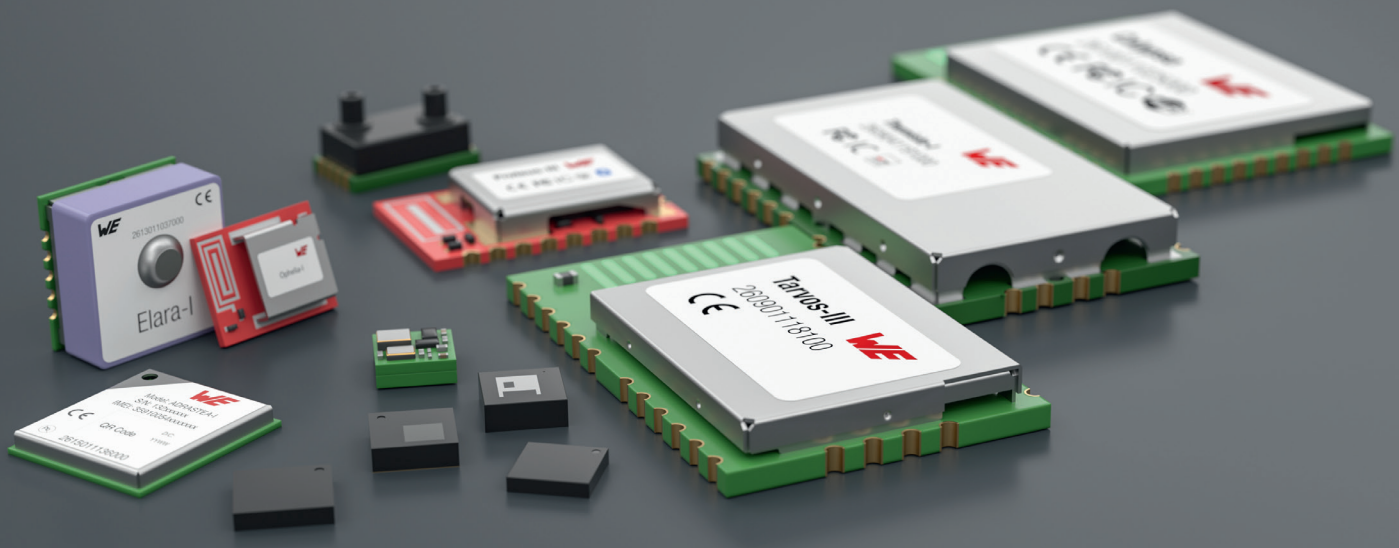


User manual

Metis-E Wireless M-Bus

2609051183000

Version 1.0

September 27, 2024

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 to include the possibility of a firmware update in the customer system design.

Revision history

Manual version	FW version	HW version	Notes	Date
1.0	1.0.0	2.2	• Initial version	September 2024

⋆ For firmware history see chapter `Firmware history`

Abbreviations

Abbreviation	Name	Description
ACK	Acknowledgement	Acknowledgement pattern confirming the reception of the transmitted data packet.
BDM	Business Development Manager	Support and sales contact person responsible for limited sales area.
CRC	Cyclic Redundancy Check	Used for error-detection in transmitted data.
RTC	Real Time Clock	
CS	Checksum	XOR checksum to check the correct transmission of the prepended bytes.
DC	Duty Cycle	Transmission time in relation of one hour. 1% means, channel is occupied for 36 seconds per hour.
EV-Board	Evaluation Board	
0xhh [HEX]	Hexadecimal	All numbers beginning with 0x are stated as hexadecimal numbers. All other numbers are decimal.
HIGH	High signal level	Signal level equals VCC.
kbps	kilo bits per second	Unit to measure data rate.
kcps	kilo chips per second	Unit to measure chip rate.
LOW	Low signal level	Signal levels equals 0 Volts.
LPM	Low power mode	Operation mode for reduced power consumption.
LSB	Least Significant Bit/Byte	Bit or byte order
MSB	Most Significant Bit/Byte	Bit or byte order
OMS	Open Metering System	System as specified by the Open Metering System Group e.V
PER	Packet Error Rate	Radio of lost packets typically expressed as percentage
PL	Payload	The real, non-redundant information in a frame / packet.
RF	Radio Frequency	Describes everything relating to the wireless transmission.
SMGW	Smart Meter Gateway	Data collector within wM-Bus.
UART	Universal Asynchronous Receiver Transmitter	The UART allows communicating with the module of a specific interface.

US	User Settings	Any relation to a specific entry in the user settings is marked in a special font and can be found in the chapter 8.
VCC	Supply voltage	
wM-Bus	wireless meter Bus or wireless M-Bus	EN 13757 -3 and -4 standards.

Contents

1. Introduction

The wireless M-Bus is the European standard for wireless meter reading. It is based on European standard EN 13757-4, covering the specification of communication between meters and data collectors, also known as gateways and so it is highly recommended to read the EN 13757-3 and EN 13757-4 in their most recent released versions. This manual presumes basic knowledge of wireless M-Bus. This is required for creating and understanding wireless M-Bus compliant data, frame structures, radio configuration and communication schemes.

1.1. Operational description

The Metis-e is a radio module in the 868 MHz frequency range for wireless communication using the wM-Bus standard between smart meters and smart meter gateways. Throughout this document, the meter and gateway are refered to as roles or wM-Bus roles, where meter is always the transmitter and gateway always the receiver. Modes define how the meter operates. Stationary (S) mode is appropriate for meters that only need to send data a few times a day. Frequent transmit (T) mode is applicable when sending greater amounts of data per day. Compact (C) mode can handle even higher data rates. The wM-Bus modes S, T and C are implemented for uplink (meter to gateway) communication as described in the OMS specification. Additionally, Metis-e relieves the host system of radio-specific tasks such as:

- checksum calculation and
- coding and decoding according to the used wM-Bus mode.

It can be deployed wherever the wireless exchange of data packets between two or more parties is required. A serial interface (UART), whose data rate and format can be adjusted flexibly, is available for communicating with the host system.

