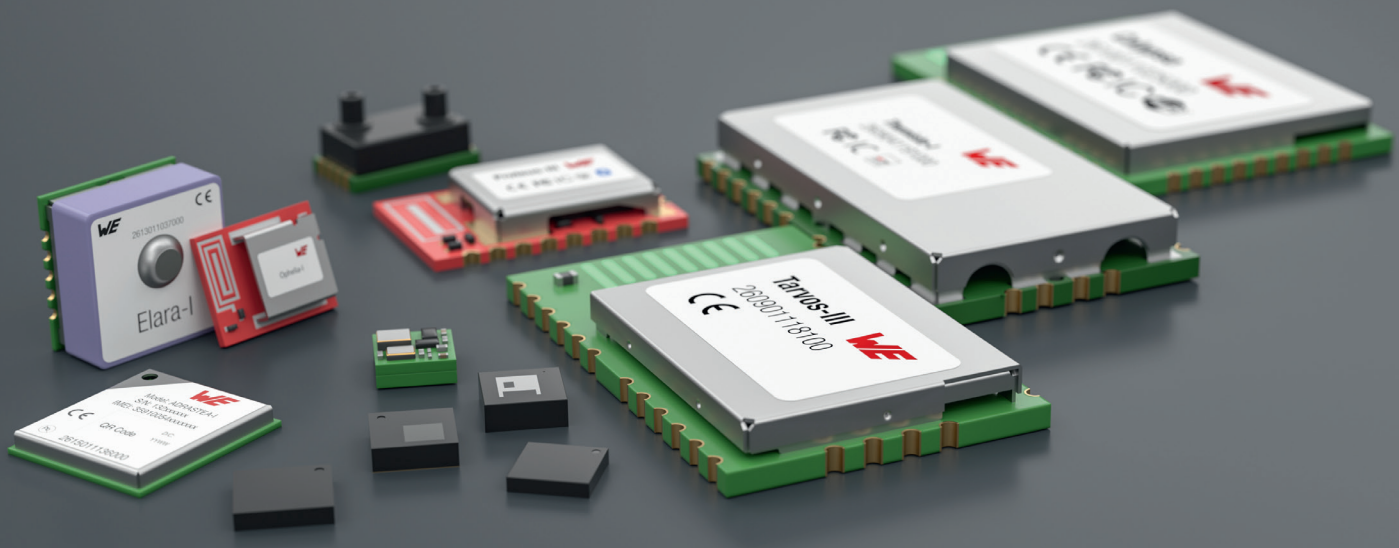


User manual

Skoll-I

2620011024000

Version 1.0

February 11, 2025

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.

Revision history

Manual version	FW version	HW version	Notes	Date
1.0	1.4.17.17	2.0	• Initial version	February 2025

Abbreviations

Abbreviation	Name	Description
BER	Bit Error Rate	The rate of bit errors in data reception.
BR	Basic Rate	Bluetooth® Classic legacy radio mode.
EDR	Enhanced Data Rate	Bluetooth® Classic radio mode with 2 and 3 Mbps for faster data transmission.
HCI	Host Controller Interface	Interface between controller and host part of the Bluetooth® specification.
HIGH	High signal level	
LOW	Low signal level	
LRM	Long Range Mode	TX mode increasing the RX sensitivity by using spreading and forward error correction.
PDS	Power Down Sleep	
PHY	Physical layer	
RF	Radio Frequency	Describes everything relating to the wireless transmission.
SPP	Serial Port Profile	Standardized Bluetooth® Classic profile for serial data transmission.
UART	Universal Asynchronous Receiver Transmitter	The UART allows communicating with the module via serial interface.
VDD	Supply voltage	

Contents

Overview of helpful application notes

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 ANR016 - Radio module migration guide

http://www.we-online.com/ANR016
Due to our long term availability policy Würth Elektronik eiSos offers beside radio modules with most recent technology and chipset still the predecessor modules. This application note describes what to consider when switching in between module generations.

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.

Firmware documentation

The details of all firmware features bundled with various application examples are part of a separate firmware description document [1].

1 Introduction

1.1 Operational description

The Skoll-I radio module is a component for wireless communication between devices such as control systems, remote controls, sensors etc. Based on the Infineon chipset CYW20819, it offers Bluetooth® 5.4 [2] connectivity with fast and secure data transmission using Bluetooth® Classic SPP profile[1] as well as Bluetooth® LE custom SPP profile. The module itself offers a wide range of configurations and possibilities to suit and optimize sophisticated customer applications. A serial interface (UART) is available for communication with the host system.
Even with its small dimension of 16.6 x 12 mm, the Skoll-I provides a strongly miniaturized integrated PCB antenna. The functionality is accessible through pads with edge castellation. This offers easy prototype building as it is suitable for hand soldering.

1.1.1 Key features

The Skoll-I offers the following key features which are described in the firmware manual [1] in more detail:

Bluetooth® connection setup and roles: The Skoll-I implements all roles of the Bluetooth® 5 standard. It can act as a master or as a slave device in Bluetooth® Classic world, as well as central or peripheral device in the Bluetooth® LE world. Thus, it can initiate the connection setup as well as being connected to an external peer device.

Connection-based data transmission:

Bluetooth® Classic Serial Port Profile (SPP) communication: The Skoll-I firmware implements the well-known Bluetooth® Classic Serial Port Profile (SPP)[1] that allows the bidirectional data transmission between several Skoll-I and/or to other Bluetooth® Classic devices implementing the SPP v1.2 profile. Once started, it offers a single COM port for serial connectivity and communication. With that, the radio module is compatible to millions of Bluetooth® Classic devices already active in the field.

Bluetooth® LE communication: In addition, it also implements the CYSPP profile, which is a custom profile that acts as the pendant of the SPP profile in the Bluetooth® LE standard.

Having both profiles implemented, it allows to participate in Bluetooth® Classic as well as in Bluetooth® LE device networks, which enables maximum flexibility.

Radio security: The Skoll-I provides all the authentication and encryption functions defined in the Bluetooth® specification. This allows to setup secure connections to authenticated devices only, and to encrypt the transmission of data.

Additional Bluetooth® 5 radio modes: Besides the legacy radio PHYs, like BR (Basic Rate) for Bluetooth® Classic and LE 1 Mbps mode for Bluetooth® LE, the Skoll-I also provides the advanced radio modes EDR (Enhanced Data Rate, 2 and 3 Mbps) and LE 2 Mbps for faster data transmission.

[1] Bluetooth® profiles are the protocols used for wireless communication. Each profile supports a selected type of applications, like audio profiles which are solely capable for wireless audio streaming applications. The Bluetooth® Classic serial port profile (SPP) is the profile optimized for exchange of generic data.

Fast serial interface: The Skoll-I offers a UART-interface to communicate with a host micro controllers using an user-defined baud rate and a simple command interface in binary or text mode.

Data mode: The Skoll-I firmware provides the "data" operation mode, in which the radio module acts as a transparent wireless bridge. Data received on the UART interface is sent via radio to the connected peer device and data received via radio interface is sent out via UART to the connected host. This allows a quick integration of the module into the end device.

OTA firmware update: The Skoll-I firmware provides over the air firmware update capabilities. Firmware updates can be applied using the Bluetooth® LE interface.

1.2 Block diagram

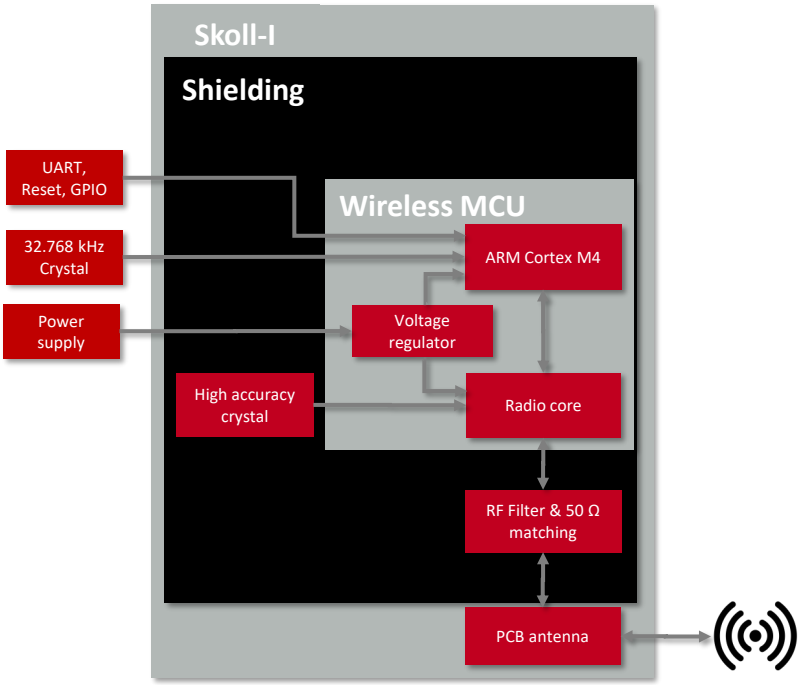


Figure 1: Block diagram

1.3 Ordering information

WE order code	Description
2620011024000	Skoll-I radio module with PCB antenna
2620029024001	EV-Kit with mounted Skoll-I radio module

Table 1: Ordering information

2 Electrical specifications

Unless otherwise stated, all the values given in the manual were measured on the Skoll-I EV-Board with T = 25 °C, VDD = 3.0 V, internal DC-DC converter active.

2.1 Operating conditions

Description	Min.	Typ.	Max.	Unit
Supply voltage (VDD)	1.71	3.0	3.3	V
Input supply voltage ramp time 0 to 3.3 V	40			µs
Temperature range	-30		+85	°C

Table 2: Operating conditions

2.2 Absolute maximum ratings

Description	Min.	Typ.	Max.	Unit
Supply voltage (VDD)	-0.5		+3.45	V

Table 3: Absolute maximum ratings

2.3 Power consumption

2.3.1 Static

Description	Test conditions	Min	Typ.	Max	Unit
Bluetooth® LE TX current consumption	Continuous TX at max output power		10.4		mA
BR TX current consumption	Continuous TX at max output power		10.4		mA
EDR TX current consumption	Continuous TX at max output power		13.2		mA
Bluetooth® LE RX current consumption	1 Mbps		6.4		mA
Bluetooth® LE RX current consumption	2 Mbps		5.8		mA
BR RX current consumption	1 Mbps, DH1		4.8		mA
EDR RX current consumption	2 Mbps, 3 Mbps, x-DH1		5.1		mA

Low power mode (PDS)	External crystal connected, no Bluetooth® connections and advertising off		270		µA
Low power mode (HID-off)	External crystal connected		1.8		µA

Table 4: Power consumption

2.3.2 Voltage supply dependency

The figure below shows the typical behavior of transmit and receive current in relation to applied supply voltage. The current consumption is given for maximum output power and when the radio is able to demodulate packages.

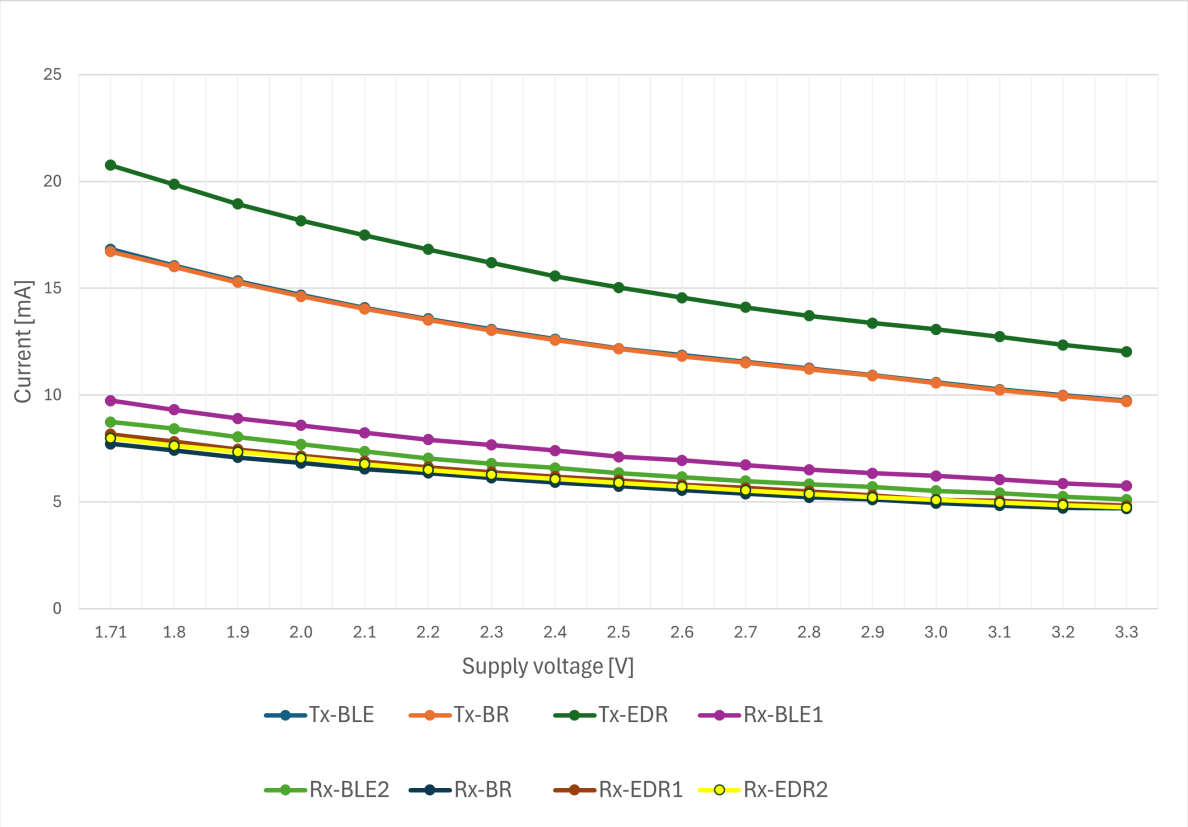


Figure 2: Typical behavior of transmit and receive current in relation to applied supply voltage

2.4 Radio characteristics

Description	Min	Typ.	Max	Unit
Max input	-20			dBm
Max radiated power 1 Mbps		3.0		dBm
Max radiated power 2 Mbps		2.6		dBm
Input sensitivity 1 Mbps, BER 0.1 %		-94		dBm
Input sensitivity 2 Mbps, BER 0.1 %		-90		dBm
Frequencies	2.402		2.480	GHz

Table 5: Radio characteristics Bluetooth® LE

Description	Min	Typ	Max	Unit
Max input	-20			dBm
Max radiated power BR 1 Mbps		2.4		dBm
Max radiated power EDR 2 Mbps		0.8		dBm
Max radiated power EDR 3 Mbps		1.1		dBm
Input sensitivity BR 1 MBps, BER 0.1 %		-91		dBm
Input sensitivity EDR 2 Mbps, BER 0.1 %		-92		dBm
Input sensitivity EDR 3 Mbps, BER 0.1 %		-87		dBm
Frequencies	2.402		2.480	GHz

Table 6: Radio characteristics Bluetooth® Classic

2.5 Pin characteristics

Property	Min	Typ	Max	Unit
Pin input low voltage			0.8	V
Pin input high voltage	2.4			V
Pin output low voltage			0.4	V
Pin output high voltage	VDD - 0.4			V
Pin output current sunk by P26-P29		16		mA
Pin output current sourced by P26-P29		16		mA
Pin output current sunk by any other I/O and control pin		8		mA
Pin output current sourced by any other I/O and control pin		8		mA
GPIO internal pull-up/pull-down resistor		45		kΩ
GPIO input capacitance			0.4	pF

Table 7: Pin characteristics

2.6 32 kHz crystal oscillator

The Skoll-I module includes pins *XL1* and *XL2* for connecting an external 32.768 kHz crystal. The external crystal shall meet the specification listed below. Additionally to the load capacitors, an external 10 MΩ resistor is needed, as shown in figure 44.

Property	Min	Typ	Max	Unit
Output frequency		32.768		kHz
Frequency Tolerance. Including aging and temperature range			250	ppm
Crystal drive level			0.5	µW
Crystal series resistance			70	kΩ
Crystal shunt capacitance			2.2	pF
Load capacitance		6.0		pF

Table 8: External crystal oscillator characteristics

3 Pinout

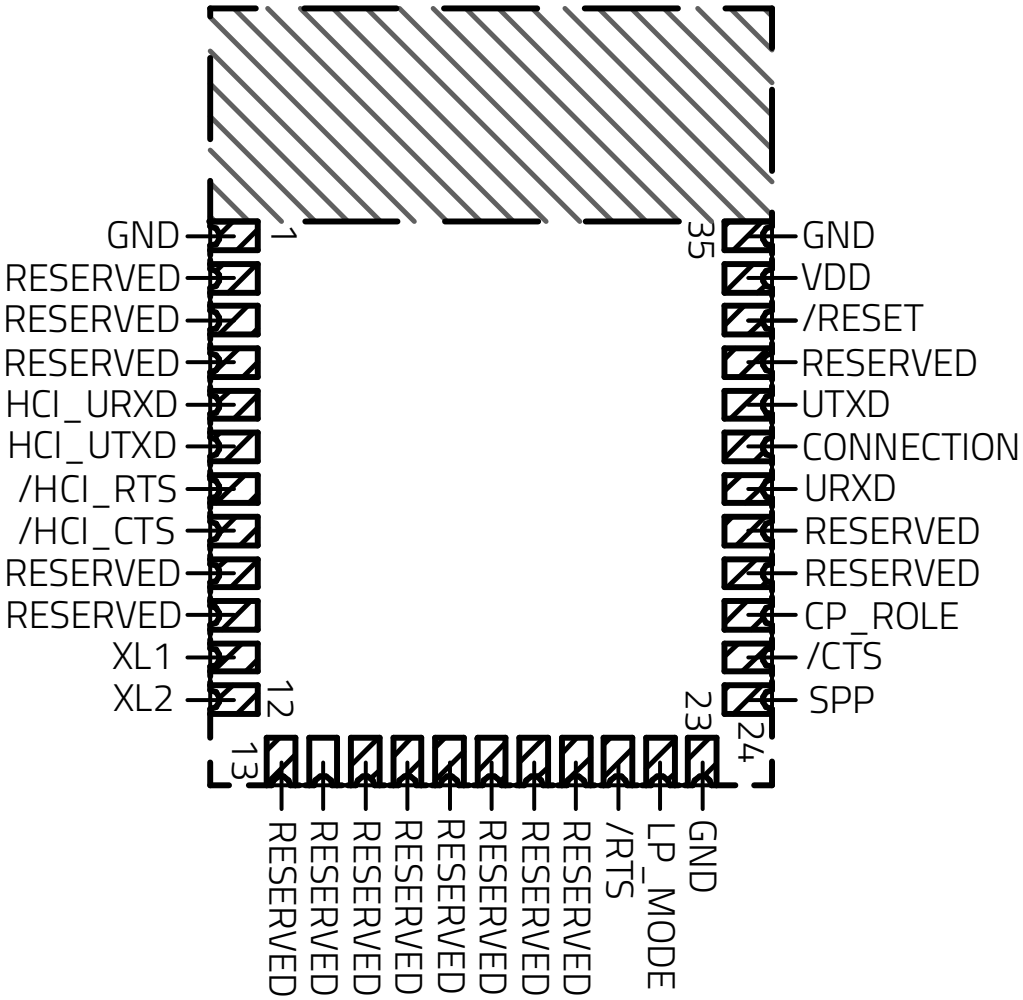


Figure 3: Pinout (top view)

No	Designation	µC pin	I/O	Description
1	*GND*	GND	Supply	Ground
2	*RESERVED*	P26	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
3	*RESERVED*	DEV_WAKE	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
4	*RESERVED*	HOST_WAKE	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
5	*HCI_URXD*	UART_RXD	Input	HCI UART RX
6	*HCI_UTXD*	UART_TXD	Output	HCI UART TX
7	*/HCI_RTS*	UART_RTS_N	Output	HCI UART RTS
8	*/HCI_CTS*	UART_CTS_N	Input	HCI UART CTS, connect to external pull-up. Also see table 10
9	*RESERVED*	P8	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
10	*RESERVED*	P15	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
11	*XL1*	XTALO_32K	Output	Connect to external oscillator (32.768 kHz)
12	*XL2*	XTALI_32K	Input	Connect to external oscillator (32.768 kHz)
13	*RESERVED*	P3	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
14	*RESERVED*	P2	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
15	*RESERVED*	P4	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
16	*RESERVED*	P6	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
17	*RESERVED*	P5	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected

18	*RESERVED*	P17	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
19	*RESERVED*	P14	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
20	*RESERVED*	P9	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
21	*/RTS*	P11, /RTS_PUART	Output	Application UART RTS. Solder but leave electrically unconnected, if not needed
22	*LP_MODE*	P12, LP_MODE	Input	Disable low power mode. Connect to pull-up, pull-down or micro controller to avoid floating state. Also see table 10
23	*GND*	GND	Supply	Ground
24	*SPP*	P13, CYSPP	I/O	Enter SPP data mode. Solder but leave electrically unconnected, if not needed. Also see table 10
25	*/CTS*	P10, /CTS_PUART	Input	Application UART CTS. Solder but leave electrically unconnected, if not needed
26	*CP_ROLE*	P1, CP_ROLE	I/O	GAP role selection. Solder but leave electrically unconnected, if not needed. See also table 10
27	*RESERVED*	P0	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
28	*RESERVED*	P28	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
29	*URXD*	P37, RX_PUART	Input	Application UART RX
30	*CONNECTION*	P27, CON-NECTION	Output	Connection status. Solder but leave electrically unconnected, if not needed. Also see table 10
31	*UTXD*	P32, TX_PUART	Output	Application UART TX
32	*RESERVED*	P29	–	µC GPIO - not addressable via Skoll-I firmware, shall be soldered but electrically unconnected
33	*/RESET*	XRES	Input	Reset pin, active low, connect to external pull-up

34	*VDD*	VDD	Supply	Supply voltage
35	*GND*	GND	Supply	Ground

Table 9: Pinout

Designation	I/O	Description
/HCI_CTS	Input	Holding this pin to LOW during boot-up, resets the HCI UART interface.
CONNECTION	Output	If this pin is set to LOW, a Bluetooth® peer has connected. If *SPP* is LOW in addition, the Bluetooth® link to the peer device is open and ready for data exchange.
SPP	I/O	This pin can be used to force the module to be in transparent data mode or command mode. If the pin is externally set to LOW, data mode is entered. In that case, payload data is exchanged transparently with the connected Bluetooth® peer, if the *CONNECTION* pin is LOW in addition. If *CONNECTION* is HIGH, the Bluetooth® link has not yet been set up. If this pin is not externally set, the radio module has entered data mode and the Bluetooth® link is open for transparent data exchange, when *SPP* is LOW. Otherwise, the module is still in command mode and the Bluetooth® link has not yet been set up. If a Bluetooth® Classic SPP link is open, setting the *SPP* pin temporary to HIGH closes the Bluetooth® Classic connection and the module returns to command mode. If a Bluetooth® LE CYSPP link is open, setting the *SPP* pin temporary to HIGH switches the module to command mode, where the host can send any UART command (such as a disconnect command) to the Skoll-I. If the pin is externally set to HIGH the Skoll-I cannot enter data mode, and thus Bluetooth® connections can not be set up.
LP_MODE	Input	This pin is used to define the radio module's sleep behaviour. LOW means that is the module is allowed to sleep, if possible. HIGH means that module must be or return to active state.

CP_ROLE	I/O	This pin can be used to force the role of the Bluetooth® LE GAP. If the pin is externally set to LOW, the Skoll-I runs in central mode, HIGH means peripheral mode. If this pin is not set externally and *CONNECTION* is LOW, it can be used as GAP role detection. If this pin is LOW, the module runs in central mode, HIGH means peripheral mode. Otherwise, it has no meaning.

Table 10: Advanced pin function description

4 Quickstart

4.1 Minimal pin configuration

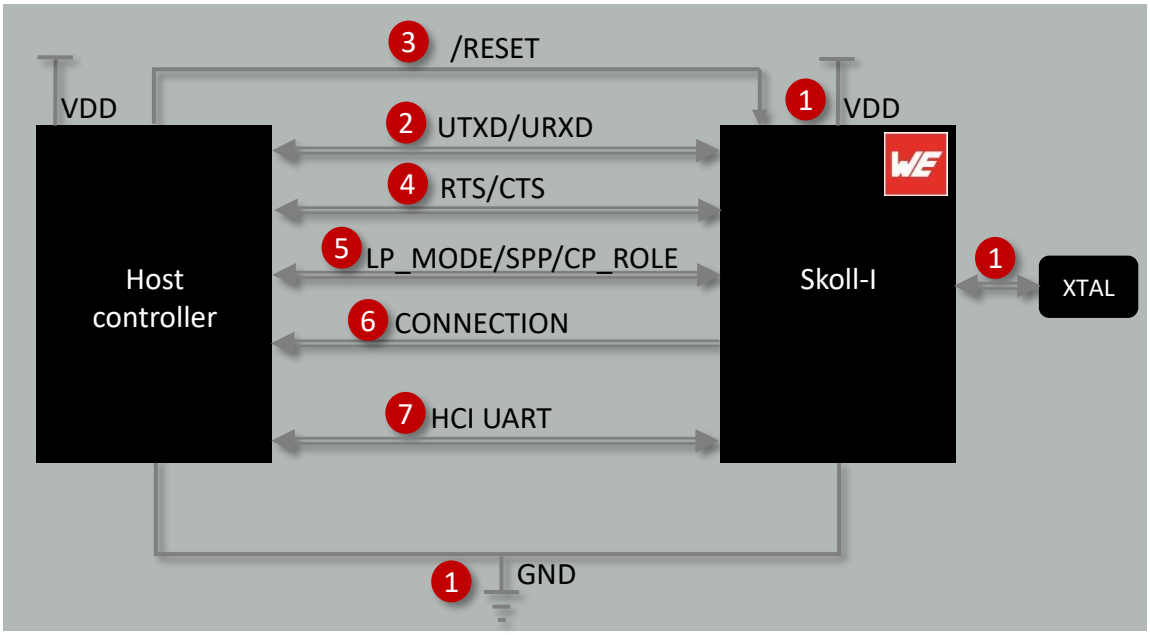


Figure 4: Minimal pin connections

The above image shows the steps to be performed to integrate the Skoll-I into a custom end device.

1. External 32.768 kHz crystal, supply voltage and ground
   First, connect the *VDD* and *GND* pins to supply the radio module with power. Furthermore, connect the external crystal to the *XL1* and *XL2* pins.

2. UART serial interface to the host
   Connect the UART pins *UTXD* and *URXD* to the host to control the module via host.

3. Reset
   Connect the */RESET* pin to the host to allow a hard reset of the module.

4. (Optional) UART flow control
   Connect the */RTS* and */CTS* pins to the host controller in case the UART flow control has to be used.

To guarantee the integrity of the payload data, it is highly recommended to use the flow control capabilities of the radio module.

5. (Optional) Device mode selection
   - Connect the *LP_MODE* pin to the host controller to define the module's low power permissions.
   - Connect the *SPP* pin to the host controller to enter/leave the CYSPP data mode.
   - Connect the *CP_ROLE* pin to the host controller to define the GAP role of the module.
6. (Optional) Status indication
   Connect the *CONNECTION* pin to the host controller to allow easy indication of the status.
7. (Optional) HCI UART for certification tests
   The pins of the HCI UART (*HCI_URXD* - */HCI_CTS*) allow to run the radio test modes. These are needed for certification tests only, and are not used otherwise.

