physical connection. Here the timing parameters like the connection interval are negotiated.

2. In case the Proteus-e has its security enabled (see user setting RF_SecFlags), a pairing request must be placed to get the permission to access the peripheral’s characteristics.

3. Afterwards a MTU request is necessary to allow a larger payload.

4. Next the discovery of the characteristics must be done and the notification of the TX characteristic has to be enabled.

After all these steps have been done, data transmission in both directions is possible.
Figure 1: Connection setup chart

4.2 Enable notifications

As described in the previous chapter 4.1 the final step for a successful connection setup is the enabling of the notification of the TX_CHARACTERISTIC. To do so, the Android’s Bluetooth® LE stack offers the following function, that has to be called with the TX_CHARACTERISTIC.
**WIRELESS CONNECTIVITY & SENSORS**

**ANR024 - Proteus-e Advanced developer guide**

IBluetoothGatt mService;

```java
/** TX NOTIFICATION
 * Enable or disable notifications/indications for a given characteristic.
 * 
 * Once notifications are enabled for a characteristic, a
 * {@link BluetoothGattCallback#onCharacteristicChanged} callback will be
 * triggered if the remote device indicates that the given characteristic
 * has changed.
 * 
 * Requires {@link android.Manifest.permission#BLUETOOTH} permission.
 * 
 * @param characteristic The characteristic for which to enable notifications
 * @param enable Set to true to enable notifications/indications
 * @return true, if the requested notification status was set successfully
 */
public boolean setCharacteristicNotification(BluetoothGattCharacteristic characteristic,
        boolean enable) {
    if (DBG) {
        Log.d(TAG, "setCharacteristicNotification() - uuid: " + characteristic.getUuid()
                + ":" + enable);
    }
    if (mService == null || mClientIf == 0) return false;
    BluetoothGattService service = characteristic.getService();
    if (service == null) return false;
    BluetoothDevice device = service.getDevice();
    if (device == null) return false;
    try {
        mService.registerForNotification(mClientIf, device.getAddress(),
                characteristic.getInstanceId(), enable);
    } catch (RemoteException e) {
        Log.e(TAG, "", e);
        return false;
    }
    return true;
}
```

**Code 1: Example code to enable the TX characteristic notification**

Please note that the iOS's Bluetooth® LE stack calls the corresponding function automatically. Thus calling a notification enable function from the app's application layer is not needed.

### 4.3 Bonding development hints

The firmware of the Proteus-e 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-e 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" message and thus the channel for data transmission can not 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 Custom firmware development

Using the Proteus-e hardware a custom firmware can be developed to better fit the customer’s needs. Based on the Nordic Semiconductor SDK (nRF5 SDK [2]) and demo examples various Bluetooth® LE profiles and custom applications can be realized and flashed on the Proteus-e module. The versatile and well documented Nordic stack ensures quick and easy realization of various standard Bluetooth® LE profiles. Chapter 5.1 contains the information needed to run Nordic standard examples on the Proteus-e hardware.

Option 1: SPP-like Firmware
- User application code
- SPP-like Bluetooth profile, command interface, edit user settings
- SoftDevice
- BT Stack, GAP, GATT

Option 2: Custom Development
- Development environment
  - Segger Embedded Studio, Keil, IAR, plus J-Link flash adapter (or compatible)
- SoftDevice or nRF Connect
  - BT Stack, GAP, GATT
- Manual, advanced user guide, support
- free code demos, all BLE profiles, flash software, developer forum

Figure 2: Options for running the Proteus-e with standard or custom firmware

5.1 Important information for custom firmware development

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

- Chip
  The Proteus-e contains the Nordic Semiconductor nRF52805 SoC. The CPU is a 64MHz ARM Cortex-M4.
- Pinout

The Proteus-e provides the following pins of the Nordic SoC with its pads. Only the ANT, RF, GND, VDD, Reset, SWDCLK and SWDIO pins are fixed. All other pins can be used for custom firmware development. For special functions like external low frequency crystal (XL) or analog input (AIN) the respective pins have to be used.