1.2. Block diagram

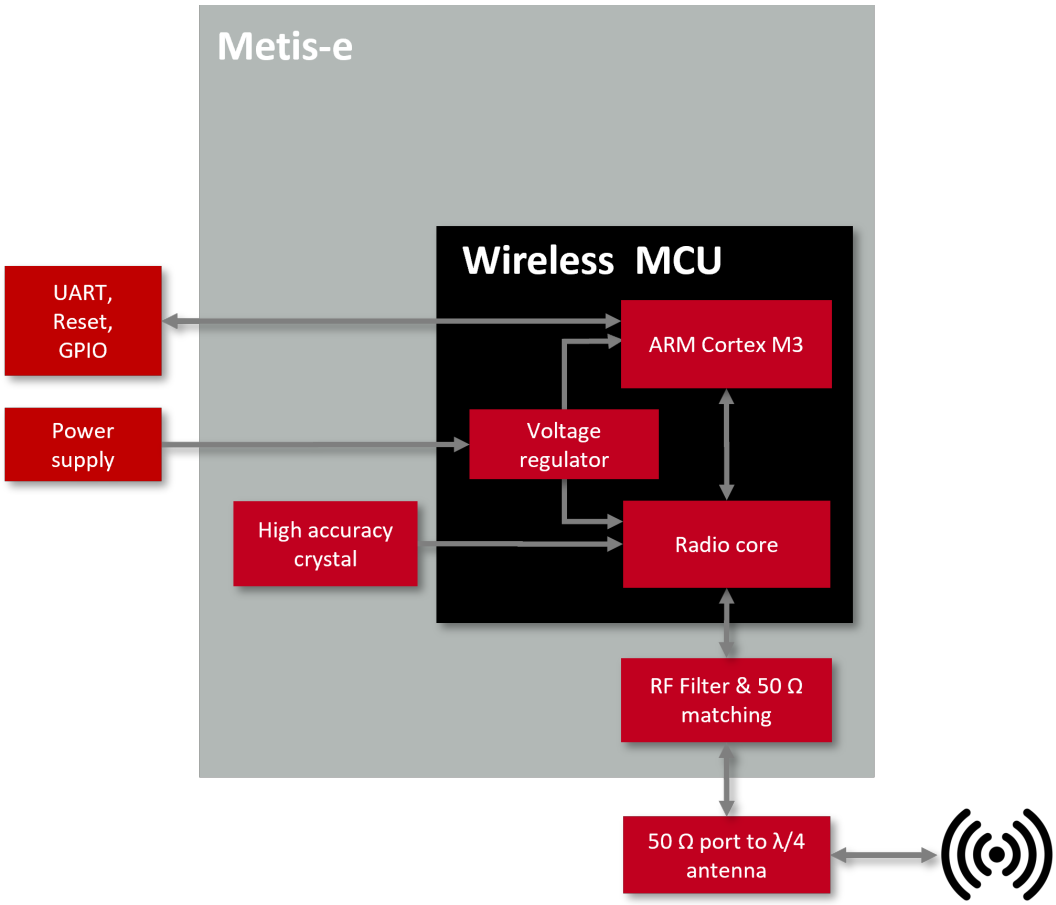


Figure 1: Block diagram

1.3. Ordering information

Item no.	Description
2609051183000	Metis-e radio module 868 MHz, tape and reel
2609059283001	EV-Kit includes Metis-e EV Board, SMA 868 MHz antenna and USB-C data cable.

Table 1: Ordering information

1.4. Intended use cases

The Metis-e is intended for use cases and applications using unidirectional communication from meter to gateway.

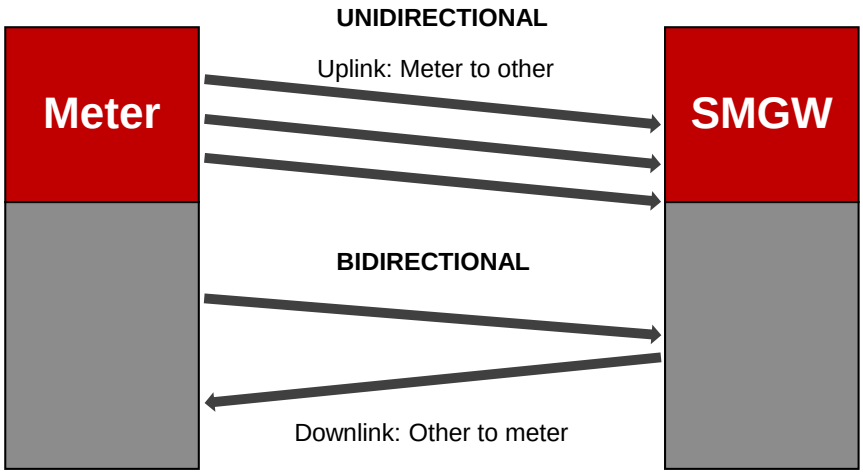


Figure 2: Overview of wM-Bus communication. The standard firmware of Metis-e implements the uplink direction as shown above.

- **Meter, send uplink, unidirectional:**
  This will allow sending metering data from a meter to a gateway. After sending is complete, the module will turn off the radio and wait for the host to provide the next packet to be transmitted. The host selects and provides the payload. The module adds the CRC fields for the physical layer automatically.

- **Gateway (data collector), receive uplink, unidirectional:**
  This will allow receiving metering data that was sent by a meter. Received packets will be output as data indication commands. The module will stay in receive mode until the host ends the receive mode. Packets with an invalid CRC will be discarded internally without any notification to the host.

By using the standby or shutdown states, a battery- powered application can be realized.

Bidirectional communication or communication on the downlink (gateway to meter) channel can be realized as a custom development service. For details about custom or customized firmware, refer to chapter 10.

2. Electrical specifications

Unless otherwise stated, measurements were taken on the EV-Board "Metis-e-EV" with T = 25 °C, VDDS = 3 V and internal DC-DC converter active. Any radio transmission in the standard firmware uses boost mode independent of the chosen output power.