4.2 Power up

After a stable power supply has been applied to the module, set the */HCI_CTS* pin to high. Then the */RESET* pin can be released to high state to boot-up the Skoll-I. As soon as the radio module has booted, a start-up message is sent via UART to the connected host MCU. From this point on, the Skoll-I is ready to be controlled via commands by the host MCU.

Variable	Value	Unit
t_{reset}	5	ms
t_{boot}	700	ms

Table 11: Start-up timings

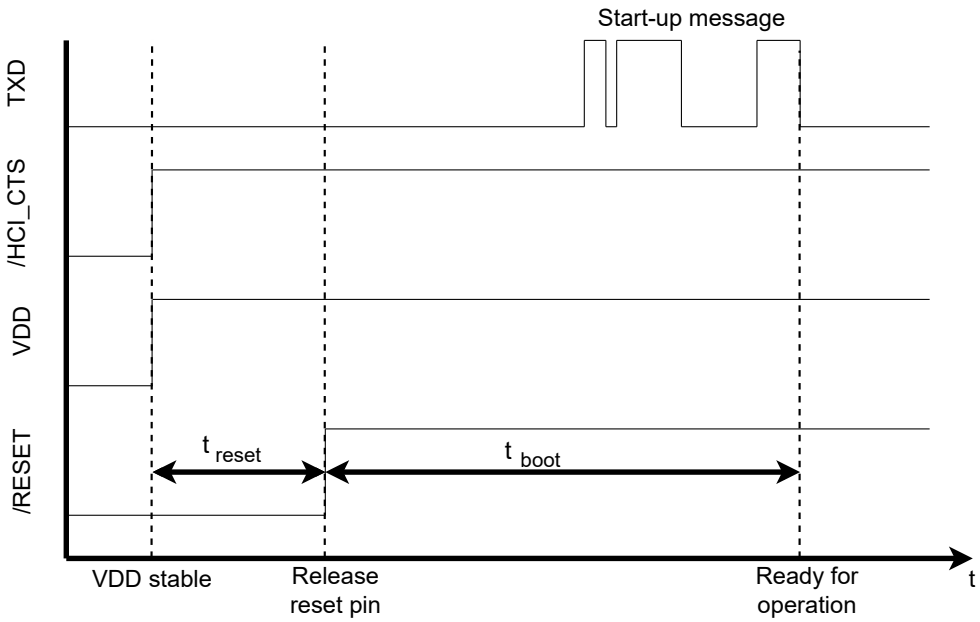


Figure 5: Power up

4.3 Quickstart example

In this quick start example we setup a Bluetooth® Classic connection between the Skoll-I radio module acting as Bluetooth® slave and a Windows PC acting as Bluetooth® master. Then we exchange data between both devices via the Bluetooth® Classic SPP profile.
The same steps can be run on any other Bluetooth®-enabled peer device, such as a smart phone.
Run the following steps:

1. First, reset the device by applying a high-low-high sequence to the */RESET* pin. This can be done on the Skoll-I EV-Board by pressing the reset button. The module will reply with a start-up message:

Info	Message
⇐ Module is ready for operation	@E,0076,BOOT...

2. Disable the Bluetooth® LE (CYSPP) interface of the Skoll-I:

Info	Message
⇒ Disable CYSPP interface	.CYSPPSP,E=0
⇐ Success	@R,000E,.CYSPPSP,0000

3. Set the Bluetooth® Classic device name such that it can be easily found on the radio during scan:

Info	Message
⇒ Set the device name to "Skoll-I"	SDN,T=01,N=Skoll-I
⇐ Success	@R,0009,SDN,0000

4. The next steps have to be executed on the Windows machine. The Bluetooth® LE interface needs to be enabled and a connection to the radio module must be set up. To do this, type "Bluetooth" in your Windows menu and enter the "Bluetooth & other devices" menu in the control panel.
   Enable Bluetooth® and click on "+" to add a new Bluetooth® device:

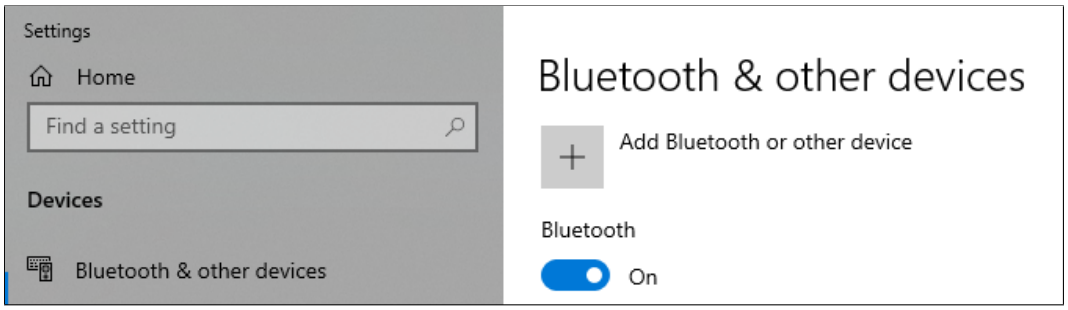


Figure 6: Windows menu

5. A window pops up, where you have to select "Bluetooth®". The PC starts to scan for Bluetooth® slave devices. As soon as the previously specified device name (here we chose "Skoll-I") is part of the scan list, click on it to connect.

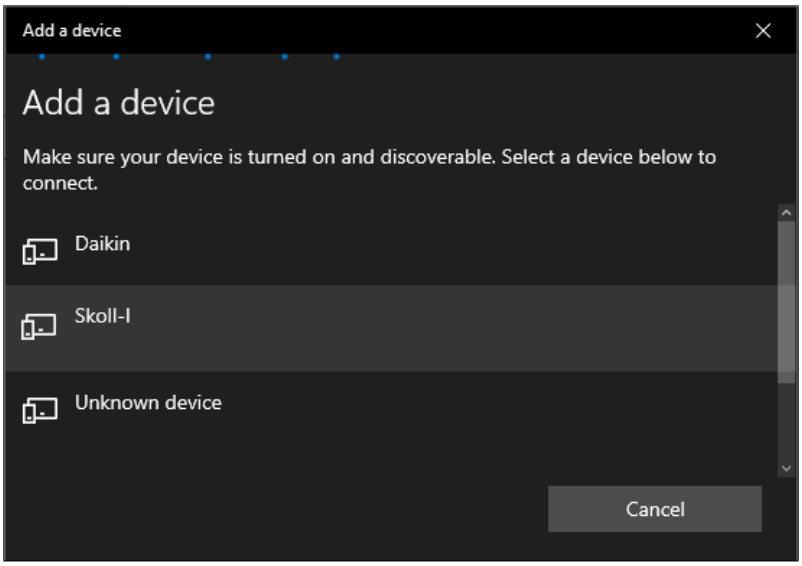


Figure 7: Add device

On the Skoll-I side, the following messages are printed:

Info	Message
⇐ Pairing has been requested	@E,001B,P,C=00,M=00,B=00,K=00,P=00
⇐ Pairing has been done	@E,000F,PR,C=00,R=0000
⇐ Encryption of communication started	@E,000E,ENC,C=00,S=00

6. Now a COM port shows up on the Windows PC, which can be opened by any terminal tool.
   Here we use hterm [3]. Open it, select the COM port, which has been created and click on "Connect". On the Skoll-I side, the following messages are printed and the *CONNECTION* pin turns low (Connection LED turns on).

Info	Message
⇐ A peer device has fully connected	@E,0024,BTCON,C=02,A=001A7DDA7113, T=01,B=00

7. The Skoll-I has entered data mode. Now, data can be transmitted transparently in both directions. First send "Hello I'm Skoll-I" to the Skoll-I,

Info	Message
⇒ Transmit data	Hello I'm Skoll-I

which is received on the PC in hterm.

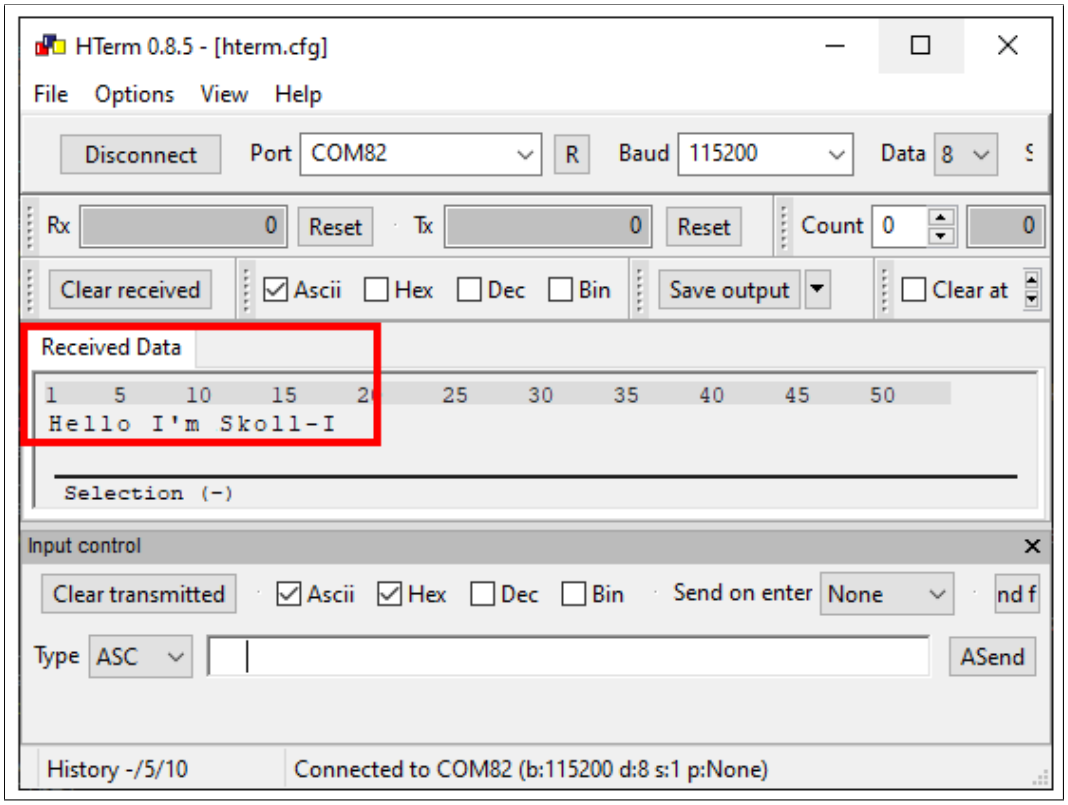


Figure 8: Received data on Windows PC

8. Then insert "Nice to meet you" on the hterm and press enter to transmit it:

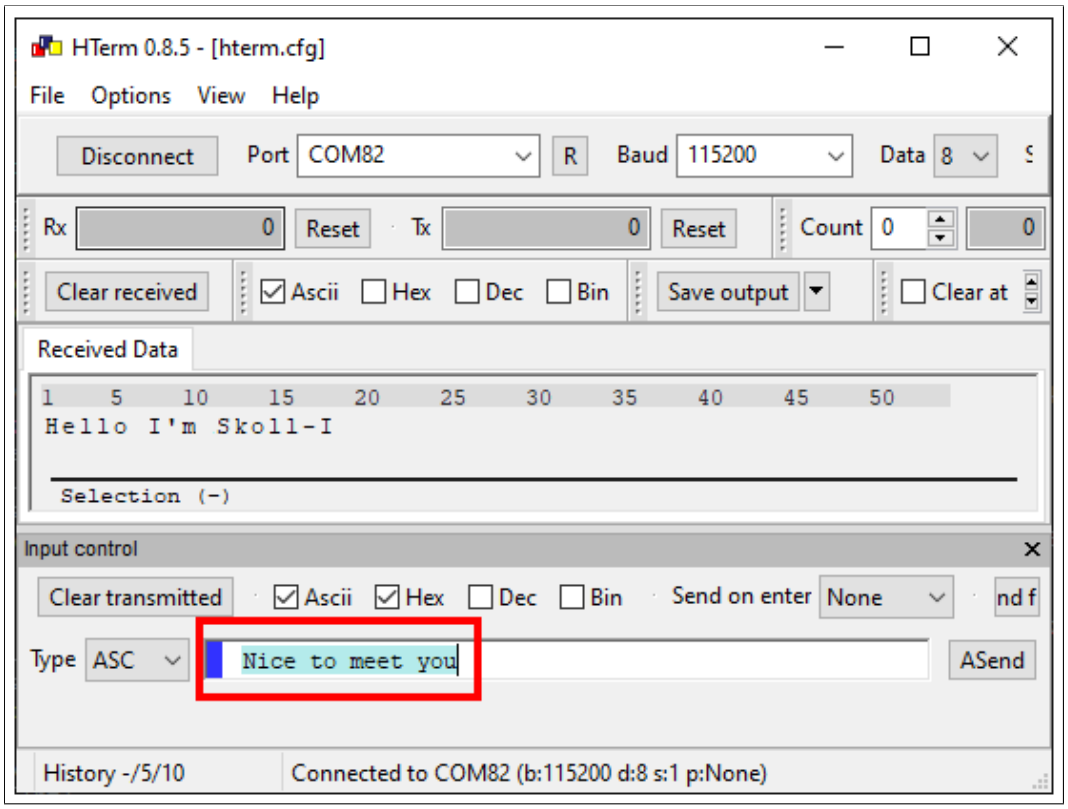


Figure 9: Transmit data on Windows PC

This data is received on the Skoll-I side:

Info	Message
⇐ Received data	Nice to meet you

9. If no more data is to be transmitted, close the COM port in hterm or disconnect in the Windows Bluetooth® menu to close the connection.

Info	Message
⇐ Peer device disconnected	@E,0012,BTDIS,C=02,R=0000

5 Functional description

The full feature set of Skoll-I is available in a separate document, the firmware documentation [1]. Nevertheless, the main features are summarized in the subsequent sections.

5.1 Serial interface: UART

The Skoll-I module acts as a slave and can be fully controlled via UART by an external host. The configuration in factory state of the UART is 115200 Baud with data format of 8 data bits, no parity and 1 stop bits ("8n1"), with flow control disabled. The baud rate, the parity, the number of stop bits and the flow control can be configured by means of the command `system_set_uart_parameters` [1]. Enabling flow control, in case the host device supports it, increases the reliability of data transmission.

Any baud rate between 5.860 and 2666.667 kBaud can be configured. However, due to the UART clock of 24 MHz, single baud rates run with 0 % error. These can simply be calculated by dividing the 24 MHz clock by a pre-scaler:

Pre-scaler	Resulting baud rate [kBaud]
9	2666.6667[1]
10	2400[1]
12	2000
15	1600[1]
16	1500
20	1200
24	1000
26	923.0769231
52	461.5384615
104	230.7692308
208	115.3846154
624	38.46153846
1248	19.23076923
2496	9.615384615
4095	5.860805861

Table 12: Example baud rates with 0 % error

The size of the UART RX buffer is 172 bytes in text mode. In binary mode, it is able to buffer up to 300 bytes.

The Skoll-I supports the following operating modes:

[1] The FTDI USB-UART converter chip used on the Skoll-I EV-Board runs this baud rate with high error rate. Thus, PC to module communication on the Skoll-I EV-Board does not work using these baud rates.

- The **command mode**, where the Skoll-I can be controlled by the host controller via commands. The functions of the radio module, like data transmission or configuration tasks, can be triggered by predefined commands, which are sent as telegrams over the UART interface. These commands can be sent "text-based", which are human readable and perfect for prototyping tasks, or "binary-based", which are optimized in terms of performance and perfect for the operation in the end device. The module detects which format is used. Therefore, both formats can be used simultaneously by the host device.
  Examples are available in chapter `Use cases and examples`, in the firmware documentation [1] as well as in our driver implementation (Wireless Connectivity SDK [4]).
- The **data mode**, where the radio module acts as a transparent wireless bridge. All data received on the UART interface will be transmitted via radio, and all data received on the radio interface will be sent out via UART to the connected host device. In this mode, data transmission can be done by the host without using any commands. Refer to chapter `5.1.1` for more details.

Switching between the two modes is possible.

5.1.1 Data mode - Transparent cable replacement via Bluetooth® LE

The *SPP* pin can be used to determine whether the module operates in **command mode** or **data mode**. Furthermore, the *CP_ROLE* pin determines, whether the device acts as Bluetooth® LE central or peripheral device.
With this, externally switching the *SPP* pin to LOW and switching the *CP_ROLE* to HIGH, let's the module run the data mode as a Bluetooth® LE peripheral, where it is connectable for other peer devices. Similar to that, *SPP* pin is LOW and *CP_ROLE* is LOW as well, lets the device operate as Bluetooth® LE central device in data mode, where it tries to connect to a Bluetooth® LE peripheral device providing the CYSPP Bluetooth® LE profile.

In both configurations, the *CONNECTION* pin shows when a Bluetooth® LE link has been established. If this is the case, data can be transparently exchanged with the peer device. Also see table `10` for a more detailed description of the module's pin functions.

The Skoll-I in data mode uses the pre-configured device settings, for example the device name shown on the Bluetooth® LE interface. These must be configured once using command mode and are stored such that they are automatically applied after each reboot. Refer to chapter `Device configuration and initialization` for more details.

5.2 Device configuration and initialization

In command mode, the device settings, for example the device name shown on the Bluetooth® LE interface, can be adjusted and stored such that they are available after each boot-up.
Another nice option to initialize a Skoll-I, independent of the device settings, is to use the so-called "init commands" [1]. Any command sent to the module can be placed in an initialization command list, which is run after each reboot. With this, actions such as disabling the Bluetooth® LE interface or starting the advertising, can be realized after each reboot.

5.3 Radio compatibility

Bluetooth® devices use so called Bluetooth® profiles to exchange data in between them. Devices are only compatible on the Bluetooth® interface if they implement and use the same profile. Skoll-I contains two pre-built profiles, as well as the option to create the needed profile during runtime to be flexible in terms of Bluetooth® device compatibility. Thus, it supports three ways of Bluetooth® communication.
The first is using the built-in Bluetooth® Classic SPP profile for serial data transmission on the Bluetooth® Classic interface. The second is the built-in Bluetooth® LE CYSPP profile, which is a custom profile providing the opportunity for serial data transmission on the Bluetooth® LE interface. For scenarios where neither ways are optimal, the third option allows to add new custom profiles to the Skoll-I at runtime, which can be tailored to the customer's application.
These options are considered in the subsequent chapters in more detail.

5.3.1 Bluetooth® Classic

On the Bluetooth® Classic interface the Skoll-I provides the standardized "Serial Port Profile v1.2" (SPP) [5]. Thus, it is compatible on the radio to any other Bluetooth® enabled device that supports this profile.

The Würth Elektronik eiSos legacy Bluetooth® Classic 2.0 radio module Puck-I, formerly known as AMB2300 or AMB2301, has been released in the early 2000s. It is integrated in various end devices in industry and medical environment and implements the SPP as well. Thus, Skoll-I is radio compatible to Puck-I as well, which means that existing Puck-I Bluetooth® systems can be extended or replaced by Skoll-I radio modules.

Refer to the chapter 8.2 or the firmware documentation [1] to find examples for SPP connection setup and communication to any SPP enabled device, like Puck-I.

5.3.2 Bluetooth® LE

For Bluetooth® LE, a standardized Bluetooth® profile for serial data transmission, like the Bluetooth® Classic SPP, does not exist. Thus, every manufacturer provides an own custom profile for this purpose.
The Skoll-I therefore brings the built-in CYSPP profile, which is compatible on the radio to any other Bluetooth® LE enabled device providing this profile.
To increase the Bluetooth® LE connectivity abilities, the Skoll-I furthermore allows to add additional Bluetooth® LE profiles to the module at runtime. One of these profiles is the "WE SPP-like" profile used in all modules of the Würth Elektronik eiSos Bluetooth® LE radio module series, like Proteus-III.
Chapter 8.3.1 contains an example on how to run the Skoll-I as Bluetooth® LE peripheral, add the "WE SPP-like" and use it for communication with Proteus modules. Chapter 8.3.3 demonstrates how to run the Skoll-I as Bluetooth® LE central and connect to a Proteus radio module for communication. More examples are placed in chapter 8.3 or the firmware documentation [1].

5.4 Sleep modes

The Skoll-I has two different sleep modes:

- The PDS (sleep) mode, where the CPU is off, but RAM is retained and radio functions are still active. Therefore, depending on the Bluetooth®/Bluetooth® LE activity, the current consumption in this mode differs between 200 µA and a few mA.
- The HID-off (deep sleep) mode, where the module is completely off. When leaving this mode, the module restarts using its default settings.

Which of the sleep modes is active, is automatically chosen by the module depending on the module's state, the configured sleep parameters and the *LP_MODE* pin.

- If the *LP_MODE* pin is set to HIGH, the module does not go to any of the sleep modes or wakes up, in case it was in sleep mode. If this pin is set to LOW, the module chooses a sleep mode depending on the current module state and the sleep parameters.
- The sleep parameters of the module determine whether the PDS or the HID-off mode is the lowest sleep mode the module is allowed to choose. The parameters can be modified using the `system_set_sleep_parameters` command.
  This command can be also used to set the module to HID-off mode for a user-selectable time, after the *LP_MODE* pin is set to LOW. This allows to module to wake-up timer-based independent of any external trigger.

For more details, refer to the Infineon firmware documentation [1].

5.5 Best practices

- To guarantee the integrity of the payload data, it is highly recommended to use the flow control capabilities of the radio module.
- When adding a custom Bluetooth® LE profile (i.e. WE SPP-like) to the Skoll-I, disable the built-in CYSPP profile, in case it's not needed.
- To support legacy connections the module does not select active security setup by default. Users are encouraged to configure the module to select secured modes when the connection partners allow that.

6 The command interface

The Skoll-I provides a text-based as well as a binary-based set of commands, which are sent via the UART interface for configuration and control of the module functions. The commands are arranged into the following groups:

- **Protocol** commands, that define the UART protocol interpretation behavior
- **System** commands, that define the generic system behavior like sleep mode, TX power, reset, setting storing
- **SPP** commands, that define the handling of the built-in Bluetooth® Classic SPP (serial port profile) connection
- **CYSPP** commands, that define the handling of the build-in Bluetooth® LE CYSPP profile connection
- **GAP** commands, that define the features related to the connection setup using generic Bluetooth® LE
- **GATT server** commands, that define the creation and handling of generic Bluetooth® LE profiles in peripheral role
- **GATT client** commands, that define the usage of generic Bluetooth® LE profiles in central role
- **SMP** commands, that define the handling of security related features of the Bluetooth® interface
- **BT** commands, that define the features related to the generic connection setup using Bluetooth® Classic

For command interface documentation, refer to the Infineon firmware documentation [1].

To safe time in evaluation and development phase, Würth Elektronik eiSos provides two tools:

1. For rapid prototyping tasks, the PC tool `WE UART Terminal` allows to use the module functions by a simple GUI.
2. For the development of the end device, the `Wireless connectivity SDK` implements the command interface in C code to drive the radio module in the most efficient way.

6.1 WE UART Terminal

The WE UART Terminal is an easy-to-use PC software for Windows, which enables complete control of the Würth Elektronik eiSos wireless modules through an intuitive GUI. It implements the UART command interface of the Skoll-I in text-based mode. Since all device functions are abstracted to buttons and drop-down menus, the WE UART Terminal significantly simplifies prototyping and product evaluation. It can be downloaded from our web page [6].

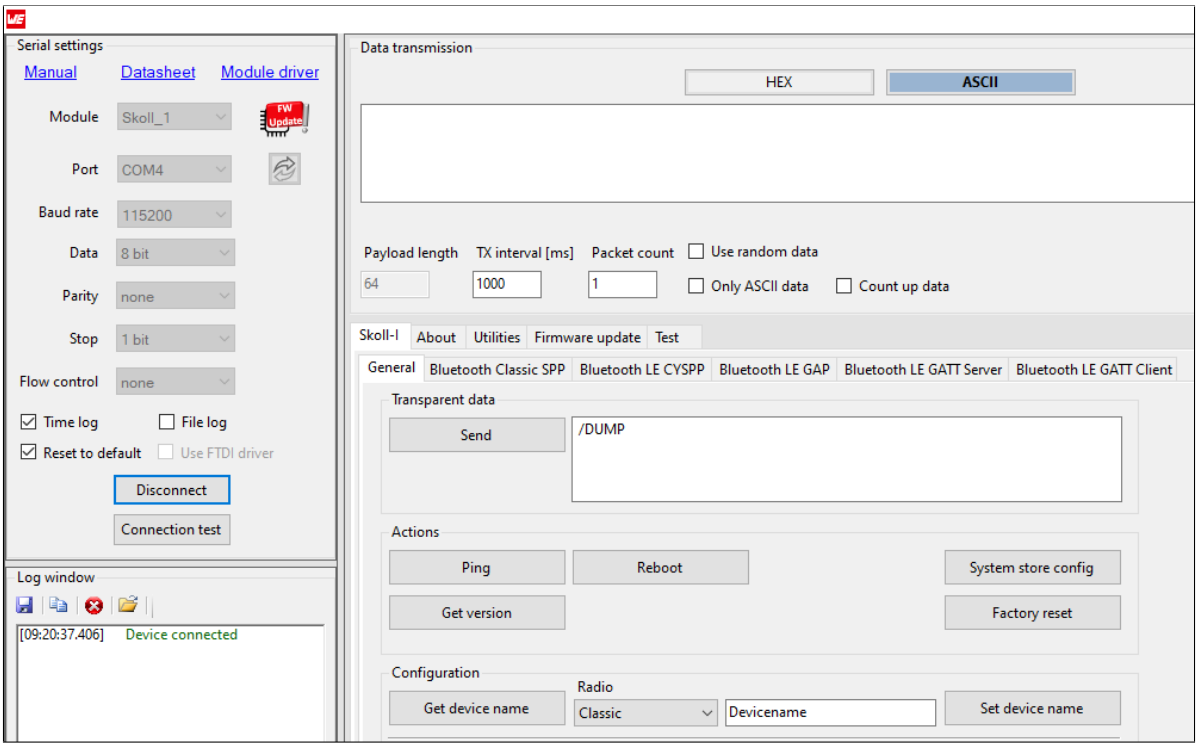


Figure 10: WE UART Terminal PC tool for prototyping

6.2 Wireless connectivity SDK

Besides the WE UART Terminal PC tool, there is also the so called "Wireless connectivity SDK", which is an implementation of all commands in binary mode into C code. This implementation can be used to quickly integrate the UART connectivity to the connected host MCU. It's available on GitHub [7].

```
...
/**
* @brief Skoll-I pins
*/
typedef struct Skoll_I_Pins_t
{
    WE_Pin_t Skoll_I_Pin_Reset;
    WE_Pin_t Skoll_I_Pin_SPP;
    WE_Pin_t Skoll_I_Pin_Connection;
} Skoll_I_Pins_t;

extern bool Skoll_I_Init(WE_UART_t *uartP, Skoll_I_Pins_t *pinoutP, void (*event_handler_in
    )(ezs_packet_t *packet), void (*transparentdata_handler_in)(uint8_t *payload, uint16_t
    payloadLength));
extern bool Skoll_I_Deinit(void);
extern bool Skoll_I_Configure();

extern bool Skoll_I_PinReset(void);
...
```

Code 1: Skoll-I/ATCommands/ATBluetoothLE.h

7 Timing parameters

7.1 Boot

After power-up or resetting the module, a boot up message is sent via the serial interface as soon as the module is ready for operation.

Description	Typ.	Unit
Boot time	600	ms

7.2 Bluetooth® LE timing parameters

The Bluetooth® LE interface is highly configurable with respect to its timing behavior. By default, the Skoll-I implements reasonable values defining its advertising, scan and connection behavior, which are a compromise between performance and power consumption.
Nevertheless, for speeding the timings up or to lower the power consumption, commands `gap_set_adv_parameters`, `gap_set_scan_parameters` and `gap_set_conn_parameters` are available.