![Pinout Diagram](image)

<table>
<thead>
<tr>
<th>No.</th>
<th>Pad Name</th>
<th>No.</th>
<th>Pad Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ANT</td>
<td>11</td>
<td>P0.00/XL1</td>
</tr>
<tr>
<td>2</td>
<td>RF</td>
<td>12</td>
<td>P0.01/XL2</td>
</tr>
<tr>
<td>3</td>
<td>SWDIO</td>
<td>13</td>
<td>P0.16</td>
</tr>
<tr>
<td>4</td>
<td>SWDCLK</td>
<td>14</td>
<td>P0.18</td>
</tr>
<tr>
<td>5</td>
<td>P0.21/Reset</td>
<td>15</td>
<td>P0.20</td>
</tr>
<tr>
<td>6</td>
<td>P0.12</td>
<td>B1</td>
<td>GND</td>
</tr>
<tr>
<td>7</td>
<td>VDD</td>
<td>B2</td>
<td>GND</td>
</tr>
<tr>
<td>8</td>
<td>P0.05/AIN3</td>
<td>B3</td>
<td>GND</td>
</tr>
<tr>
<td>9</td>
<td>P0.04/AIN2</td>
<td>B4</td>
<td>GND</td>
</tr>
<tr>
<td>10</td>
<td>P0.14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Hardware for development & debugging

Using Segger J-Link flasher and the SWD interface is required for firmware development and debugging. Checkout the Proteus-e evaluation board. It provides the easiest way to develop firmware based on Proteus-e module or apps for the SPP-like profile.
Software development environment
Nordic Semiconductor provides software packages for several compilers (KEIL, IAR, GCC, Segger Embedded).
It includes the required Bluetooth® LE stack (“Softdevice”), many demo examples for Bluetooth® LE profiles and services to conveniently develop a custom firmware on base 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 in 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) as a starting point. See also chapter 5.1.1 for more information how to run Nordic standard examples on top of the Proteus-e.

Clock sources
The Proteus-e module contains a dedicated RF clock (HFCLK). The Proteus-e 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 nRF Connect SDK 17.0.2:

```c
// <o> NRF_SDH_CLOCK_LF_SRC - SoftDevice clock source.
// <o> NRF_CLOCK_LF_SRC_RC
// <1=> NRF_CLOCK_LF_SRC_XTAL
// <2=> NRF_CLOCK_LF_SRC_SYNTH
#ifndef NRF_SDH_CLOCK_LF_SRC
#define NRF_SDH_CLOCK_LF_SRC 0
#endif

// <o> NRF_SDH_CLOCK_LF_RC_CTIV - SoftDevice calibration timer interval.
#ifndef NRF_SDH_CLOCK_LF_RC_CTIV
#define NRF_SDH_CLOCK_LF_RC_CTIV 16
#endif

// <o> NRF_SDH_CLOCK_LF_RC_TEMP_CTIV - SoftDevice calibration timer interval under constant temperature.
// <i> How often (in number of calibration intervals) the RC oscillator shall be calibrated
// <i> if the temperature has not changed.
#ifndef NRF_SDH_CLOCK_LF_RC_TEMP_CTIV
#define NRF_SDH_CLOCK_LF_RC_TEMP_CTIV 2
#endif

// <o> NRF_SDH_CLOCK_LF_ACCURACY - External clock accuracy used in the LL to compute timing.
// <0> NRF_CLOCK_LF_ACCURACY_250_PPM
// <1> NRF_CLOCK_LF_ACCURACY_500_PPM
// <2> NRF_CLOCK_LF_ACCURACY_150_PPM
// <3> NRF_CLOCK_LF_ACCURACY_100_PPM
// <4> NRF_CLOCK_LF_ACCURACY_75_PPM
// <5> NRF_CLOCK_LF_ACCURACY_50_PPM
// <6> NRF_CLOCK_LF_ACCURACY_30_PPM
// <7> NRF_CLOCK_LF_ACCURACY_20_PPM
```
WIRELESS CONNECTIVITY & SENSORS
ANR024 - Proteus-e Advanced developer guide

Code 2: sdk_config.h

• 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 SDK 17.0.2:

```c
sv_power_dcdc_mode_set(NRF_POWER_DCDC_ENABLE);
```

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

• Certification and Bluetooth®-Listing
Custom firmware may require additional certification. Any (end-)device containing Bluetooth®
IP must be listed by the Bluetooth® SIG which requires membership and qualification.
Please contact the Bluetooth® SIG or your preferred Bluetooth® certification laboratory to
obtain the Bluetooth®-listing

To make use of the existing certification and listing of the Proteus-e, it is manda-
tory to use the Bluetooth® stack Nordic Semiconductor S112 in version 7.3.0.

• Serial number
The unique serial number (used for tracing and the generation of the Proteus-e BTMAC)
is placed in the user information configuration register (UICR->Customer[0]) and will be
removed by flashing a customer firmware onto the SoC.
5.1.1 How to adapt Nordic Semiconductor SDK examples to run on the Proteus-e hardware?

The following description is based on the SDK 17.0.2. 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-e:

1. Open the desired example project for the nRF52805 radio chip and compile.

2. In case of success, enable the DCDC by adding the following line at the end of the stack init function.

```c
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. If no external crystal has been connected to the radio module, enable the internal RC-oscillator as shown in code example 2.

4. Go to the file board.h and add the include for the Proteus-e.h board file.