2.1. Recommended operating conditions

Description	Min.	Typ.	Max.	Unit
Ambient temperature	-40	25	85	°C
Supply voltage (VDDS)	2.2[1]	3.0	3.8	V
Rising supply voltage slew rate	0		100	mV/µs
Falling supply voltage slew rate	0		20	mV/µs
Falling supply voltage slew rate, with low power flash settings			3	mV/µs

Table 2: Recommended operating conditions

2.2. Absolute maximum ratings

Description	Min.	Typ.	Max.	Unit
Supply voltage (VDDS)	-0.3		4.1	V
Voltage on any digital pin	-0.3		VDDS + 0.3, max 4.1	V
Input RF level			10	dBm
Output RF level, with boost mode		14		dBm

Table 3: Absolute maximum ratings

[1] When the whole temperature range is used, a minimum voltage of 2.4 V is recommended.

2.3. Power consumption

As a DC/DC voltage regulator is integrated, the current consumption strongly depends on the supplied voltage level.

Supply Voltage	Current Consumption
3.8 V	26 mA
3.6 V	28 mA
2.2 V	44 mA

Table 4: Power consumption TX 14 dBm at different supply voltages

The transmit and receive currents depend on the impedance matching. Especially the transmit current varies depending on antenna selection and matching.

Load Impedance	Current Consumption
Open	38 mA
50 Ohm	28 mA
0 Ohm	18 mA

Table 5: Power consumption TX 14 dBm, 3.6 V at loads with different impedances

The indicated values are the complete current consumption for radio and active MCU. Not to be confused with only radio or only CPU core currents, as sometimes stated by others.

STOP

A stable power supply is indispensable to ensure valid operating conditions for the module.

2.3.1. Static

The current consumption is the sum of the CPU current and radio TX or RX current in active modes.

Description	Typ.	Unit
TX current 14 dBm output power, boost mode	28	mA
RX current	8	mA
Low power (standby) radio off, UART off, RTC running, full RAM retention	1.6	µA
Low power (shutdown) radio off, UART off, RTC off, no RAM retention	0.2	µA

Table 6: Power consumption @3.6 V

2.3.2. Voltage supply dependency

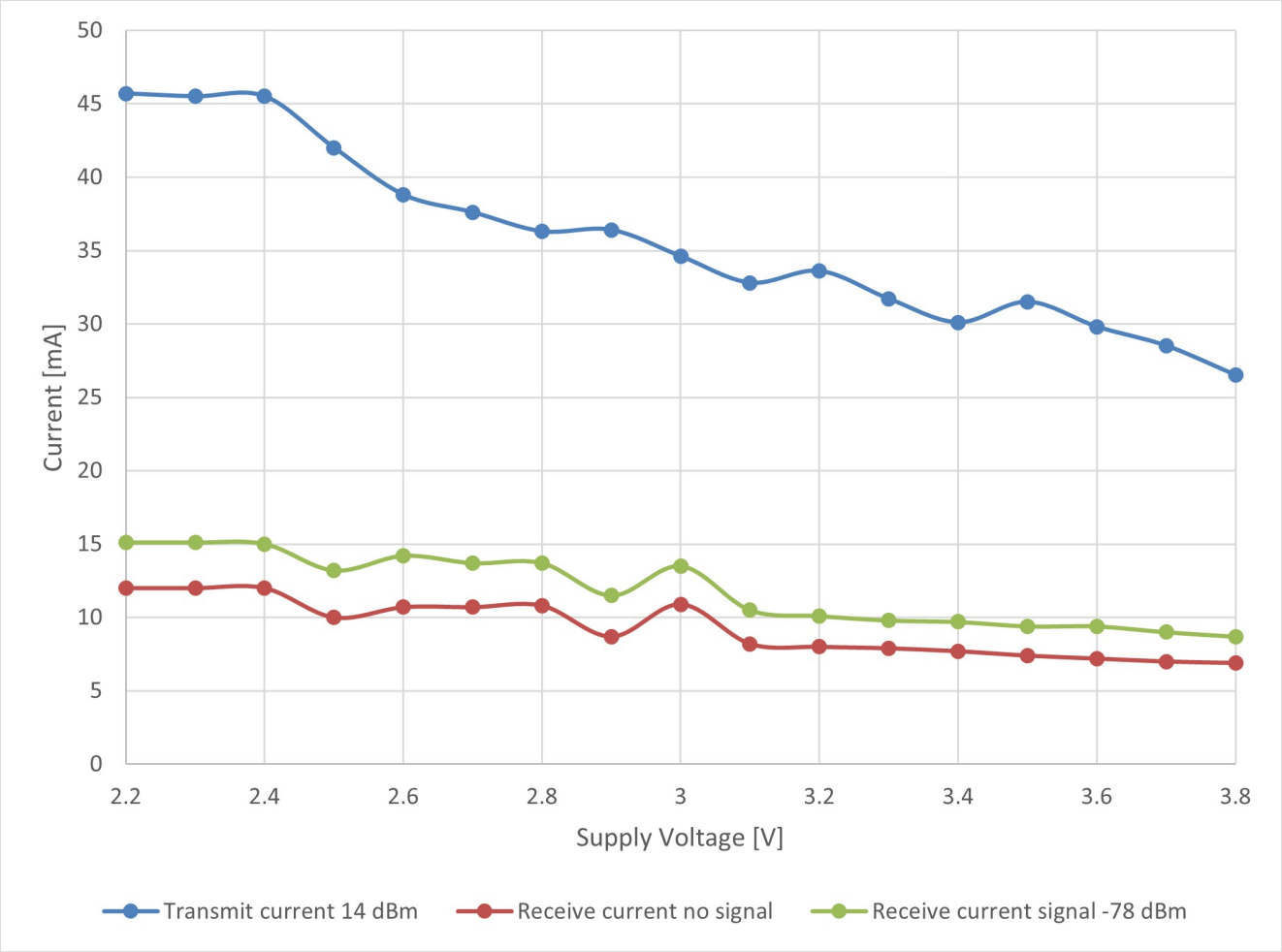


Figure 3: Typical behavior of transmit and receive current in relation to applied supply voltage

2.4. Radio characteristics

Description	Min	Typ.	Max	Unit
RF frequency				
S mode uplink		868.3		MHz
T mode uplink		868.95		MHz
C mode uplink		868.95		MHz
RF chip rate [2]				
S mode uplink		32.768		kcps
T mode uplink		100		kcps
C mode uplink		100		kcps
RX sensitivity				
S mode uplink		-107		dBm
T mode uplink		-104		dBm
C mode uplink		-104		dBm
TX power	0	14	14	dBm