7.3 Bluetooth® LE and Bluetooth® Classic connection based data transmission

After a connection has been setup in Bluetooth® Classic SPP or Bluetooth® LE CYSPP mode, data can be transmitted transparently to the Skoll-I. The radio module buffers the data and sends it to the peer as soon as possible. If the internal buffer is full, the UART flow control pin */RTS* turns high to show that the host has to pause its data transmission. As soon as the buffer has some free space again, the */RTS* pin turns low.

7.3.1 CYSPP - Maximum data throughput

To get the highest throughput, use the following test setup:

- One Skoll-I radio module connected to a fast micro controller (e.g. STM32 on NUCLEO-F401RE) in CYSPP mode
- UART baud rate of 2.666 MBaud with HW flow control enabled
- UART protocol in binary mode
- Android smartphone with nRF Connect app [8]
- Connection priority high (11.25 - 15 ms), MTU of 517 Bytes
- Radio mode as specified in the table below

Radio mode	Characteristic	Data length [kByte]	Transmission time [ms]	Throughput [kByte/s]
1 Mbit/s	Unacknowledged	153.6	2000	76.8
1 Mbit/s	Acknowledged	153.6	9080	16.9

Table 13: CYSPP maximum throughput, packet error rate = 0%

7.3.2 SPP - Maximum data throughput

To get the highest throughput, use the following test setup:

- One Skoll-I radio module connected to a fast micro controller (e.g. STM32 on NUCLEO-F401RE) in SPP mode
- UART baud rate of 2.666 MBaud with HW flow control enabled
- UART protocol in binary mode
- Android smartphone with serial terminal app [9]

Radio mode	Data length [kByte]	Transmission time [ms]	Throughput [kByte/s]
3 Mbit/s (EDR)	153.6	929	165.34

Table 14: SPP maximum throughput, packet error rate = 0%

8 Use cases and examples

The documentation [1] of the firmware provided by Infineon contains numerous examples for Bluetooth® connectivity as well as for low power operation. Additional examples and use cases can be found in the corresponding subsections.

The Skoll-I is a versatile radio module that supports both Bluetooth® LE and Bluetooth® Classic standards for wireless data transfer. A typical application is transferring data similar to a serial port from one point to another. In Bluetooth® Classic, this is commonly achieved using the Bluetooth® Serial Port Profile (SPP). Although Bluetooth® LE by default does not have an equivalent standardized profile, the Skoll-I module can utilize custom profiles using the Bluetooth® LE Generic Attribute Profile (GATT). This allows for serial data transfer over Bluetooth® LE in a similar manner to Bluetooth® Classic SPP.
Such a profile, called CYSPP, is already built into the module, so that the user can start sending and receiving data without having to create any custom profile at all. It is however possible to create more custom profiles, enabling the module to establish Bluetooth® LE WE SPP-like communication with Würth Elektronik eiSos "Proteus" series of Bluetooth® LE radio modules as well. Examples for these types of communication are provided in the following sections.

The Bluetooth® LE examples discuss the Skoll-I module in two different roles: central and peripheral. In Bluetooth® LE communication, the central role refers to the device that initiates connections and manages data transfer, while the peripheral role denotes the device that advertises its availability and responds to connection requests from the central device.
In Bluetooth® Classic, the roles are called master and slave, where the master is the one initiating the Bluetooth® connection, similar to the central in Bluetooth® LE. The slave then accepts the connection request, similar to the peripheral in Bluetooth® LE.

The Wireless Connectivity SDK [4] available on GitHub contains the implementation of the command API functions and examples in C code.

8.1 Bluetooth® LE examples using CYSPP

When CYSPP mode is started, the EZ-Serial firmware platform for the Skoll-I module manages the entire connection process and data pipe setup. If Skoll-I modules are used on both ends of the connection, CYSPP mode with complementary roles (peripheral on one end, central on the other) shall be started. The modules will then automatically connect and prepare the data pipe as described below.
In practice, this means that, if it is intended that two Skoll-I modules communicate via CYSPP as a cable replacement in a transparent manner, two Skoll-I modules need to be set up as follows: the first module as described in chapter 8.1.1, and the second Skoll-I module as described in chapter 8.1.2. This is a straightforward process, as most of the steps are taken automatically out of the box. The CYSPP mode needs to be started either manually or enabling auto-start with WE UART Terminal PC tool [6] from Würth Elektronik eiSos. A practical, easy tutorial for this can be found in chapter 8.1.3, while the technical details are shown in

chapter 8.1.1 and chapter 8.1.2.

If a third-party device is being used, such as a Bluetooth® LE enabled smartphone, for one end of the connection, it will need to be configured to follow the same procedure. For configuration examples in each mode, refer to the provided examples, which include connections to a remote computer or a smartphone using both CYSPP and SPP.

When the Skoll-I module is building up a communication pipeline in CYSPP mode, it generally follows these steps:

1. The EZ-Serial firmware platform for the Skoll-I module begins advertising with the configured advertisement settings.
2. Upon connection, the remote peer must subscribe to one of the two "Data" characteristics:
   a) Acknowledged Data - enable indications (ensures reliability)
   b) Unacknowledged Data - enable notifications (allows faster potential throughput)
3. The EZ-Serial firmware platform for the Skoll-I module will assert the *CONNECTION* pin, signaling that CYSPP is ready for data transmission.
4. The data pipe will remain open until the central device disconnects, unsubscribes from the data characteristic, or the *SPP* pin is de-asserted locally.

8.1.1 Starting CYSPP out of the box in peripheral mode (being connected to from a remote device)

The firmware platform for the Skoll-I module's factory default configuration automatically starts CYSPP operation in the peripheral role after booting. To establish a CYSPP data pipe, simply scan and connect from a remote device, then subscribe to the desired acknowledged or unacknowledged data characteristic as described in the section "Sending and receiving data in CYSPP data mode."

In peripheral mode, besides ensuring that the module is started in CYSPP mode, no further action is required to run communicating via CYSPP.

The CYSPP mode can be started using any of these three methods:

1. Assert (LOW) the *SPP* pin externally. This pin may be connected to ground in hardware designs which require CYSPP operation only and never need API communication. This pin can also be used to enter CYSPP mode, even if the CYSPP profile is disabled in the platform configuration.
2. Use the `p_cyspp_start (.CYSPPSTART, ID=10/2)` API command. This command can be used to enter CYSPP mode, even if the CYSPP profile is disabled in the platform configuration.
3. Have a remote GATT Client connect and subscribe to the CYSPP acknowledged data characteristic (enabling indications) or unacknowledged data characteristic (enabling notifications). This method will enter CYSPP mode only if the CYSPP profile is enabled in the platform configuration.

When starting CYSPP mode locally using either the *SPP* pin or the `p_cyspp_start (.CYSPPSTART, ID=10/2)` API command, the data pipe will not be immediately available because the remote device must still connect and set up proper GATT data subscriptions. If 100% data delivery is required in this context, the host should monitor the *CONNECTION* pin to determine when it is safe to begin sending data from the host for Bluetooth® LE transmission. Once the *CONNECTION* pin is asserted while the *SPP* pin is also asserted, the host may send and receive data over CYSPP Bluetooth® LE profile.
Note: Externally asserting (LOW) the *SPP* pin will always begin CYSPP operation, even if the profile has been disabled in the platform configuration via the `p_cyspp_set_parameters (.CYSPPSP, ID=10/3)` API command. If you do not require CYSPP operation, you should ensure that this pin remains electrically floating or externally de-asserted (HIGH).

In this example, the complete boot and CYSPP connection process is demonstrated using the Skoll-I in peripheral mode.

1. First of all, the device needs to be reset by applying a high-low-high sequence to the */RESET* pin. This can be done on the Skoll-I EV-Board by pressing the reset button. The module will reply with a start-up message and signals that the CYSPP-triggered advertisement has started:

Info	Message
⇐ Module is ready for operation	@E,003B,BOOT,E=0101021C,S=02020355, P=0103,H=B1,C=00,A=20737A1A21D3
⇐ CYSPP-triggered advertisement started	@E,000E,ASC,S=01,R=03

2. Then a connection can be established from a remote device:

Info	Message
⇐ Connection established with remote device	@E,0035,C,C=40,A=00A050422A0F,T=00, I=0006,L=0000,O=0064,B=00

3. Then the remote client should write [01 00] to CCCD for unacknowledged data to enable notifications from that characteristic.

Info	Message
⇐ Remote client writes [01 00] to CCCD for unacknowledged data to enable notifications from that characteristic.	@E,001A,W,C=40,H=0012,T=00,D=0100
⇐ CYSPP status update (0x01): 0x01: Subscribed to unacknowledged data	@E,000C,.CYSPP,S=01

The host can now send data to the module, which will then transmit it to the remote peer device using the CYSPP profile over Bluetooth® LE. Similarly, any data received by the host will come from the remote peer device.

8.1.2 Starting CYSPP out of the box in central mode (connecting to a remote device that also supports CYSPP)

Starting CYSPP client mode with factory default settings also requires no reconfiguration, since CYSPP mode will start automatically. However, the CP_ROLE pin must be asserted (LOW) at boot time or set G=1 using the `p_cyspp_set_parameters (.CYSPPSP, ID=10/3)` command, which can be initiated by using one of the provided Würth Elektronik eiSos tools.

In this example, the complete boot and CYSPP connection process is demonstrated using the Skoll-I in central mode.

Info	Message
⇐ Boot event	@E,003B,BOOT,E=0101011A,S=03030035, P=0103, H=05,C=01,A=00A050E3835F
⇐ CYSPP-triggered scan started	@E,000E,SSC,S=02,R=03
⇐ Scan result (advertisement fields separated for easier interpretation)	@E,0062,S,R=00,A=00A050421650,T=00, S=D1,B=00,D=020106110700A10C2000089 A9EE21115A13333336507FF310100000000
⇐ CYSPP-triggered scan stopped	@E,000E,SSC,S=00,R=03
⇐ Connection established with remote device	@E,0035,C,C=04,A=00A050421650,T=00, I=0006,L=0000,O=0064,B=00
⇐ GATT discovery result (0x1800)	@E,0029,DR,C=04,H=0001,R=0007,T=2800, P=00,U=0018
⇐ GATT discovery result (0x1801)	@E,0029,DR,C=04,H=0008,R=000B,T=2800, P=00,U=0118
⇐ GATT discovery result (CYSPP service)	@E,0045,DR,C=04,H=000C,R=0015,T=2800, P=00, U=00A10C2000089A9EE21115A133333365
⇐ Remote procedure complete	@E,0010,RPC,C=04,R=060A
⇐ GATT discovery result (service declaration)	@E,0029,DR,C=04,H=000C,R=0000,T=2800, P=00,U=0028
⇐ GATT discovery result (characteristic declaration)	@E,0029,DR,C=04,H=000D,R=0000,T=2803, P=00,U=0328
⇐ GATT discovery result (CYSPP ack'd data)	@E,0045,DR,C=04,H=000E,R=0000,T=0000, P=00, U=01A10C2000089A9EE21115A133333365
⇐ GATT discovery result (configuration descriptor)	@E,0029,DR,C=04,H=000F,R=0000,T=2902, P=00,U=0229
⇐ GATT discovery result (characteristic declaration)	@E,0029,DR,C=04,H=0010,R=0000,T=2803, P=00,U=0328
⇐ GATT discovery result (CYSPP unack'd data)	@E,0045,DR,C=04,H=0011,R=0000,T=0000, P=00, U=02A10C2000089A9EE21115A133333365

Info	Message
⇐ GATT discovery result (configuration descriptor)	@E,0029,DR,C=04,H=0012,R=0000,T=2902, P=00,U=0229
⇐ GATT discovery result (characteristic declaration)	@E,0029,DR,C=04,H=0013,R=0000,T=2803, P=00,U=0328
⇐ GATT discovery result (CYSPP RX flow control)	@E,0045,DR,C=04,H=0014,R=0000,T=0000, P=00, U=03A10C2000089A9EE21115A133333365
⇐ GATT discovery result (configuration descriptor)	@E,0029,DR,C=04,H=0015,R=0000,T=2902, P=00,U=0229
⇐ Remote descriptor discovery complete	@E,0010,RPC,C=04,R=0000
⇐ CYSPP status update (0x10): 0x10: CYSPP peer support verified	@E,000C,.CYSPP,S=10
⇐ Remote server acknowledged the write operation that enabled indications on RX flow control characteristic.	@E,0017,WRR,C=04,H=0015,R=0000
⇐ CYSPP status update (0x14):	@E,000C,.CYSPP,S=14 • 0x10: CYSPP peer support verified • 0x04: Subscribed to RX flow control
⇐ Remote server pushes a "flow allowed" value via an indication from the RX flow control characteristic.	@E,0018,D,C=04,H=0014,S=02,D=00
⇐ Remote server acknowledged write operation which enabled notifications on unacknowledged data characteristic	@E,0017,WRR,C=04,H=0012,R=0000
⇐ CYSPP status update (0x15):	@E,000C,.CYSPP,S=15 • 0x10: CYSPP peer support verified • 0x04: Subscribed to RX flow control • 0x01: Subscribed to unacknowledged data

The host can now send data to the module, which will then transmit it to the remote peer device using the CYSPP profile over Bluetooth® LE. Similarly, any data received by the host will come from the remote peer device.

8.1.3 Connecting two Skoll-I modules to each other via CYSPP (using WE UART Terminal)

This tutorial provides a step-by-step guide on setting up and using the CYSPP Bluetooth® LE profile to establish a wireless connection between two Skoll-I modules using the WE UART Terminal tool [6] from Würth Elektronik eiSos. The following instructions show how to configure the modules to communicate transparently over Bluetooth®, enabling the transmission of data between them.

This tutorial focuses more on the practical steps of building up a CYSPP pipeline. The step-by-step description can be found in chapters 8.1.1 and chapter 8.1.2, in case further details are needed.

No matter if an EV-Boards or standalone modules are used, this tutorial will help achieve a seamless connection and data exchange. Let's get started!

1. Take two Skoll-I modules and connect them to a computer. If EV-Boards are being used, the USB cable simply needs to be connected to the computer. The two modules do not necessarily have to be connected to the same computer, as the wireless link happens completely over Bluetooth®. For both modules, the WE UART Terminal tool needs to be started from Würth Elektronik eiSos.

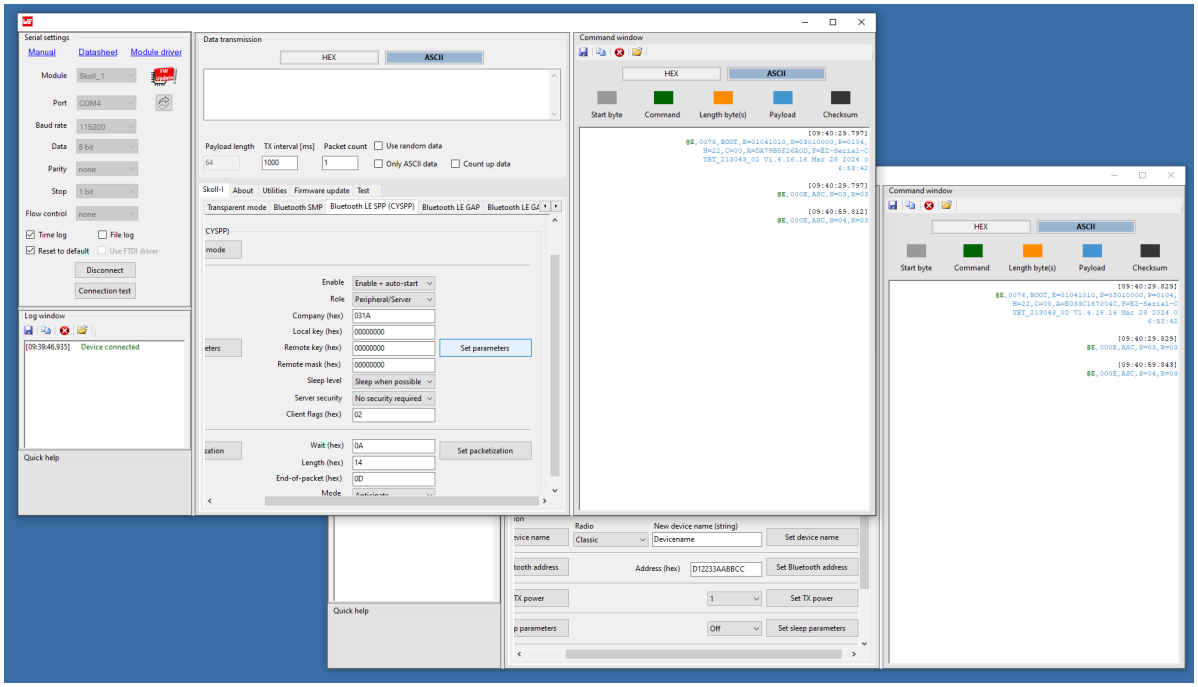


Figure 11: Connecting Skoll-I modules to the computer and starting WE UART Terminal

2. For the first module, go to the CYSPP tab and enable auto-start, and set the role to "Peripheral". Click "Set parameters".

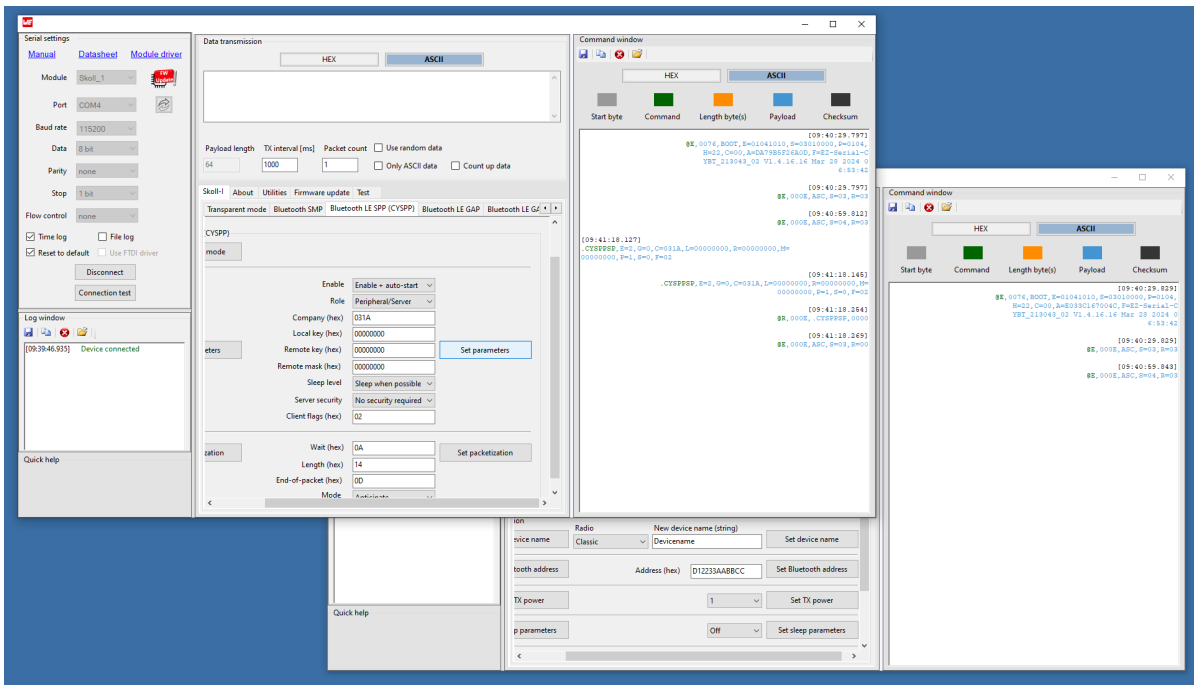


Figure 12: Setting the first module to Peripheral mode

3. For the first module, go to the General tab and click the "System store config" button to store the settings so that they are retained even after a reset.

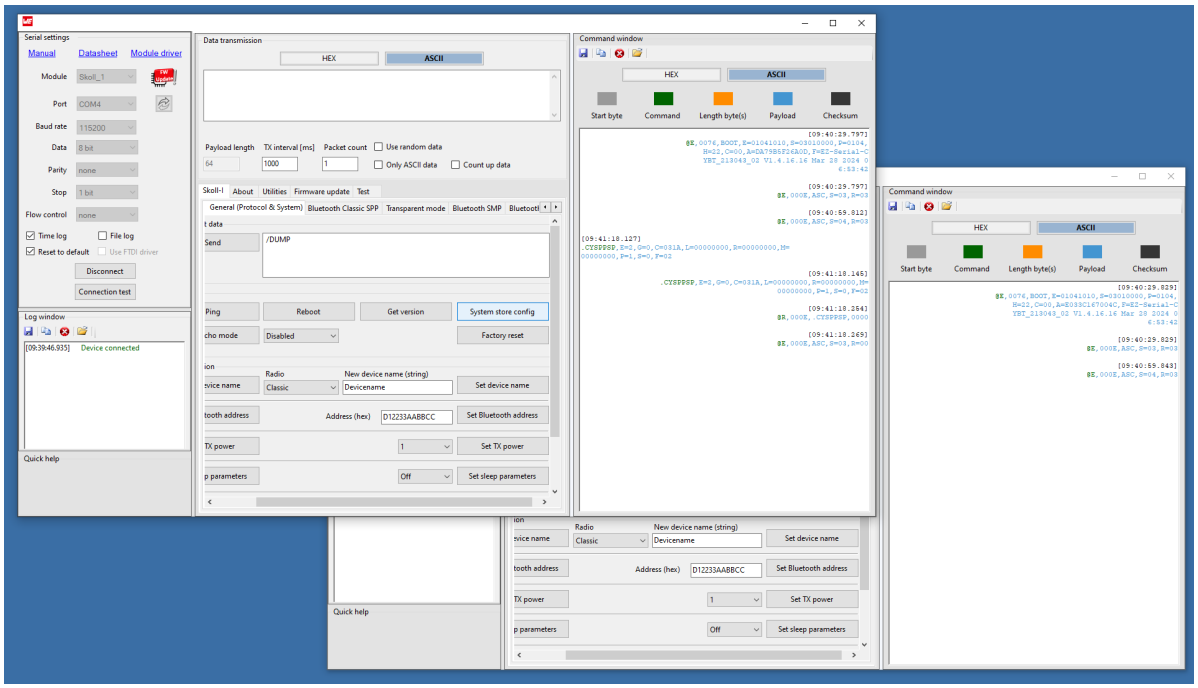


Figure 13: Storing the system configuration for the first module

4. Now, for the second module, perform similar steps: go to the CYSPP tab and enable auto-start, but set the role to "Central". Click "Set parameters".

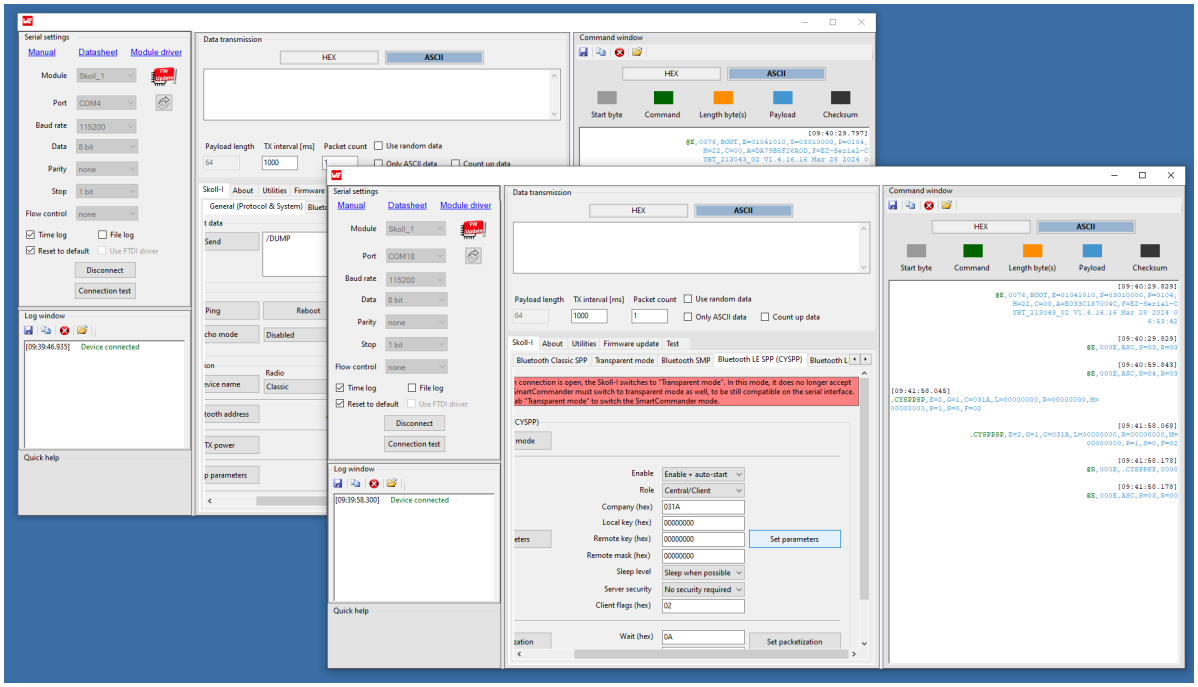


Figure 14: Setting the second module to Central mode

5. For the second module, go to the General tab and click the "System store config" button to store the settings so that they are retained even after a reset.

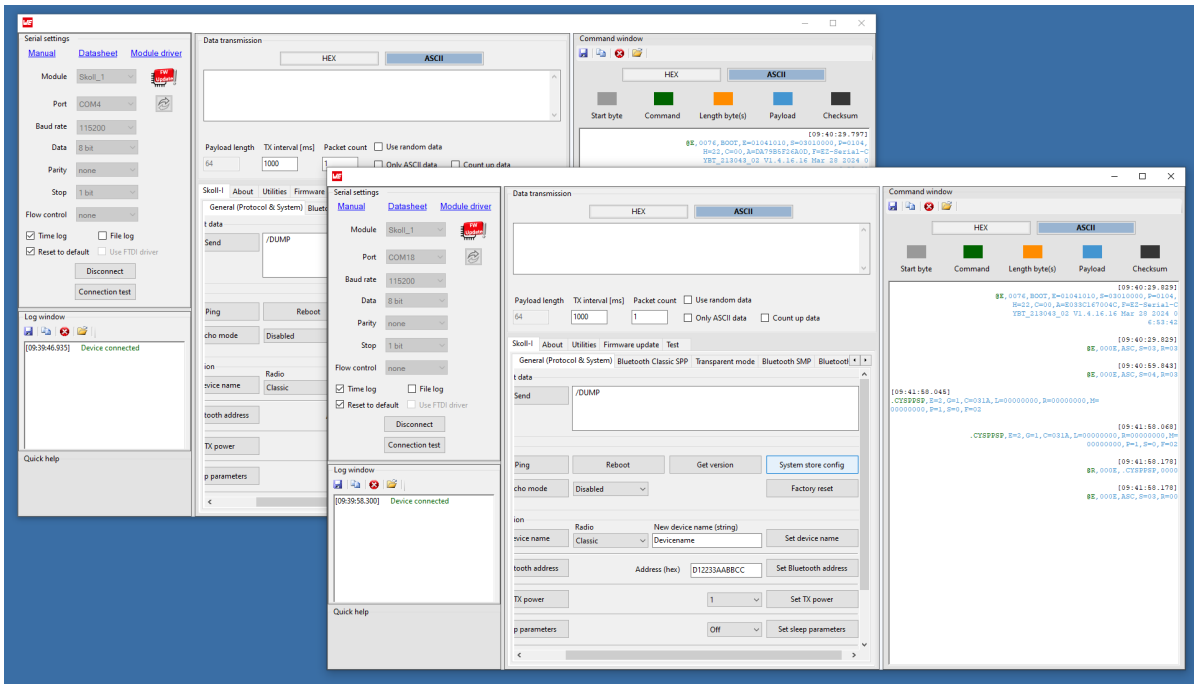


Figure 15: Storing the system configuration for the second module

6. Now, reset both modules. If EV-Boards are being used, press the RESET button. The two modules will automatically connect to each other based on the key set in the CYSPP set-

tings (by default it is 00000000). In the WE UART Terminal tool, "@E,000C,.CYSPP,S=05" will be shown for the peripheral module, and "@E,000C,.CYSPP,S=35" for the central module. This indicates that the CYSPP transparent pipeline was established successfully.