```c
#if defined(BOARD_PCA10040)
#include "pca10040.h"
#elif defined(BOARD_PROTEUSE)
#include "Proteuse.h"
#else
#error "Board is not defined"
#endif
```

If you have a Nordic evaluation board available, please check that the original example without modifications runs successfully on the Nordic evaluation board.
5. Then create the Proteus-e board file. To do so, please copy the board file of the Nordic evaluation board (like PCA10040) and add the pinout, led button numbering, button numbering and clock definition of the Proteus-e:

```c
#ifndef PROTEUS_E_H
#define PROTEUS_E_H

#define NRF_PIN_LED_1 0
#define NRF_PIN_BUSY_UARTENABLE 1
#define NRF_PIN_UARTRX 4
#define NRF_PIN_GPIO2 5
#define NRF_PIN_OPERATIONMODE 12
#define NRF_PIN_UARTCTS 14
#define NRF_PIN_UARTTX 16
#define NRF_PIN_UARTRX 18
#define NRF_PIN_GPIO0 20
#define NRF_RESET 21

#define LEDS_ACTIVE_STATE 1
#define LEDS_NUMBER 1
#define LEDS_LIST { NRF_PIN_LED_1 }
#define BSP_LED_0 NRF_PIN_LED_1

#define BUTTONS_ACTIVE_STATE 0
#define BUTTON_PULL NRF_GPIO_PIN_PULLUP
#define BUTTONS_NUMBER 1
#define BUTTONS_LIST { NRF_PIN_BUSY_UARTENABLE }
#define BSP_BUTTON_0 NRF_PIN_BUSY_UARTENABLE

#define RX_PIN_NUMBER NRF_PIN_UARTRX
#define TX_PIN_NUMBER NRF_PIN_UARTTX
#define CTS_PIN_NUMBER NRF_PIN_UARTCTS
#define RTS_PIN_NUMBER NRF_PIN_UARTRXTS