Table 7: Radio characteristics

2.5. Pin characteristics

Property	Value	Unit
Default GPIO maximum current	2	mA
Maximum current of *RX_IND*,*TX_IND*	4	mA
Pull-up current (T = 25 °C, VDDS = 1.8 V)	71.7	µA
Pull-down current (T = 25 °C, VDDS = 1.8 V)	21.1	µA
Pull-up current (T = 25 °C, VDDS = 3.8 V)	277	µA
Pull-down current (T = 25 °C, VDDS = 3.8 V)	113	µA

Table 8: Pin characteristics

[2] S mode uses Manchester encoding, so the resulting data rate is 1/2 of the chip rate
T mode uses 3 out of 6 encoding, so the resulting data rate is 2/3 of the chip rate
C mode uses NRZ encoding, so the resulting data rate is equal to the chip rate

3. Pinout

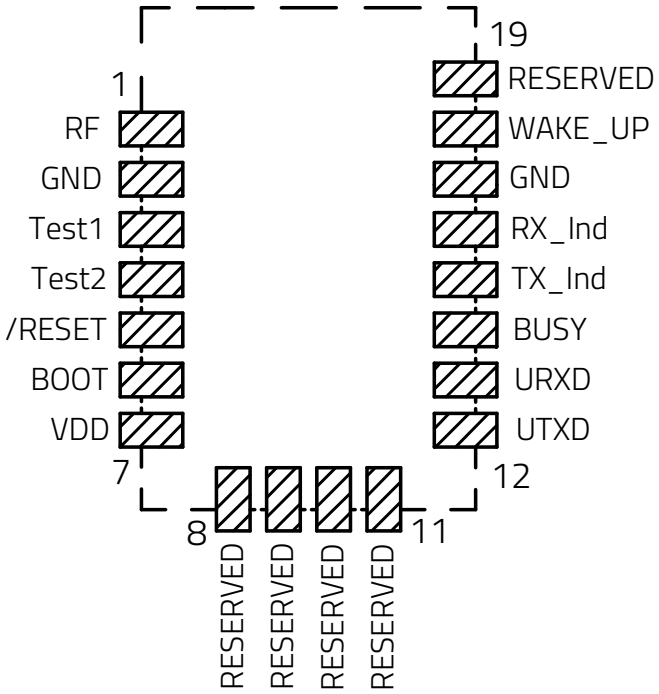


Figure 4: Pinout (top view)

No	Designation	I/O	Description
1	*RF*	I/O	50 Ω radio connection to transceiver.
2, 17	*GND*	Supply	Negative supply voltage.
3	*Test1*	I/O	Testpin, DO NOT CONNECT.
4	*Test2*	I/O	Testpin, DO NOT CONNECT.
5	*/RESET*	Input	Apply a rising edge to reset the module (see chapter 9.1.1). Pin has internal pull-up of 100k Ω. Low level holds module in reset state.
6	*BOOT*	Input	Connect HIGH level or leave open to use application firmware. Connect LOW level to enable the UART bootloader for firmware updates. It uses internal pull up during start up sequence.
7	*VDD*	Supply	Positive supply voltage.
8	*RESERVED*	GPIO	Reserved for future use. Do not connect. Internally connected to DIO_7.
9	*RESERVED*	GPIO	Reserved for future use. Do not connect. Internally connected to DIO_5.
10	*RESERVED*	GPIO	Reserved for future use. Do not connect. Internally connected to X32k_Q2.
11	*RESERVED*	GPIO	Reserved for future use. Do not connect. Internally connected to X32k_Q1.
12	*UTXD*	Output	UART transmission, bootloader TX.
13	*URXD*	Input	UART reception, bootloader RX. Internal pull-up.
14	*BUSY*	Output	A HIGH level indicates busy module.
15	*TX_IND*	Output	Indicates RF data transmission, active = high. Do not connect if not needed.
16	*RX_IND*	Output	Indicates RF data reception, active = high. Do not connect if not needed.
18	*WAKE_UP*	Input	Apply a falling edge to wake-up from shutdown or standby mode. Uses an internal pull-down.
19	*RESERVED*	GPIO	Reserved for future use. Do not connect. Internally connected to DIO_3.

Table 9: Pinout

4. Quickstart

4.1. Minimal pin configuration

In factory state, the module is immediately ready for operation in command mode. The following pins are required in the minimal configuration:
/RESET, *BOOT*, *VCC*, *GND*, *BUSY*, *UTXD* and *URXD*.

If the module is connected to a PC, a converter (TTL to RS-232 or TTL to USB) is necessary to achieve interface compatibility. The Metis-e EV-Board already implements such a USB converter to be connected to a PC. Not interpreting the *BUSY* line of the module, as described in this manual, may cause undefined behavior.
For enabling a quick wake-up (after Standby), the pin *WAKE-UP* has to be connected.
The lines *BOOT* and *WAKE-UP* may be connected via external pull-up /-down to a fixed level according to their description, when not switched by a host.
In case of the *WAKE-UP* pin, the external pull-up has to be selected accordingly in comparison with the internal resistor depending on the pin charactersitics. See table 8.

4.2. Power up

Recommended procedure for starting the module:
Set and hold the */RESET* pin to LOW. After supply voltage is applied to the module, the */RESET* pin shall be hold to LOW level for another Δt of at least 1 ms after the *VCC* is stable, to ensure a safe start-up. The module will send a `CMD_RESET_IND` message as well as showing a low level of the *BUSY* line once it is booted into application. If the module is used on a battery-powered system, using a matching reset-IC is highly recommended to ensure a correct power up and stable behavior towards battery getting empty.