7. Now we change both WE UART Terminal tools to transparent mode so that they handle all incoming and outgoing data. For the first module, go to the "Transparent mode" tab and click the "Switch" button to change the WE UART Terminal tool to transparent mode.

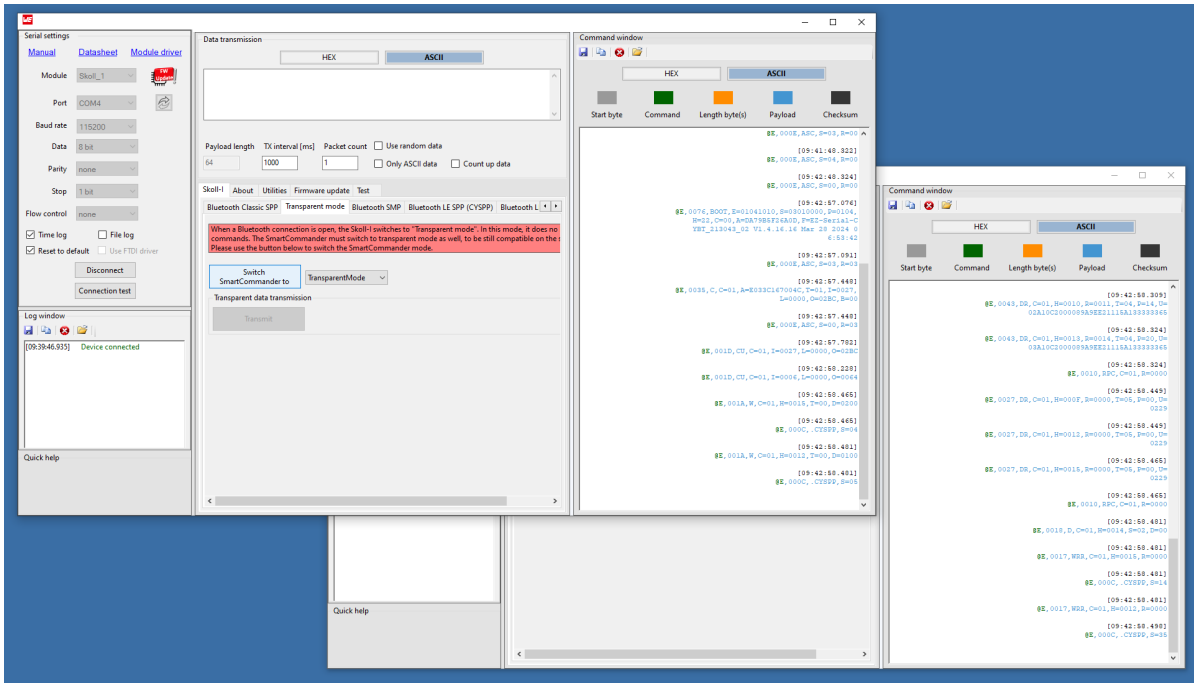


Figure 16: Switching the first module to transparent mode

8. Now do the same for the second module. In the other WE UART Terminal tool, go to the "Transparent mode" tab and click the "Switch" button to change the WE UART Terminal tool to transparent mode.

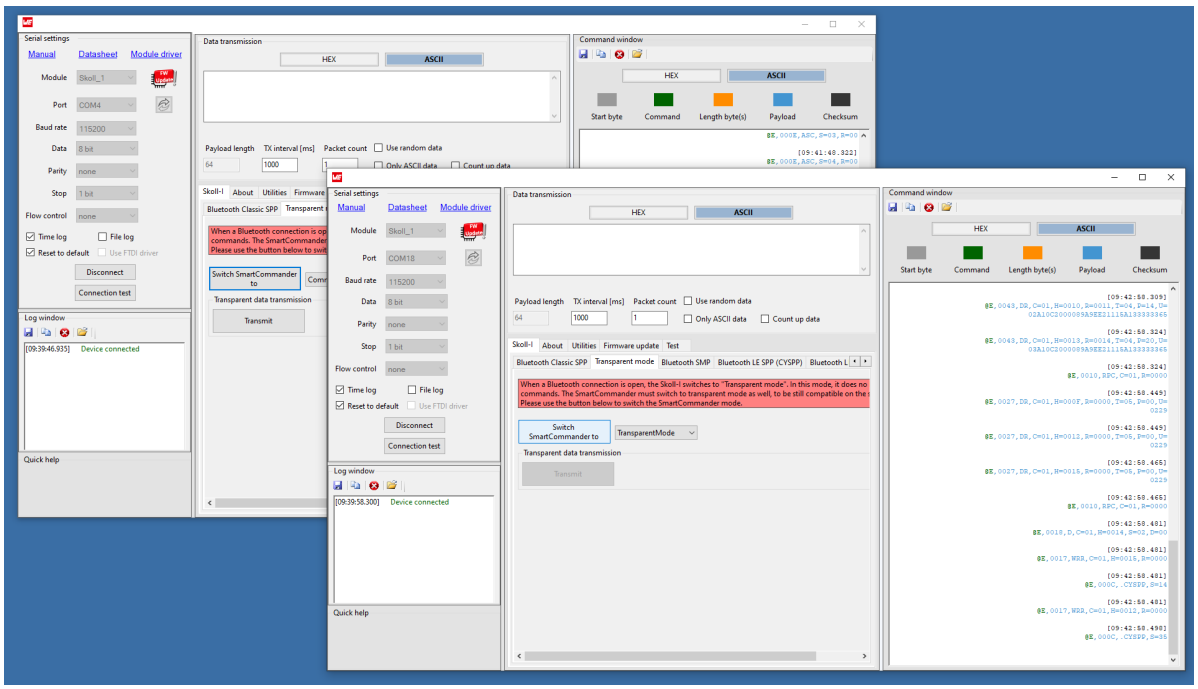


Figure 17: Switching the second module to transparent mode

9. Let's try to transmit some transparent data! In the entry field at the top of the WE UART Terminal tool, type the message "Hello Skoll-I!", then click the "Transmit" button in the "Transparent data transmission" group below. The string should be sent out immediately and appear on the other module.

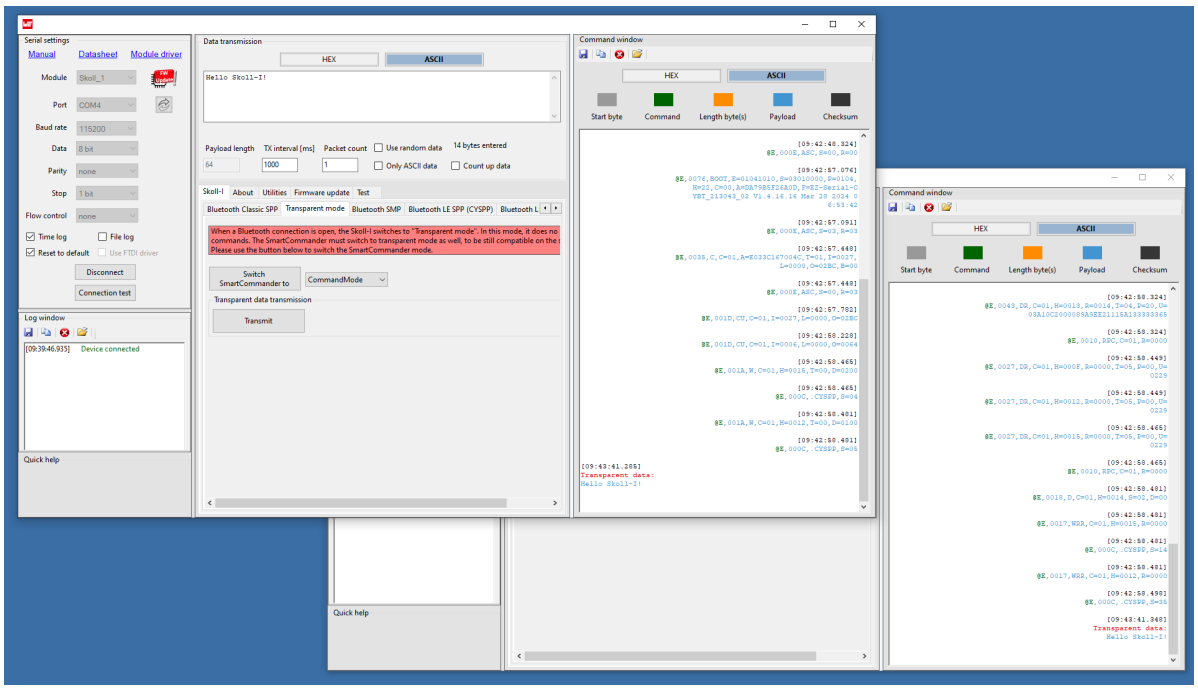


Figure 18: Transmitting data from the first module

10. Now let's do it in the other direction. Go to the second module and in the WE UART Terminal tool, type "Hello there!" in the entry field at the top, then click the "Transmit" button. The string should be sent out immediately and appear on the first module, the one that sent out the message in Step 9.

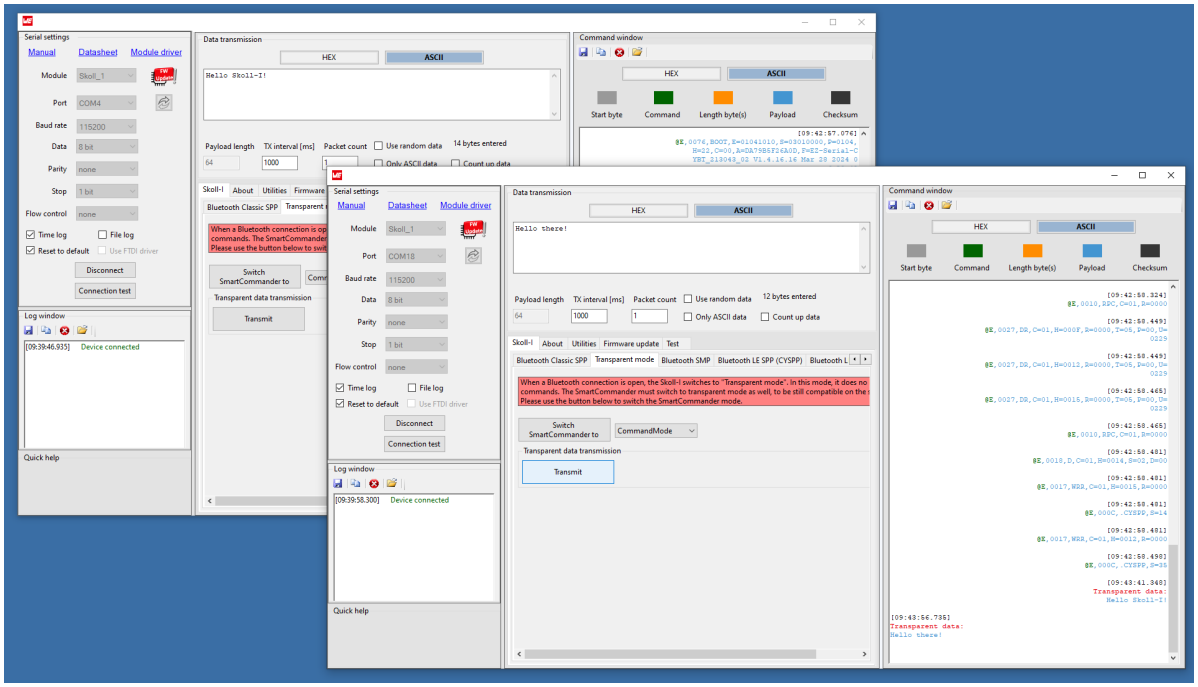


Figure 19: Transmitting data from the second module

11. Go back to the first module's WE UART Terminal tool and verify that indeed, the messages were sent in both directions.

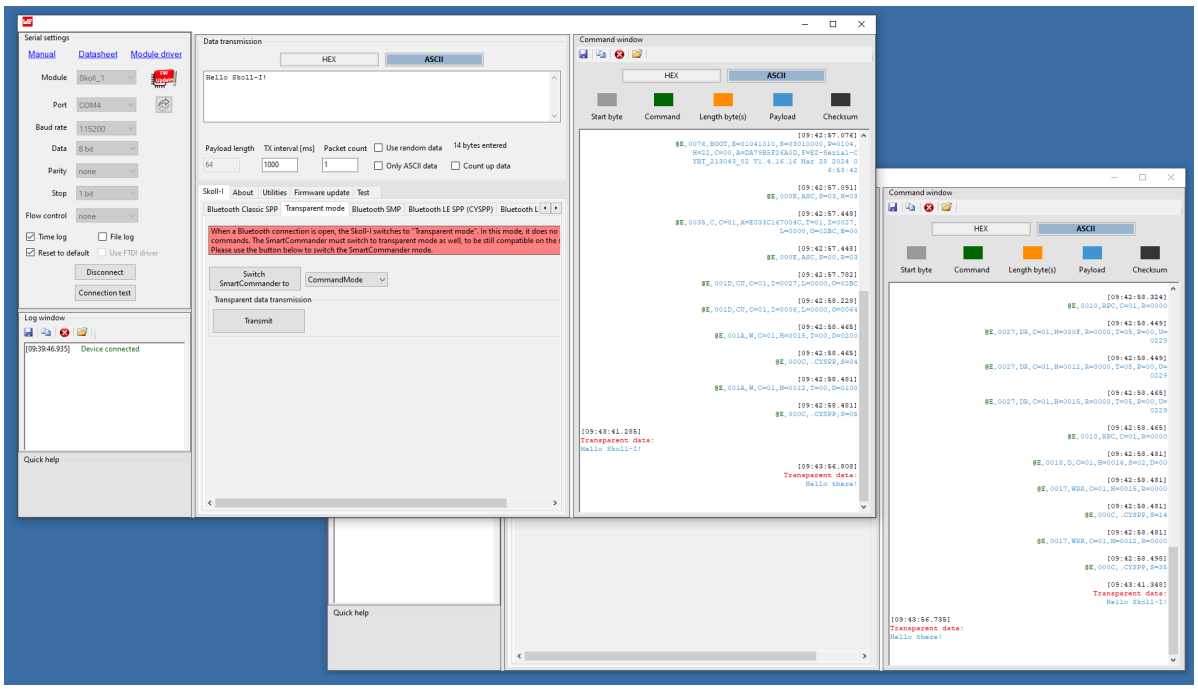


Figure 20: Verifying bidirectional data transmission

12. Congratulations! You have successfully sent data in both directions using the CYSPP Bluetooth® LE profile between two Skoll-I modules. Any kind of data can be sent. Of course, the setup can be done without WE UART Terminal too; any host, terminal program, or even your host micro controller can be used to do the same setup.

8.1.4 Connecting the Skoll-I to a smartphone with CYSPP profile

Connecting a Skoll-I Bluetooth® module to a smartphone using the CYSPP profile with the WE Bluetooth LE Terminal application [10, 11] is a straightforward process that can be completed in just a few easy steps. This tutorial will guide through each step, ensuring a smooth setup experience. By the end, you'll be able to send and receive messages seamlessly. Let's get started!

This example will be demonstrated on base of an Android phone, but can be done with any iOS device in the same way.

1. Download the WE Bluetooth LE Terminal app application from the app store and install it on a smartphone.
2. Power up the Skoll-I Bluetooth® module. As the WE Bluetooth LE Terminal application supports automatic connection setup, no further steps are required besides powering the module up with the default factory firmware. If an EV-Board is being used, connect it to a computer and open up a serial terminal program to monitor incoming messages from the module side. In this example, we are using the program "HTerm" [3]. After successful booting, the module prints a boot-up message to the serial port.

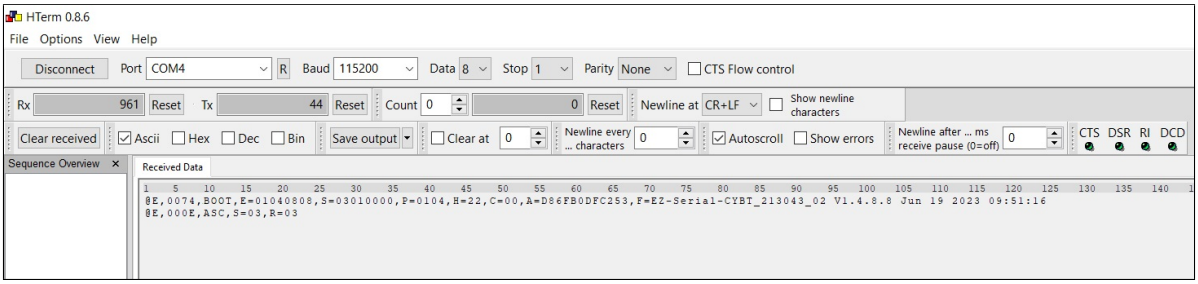


Figure 21: Boot-up message from the module

3. On the smartphone, open up the WE Bluetooth LE Terminal application.

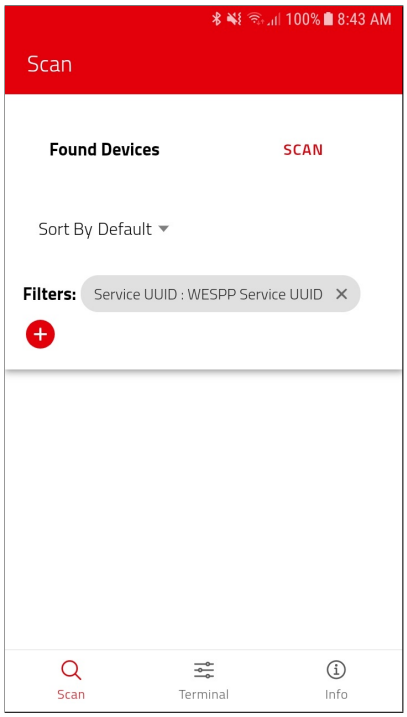


Figure 22: Start screen of the WE Bluetooth LE Terminal application

4. Remove all scan filters and click "Scan". In a few seconds, the module should appear on the device list. By default, it looks like "EZ-Serial..." followed by a part of the Bluetooth® MAC address of the device.

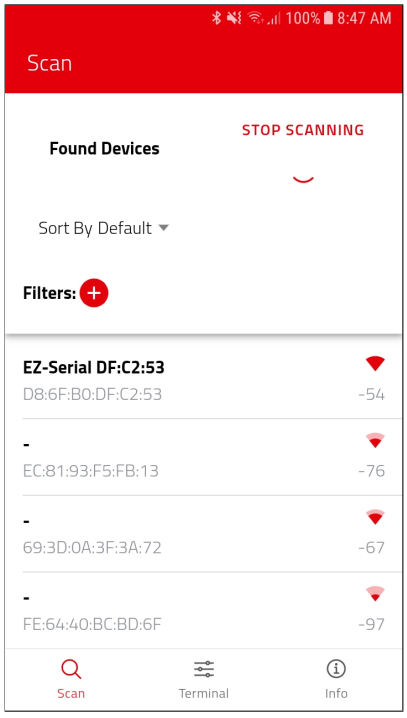


Figure 23: Scanning process in the WE Bluetooth LE Terminal application

5. Tap on the device name. This should bring up a pop-up where the module and the data mode can be selected. Here, select "Skoll-I" as the module and "Unacknowledged Data Mode" as the data mode. Then tap the "Select" button at the bottom.

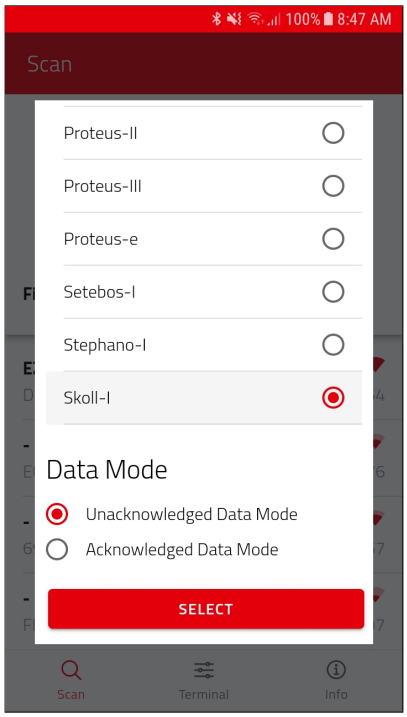


Figure 24: Selecting the module and the data mode in WE Bluetooth LE Terminal

6. After a few seconds, the connection should be set up successfully. Everything is ready to send and receive messages! The module has automatically changed its serial interface to transparent CYSPP mode, so any incoming data will be transferred to the smartphone from this point. The same applies in the other direction, any data sent by the smartphone is going to be transferred to the module's serial interface.

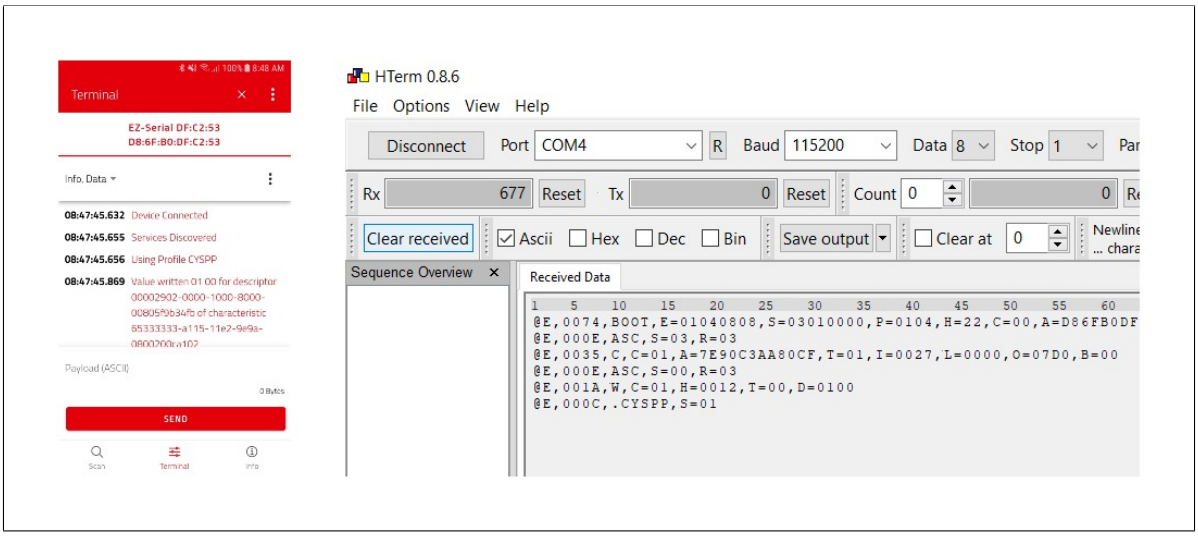


Figure 25: Successful CYSPP connection on the smartphone side vs. on the module side

7. Try to send a message from the smartphone to the module. Type "Hello from smartphone" in the WE Bluetooth LE Terminal application into the entry field, then tap "Send". On the module side, the message should arrive immediately.

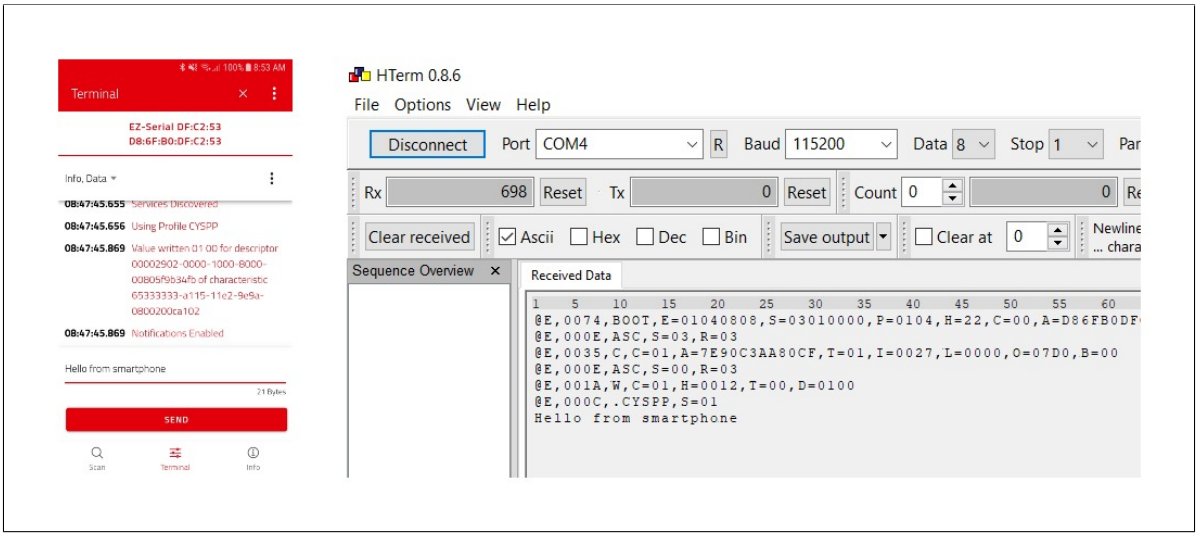


Figure 26: Sending a message via CYSPP from a smartphone to the module

8. Then, try to do the same from the module side. On the computer, in the serial terminal program, type "Hello from computer" and send the string to the serial port. The message immediately appears on the WE Bluetooth LE Terminal app.

Figure 27: Sending a message via CYSPP from the module to a smartphone

9. Congratulations! You successfully sent data in both directions using the CYSPP Bluetooth® LE profile. Any kind of data can be sent. (Note: From the module side, messages which are longer than 21 characters are divided up into smaller packages that are being sent one after each other.)

8.2 Bluetooth® Classic examples using SPP profile

Bluetooth® Classic Serial Port Profile (SPP) is a wireless communication protocol designed to emulate a traditional serial cable connection over Bluetooth®. It enables the transmission of data between devices, such as computers and peripherals, through a virtual serial port, offering a convenient and efficient way to replace traditional wired connections. For example, SPP can create a virtual COM port on a computer, allowing it to communicate with industrial devices or send serial data to a phone seamlessly. This profile is widely used in various applications, including industrial automation, health-care devices and consumer electronics, due to its reliable and straightforward implementation.

However, while Bluetooth® Classic SPP has its advantages, it also comes with some disadvantages when compared to WE SPP-like Bluetooth® LE profiles. One key advantage of SPP is its established presence and widespread compatibility with many existing devices and systems, making it a reliable choice for applications that require stable and continuous data transmission. Additionally, SPP supports higher data rates, which can be beneficial for applications needing faster data transfer.

On the downside, SPP typically consumes more power than Bluetooth® LE based profiles, which can be a significant drawback for battery-operated devices. Moreover, SPP often has longer connection establishment times and does not scale as efficiently to a large number of devices. In contrast, SPP-like Bluetooth® LE profiles, such as CYSPP or the WE SPP-like profile, are optimized for lower power consumption and quicker connection times, making them more suitable for modern IoT environments which demand energy efficiency and support for numerous devices.