#endif // PROTEUS_E_H
```

Code 3: Content of the Proteus.e.h

6. In the project options, we need to link to the Proteus-e hardware instead to the Nordic evaluation board hardware. This can be done by adding "BOARD_PROTEUSE" macro and by removing the respective macro of the Nordic platform in the precompiler options of the project.

7. Then check that the application code uses the pins names defined in the Proteus-e.h. Probably peripheral pins (UART, SPI,...), LED pins and/or button pins have to be adapted to fit the pin definition of the Proteus-e.h.

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

8. Now all necessary changes have been done. Thus, recompile the whole project and check for warnings and errors.
9. 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.

10. After this, flash the compiled project code onto the chip using Segger Embedded (or the IDE of your choice) without erasing the flash area of the Softdevice.

11. Now, the whole code has been flashed and testing can start.

5.1.2 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.

- 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 behaviour. 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.

- Checkout the errata sheet of the nRF52 SoC to have an overview of known issues with the nRF52 SoC and possible software workarounds.

- Checkout the sections "Known issues" of the used SDK and soft device versions to be aware of potential issues.

5.1.3 Qualifying the Proteus-e with respect to Bluetooth® 5.2

The Proteus-e has been listed as end product with respect to Bluetooth® 5.1 specification. In case a listing with respect to a newer version of the Bluetooth® standard is desired another Bluetooth® LE stack must be used.

The end product listing (EPL) mainly has to be built up by adding two parts:

1. The listing of the controller subsystem, that contains the test of the module and/or radio chip hardware to be Bluetooth® compliant. The hardware of the Proteus-e fulfills the specifications to be listed as a Bluetooth® 5.2 controller subsystem.

2. The listing of the host subsystem, that contains the test of the Bluetooth® stack used within the product. The Bluetooth® stack used in the Proteus-e is the S112 V7.3.0, that does not fulfill the specifications to be listed as a Bluetooth® 5.2 host subsystem. However, another Bluetooth® 5.2 listed stack, like “Zephyr BLE Host” (nRF Connect SDK [1]) developed by Nordic Semiconductor, can be used to create a new Bluetooth® 5.2 listed end product listing.

Please refer to Application Note ANR27 [3] for more information on the Bluetooth® SIG listing process and options.
6 References


7 Important notes

The Application Note and its containing information ("Information") is based on Würth Elektronik eiSos GmbH & Co. KG and its subsidiaries and affiliates ("WE eiSos") knowledge and experience of typical requirements concerning these areas. It serves as general guidance and shall not be construed as a commitment for the suitability for customer applications by WE eiSos. While WE eiSos has used reasonable efforts to ensure the accuracy of the Information, WE eiSos does not guarantee that the Information is error-free, nor makes any other representation, warranty or guarantee that the Information is completely accurate or up-to-date. The Information is subject to change without notice. To the extent permitted by law, the Information shall not be reproduced or copied without WE eiSos’ prior written permission. In any case, the Information, in full or in parts, may not be altered, falsified or distorted nor be used for any unauthorized purpose.

WE eiSos is not liable for application assistance of any kind. Customer may use WE eiSos’ assistance and product recommendations for customer’s applications and design. No oral or written Information given by WE eiSos or its distributors, agents or employees will operate to create any warranty or guarantee or vary any official documentation of the product e.g. data sheets and user manuals towards customer and customer shall not rely on any provided Information. THE INFORMATION IS PROVIDED "AS IS". CUSTOMER ACKNOWLEDGES THAT WE EISOS MAKES NO REPRESENTATIONS AND WARRANTIES OF ANY KIND RELATED TO, BUT NOT LIMITED TO THE NON-INFRINGEMENT OF THIRD PARTIES’ INTELLECTUAL PROPERTY RIGHTS OR THE MERCHANTABILITY OR FITNESS FOR A PURPOSE OR USAGE. WE EISOS DOES NOT WARRANT OR REPRESENT THAT ANY LICENSE, EITHER EXPRESS OR IMPLIED, IS GRANTED UNDER ANY PATENT RIGHT, COPYRIGHT, MASK WORK RIGHT, OR OTHER INTELLECTUAL PROPERTY RIGHT RELATING TO ANY COMBINATION, MACHINE, OR PROCESS IN WHICH WE EISOS INFORMATION IS USED. INFORMATION PUBLISHED BY WE EISOS REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE A LICENSE FROM WE eiSos TO USE SUCH PRODUCTS OR SERVICES OR A WARRANTY OR ENDORSEMENT THEREOF.

The responsibility for the applicability and use of WE eiSos’ components 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 and investigate, where appropriate, and decide whether the device with the specific characteristics described in the specification is valid and suitable for the respective customer application or not. The technical specifications are stated in the current data sheet and user manual of the component. Therefore the customers shall use the data sheets and user manuals and are cautioned to verify that they are current. The data sheets and user manuals can be downloaded at www.we-online.com. Customers shall strictly observe any product-specific notes, cautions and warnings. WE eiSos reserves the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time without notice.

WE eiSos will in no case be liable for customer’s use, or the results of the use, of the components or any accompanying written materials. IT IS CUSTOMER’S RESPONSIBILITY TO VERIFY THE RESULTS OF THE USE OF THIS INFORMATION IN IT’S OWN PARTICULAR ENGINEERING AND PRODUCT ENVIRONMENT AND CUSTOMER ASSUMES THE ENTIRE RISK OF DOING SO OR FAILING TO DO SO. IN NO CASE WILL WE EISOS BE LIABLE FOR
CUSTOMER’S USE, OR THE RESULTS OF IT’S USE OF THE COMPONENTS OR ANY ACCOMPANYING WRITTEN MATERIAL IF CUSTOMER TRANSLATES, ALTERS, ARRANGES, TRANSFORMS, OR OTHERWISE MODIFIES THE INFORMATION IN ANY WAY, SHAPE OR FORM.

If customer determines that the components are valid and suitable for a particular design and wants to order the corresponding components, customer acknowledges to minimize the risk of loss and harm to individuals and bears the risk for failure leading to personal injury or death due to customers usage of the components. The components have been designed and developed for usage in general electronic equipment only. The components are not authorized for use in equipment where a higher safety standard and reliability standard is especially required or where a failure of the components is reasonably expected to cause severe personal injury or death, unless WE eiSos and customer have executed an agreement specifically governing such use. Moreover WE eiSos components are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation, transportation signal, disaster prevention, medical, public information network etc. WE eiSos must be informed about the intent of such usage before the design-in stage. In addition, sufficient reliability evaluation checks for safety must be performed on every component which is used in electrical circuits that require high safety and reliability functions or performance. COSTUMER SHALL INDEMNIFY WE EISOS AGAINST ANY DAMAGES ARISING OUT OF THE USE OF THE COMPONENTS IN SUCH SAFETY-CRITICAL APPLICATIONS.
List of Figures

1. Connection setup chart ................................................. 20
2. Options for running the Proteus-e with standard or custom firmware .......... 23
3. Pinout ................................................................. 24

List of Tables

1. RF-packet format to transmit data ........................................... 9
2. RF-packet format to transmit commands, like remote GPIO commands (see chapter 3.4) ........................................... 9
3. Packet command format ..................................................... 10
Contact
Würth Elektronik eiSos GmbH & Co. KG
Division Wireless Connectivity & Sensors

Max-Eyth-Straße 1
74638 Waldenburg
Germany

Tel.: +49 651 99355-0
Fax.: +49 651 99355-69
www.we-online.com/wireless-connectivity