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

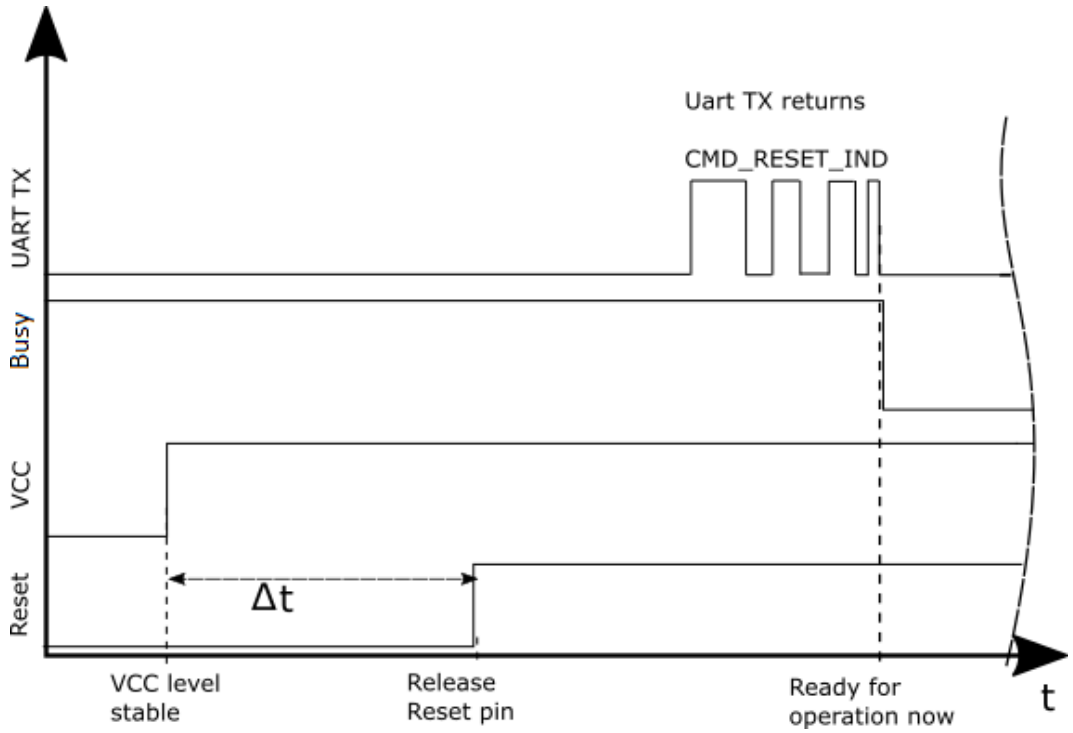
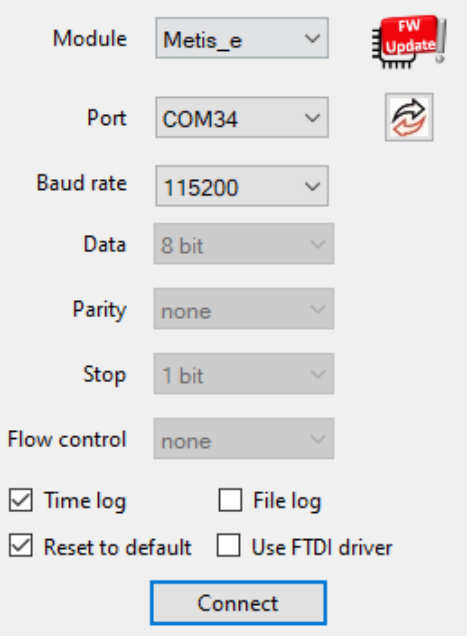


Figure 5: Power up

4.3. Quickstart example

This chapter illustrates how to send and receive a wM-Bus frame using the tool "WE UART Terminal" provided by Würth Elektronik eiSos. This tool can be downloaded from *our website*. The following wM-Bus frame is an example frame as stated by the *OMS specification Annex N* "5.2 wM-Bus Example with ACC-NR":
19 47 93 44 44 33 22 11 55 37 35 72 8C 20 75 8B 88 77 66 55 93 44 55 08 FF 04 00 00 13 93 (including L-field and CRCs)

Sending and receiving: Example wM-Bus frame
Connect the two devices (modules, EV-boards) to a PC. A minimum distance of 2 meters between the devices should be kept to avoid overmodulation of the receivers. Alternatively, the TX power must be reduced to avoid overmodulation on small distances in between sender and receiver.
Open one instance of the WE UART Terminal for each used device. The two corresponding COM ports have to be selected and opened with a default configuration of 115200 baud, 8 data bits, 1 stop bit and parity set to none (8n1). Open the COM port by clicking on the "Connect" button.



As soon as the module is ready for operation (at start-up or after a reset), the device sends a `CMD_RESET_IND` message on the UART. It may be necessary to push the reset button (or perform `CMD_RESET_REQ`) to trigger a reset and see this message.

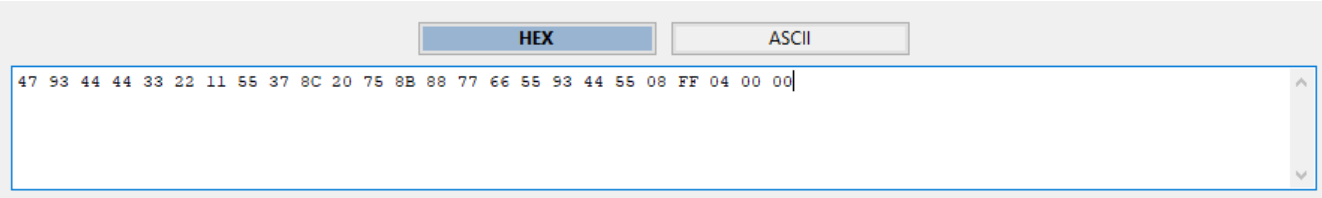
```
CMD_RESET_IND:
   02 86 00 84
```

4.3.1. Role Meter - Transmitting, Uplink

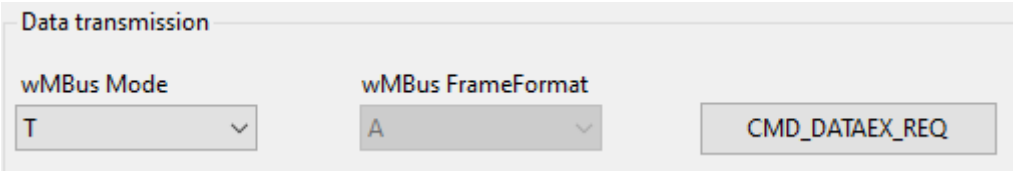
The module is already in `wMBus_Role` "meter" by default and can be used to transmit data. No further configuration is required.
To send the example data, the `CMD_DATAEX_REQ` is used. The command `CMD_DATAEX_REQ` has the following structure:

Start signal	Command	Length	Payload	CS
0x02	0x01	2 byte	Length bytes	1 byte

The wM-Bus frame can be entered in the "Data transmission" area at the top of the middle pane. Select "HEX" at the top and then enter the wM-Bus frame into the input area. The module will calculate the CRC of the wM-Bus frame and adds them before radio tranmission. Therefore, only the data of the wM-Bus, without L-field and CRCs, shall be entered as parameter:
47 93 44 44 33 22 11 55 37 8C 20 75 8B 88 77 66 55 93 44 55 08 FF 04 00 00



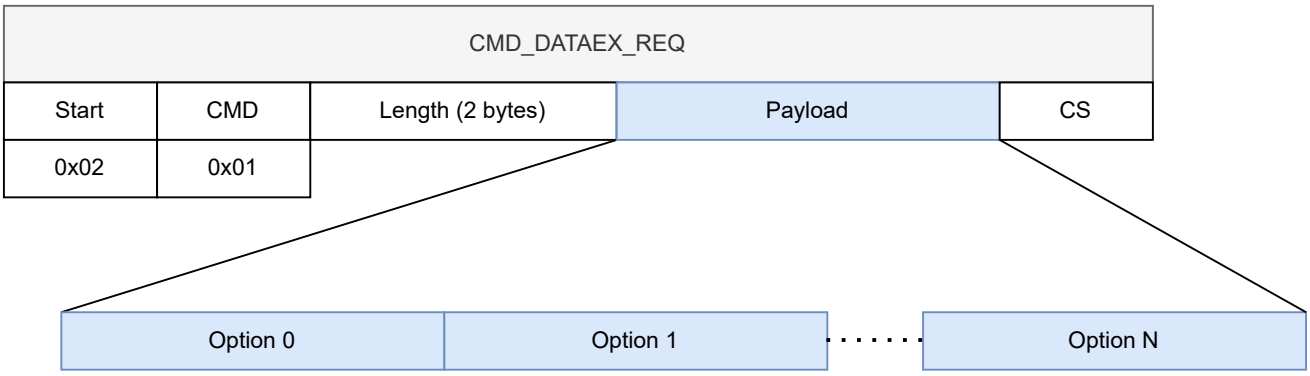
Besides the data, both `wMBus_TxMode` and `wMBus_FrameFormat` have to be selected. Both are available via a drop-down box. In this example, the frame will be sent using wM-Bus mode T. Only frame format "A" is allowed in this mode, so a selection in the tool is not possible. To send the command and trigger the transmission, click on the "CMD_DATAEX_REQ" button.



The command will be created and sent via UART to the module. The full command will be printed in the "Log" pane. The lines separate the options representing the parameters:

```
CMD_DATAEX_REQ:
02 01 2100
040101050101061947934444332211553 78C20758B887766559344550 8
FF040000 65
```

In this example, the payload consists of 3 options for the send command and does not include the TX power configuration option. Besides the data to be sent, the payload contains the wM-Bus mode and frame format to be used, too. In this example, the wM-Bus packet data is 47 93 44 44 33 22 11 55 37 8C 20 75 8B 88 77 66 55 93 44 55 08 FF 04 00 00 with length (L-field) of 25 (0x19) bytes and is going to be sent in wM-Bus mode T with frame format "A". The checksum CS is an XOR combination of all previous bytes, which is 0x65 in this case.
The format of `CMD_DATAEX_REQ` is shown in the figure below.



In this example:

Option 0 indicates the wireless M-Bus T Mode for transmit (0x01) and is shown as:

Option 0 wMBus_TxMode
0x04 0x01 0x01

Option 1 indicates the frame format A (0x01) and is shown as:

Option 1 wMBus_FrameFormat
0x05 0x01 0x01

Option 2 indicates the wM-Bus raw data package, which is starting with the raw data identifier 0x06, then the L-field 0x19 and continues with wM-Bus data :
0x47 93 44 44 33 22 11 55 37 8C 20 75 8B 88 77 66 55 93 44 55 08 FF 04 00 00.

Option 2 wM-Bus package raw data
0x06 0x19 0x47 93 44 44 33 22 11 55 37 8C 20 75 8B 88 77 66 55 93 44 55 08 FF 04 00 00

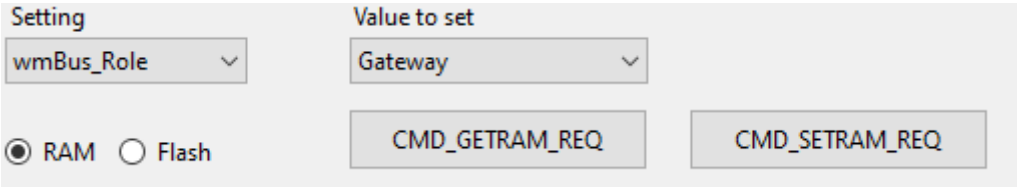
The TX power option is not used in this example. Refer to chapter 7.2.1 for more details on this option.

The entire UART command's length field results in the size of the payload field, which is the sum of all options. So $3 + 3 + 27 = 33$ bytes of payload, which is represented due to LSB first notation as 0x21 00 as value inside lenght of the command.

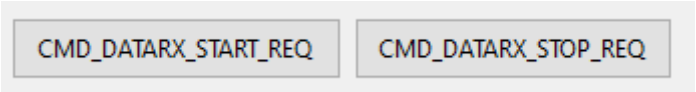
4.3.2. Role gateway - Receiving, Uplink

For the module to receive a packet from a smart meter, it must be configured as a gateway and set to receiving mode.