8.2.1 Connecting the Skoll-I to another module or device via SPP profile

This tutorial guides through the process of establishing a Bluetooth® Serial Port Profile (SPP) connection between two Skoll-I modules. The SPP profile enables wireless serial communication, which is commonly used in various applications, such as data logging, sensor networks and industrial automation. By following these steps, one module will be configured as the "master" and the other as the "slave," a Bluetooth® inquiry will be initiated, a connection established and data will be transmitted transparently between the modules.

The serial terminal program HTerm [3] will be used to send commands and view responses from the modules. Let's get started with setting up the modules and establishing a wireless communication link!

1. Take two Skoll-I modules and connect them to a computer. If EV-Boards are being used, the USB cable needs to be connected to the computer. The two modules do not necessarily have to be connected to the same computer, as the wireless link happens entirely over Bluetooth®. For both modules, start a serial terminal program. In this tutorial, we are using HTerm. By default, the two Skoll-I modules can see and connect to each other via SPP, so the connection process is straightforward and easy. A connection from the first module to the second module will be initiated, meaning that the first module is in the "master" role, while the second module is a "slave". The "slave" module doesn't have to do anything, as the entire connection process is handled by the "master" module. The

second module just has to wait for the connection request. This means that the second module doesn't necessarily have to be a Skoll-I; it can be any other module that supports the SPP profile, such as a smartphone, a computer or an industrial device.

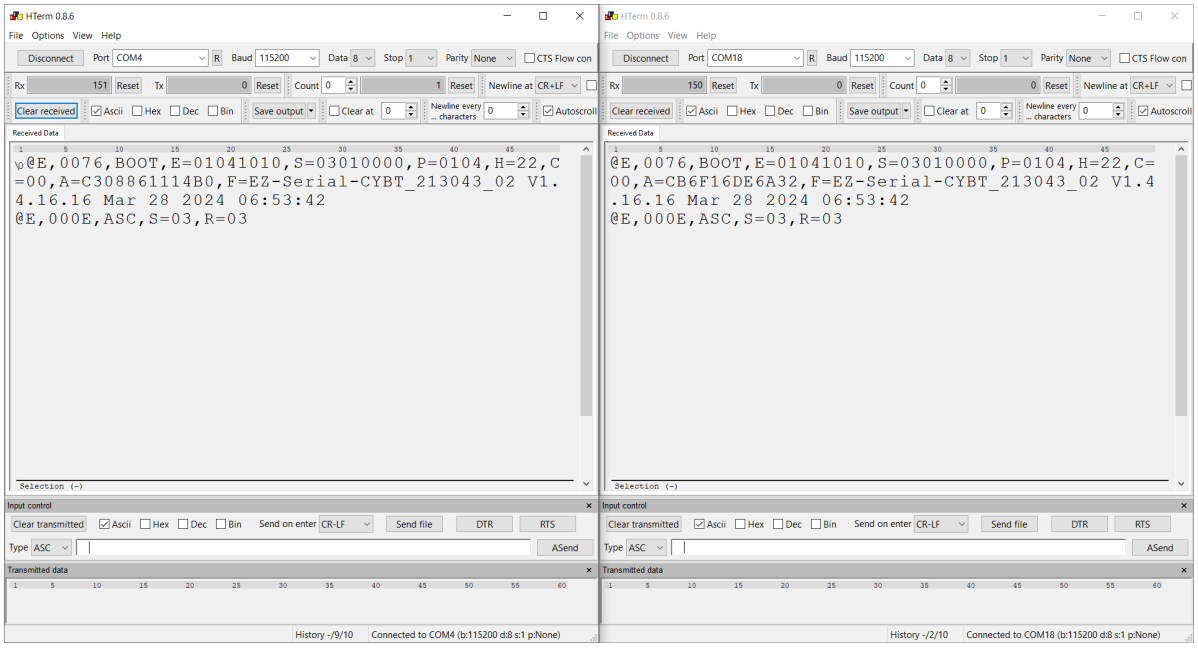


Figure 28: Connecting two Skoll-I modules to a computer

2. For the first module, go to the serial terminal program and send the following command: "/BTI, D=3,F=1". This starts the Bluetooth® inquiry and lists the available devices with which the module can initiate a connection. The parameters have the following meanings: D: Duration ranging from 3 to 30 seconds, F: 0 - Inquiry all (name and address), 1 - Inquiry name. After 3 seconds, the list of available devices is printed to the serial port of the first module. The device, with which the connection shall be established, can be selected based on the address of the device. In this case, we select the second module.

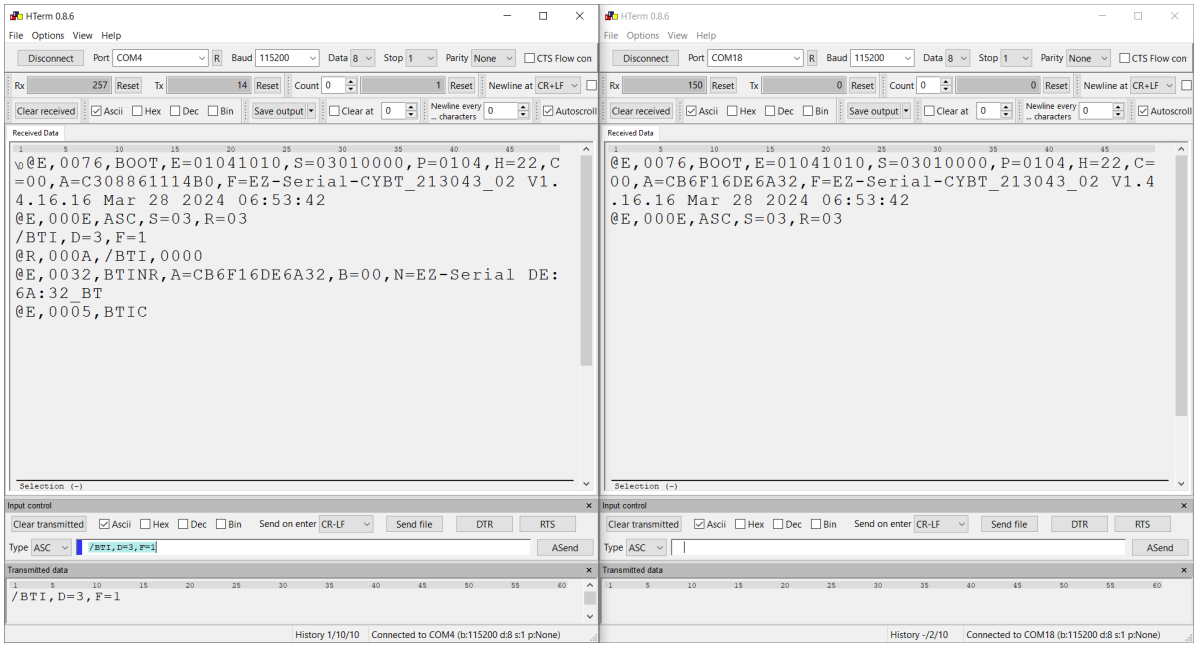


Figure 29: Starting Bluetooth® inquiry on the first module

3. Let's initiate a connection from the first module to the second module. For the first module, go to the serial terminal program and send the following command:
"/BTC,A=CB6F16DE6A32,T=1",
where the parameter "A=" is the address of the device we would like the module to connect to. Replace the address accordingly with the address of the device you would like to connect to, then send the command to the first Skoll-I "master" module.

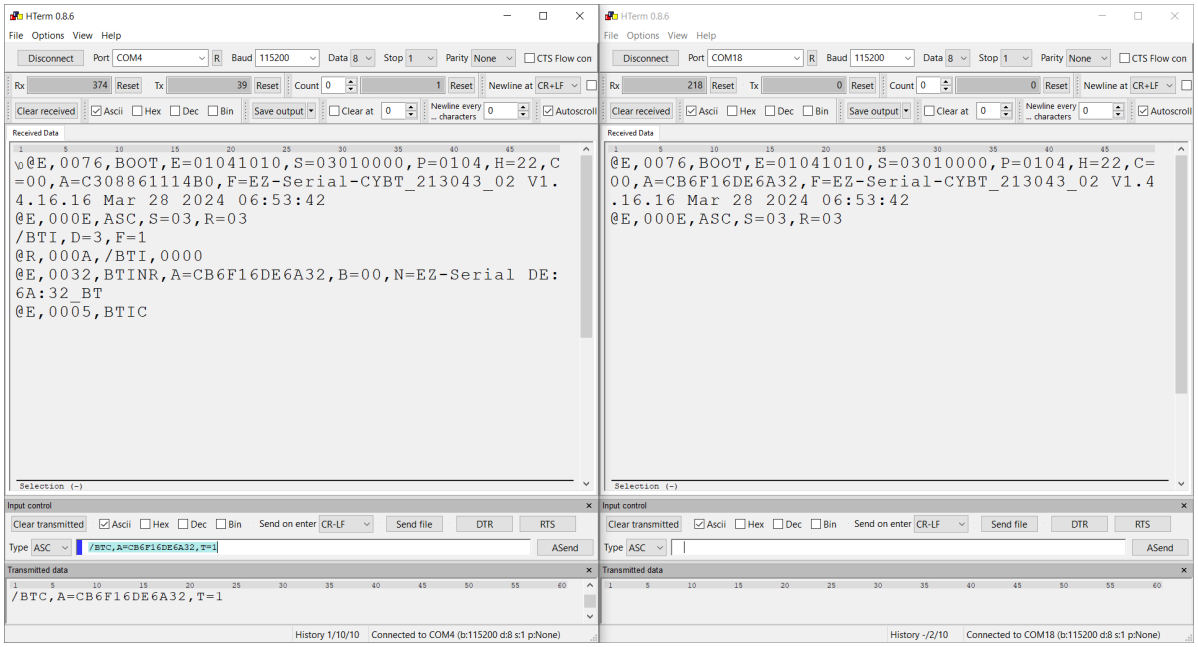


Figure 30: Initiating a connection from the first module to the second module

4. After a short time, the connection between the two modules is established. “@E,0024,BTCON,C=01 can be seen, indicating that the two modules are now connected via SPP. From this point on, the modules automatically switch to transparent mode, meaning that any data sent to the module from this point is going to be transmitted to the other module via Bluetooth®.

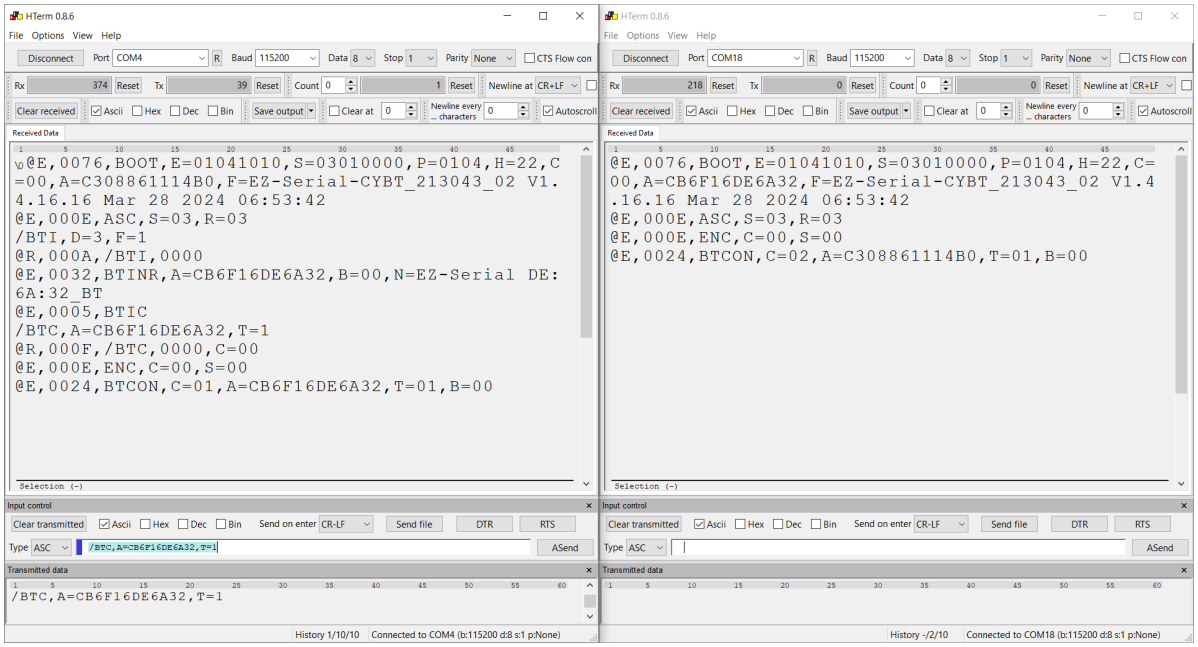


Figure 31: Connection established between the two modules

5. Let’s try to transmit some transparent data! For the first, "master" module, in the entry field of the serial terminal program, type the message “Hello Skoll-I!”. Then send the raw string to the module. The string should be sent out immediately and appear on the second, "slave" module.

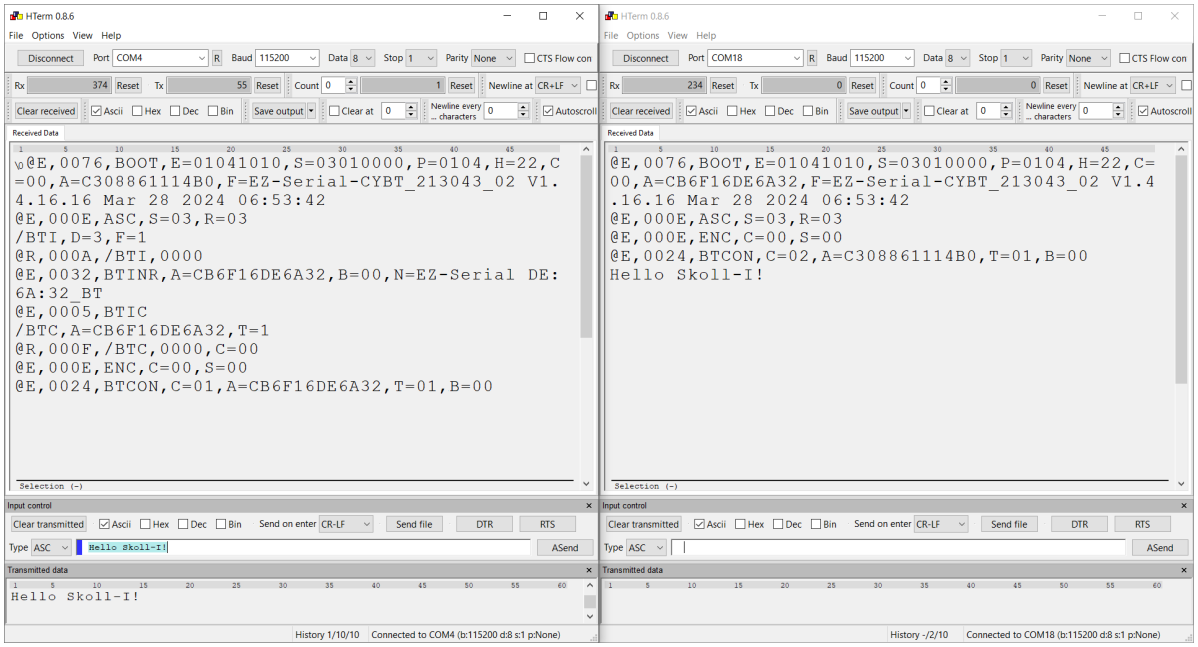


Figure 32: Sending data from the master module to the slave module

6. Now let's do it in the other direction. Go to the second, "slave" module and type "Hello there!" in the entry field of the serial terminal program. Then send the raw string to the module. The string should be sent out immediately and appear on the first, "master" module, the one that sent out the message in the previous step.

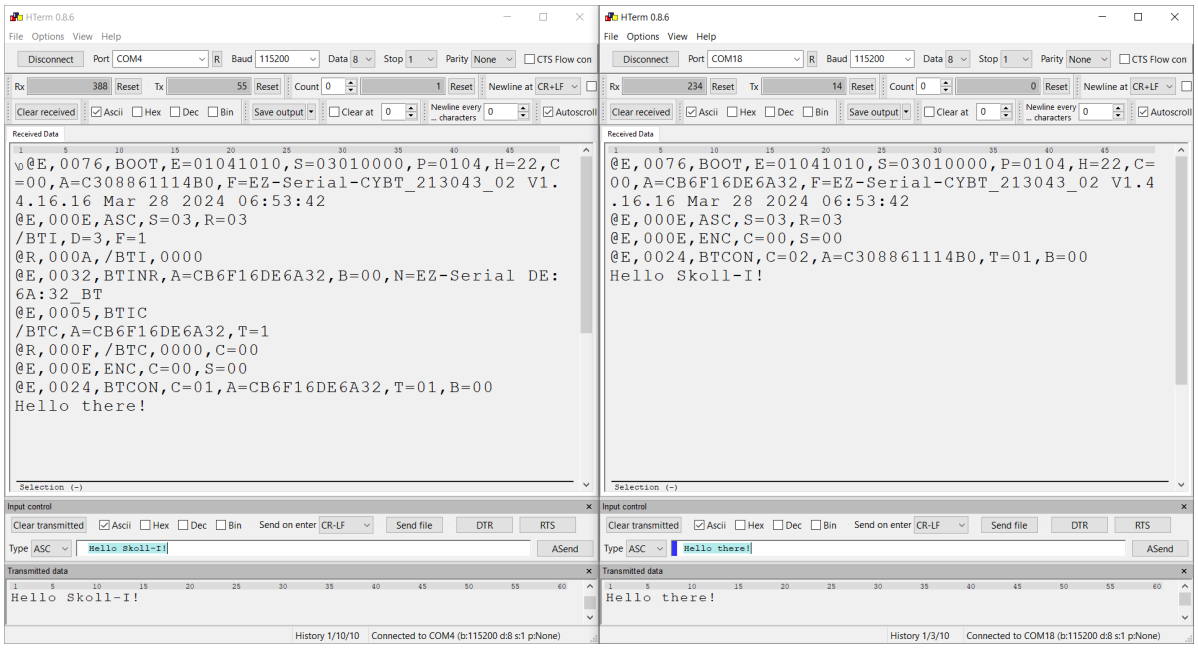


Figure 33: Sending data from the slave module to the master module

7. Congratulations! You successfully sent data in both directions using the Bluetooth Classic SPP profile. Any kind of data can be sent.

8.2.1.1 Exiting the SPP mode

The SPP can be controlled through the hardware GPIO for Skoll-I modules. The *SPP* pin, which is also used for CYSPP, can control the SPP connection state as follows:

- By default, the *SPP* pin is set to a HIGH state.
- Once an SPP connection is active, the *SPP* pin will be set to a LOW state.
- If the *SPP* pin is set to HIGH by an external MCU while an SPP connection is active, the SPP connection will be terminated.

8.2.2 Connecting the Skoll-I to an Android smartphone with SPP profile

Similarly to the CYSPP example, connecting a Skoll-I Bluetooth® module to an Android smartphone using the Bluetooth® Classic SPP profile is a straightforward process, which can be completed in just a few easy steps. In this example, we are going to use the Serial Bluetooth® Terminal app [9] to initiate the connection and send data back and forth between the module and a smartphone. This tutorial will guide through each step, ensuring a smooth setup experience. By the end, messages will be sent and received seamlessly. Let's get started!

Note that iOS devices do not support the Bluetooth® Classic SPP profile, and hence are not compatible to Skoll-I on the Bluetooth® Classic interface.

1. Download the Serial Bluetooth® Terminal [9] application from the Google Play Store and install it on an Android smartphone.
2. Power up the Skoll-I Bluetooth® module. As the Skoll-I module firmware supports automatic connection setup, no further steps need to be done with the module besides powering it up with the default factory firmware. If an EV-Board is being used, connect it to your computer and open up a serial terminal program to monitor incoming messages from the module side. In this example, we are using the program "HTerm" [3]. After successful booting, the module prints a bootup message to the serial port.

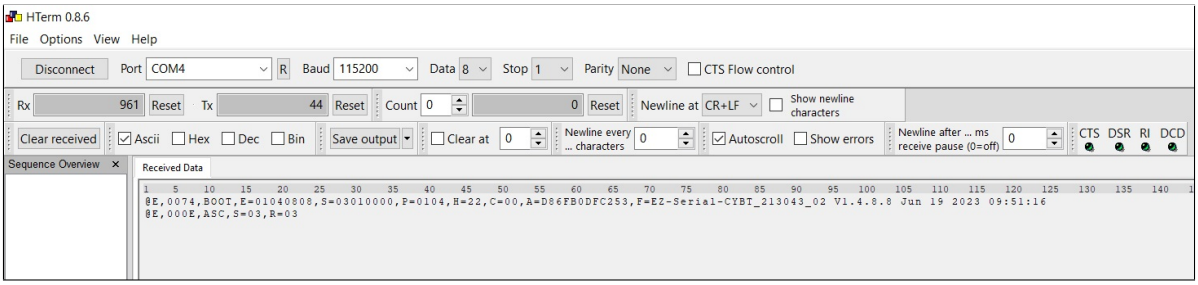


Figure 34: Boot-up message from the module

3. On the smartphone, open up the Bluetooth® Settings and start scanning for nearby Bluetooth® devices. After a few seconds, the module should appear on the list of available devices. By default, it looks like "EZ-Serial..." followed by a part of the Bluetooth® MAC address of the device. Tap on the device to automatically connect and pair with the smartphone.

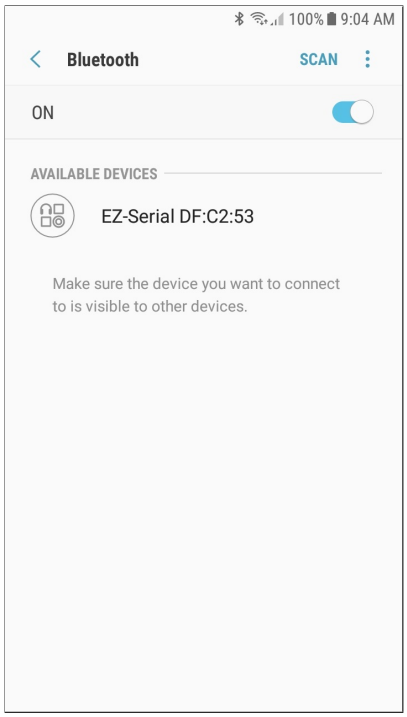


Figure 35: Connecting to the module in Bluetooth® settings

4. On the Android smartphone, open up the Serial Bluetooth® Terminal application.

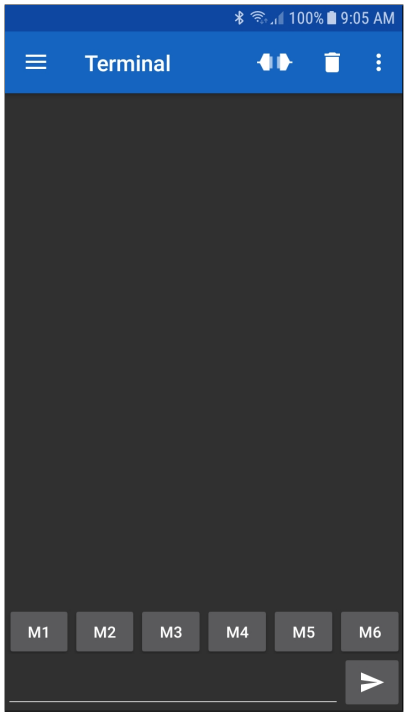


Figure 36: Start screen of the Serial Bluetooth® Terminal application

5. Go to the menu and select "Devices". The module should appear on the device list. By

default, it looks like "EZ-Serial..." followed by a part of the Bluetooth® MAC address of the device and closed by "_BT".

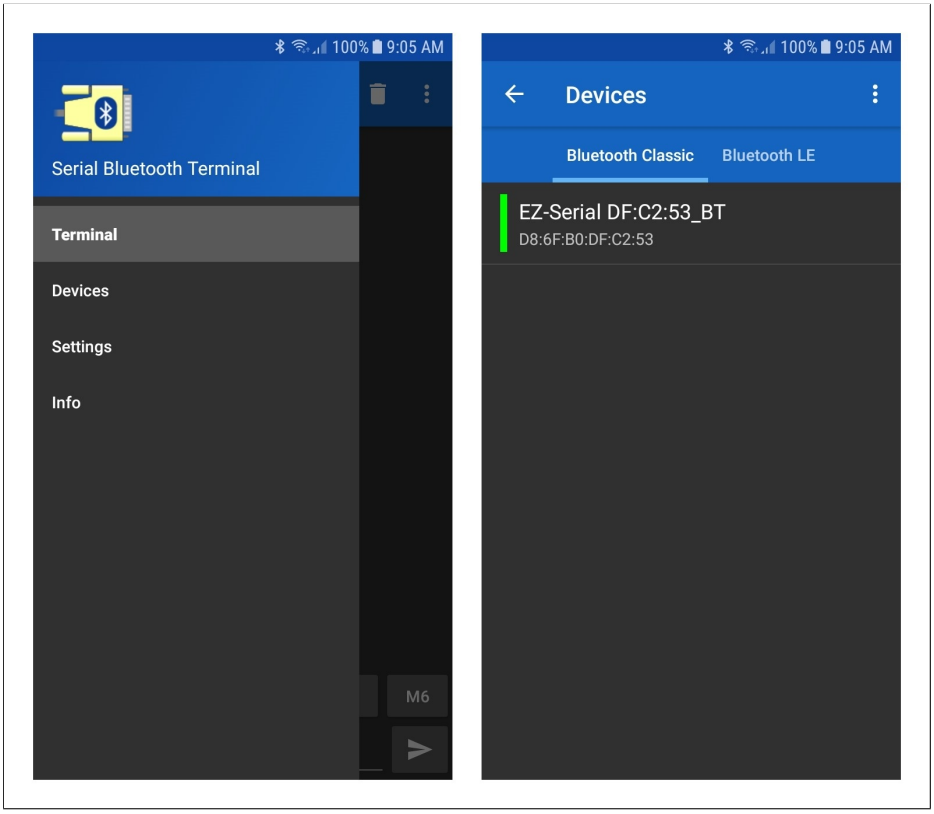


Figure 37: Selecting the module under the Devices menu

6. Tap on the device name. This should initiate the automatic connection setup process.
7. After a few seconds, the connection should be set up successfully. All is set and ready to send and receive messages! The module has automatically changed its serial interface to transparent SPP mode, so any incoming data will be transferred to the smartphone from this point. The same applies in the other direction. Any data sent by the smartphone is going to be transferred to the module's serial interface.

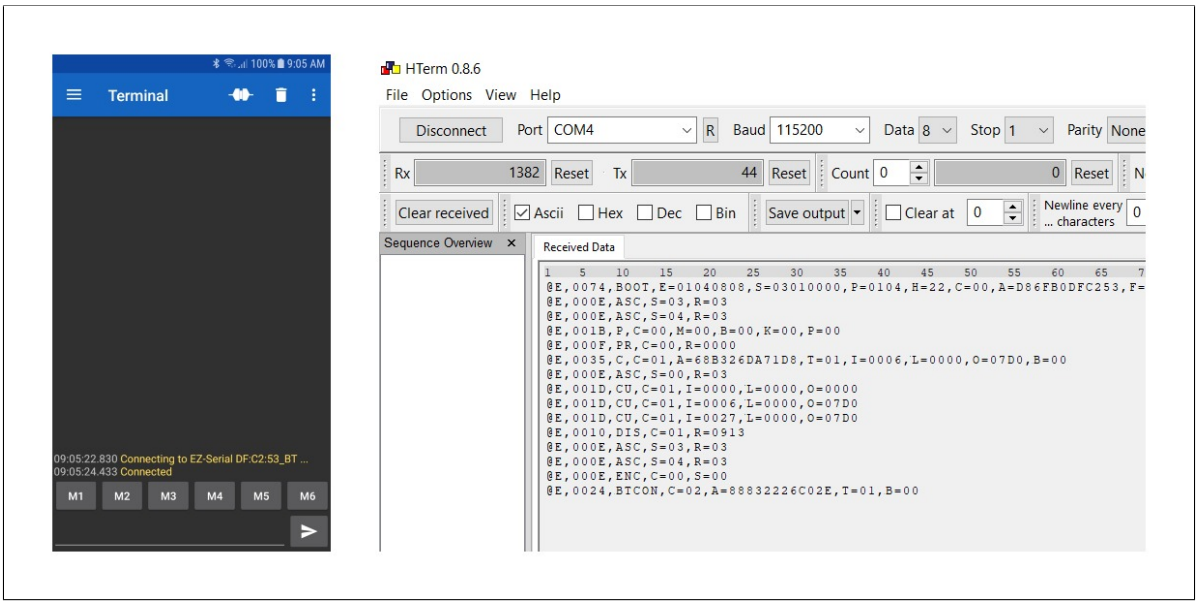


Figure 38: Successful SPP connection on the smartphone side vs. on the module side

8. Try to send a message from the smartphone to the module. Type "Hello from smartphone" in the Serial Bluetooth® Terminal application into the entry field, then tap "Send". On the module side, the message should arrive immediately.

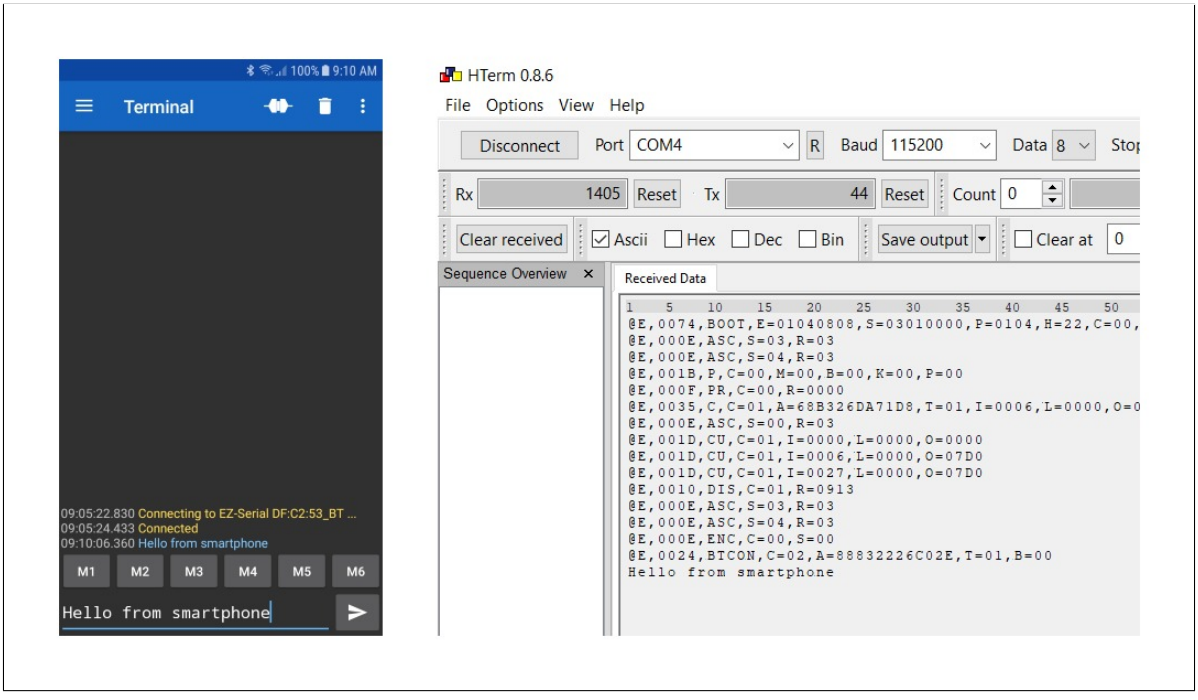


Figure 39: Sending a message via SPP from a smartphone to the module

9. Then, try to do the same from the module side. On the computer, in the serial terminal program, type "Hello from computer" and send the string to the serial port. The message appears immediately in the Serial Bluetooth® Terminal app.

Figure 40: Sending a message via SPP from the module to a smartphone

10. Congratulations! You successfully sent data in both directions using the Bluetooth® Classic SPP profile. Any kind of data can be sent.

8.2.3 Connecting the Skoll-I to a Windows PC and creating a virtual serial port with SPP profile

This tutorial guides through the process of connecting a Skoll-I Bluetooth® module to a Windows PC using the Serial Port Profile (SPP). This makes the Skoll-I module a versatile and cost-effective solution for wireless communication, ideal for various applications such as data logging, wireless control and serial data transmission. By leveraging the SPP profile, a virtual COM port can be created on a PC, enabling seamless bidirectional serial data communication with the Bluetooth® module.

This step-by-step guide will cover everything from configuring a Bluetooth® module to setting up the virtual COM port on Windows. By the end of this tutorial, serial data will be sent and received wirelessly, expanding the potential of projects and applications. Let's get started!

A step-by-step tutorial can be found under the Quick Start Example section, in chapter 4.3.

8.3 Bluetooth® LE examples using WE SPP-like profile (communicate with Proteus devices)

8.3.1 Skoll-I peripheral: Add WE SPP-like profile

The Würth Elektronik eiSos "Proteus" series of Bluetooth® LE radio modules use the so called "WE SPP-like" profile on the Bluetooth® interface. The use of it, is similar to the build-in CYSPP profile provided by the Skoll-I. Both can be used to exchange arbitrary data that are not bound to a specific use case.
Since the Skoll-I provides the opportunity to add custom profiles at run time, it's possible to add new profiles to the Skoll-I, when acting as Bluetooth® LE peripheral device.

In this example, it is demonstrated how to add the WE SPP-like profile to the Skoll-I, such that other Proteus devices can connect to Skoll-I. After adding the custom profile to the Skoll-I, it is stored in flash. Thus, on next boot-up it can be re-used without the need of adding it again.

1. First of all, reset the device by applying a high-low-high sequence to the */RESET* pin. This can be done on the Skoll-I EV-Board by pressing the reset button. The module will reply with a start-up message:

Info	Message
⇐ Module is ready for operation	@E,0076,BOOT...

2. (Optional) In case any modification on the GATT database has been done before, first apply a factory reset:

Info	Message
⇒ Factory reset	/RFAC
⇐ Success	@R,000B,/RFAC,0000 @E,0005,RFAC
⇐ Module is ready for operation	@E,0076,BOOT...

3. (Optional) In case the built-in CYSPP profile is no longer needed, it can be disabled:

Info	Message
⇒ Disable CYSPP profile	.CYSPPSP,E=0
⇐ Success	@R,000E,.CYSPPSP,0000

4. Then, the attributes of the WE SPP-like profile must be added using the `/CAC` command. First, the service is added using the UUID of the SPP-like service **0x6E400001C35211E5953D0002A5D5C51B**:

Info	Message
⇒ Create the WE SPP-like service	/CAC,T=00,P=02,L=0012,D=0028 **1BC5D5A502003D95E51152C30100406E**
⇐ Success, but more information needed	@R,0018,/CAC,0000,H=001D,V=0001

5. Then, the RX characteristic (central to peripheral data transmission via write command) is added using its UUID **6E400002C35211E5953D0002A5D5C51B**:

Info	Message
⇒ Create the WE SPP-like RX char.	/CAC,T=00,P=02,L=0015,D=03280C1F00 **1BC5D5A502003D95E51152C30200406E**
⇐ Success, but more information needed	@R,0018,/CAC,0000,H=001E,V=0001
⇒ Create the value field of the RX char. without initial value	/CAC,T=01,P=8F,L=0080,D=
⇐ Success	@R,0018,/CAC,0000,H=001F,V=0000

6. Then, the TX characteristic (peripheral to central data transmission via notification) is added, using its UUID 6E400003C35211E5953D0002A5D5C51B:

Info	Message
⇒ Create the WE SPP-like RX char.	/CAC,T=00,P=02,L=0015,D=0328102100 **1BC5D5A502003D95E51152C30300406E**
⇐ Success, but more information needed	@R,0018,/CAC,0000,H=0020,V=0001
⇒ Create the value field of the RX char. without initial value	/CAC,T=01,P=8B,L=0080,D=
⇐ Success	@R,0018,/CAC,0000,H=0021,V=0000

7. At last, the descriptor CCCD of the TX characteristics is added to be able to subscribe to the notifications:

Info	Message
⇒ Create the CCCD of the WE SPP-like RX char.	/CAC,T=00,P=0A,L=0004,D=02290000
⇐ Success	@R,0018,/CAC,0000,H=0022,V=0000

8. Now, the added attributes must be validated and stored:

Info	Message
⇒ Validate the entered attributes	/VGDB
⇐ Success	@R,0012,/VGDB,0000,V=0000
⇒ Store the configuration	/SCFG
⇐ Success	@R,000B,/SCFG,0000

8.3.2 Skoll-I peripheral: Transmit/Receive data from device using WE SPP-like profile

In case the WE SPP-like profile has been added to the Skoll-I (as described in chapter 8.3.1), another Proteus device can connect to it and payload data can be exchanged:

1. First, advertising must be started:

Info	Message
⇒ Start advertising	/A,M=00,T=03,C=07,H=0040,D=0000,L=0040, O=0000,F=01
⇐ Success	@R,0008,/A,0000

2. Then connect with a central device, which implements the WE SPP-like profile, to the Skoll-I. The following event messages appear and the LED on the EV-Board connected to the *CONNECTION* pin lights up:

Info	Message
⇐ Peer device connected	@E,0035,C,C=01,A=657C514E4137,T=01, I=0024,L=0000,O=01F4,B=00
⇐ Connection has been updated	@E,001D,CU,C=01,I=0024,L=0000,O=01F4
⇐ Notifications have been enabled	@E,001A,W,C=01,H=0022,T=00,D=0100

Note that the 0x01 which is prepended to the payload data, is only needed if data is exchanged with a Proteus module.

3. Then enter "hello" (0x68656C6C6F) on the central device and send it:

Info	Message
⇐ Received data "0x68656C6C6F" in RX characteristic	@E,0020,W,C=01,H=001F,T=01, D=0168656C6C6F

4. On Skoll-I, respond with "hey there" (0x686579207468657265):

Info	Message
⇒ Send notification to TX characteristic	/NH,C=01,H=0021,D=01686579207468657265
⇐ Data transmission success	@R,0009,/NH,0000

5. The message "hey there" has been received on the central device.
6. If no more payload needs to be exchanged, the Skoll-I can close the connection:

Info	Message
⇒ Disconnect	/DIS,C=01
⇐ Success	@R,000A,/DIS,0000 @E,0010,DIS,C=01,R=0900

8.3.3 Skoll-I central: Connect to a Proteus radio module using WE SPP-like profile

The Würth Elektronik eiSos "Proteus" series of Bluetooth® LE radio modules uses the so called "WE SPP-like" profile on the Bluetooth® interface. The use of it, is similar to the build-in CYSPP profile provided by the Skoll-I. Both can be used to exchange arbitrary data that are not bound to a specific use case.
When acting as Bluetooth® LE central device, the Skoll-I brings the opportunity to connect to other Bluetooth® LE devices and use their Bluetooth® LE profiles.

In this example, it is demonstrated how to connect to a Proteus device and use the WE SPP-like profile for communication.

1. First of all, reset the device by applying a high-low-high sequence to the */RESET* pin. This can be done on the Skoll-I EV-Board by pressing the reset button. The module will reply with a start-up message:

Info	Message
⇐ Module is ready for operation	@E,0076,BOOT...

2. Then stop advertising and start scanning:

Info	Message
⇒ Stop advertising	/AX
⇐ Success	@R,0009,/AX,0000
⇒ Start scanning with duplicate filter enabled	/S,M=01,I=0100,A=01,F=00,D=01,O=0000
⇐ Success, scan state changed	@R,0008,/S,0000 @E,000E,SSC,S=01,R=00

Info	Message
⇐ Received scan result	@E,0052,S,R=00,A=0018DA000001,T=00,S=C1, B=00,D=020106110...
⋮	⋮

The MAC address of the scanned device "0018DA 000001" states that it's a Proteus device, as it uses the Würth Elektronik eiSos vendor ID 0x0018DA.

3. Stop the scan:

Info	Message
⇒ Stop scanning	/SX
⇐ Success, scan state changed	@R,0009,/SX,0000 @E,000E,SSC,S=00,R=00

4. Connect to the device with MAC "0018DA 000001":

Info	Message
⇒ Connect	/C,T=0,A=0018DA000001
⇐ Connected, and connection parameters updated	@E,0035,C,C=01,A=0018DA000001,T=00, I=0006,L=0000,O=0064,B=00 @E,001D,CU,C=01,I=0027,L=0000,O=0190

Now, the LED on the EV-Board connected to the *CONNECTION* pin lights up.

5. Now, the provided Bluetooth® LE services and characteristics of the Proteus device must be discovered:

Info	Message
⇒ Discover services	/DRS,C=01
⇐ Success, 3 services found	@R,000A,/DRS,0000 @E,0027,DR,C=01,H=0001,R=0009,T=01,P=00, U=0018 @E,0027,DR,C=01,H=000A,R=000A,T=01,P=00, U=0118 @E,0043,DR,C=01,H=000B,R=FFFF,T=01,P=00, U=**1BC5D5A502003D95E51152C30100406E**
⇐ Discovery completed	@E,0010,RPC,C=01,R=0000

The service with UUID "1BC5D5A502003D95E51152C30100406E" is the WE SPP-like profile service. Thus the peer device definitely implements the SPP-like profile.

Info	Message
⇒ Discover characteristics	/DRC,C=01,S=0
⇐ Success, 6 characteristics found	@R,000A,/DRC,0000 @E,0027,DR,C=01,H=0002,R=0003,T=04,P=02,U=002A @E,0027,DR,C=01,H=0004,R=0005,T=04,P=02,U=012A @E,0027,DR,C=01,H=0006,R=0007,T=04,P=02,U=042A @E,0027,DR,C=01,H=0008,R=0009,T=04,P=02,U=A62A @E,0043,DR,C=01,H=000C,R=**000D**,T=04,P=0C,U=**1BC5D5A502003D95E51152C30200406E** @E,0043,DR,C=01,H=000E,R=**000F**,T=04,P=10,U=**1BC5D5A502003D95E51152C30300406E**
⇐ Discovery completed	@E,0010,RPC,C=01,R=0000

The characteristics of the WE SPP-like service for transmitting data (UUID is "1BC5D5A502003D95E51152C30200406E", RX characteristic) and receiving data (UUID is "1BC5D5A502003D95E51152C30300406E", TX characteristic) have been also found.

Info	Message
⇒ Discover descriptors	/DRD,C=01,S=0
⇐ Success, 1 descriptor found	@R,000A,/DRD,0000 @E,0027,DR,C=01,H=**0010**,R=0000,T=05,P=00,U=0229
⇐ Discovery completed	@E,0010,RPC,C=01,R=0000

This is the descriptor of the characteristic we must subscribe to.

6. The next step is to subscribe to the descriptor of the TX characteristic, such that the Proteus device can send notifications to the Skoll-I.

Info	Message
⇒ Enable notification on handle 0x0010 by writing bit 0 to it (0x0100 in LSB)	/WRH,C=01,H=**0010**,T=1,D=0100
⇐ Success	@R,000A,/WRH,0000

7. Now the devices are fully connected to each other, and data can be exchanged.

8.3.4 Skoll-I central: Transmit/Receive data from device using WE SPP-like profile

In case the connection has been setup to a Proteus device using the WE SPP-like profile as described in chapter 8.3.3, payload data can be exchanged:

1. To transmit data to the Proteus device, it must be written to the handle of the RX characteristic:

Info	Message
⇒ Transmit "hello" (0x68656C6C6F) to the Proteus device	/WRH,C=01,H=**000D**,T=1,D=0168656C6C6F
⇐ Success	@R,000A,/WRH,0000

Note that the 0x01 which is prepended to the payload data, is only needed if data is exchanged with a Proteus module.

2. The data has been received on the Proteus device. It responds with "hey there" (0x686579207468657265):

Info	Message
⇐ Received data on the TX characteristic	@E,002A,D,C=01,H=**000F**,S=01, D=01686579207468657265

3. If no more payload needs to be exchanged, the Skoll-I can close the connection:

Info	Message
⇒ Disconnect	/DIS,C=01
⇐ Success	@R,000A,/DIS,0000 @E,0010,DIS,C=01,R=0900

8.4 General examples

In this section, a variety of tutorials for the Skoll-I Bluetooth® module, that do not fit into other specific categories, will be presented. These general examples cover a range of applications and configurations which are not about direct Bluetooth® connection, but they provide with versatile and practical insights and use cases for Skoll-I modules.

8.4.1 Changing device name and appearance

The firmware platform for the Skoll-I Bluetooth® module supports different device names for Bluetooth® LE and Bluetooth® Classic communication. The device name can easily be changed for both modes with simple commands.

Info	Message
⇒ Setting the device name for Bluetooth® Classic to "Skoll-I"	SDN,T=01,N=Skoll-I
⇐ Device name updated successfully	@R,0009,SDN,0000
⇒ Setting the device name for Bluetooth® LE to "Skoll-I"	SDN,T=00,N=Skoll-I
⇐ Device name updated successfully	@R,0009,SDN,0000

It is possible to include parts of the device MAC address in the device name. For that, the macros " %M4:%M5:%M6" can be used, with which parts of the device address can be selected and used in the device name setting command.

Info	Message
⇒ Setting the device name for Bluetooth® Classic to "Skoll-I" and the last three bytes of the MAC address	SDN,T=01,N=Skoll-I %M4:%M5:%M6
⇐ Device name updated successfully	@R,0009,SDN,0000
⇒ Setting the device name for Bluetooth® LE to "Skoll-I" and the last three bytes of the MAC address	SDN,T=00,N=Skoll-I %M4:%M5:%M6
⇐ Device name updated successfully	@R,0009,SDN,0000

This will result in a partial appearance of the device MAC address in the device name (for example: Skoll-I 13:10:57).

The firmware platform for Skoll-I Bluetooth® module uses the device name and appearance to populate the GAP service's name and appearance characteristic values in the GATT database. If the firmware platform for Skoll-I Bluetooth® module is allowed to automatically manage the advertisement and scan response data content (default behavior), it also includes up to 29 bytes of the device name in the scan response packet. (The limit of 29 bytes is due to a Bluetooth® LE specification limit on the maximum scan response payload, which is 31 bytes - the other two bytes are needed for the field length and field type values that are part of the

device name field.)

Note: The firmware platform for Skoll-I Bluetooth® module limits the device name length to 64 bytes to minimize internal SRAM requirements.

The device appearance value is a 16-bit field made up of a 10-bit and 6-bit subfield. Allowed values are defined by the Bluetooth®® SIG and can be found at developer.bluetooth.org.

Changes made to the device name and appearance values take effect immediately. They are written to the local GATT characteristics for these two values (always present), and the device name is updated in the scan response packet if user-defined advertisement content has not been enabled with the **gap_set_adv_parameters** (SAP) API command.

In the following table, an example on how the device appearance can be changed is shown:

Info	Message
⇒ Set device appearance to "Generic Computer" (0x0080)	SDA,A=0080
⇐ Device appearance updated successfully	@R,0009,SDA,0000

These steps can be easily performed using the WE UART Terminal tool [6] from Würth Elektronik eiSos, making these steps straightforward and quick.

8.4.2 Performing a factory reset

The factory reset command restores the Skoll-I Bluetooth® module to its default settings, erasing all user configurations and data, and then reboots the module with the default factory settings.

A factory reset of the module can be done by simply sending the command "/RFAC" over the serial interface.

Info	Message
⇒ Trigger factory reset	/RFAC
⇐ Response indicates success	@R,000B,/RFAC,0000
⇐ Event indicates factory reset completed	@E,0005,RFAC

Similarly to the device configuration changes, the factory reset can also be performed, using the WE UART Terminal tool [6] from Würth Elektronik eiSos, and simply clicking the "Factory reset" button.

9 Firmware update

The Skoll-I provides two ways of programming firmware in its memory. The new firmware can be brought onto module using the HCI UART interface or over-the-air (OTA) using a Bluetooth® LE connection.

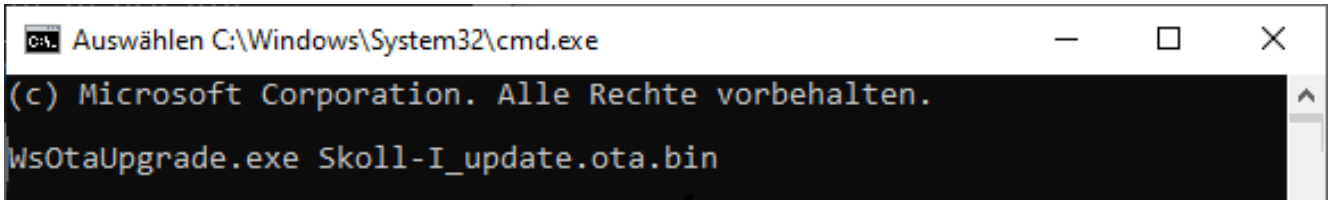
9.1 OTA via Bluetooth® LE

When using the Bluetooth® LE interface, a Bluetooth® enabled Windows PC has to set up a Bluetooth® connection to the radio module and run a PC tool to perform the update. To do so, the following steps need to be done:

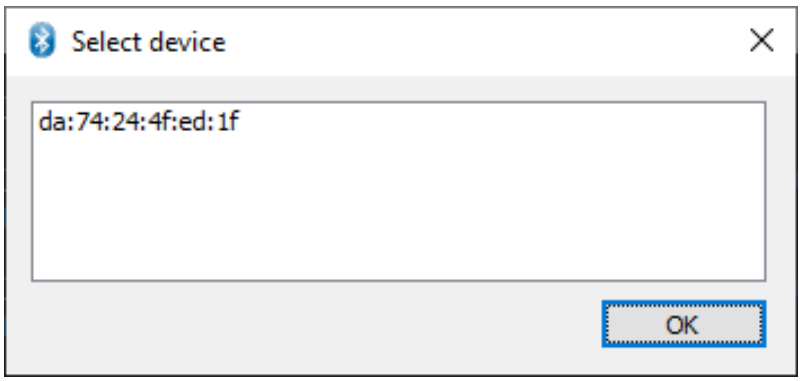
1. Download the Windows PC tool *WsOtaUpgrade.exe* .
2. Download the OTA bin file of the new firmware from product website and place it next to the PC tool.
3. Open the Windows command line and go to the directory where the executable and the bin-file are placed.
4. Now, we need to make the Skoll-I connectable. If it is not advertising, start advertising such that any peer device can connect.

Info	Message
⇒ Start advertising with 40 ms advertising interval	/A,T=03,H=0040,D=00,C=07,F=01\r\n
⇐ Response from module "Success"	@R,0008,/A,0000\r\n

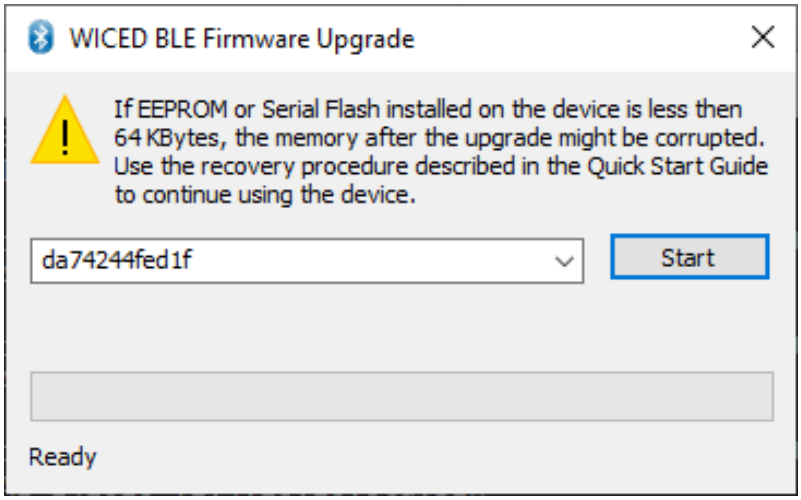
5. Then go to the Bluetooth® menu of you PC "Settings > Devices > Bluetooth® & other devices", turn on Bluetooth®, press "Add Bluetooth® or other device" and select the device you want to update.
6. Run the executable followed by the name of the bin file.



7. A menu opens where you have to choose the MAC of the device to update. Press OK.



8. Press start and wait until update has finished.



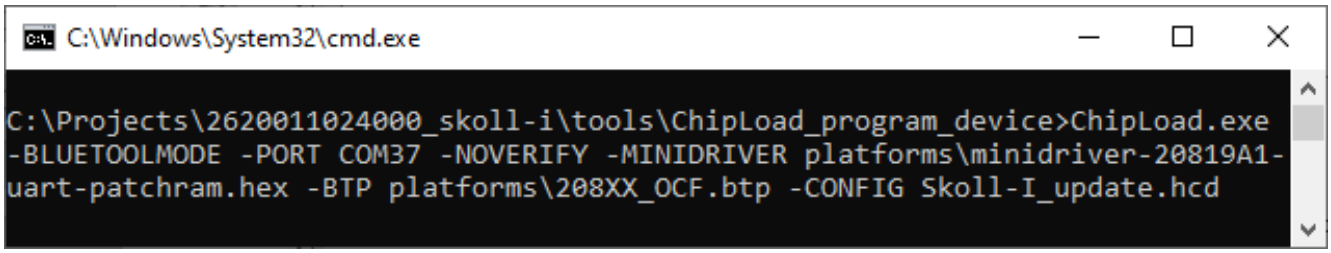
9.2 Production programming via UART

Using the production interface is not intended to perform updates of Würth Elektronik eiSos standard product firmware. Production firmware images and binary files for Würth Elektronik eiSos wireless connectivity modules are not publicly available.

When using the HCI UART interface, the respective UART pins (*HCI_URXD* - */HCI_CTS*) must be connected to a Windows PC. This can be realized using a UART to USB converter cable (i.e. FTDI TTL-232R [12]).
To run the programming process, execute the following steps:

1. Download the Windows PC tool ChipLoad.exe .
2. Place the update hcd file next to the PC tool.
3. Open the Windows command line and go to the directory, where the executable and the hcd-file are placed.

4. Connect the PC to the HCI UART pins (*HCI_URXD* - */HCI_CTS*) of the radio module.
5. Run the executable using the right COM port name and hcd-file name.



6. Wait until update has finished.

10 Firmware history

Version 1.4.17.17 "Release"

- Initial version
- Uses CY-WICED Bluetooth® stack version 3.1.0.0

11 Hardware history

Version 2.0 "Release"

- Initial hardware version

12 Design in guide

12.1 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.

No fixed values can be recommended, as these depend on the circumstances of the application (main power source, interferences etc.).

STOP

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.

- 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.

Again, no fixed values can be recommended, as they depend on the influencing circumstances of the application (antenna, interferences etc.).