`wMBus_Role` gateway can be set using the `CMD_SETRAM_REQ`. In the WE UART Terminal, select "wmBus_Role" as a setting with "Gateway" as value. By default "RAM" is selected, so `CMD_SETRAM_REQ` will be used. Click on "CMD_SETRAM_REQ" to set the setting:



Since the default `wMBus_RxMode` for receiving is C + T mode, no action needs to be taken to receive T mode packets from meters.
To start receiving-mode, `CMD_DATARX_START_REQ` is used:



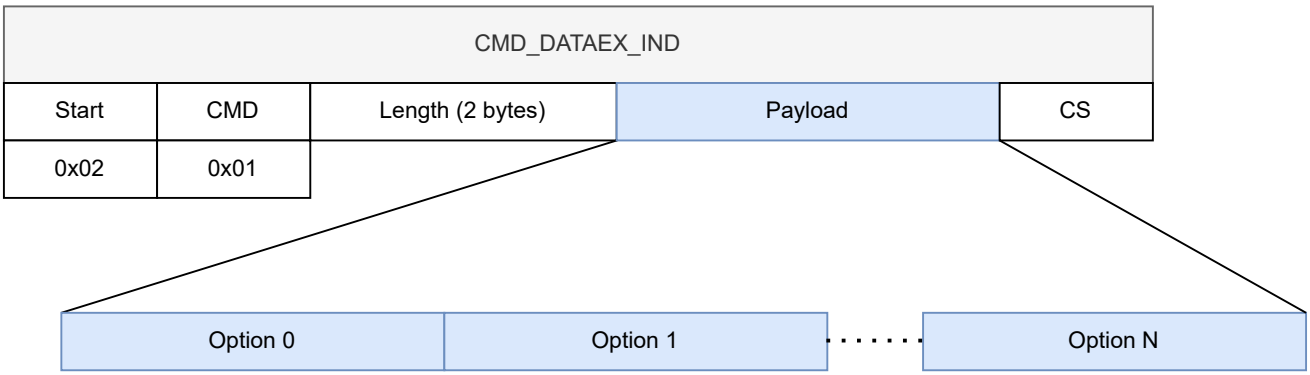
The module is now receiving and waiting for wM-Bus packets. When the sender sends a packet, as shown in the previous section, the second module receiving this packet will send a `CMD_DATAEX_IND` message and go back to receiving. The format of the `CMD_DATAEX_IND` is as follows:

Start signal	Command	Length	Payload	CS
0x02	0x81	2 bytes	Length bytes	1 byte

with payload containing the Options of RSSI value, wMBus_RxMode, wMBus_FrameFormat, and received wMBus_data.

```
                                                    [16:26:58.398]
                                                CMD_DATAEX_IND:
                                                        02 81 24
0D01C0|03|01|02|05|01|01|06194793444433221155378C20758B8877665593
                                                445508FF040000 28
```

The `CMD_DATAEX_IND` is very similar to the `CMD_DATAEX_REQ` command. The structure is as shown below:



In this example :
Option 0 indiciates the RSSI value and is shown as:

Option 0 RSSI value
0x0D 0x01 0xC0

The RSSI value is given as two's complement and in this example is -64 (0xC0).

Option 1 indicates the `wMBus_RxMode` and is used to receive the wM-Bus frame:

Option 1 wMBus_RxMode
0x03 0x01 0x02

The data was received using T-mode (0x02) in this example.

Option 2 indicates the frame format of the received wM-Bus frame:

Option 2 wMBus_FrameFormat
0x05 0x01 0x01

In this case, the frame format A (0x01) is used.

Option 3 indicates the wM-Bus raw data packet, which starts with 0x06 as the identifier for the raw data payload, followed by the L-field 0x19, which is also the length of the option and continues with the wireless M-Bus data payload:
0x47 93 44 44 33 22 11 55 37 8C 20 75 8B 88 77 66 55 93 44 55 08 FF 04 00 00. The CRCs are internally checked and removed by the module and only the raw data is output. In case of wrong CRCs the message is discarded without notification.

Option 3 wM-Bus package raw data
0x06 0x19 0x47 93 44 44 33 22 11 55 37 8C 20 75 8B 88 77 66 55 93 44 55 08 FF 04 00 00

5. Functional description

As described in chapter 1.4, Metis-e implements the uplink direction of the wM-Bus specification. This means, data transmission is only possible in the direction meter to gateway. Metis-e has a usersetting wMBus_Role, which configures the module as either meter (transmission only) or gateway (reception only).

5.1. Physical layer

At the physical layer, the Metis-e can be configured to use one of the following wM-Bus modes. The value as stated in the "Option" column are used as index for wMBus_TxMode and wMBus_RxMode

Option	wM-Bus mode	wM-Bus role	Chip rate [kcps][3]	Frequency [MHz]	RF operation
0	S	Meter / Gateway	32.768	868.3	RX/TX
1	T	Meter	100	868.95	TX only
2	T	Gateway	-	868.95	RX only
3	C + T	Gateway	-	868.95	RX only
4	C	Meter	100	868.95	TX only
5	C	Gateway	-	868.95	RX only

Table 10: Mapping of available wM-Bus modes and corresponding radio parameters.

wM-Bus mode of gateway receives...	...from meter in wM-Bus mode
S	S
C + T	C, T
T	T
C	C

Table 11: Compatibility of the wM-Bus modes between meter and gateway. The left column shows the selected wM-Bus mode of the gateway. The right column shows, which wM-Bus modes can be received.

The wM-Bus modes for receiving and transmitting are handled separately. The wM-Bus mode for the RX operation is selected by using the wMBus_RxMode and is valid as long as the runtime-setting is not changed. In contrast, the wM-Bus mode for a TX operation is set via a parameter in the CMD_DATAEX_REQ and is only valid for the specified transmission. There is no default wMBus_TxMode and it has to be set for every transmission.

[3] S mode uses Manchester encoding, so the resulting data rate is 1/2 of the chip rate
T mode uses 3 out of 6 encoding, so the resulting data rate is 2/3 of the chip rate
C mode uses NRZ encoding, so the resulting data rate is equal to the chip rate

5.2. Operating modes

The module has certain operating modes, which have to be entered to perform certain functions and tasks.

Operating mode	Available functionalities
Idle mode	Configure the module. Trigger data transmission. Switch to other operating modes.
Receiving mode	Receive wM-Bus packages.
Transmitting mode	Currently transmitting. Will automatically switch to idle mode afterwards.
Standby/Shutdown	Low power modes with disabled UART interface.

After boot-up, the module enters idle mode. The idle mode is the default operating mode and any other mode can only be entered if the module is in idle mode. For example, it is not possibe to enter the standby mode while the module is in receiving mode.