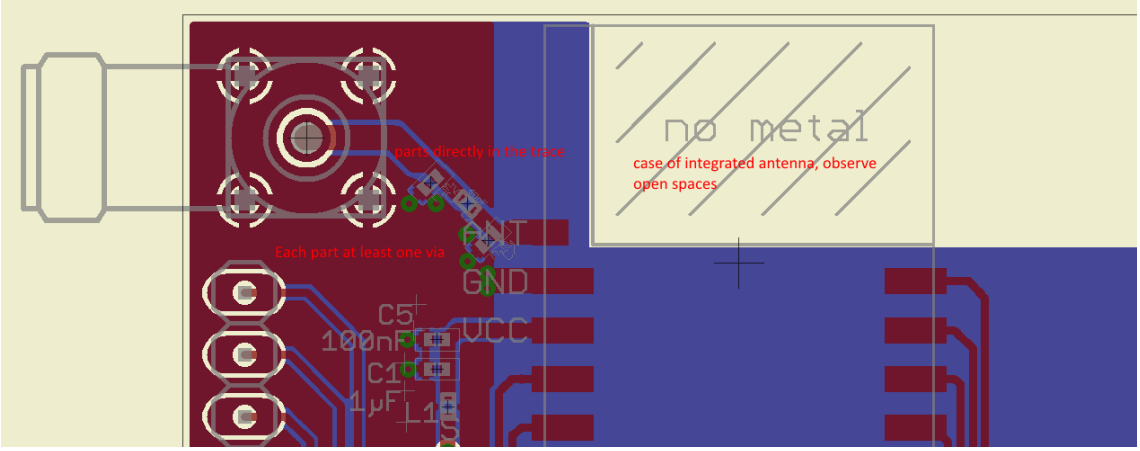


Figure 41: Layout

- 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.
- 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.

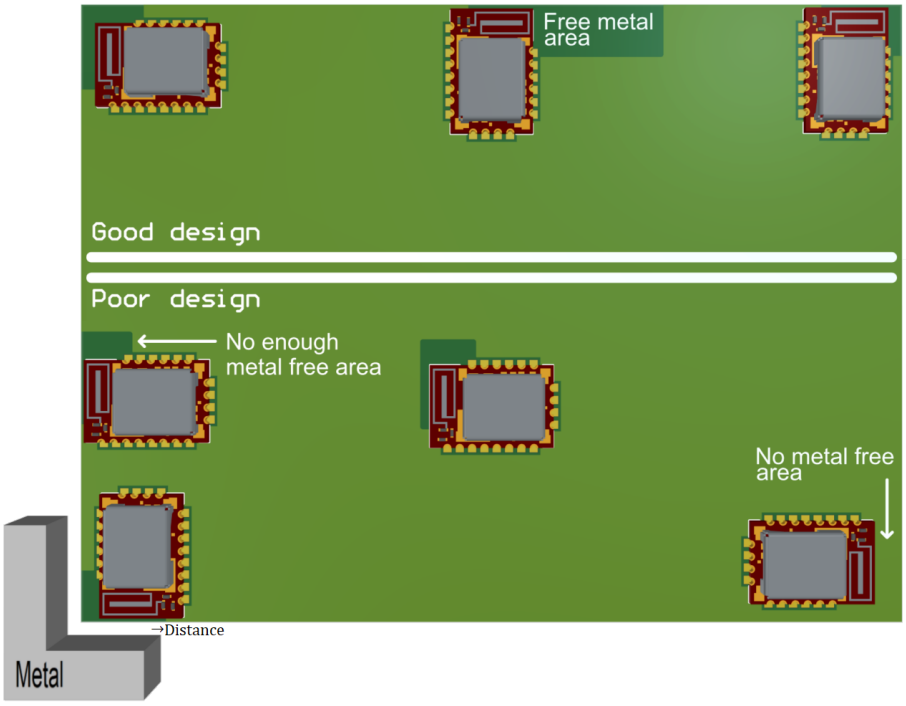


Figure 42: Placement of the module with integrated antenna

13 Reference design

Skoll-I was tested and certified on the corresponding Skoll-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 Skoll-I EV-Board.

13.1 Low frequency crystal

The Skoll-I needs a low frequency watch crystal. The crystal and its external components shall be connected as follow:

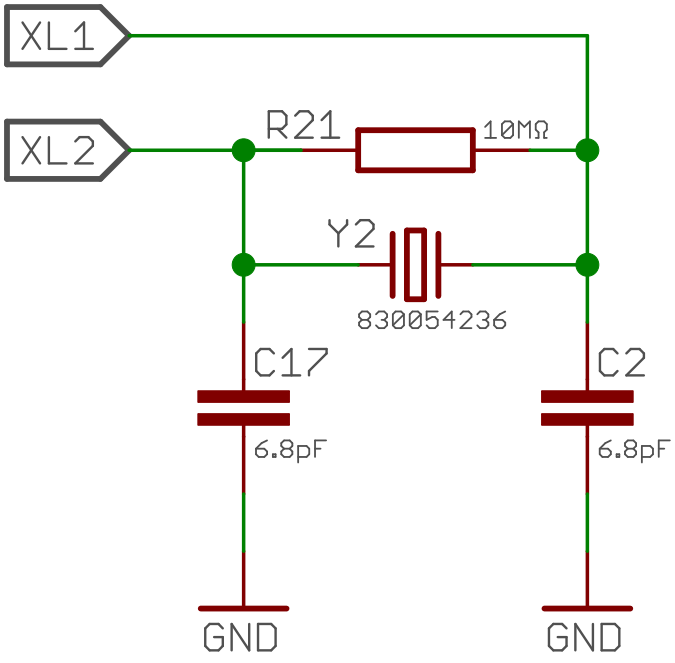


Figure 43: 32.768 kHz external oscillator circuit

The input capacitance of the pad XL1 and XL2 is 0.4 pF. Depending on parasitic capacitance of PCB, the values of C2 and C17 can be calculated as follows.

The load capacitance seen by the crystal is given by

$$C_l = \frac{C2_l * C17_l}{C2_l + C17_l} \quad (1)$$

If $C2_l$= $C17_l$ = C, then

$$C_l = \frac{C}{2} \quad (2)$$

whereas,

$$C2 = C - C_{XL1} - C_{PCB} \tag{3}$$

$$C17 = C - C_{XL2} - C_{PCB} \tag{4}$$

C_l = Load capacitance of watch crystal.
C_{XL1} = Input capacitance of Pad XL1 (0.4 pF)
C_{XL2} = Input capacitance of Pad XL2 (0.4 pF)
C_{PCB} = Parasitic capacitance of PCB

The parasitic capacitance of the PCB can vary depending on design and track length. With a PCB capacitance of 4.8 pF that includes the capacitance of the pads of resistor R21, the value of C2 and C17 results in 6.8 pF, which was tested on the Skoll-IEV-Board.

13.1.1 Low frequency crystal layout

- The crystal and the external components should be positioned as near as possible to the module to reduce stray capacitance and inductance.
- The crystal traces should be kept far away from any high frequency signals.
- The crystal traces should be encircled by a solid ground plane, which must be directly connected to the reference ground plane with vias.

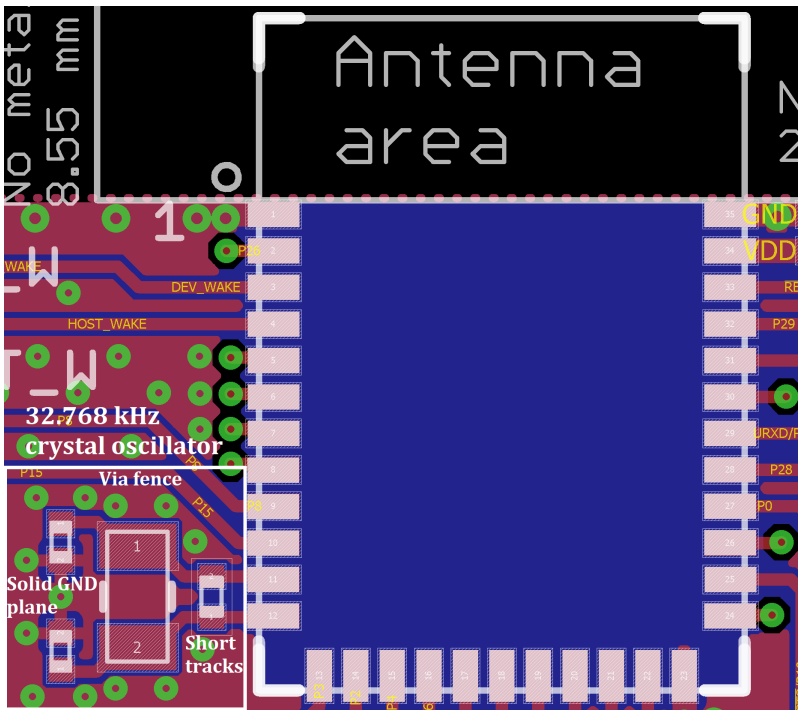


Figure 44: Crystal layout example

13.2 EV-Board

13.2.1 Schematic

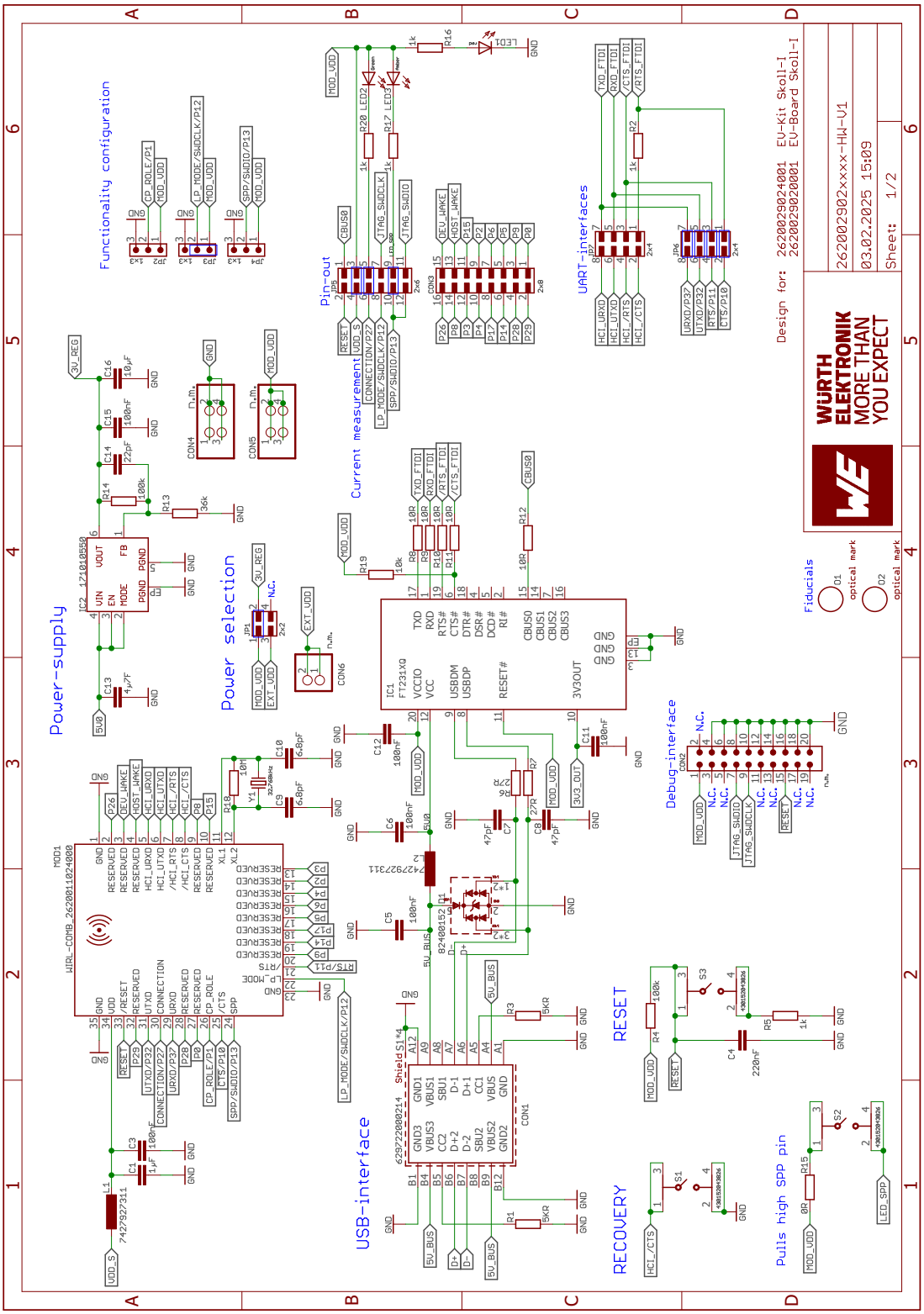


Figure 45: Reference design: Schematic, most important parts

13.2.2 Layout

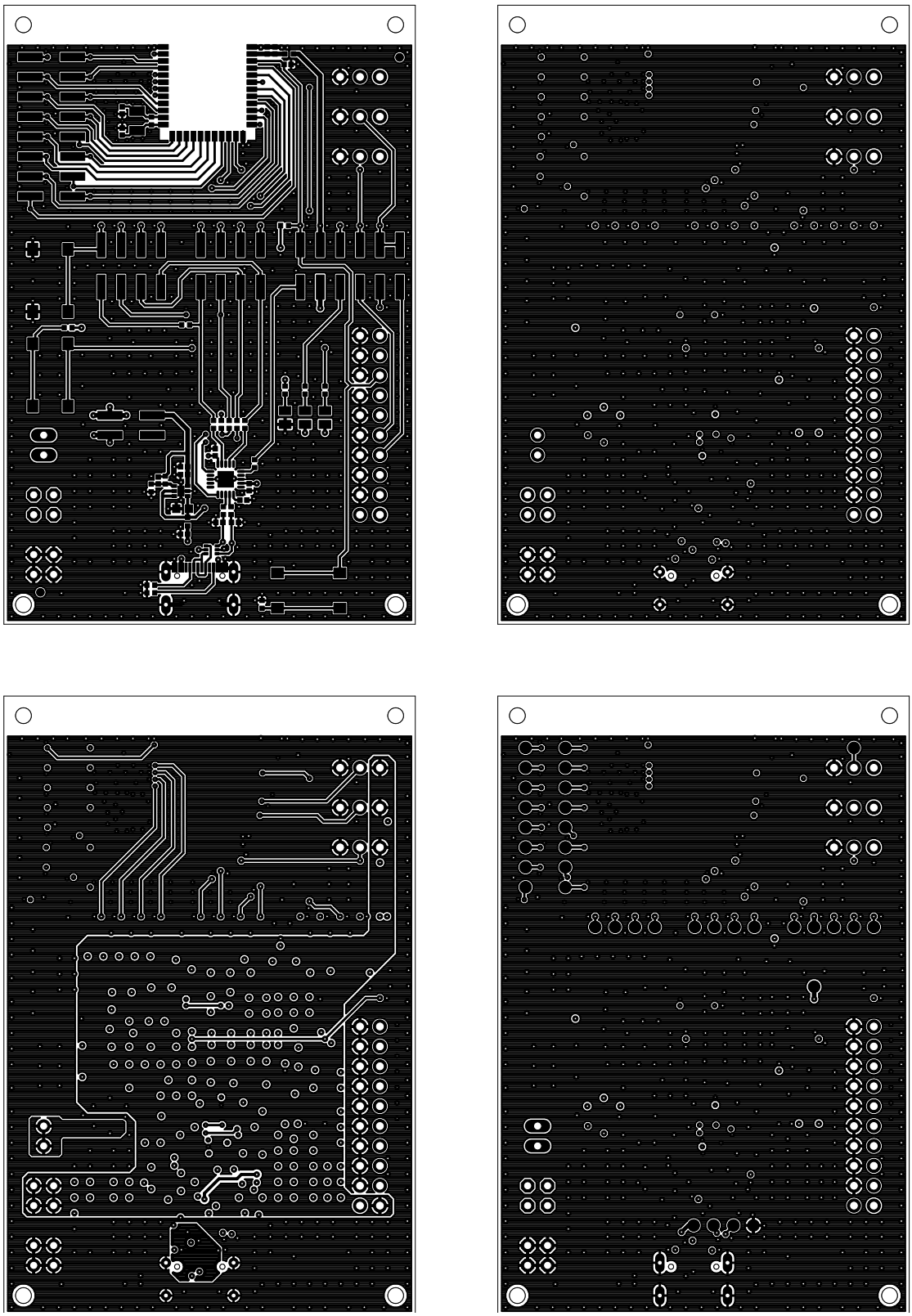


Figure 46: Top layer (upper left), second layer (upper right), third layer (bottom left), fourth layer (bottom right)

14 Manufacturing information

14.1 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*.

14.2 Soldering

14.2.1 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 seconds
Ramp-up rate (T_L to T_P)		3 °C / second max.
Liquidous temperature	T_L	217 °C
Time t_L maintained above T_L	t_L	60 - 150 seconds
Peak package body temperature	T_P	260 °C
Time within 5 °C of actual peak temperature	t_P	20 - 30 seconds
Ramp-down Rate (T_P to T_L)		6 °C / second max.
Time 20 °C to T_P		8 minutes max.

Table 15: 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.

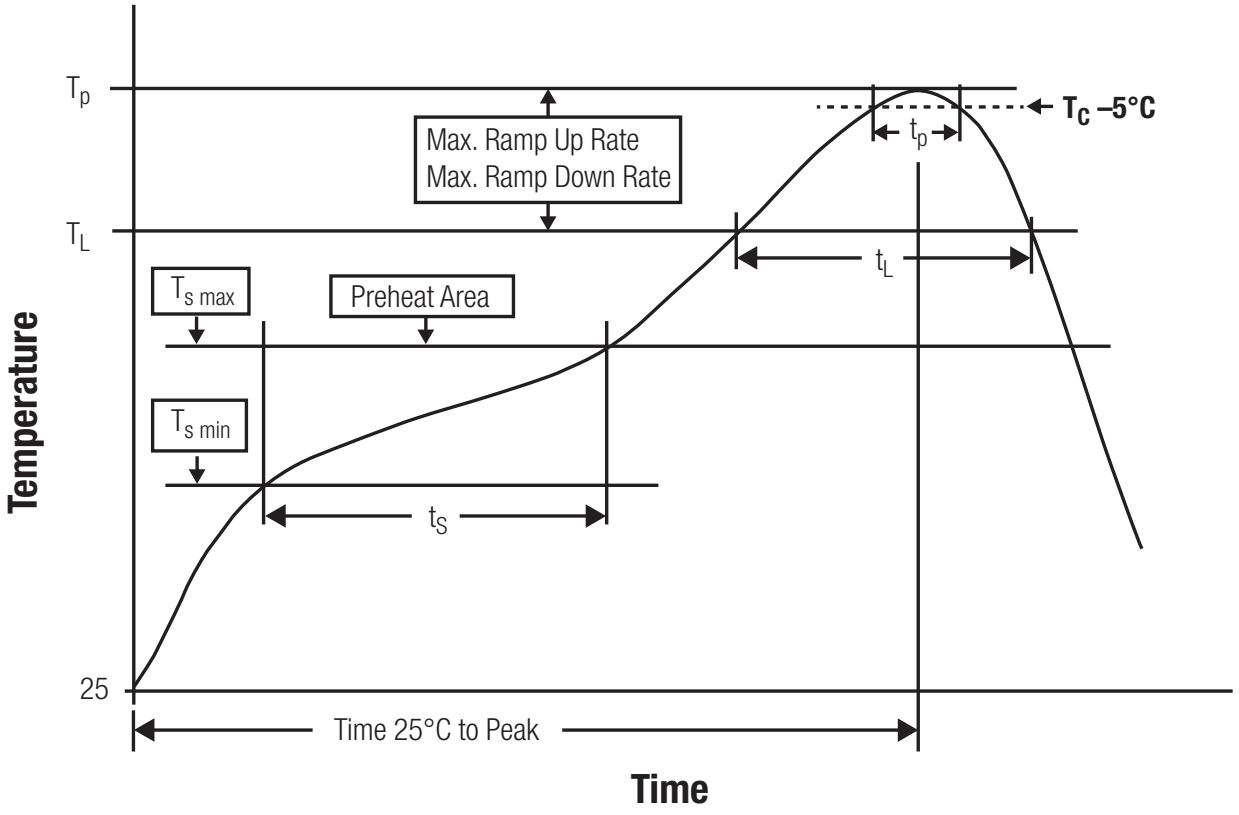


Figure 47: Reflow soldering profile

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

14.2.2 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.

14.2.3 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 behaviour of the device. This might be critical for components with high power.

14.2.4 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.

14.3 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 2. 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.

14.4 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.

15 Physical specifications

15.1 Dimensions

Dimensions
16.61 x 12 x 1.7 mm

Table 16: Dimensions

15.2 Weight

Weight
0.55 g

Table 17: Weight

15.3 Module drawing

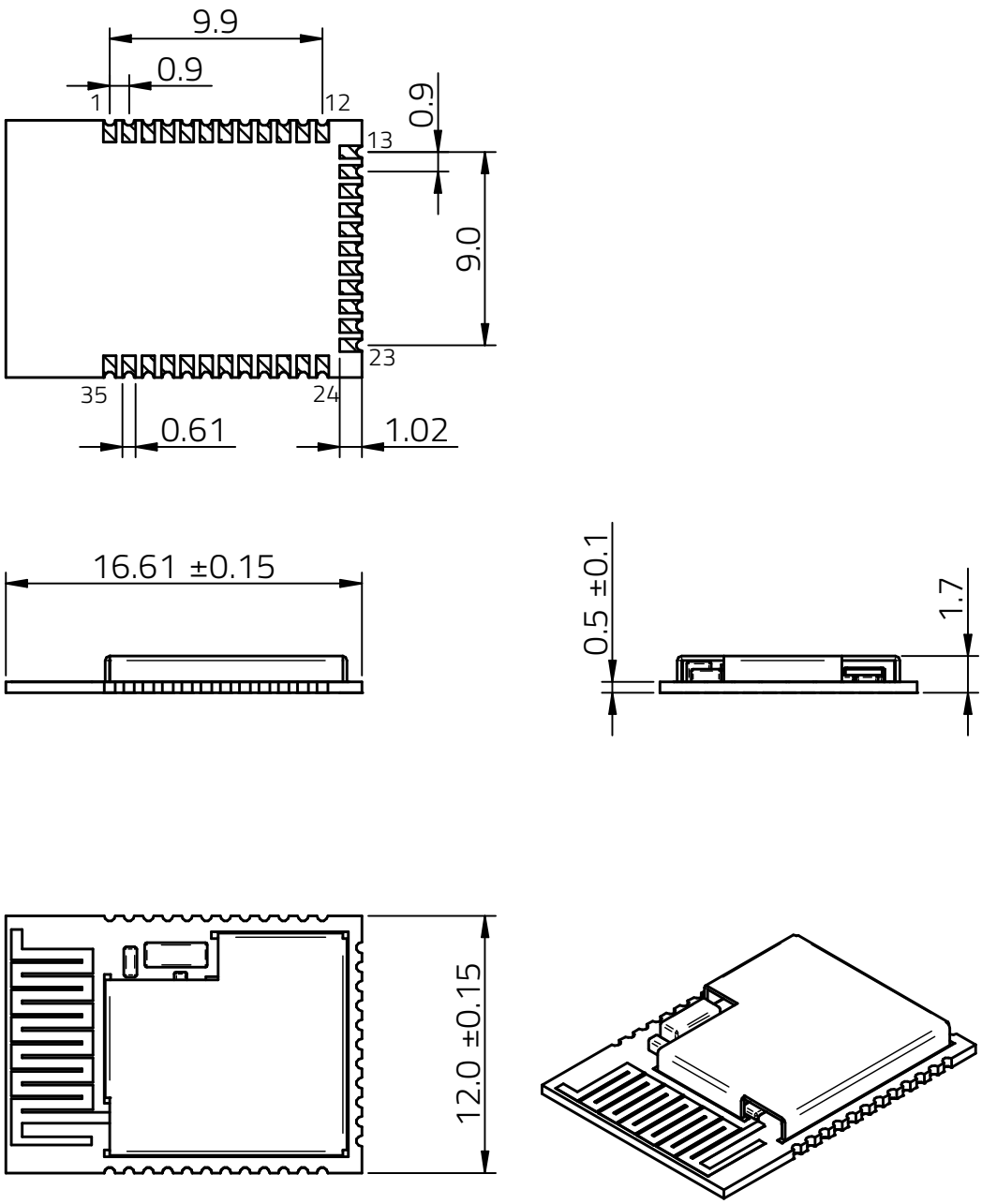


Figure 48: Module dimensions [mm]

15.4 Footprint

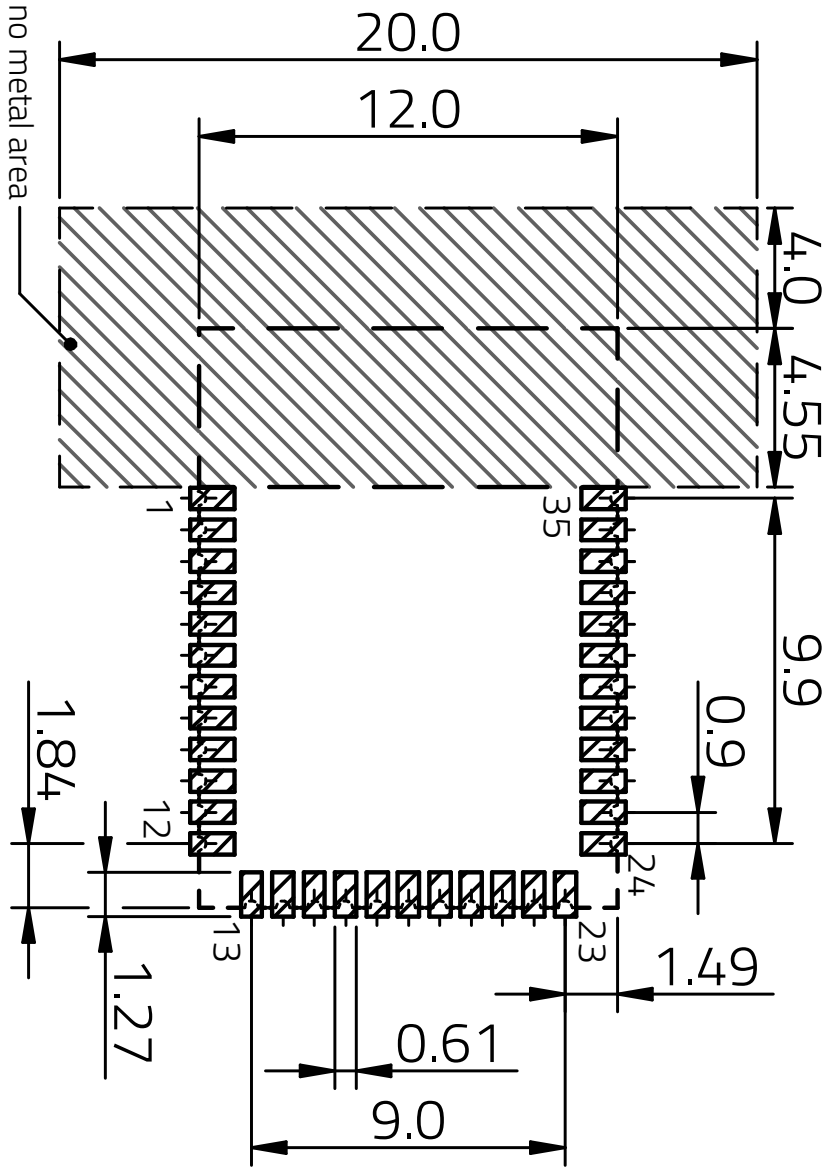


Figure 49: Footprint and dimensions [mm]

15.5 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 49). Even though metal parts would influence the characteristic of the antenna, but the direct influence and matching keep an acceptable level.

16 Marking

16.1 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 Skoll-I the label is as follows:

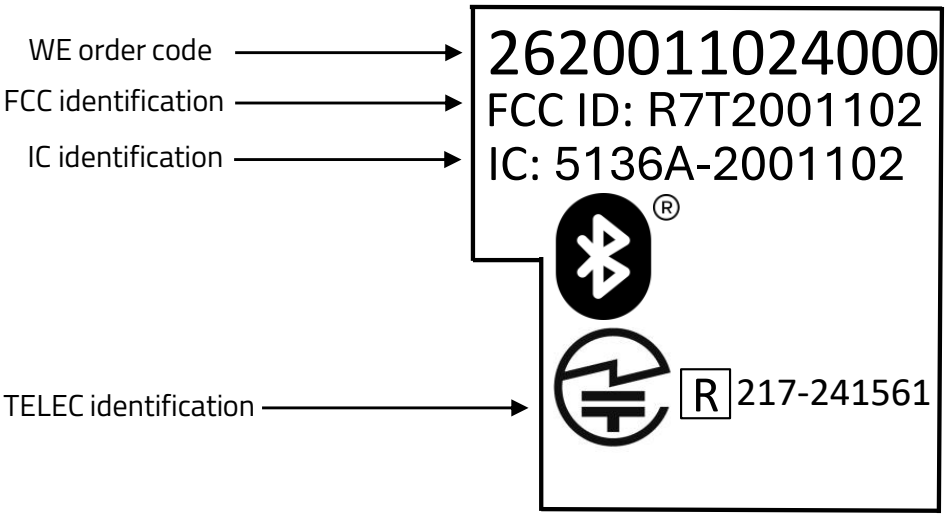


Figure 50: Label of the Skoll-I

16.2 Lot number

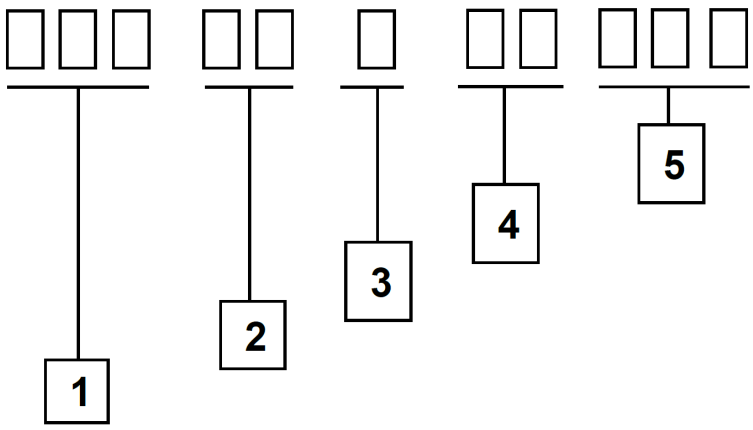


Figure 51: Lot number structure

The 11 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 and can be translated according to the following table.

Block	Information	Example(s)
1	eiSos internal, 3 digits	685
2	eiSos internal, 2 digits	45
3	production year, 1 digits	4 means 2024
4	calender week, 2 digits	23 means week 23
5	eiSos internal, 3 digits	123

Table 18: Lot number details

17 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 4 dBm.
- The total amount of capacitance of all capacitors is 19.9 µF.
- The total amount of inductance of all inductors is 2.206 µH.

18 Bluetooth SIG qualification

Type	Data
Design name	2620011024000
DN	Q304774
Specification name	5.4
Project type	Core Complete

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 Skoll-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® qualification of the end device, refer to the application note ANR027 [13].

19 Regulatory compliance information

19.1 Important notice EU

The use of RF frequencies is limited by national regulations. The Skoll-I has been designed to comply with the RED directive 2014/53/EU of the European Union (EU).
The Skoll-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.

19.2 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 Skoll-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*

19.3 Important notice FCC

The use of RF frequencies is limited by national regulations. The Skoll-I has been designed to comply with the FCC Part 15.
The Skoll-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.

19.4 Conformity assessment of the final product

The Skoll-I is a subassembly. It is designed to be embedded into other products (products incorporating the Skoll-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 Skoll-I carried out by Würth Elektronik eiSos does not replace the required conformity assessment of the final product.

19.5 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.

19.6 EU Declaration of conformity

EU DECLARATION OF CONFORMITY

Radio equipment: **2620011024000**

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: 2620011024000

The object of the declaration described above is in conformity with the relevant Union harmonisation legislation Directive 2014/53/EU.
It also complies to 2011/65/EU with its amending Annex II EU 2015/863. Following harmonised norms or technical specifications have been applied:

EN 300 328-1 V2.2.2 (2019-07)
EN 301 489-1 V2.2.3 (2019-11)
EN 301 489-17 V3.2.4 (2020-09)
EN 62479 : 2010
EN 50663: 2017
EN 62368-1: 2014/AC: 2015/A11: 2017

i.A. G. Erlandt

Trier, 4th of September 2024
Place and date of issue

19.7 FCC Compliance Statement (US)

FCC ID: R7T2001102

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.

TCB

GRANT OF EQUIPMENT AUTHORIZATION

TCB

Certification
Issued Under the Authority of the
Federal Communications Commission
By:

Timco Engineering, Inc.
13146 NW 86th Drive Suite 400
Alachua, FL 32615

Date of Grant: 09/05/2024

Application Dated: 09/05/2024

Wuerth Elektronik eiSos GmbH & Co KG
Max-Eyth-Strasse 1
Waldenburg, 74638
Germany

Attention: Gudrun Eckhardt , Teamleader Hardware Development

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: R7T2001102
Name of Grantee: Wuerth Elektronik eiSos GmbH & Co KG
Equipment Class: Part 15 Spread Spectrum Transmitter
Notes: A Bluetooth module.
Modular Type: Single Modular

Grant Notes	FCC Rule Parts	Frequency Range (MHZ)	Output Watts	Frequency Tolerance	Emission Designator
	15C	2402.0 - 2480.0	0.0024		

Output power listed is conducted. Single Modular Approval for portable RF Exposure conditions. Co-location of this module with other transmitters that operate simultaneously are required to be evaluated using the FCC multi-transmitter procedures. Approved for OEM integration only. The grantee must provide OEM integrators, or end-users if marketed directly to end-users, with installation and operating instructions for satisfying FCC multi-transmitter product guidelines. This grant is valid only when the device is sold to OEM integrators and the OEM integrators are instructed to ensure that the end-user has no manual instructions to remove or install the device.

TCB

GRANT OF EQUIPMENT AUTHORIZATION

TCB

Certification
Issued Under the Authority of the
Federal Communications Commission
By:

Timco Engineering, Inc.
13146 NW 86th Drive Suite 400
Alachua, FL 32615

Date of Grant: 09/05/2024

Application Dated: 09/05/2024

Wuerth Elektronik eiSos GmbH & Co KG
Max-Eyth-Strasse 1
Waldenburg, 74638
Germany

Attention: Gudrun Eckhardt , Teamleader Hardware Development

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:	R7T2001102
Name of Grantee:	Wuerth Elektronik eiSos GmbH & Co KG
Equipment Class:	**Digital Transmission System**
Notes:	**A Bluetooth module.**
Modular Type:	**Single Modular**

Grant Notes	FCC Rule Parts	Frequency Range (MHZ)	Output Watts	Frequency Tolerance	Emission Designator
	15C	**2402.0 - 2480.0**	**0.0028**		

Output power listed is conducted. Single Modular Approval for portable RF Exposure conditions. Co-location of this module with other transmitters that operate simultaneously are required to be evaluated using the FCC multi-transmitter procedures. Approved for OEM integration only. The grantee must provide OEM integrators, or end-users if marketed directly to end-users, with installation and operating instructions for satisfying FCC multi-transmitter product guidelines. This grant is valid only when the device is sold to OEM integrators and the OEM integrators are instructed to ensure that the end-user has no manual instructions to remove or install the device.

19.8 IC Compliance Statement (Canada)

Certification Number: 5136A-2001102
HVIN: 2001102
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.

CANADIAN CERTIFICATION
TECHNICAL ACCEPTANCE CERTIFICATE

Certification No. ➢ **IC:** 5136A-2001102

Issued To ➢ Würth Elektronik eiSos GmbH & Co. KG
Max-Eyth-Str. 1 · 74638
Waldenburg,
Germany

Tested By ➢ DEKRA Testing and Certification (Suzhou) Co., Ltd.
Company No.: 4075B
No. 99, Hongye Road, Suzhou Industrial Park, Suzhou,
Jiangsu Province, 215006, P. R. China
+86-18112256003; Yingfei.wang@dekra.com

Type of Equipment ➢ Other

Type of Service ➢ New Certification (Single)

Hardware Version Identification Number (HVIN) ➢ 2001102

Firmware Version Identification Number (FVIN) ➢ N/A

Product Marketing Name: (PMN) ➢ 2001102

Modular Approval Type ➢ Modular Approval (MA)

Host Marketing Name (HMN) ➢ N/A

FREQUENCY RANGE	EMISSION DESIGNATIONS NECESSARY BANDWIDTH & EMISSION CLASSIFICATION	R.F. POWER	ANTENNA INFO	ISED STANDARD/ ISSUE & DATE	
2402-2480MHz	918KF1D	0.0024W	PCB; -0.5dBi	RSS-247	Issue 3; Aug. 2023
2402-2480MHz	1M21G1D	0.0017W	PCB; -0.5dBi	RSS-247	Issue 3; Aug. 2023
2402-2480MHz	986KF1D	0.0028W	PCB; -0.5dBi	RSS-247	Issue 3; Aug. 2023
2402-2480MHz	2M10F1D	0.0025W	PCB; -0.5dBi	RSS-247	Issue 3; Aug. 2023

Note 1: This equipment also complies with RSS-102, Issue 5 (March 2015) and RSS-Gen, Issue 5 (April 2018).

Certification of equipment means only that the equipment has met the requirements of the above-noted specification. Licence 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.

I hereby attest that the subject equipment was tested and found in compliance with the above-noted specifications.

La certification de l'équipement signifie uniquement que l'équipement a satisfait aux exigences de la spécification susmentionnée. Les demandes de licence, le cas échéant pour utiliser un équipement certifié, sont traitées en conséquence par le bureau émetteur d'ISED et dépendront de l'environnement radio, du service et du lieu d'exploitation existants. Ce certificat est délivré à condition que le titulaire se conforme et continuera de se conformer aux exigences et procédures émises par ISED. L'équipement pour lequel ce certificat est délivré ne doit pas être fabriqué, importé, distribué, loué, mis en vente ou vendu à moins que l'équipement ne soit conforme aux spécifications et procédures techniques applicables émises par ISED.

J'atteste par la présente que le matériel a fait l'objet d'essai et jugé conforme à la spécification ci-dessus.

ISSUED UNDER THE AUTHORITY OF MINISTER OF INDUSTRY
DÉLIVRÉ AVEC L'AUTORISATION DU MINISTRE DES INDUSTRIES

DATE: September 11, 2024

Bruno Clavier, General Manager

19.9 FCC and IC requirements to OEM integrators

This module has been granted modular approval. OEM integrators for host products may use the module in their final products without additional FCC/IC (Industry Canada) certification if they meet the following conditions. Otherwise, additional FCC/IC approvals must be obtained. The host product with the module installed must be evaluated for simultaneous transmission requirements.

- The user's manual for the host product must clearly indicate the operating requirements and conditions that must be observed to ensure compliance with current FCC/IC RF exposure guidelines.
- A label must be affixed to the outside of the host product with the following statements:
  This device contains FCCID: R7T2001102
  This equipment contains equipment certified under ICID: 5136A-2001102
- The final host / module combination may also need to be evaluated against the FCC Part 15B criteria for unintentional radiators in order to be properly authorized for operation as a Part 15 digital device.
- If the final host / module combination is intended for use as a portable device (see classifications below) the host manufacturer is responsible for separate approvals for the SAR requirements from FCC Part 2.1093 and RSS-102.

OEM requirements:
The OEM must ensure that the following conditions are met.

- End users of products, which contain the module, must not have the ability to alter the firmware that governs the operation of the module. The agency grant is valid only when the module is incorporated into a final product by OEM integrators.
- The end-user must not be provided with instructions to remove, adjust or install the module.
- The Original Equipment Manufacturer (OEM) must ensure that FCC labeling requirements are met. This includes a clearly visible label on the outside of the final product. Attaching a label to a removable portion of the final product, such as a battery cover, is not permitted.
- The label must include the following text:
  Contains FCC ID: R7T2001102
  The enclosed device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:
  (i.) this device may not cause harmful interference and
  (ii.) this device must accept any interference received, including interference that may cause undesired operation.

  When the device is so small or for such use that it is not practicable to place the statement above on it, the information required by this paragraph shall be placed in a prominent location in the instruction manual or pamphlet supplied to the user or, alternatively, shall be placed on the container in which the device is marketed. However, the FCC identifier or the unique identifier, as appropriate, must be displayed on the device.

- The user manual for the end product must also contain the text given above.
  - Changes or modifications not expressly approved could void the user's authority to operate the equipment.
  - The OEM must ensure that timing requirements according to 47 CFR 15.231(a-c) are met.
  - The OEM must sign the OEM Modular Approval Agreement.
  - The module must be used with only the following approved antenna(s).
- The OEM shall perform testing in accordance to 996369 D04 Module Integration Guide V01.

19.9.1 Pre-certified antennas

The Skoll-I is pre-certified with the following antennas.

Product	Certified antenna
Skoll-I	PCB antenna included in the Skoll-I

19.10 TELEC radio law approval

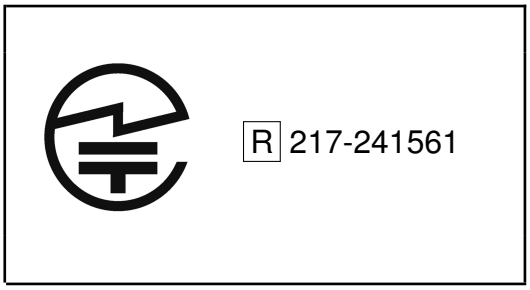
Japanese Radio Law Compliance

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)

19.10.1 Label

2620011024000:



After integration of the Skoll-I 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.

19.10.2 Certified antennas

The Skoll-I is pre-certified with the following antennas.

Product	Certified antenna
Skoll-I (2620011024000)	PCB antenna included in the Skoll-I

JAPAN MIC
TYPE CERTIFICATION
CERTIFICATE NUMBER 217-241561

CERTIFICATE HOLDER:

Company Name	:	Würth Elektronik eiSos GmbH & Co. KG
Postal Address	:	Max-Eyth-Str. 1 · 74638 Waldenburg, Germany
Representative Name	:	Matthias Hauser, wcs@we-online.de

MANUFACTURER:

Company Name	:	Würth Elektronik eiSos GmbH & Co. KG
Postal Address	:	Max-Eyth-Str. 1 · 74638 Waldenburg, Germany

PRODUCT DESCRIPTION

Product Name	:	2620011024000
Trademark/Trade Name	:	
Model Number(s)	:	2620011024000
Category	:	Unlicensed Device (Act 38-2-2.1.1)

Based on the evidence presented in the Technical Documentation, TIMCO Engineering, Inc., as a Registered Certification and Approval Body (217) recognized by Japan MIC, declares that the listed product is in conformity with the Technical Regulations Conformity Certification of Specified Radio Equipment, and the Technical Specifications.

The products placed on the Japanese market must bear the following marking:

R 217-241561

This certificate is limited to products that are identical to the type assessed for this application for certification and is issued under the provision that TIMCO Engineering Inc. nor its subsidiary companies accept any liability concerning the contents of this document other than forced by law. Reproduction of the Certificate (with Annex) in full is allowed. Reproduction of parts of this certificate may only be allowed by written permission of TIMCO Engineering, Inc.

RECOGNIZED CERTIFICATION BODY
Certificate issued by: TIMCO Engineering, Inc. (217)
Name and Signature: Bruno Clavier
Date: September 12, 2024

PRODUCT SPECIFICATIONS

Low power data communications system in the 2.4GHz band
Item19,Paragraph1,Article2

F1D, G1D 2441MHz	0.04~0.15mW/MHz
F1D 2402-2480MHz(2MHz Sep 40ch)	2.5mW

Antenna

PCB Antenna, with a maximum gain of -0.5dBi for 2.4GHz Band

19.11 ETA-WPC (India)

Registration No: ETA-SD-20241111071 Date: 21-11-2024

The Skoll-I complies with the provisions on the Equipment Type Approval WPC Wing for India.

19.11.1 ETA-WPC certificate

सत्यमेव जयते

Government of India
Ministry of Communications
Department of Telecommunications
WPC Wing
Sanchar Bhawan, New Delhi-110001.

[Generation of Equipment Type Approval (ETA) through self-declaration issued under O.M. No. ETA-WPC /Policy/2018-19 dated 26 February, 2019].

THIS ETA IS ISSUED FOR A SINGLE MODEL WITH MODEL NAME Skoll-I (2620011024000)

Registration No: ETA-SD-20241111071 Date: 21-11-2024

I). Details of Applicant and Parameters of Equipment:

1.	Name & Address of the first Applicant. (Indian Manufacturer/ Authorised Indian representative for foreign manufacturer)	WURTH ELECTRONICS SERVICES INDIA PRIVATE LIMITED, Ground and 1st Floor, No. 3, Prestige Sterling Square, Madras Bank Road, Next to Airlines Hotel, Banglore, Bengaluru Bangalore Urban, Karnataka, 560001, Bangalore Urban,KARNATAKA,560001
2.	Equipment category	Bluetooth (BR/EDR) & Bluetooth (LE) Module
3.	Make	Wurth Elektronik eiSos GmbH & Co KG,Germany
4.	Model	Skoll-I (2620011024000)
5.	Frequency range(s) of Equipment	1. 2400-2480 MHz
6.	Max output power/Field strength/PSD	1. E.I.R.P. (dBm). 3.16

1 / 2

Figure 52: ETA-WPC certificate page 1

7.	Applicable Gazette Notification(s)	1. 45 (E) Dated 28-01-2005	
8.	RF Test Report details:-		
	Name&Address /Country of accredited laboratory issuing the RF test report	Accreditation Certificate Reference/Number	Test Report No. and Date
	DEKRA Testing & Certification (Suzhou) Co., Ltd. & Hongye Rd., Suzhou Industrial Park, Suzhou, 215006, Jiangsu, China	L5313	2470363R-RF-CE-P17V03 & 23-08-2024
	DEKRA Testing & Certification (Suzhou) Co., Ltd. & Hongye Rd., Suzhou Industrial Park, Suzhou, 215006, Jiangsu, China	L5313	2470363R-RF-CE-P17V02 & 23-08-2024

II). Terms and Conditions

(i). This certificate will not be valid in case any change in the above parameters and not conforming to the Gazette Notification mentioned in sl.no 7 above.
(ii). Use of such equipment has been exempted from licensing requirement vide Gazette Notification mentioned in sl. no. 7, on Non-interference,Non-protectionand sharing (non-exclusive) basis.
(iii). Use of such equipment in case not conforming to above notification will require a specific wireless operating license, as applicable from this Ministry.
(iv). Field units of WPC Wing reserve the right for sample check/audit carried out for the purpose of RF analysis/spectrum monitoring in view to avoid interference to other wireless users and ensure compliance of technical parameters mentioned in sl no. 5,6&7.
(v). This certificate is valid only for equipment which are exempted from import licensing requirements as per the Import Policy of DGFT and for import of such device, a self-declaration based, system generated (Saralsanchar) Import undertaking/ permission is required.
(vi). The applicant is liable for prosecution under Indian Law in case of any wrong declaration/ submission of ingenuine RF test report(s) for issue of ETA through Self-Declaration.

Note:
1. Once ETA through self-declaration is generated for a model, subsequently it may be utilized by other person(s) for import/usage purpose in India.

2. The importers of above model shall comply with other import related requirements, if any, with Customs.

This is Self-generated certificate. Hence, no signature is required. It may be downloaded/verified from the website https://saralsanchar.gov.in.

2 / 2

Figure 53: ETA-WPC certificate page 2

19.12 Certification of the end device

For the certification of the end device, which integrates the Skoll-I, it is necessary to set the Skoll-I to transmission mode and check the radio emissions.

By default the Skoll-I already implements the HCI (Host Controller Interface) that is defined in the Bluetooth® specification [2]. It provides on the HCI UART (*HCI_URXD - /HCI_CTS*) interface all the test commands needed for certification tests. To run the tests, connect the Bluetooth® tester to the HCI UART of the Skoll-I with 115200 Baud, 8N1 and flow control enabled. Then send a HCI reset command to check whether it responds correctly.

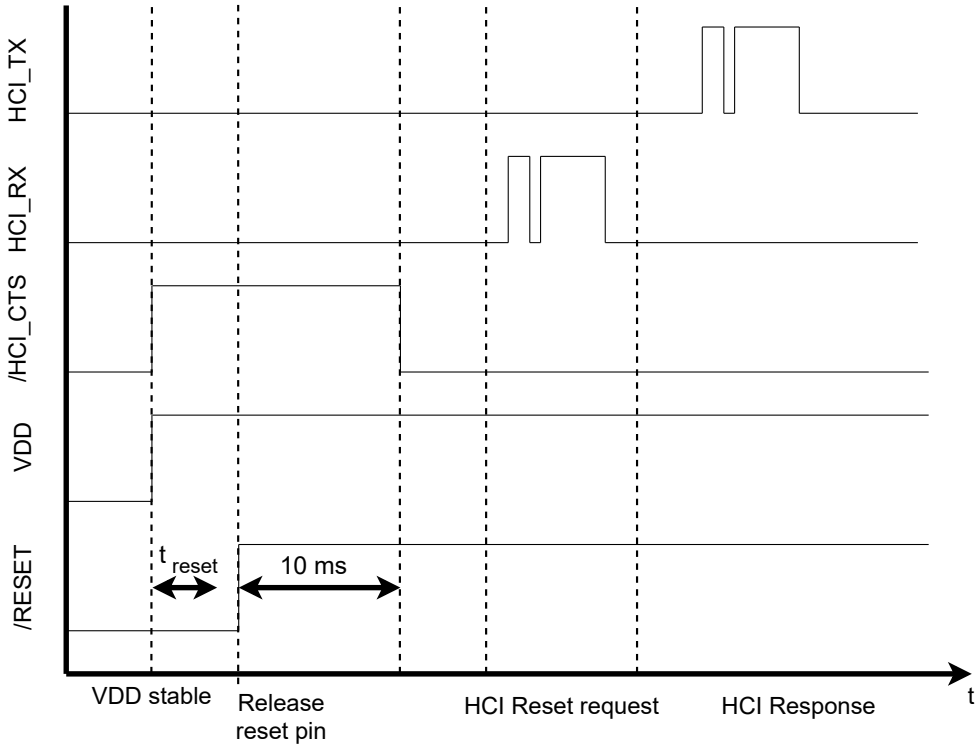


Figure 54: Power up sequence for HCI mode

Info	Message
⇒ Sent HCI reset command	0x01 03 0C 00
⇐ Response from module "Success"	0x04 0E 04 01 03 0C 00

In case this does not work, the HCI UART needs to be reset. To do so, pull the */HCI_CTS* pin to LOW and reset the Skoll-I. On the Skoll-I EV-Board this can be done by holding the recovery button, while pressing the reset button press for a short while.

Now the tester can control the radio module by HCI commands. Refer to Bluetooth® specification for HCI command documentation.

20 References

[1] Infineon. EZ Serial firmware manual. https://www.we-online.com/um-ezserial.

[2] Bluetooth®. Bluetooth® Core Specification, version 5.4. https://www.bluetooth.com/specifications/specs/core-specification-5-4/.

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[4] Würth Elektronik. Wireless Connectivity SDK for Raspberry Pi - Radio module drivers in C-code. https://github.com/WurthElektronik/WirelessConnectivity-SDK.

[5] Bluetooth®. Bluetooth® Serial port profile 1.2. https://www.bluetooth.com/specifications/specs/serial-port-profile-1-2/.

[6] Würth Elektronik. WE UART Terminal PC tool (Smart Commander). https://www.we-online.de/wcs-software.

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[8] Nordic Semiconductor. nRF Connect app for Android. https://play.google.com/store/apps/details?id=no.nordicsemi.android.mcp.

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21 Important notes

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

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.

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 source code 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.

Best care and attention
Any product-specific data sheets, manuals, application notes, PCNs, warnings and cautions must be strictly observed in the most recent versions and matching to the products revisions. These documents can be downloaded from the product specific sections on the wireless connectivity and sensors homepage.

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 Business Development Engineer (BDM) or the internal sales person in charge should be contacted who will be happy to support in this matter.

Product improvements
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 Business Development Engineer (BDM), the internal sales person or the technical support team in charge should be contacted. The basic responsibility of the customer as per section 21 and 21 remains unaffected.
All software like ¨wireless connectivity SDK¨, ¨Sensor SDK¨ or other source codes as well as all PC software tools are not subject to the Product Change Notification information process.

Product life cycle
Due to technical progress and economical evaluation, we also reserve the right to discontinue production and delivery of products. As a standard reporting procedure of the Product Termination Notification (PTN) according to the JEDEC-Standard we will inform at an early stage about inevitable product discontinuance. According to this, we cannot ensure that all products within our product range will always be available. Therefore, it needs to be verified with the Business Development Engineer (BDM) or the internal sales person in charge about the current product availability expectancy before or when the product for application design-in disposal is considered. The approach named above does not apply in the case of individual agreements deviating from the foregoing for customer-specific products.

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General terms and conditions
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22 Legal notice

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23 License terms

These License terms will take effect upon the purchase and usage of the Würth Elektronik eiSos GmbH & Co. KG wireless connectivity products. You hereby agree that these license terms are applicable to the product and the incorporated software, firmware and source codes (collectively, "Software") made available by Würth Elektronik eiSos in any form, including but not limited to binary, executable or source code form. The software included in any Würth Elektronik eiSos wireless connectivity product is purchased to you on the condition that you accept the terms and conditions of these license terms. You agree to comply with all provisions under these license terms.

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You are responsible for using the Würth Elektronik eiSos wireless connectivity product with the incorporated firmware in compliance with all applicable product liability and product safety laws. You acknowledge to minimize the risk of loss and harm to individuals and bear the risk for failure leading to personal injury or death due to your usage of the product.
Würth Elektronik eiSos' products with the incorporated firmware are not authorized for use in safety-critical applications, or where a failure of the product is reasonably expected to cause severe personal injury or death. Moreover, Würth Elektronik eiSos' products with the incorporated firmware are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc. You shall inform Würth Elektronik eiSos about the intent of such usage before design-in stage. In certain customer applications requiring a very high level of safety and in which the malfunction or failure of an electronic component could endanger human life or health, you must ensure to have all necessary expertise in the safety and regulatory ramifications of your applications. You acknowledge and agree that you are solely responsible for all legal, regulatory and safety-related requirements concerning your products and any use of Würth Elektronik eiSos' products with the incorporated firmware in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by Würth Elektronik eiSos. YOU SHALL INDEMNIFY WÜRTH ELEKTRONIK EISOS AGAINST ANY DAMAGES ARISING OUT OF THE USE OF WÜRTH ELEKTRONIK EISOS' PRODUCTS WITH THE INCORPORATED FIRMWARE IN SUCH SAFETY-CRITICAL APPLICATIONS.

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The incorporated firmware created by Würth Elektronik eiSos is and will remain the exclusive property of Würth Elektronik eiSos.

Firmware update(s)
You have the opportunity to request the current and actual firmware for a bought wireless connectivity product within the time of warranty. However, Würth Elektronik eiSos has no obligation to update a modules firmware in their production facilities, but can offer this as a service on request. The upload of firmware updates falls within your responsibility, e.g. via ACC or another software for firmware updates. Firmware updates will not be communicated automatically. It is within your responsibility to check the current version of a firmware in the latest version of the product manual on our website. The revision table in the product manual provides all necessary information about firmware updates. There is no right to be provided with binary files, so called "firmware images", those could be flashed through JTAG, SWD, Spi-Bi-Wire, SPI or similar interfaces.

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