In addition, the receiving mode and transmitting mode can only be entered, if the correct `wMBus_Role` is set. Receiving mode can only be entered, if the Metis-e is currently in `wMBus_Role` gateway. The transmitting mode can only be entered if the module is in `wMBus_Role` meter. If the module is in the wrong operating mode to perform an action, or the wrong `wMBus_Role` is selected, the command will fail with status "wrong state" (0x01 0x01 0x06).

Operating mode	Allowed role	Operating mode is entered upon . . .
Idle mode	Meter, gateway	Default mode after startup. `CMD_RESET_REQ`, `CMD_DATARX_STOP_REQ`
Receiving mode	Gateway	`CMD_DATARX_START_REQ`
Transmitting mode	Meter	`CMD_DATAEX_REQ`
Standby/Shutdown	Meter, gateway	`CMD_STANDBY_REQ`, `CMD_SHUTDOWN_REQ`

The following flow chart shows the operation modes and relations.

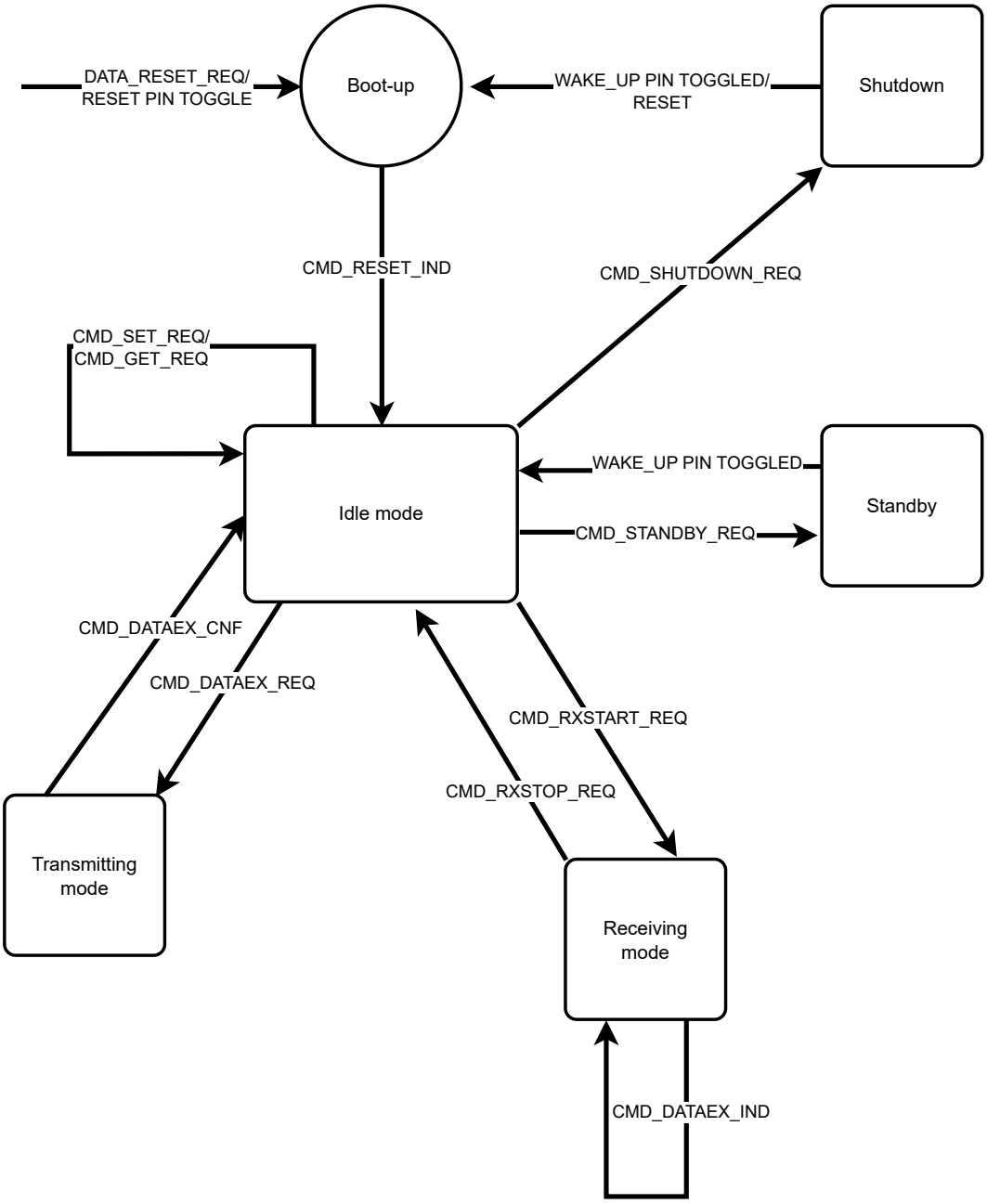


Figure 6: Overview of the available operation modes

5.3. System configuration parameters

The parameters which determine the functionality of the module are classified into two categories. The non-volatile user settings (see chapter 8) values, which can be modified using the CMD_SET_REQ and the values are retained after a power reset.

Note that each CMD_SET_REQ will consume one flash erase/write cycle, which are limited due to the hardware (guaranteed are 100k cycles, see TI CC13x0 datasheet).

On the other hand, the volatile settings (called "Runtime settings") can be accessed by using the `CMD_SETRAM_REQ` and are used to quickly (but temporarily) modify specific parameters without using flash cycles. Runtime settings are only valid until a reset is performed and shall be used when frequent updates of settings are necessary. On startup of the module, they are initialized with the corresponding user setting.

6. Host connection

6.1. Serial interface: UART

The configuration in factory state of the UART is 115200 Baud with data format of 8 data bits, no parity and 1 stop bit ("8n1"). The baud rate of the UART can be configured by means of the user setting `UART_Baudrate`. The data format is fixed to 8n1.
The output of characters on the serial interface runs with secondary priority. For this reason, short interruptions may occur between the outputs of individual successive bytes.The host must not implement too strict timeouts between two bytes to be able to receive packets that have interruptions in between. Up to four full byte durations (32 bit) delay between two successive bytes shall be accepted by the host.
For the direction "host to module" the host must respect byte-wise the line *BUSY*, which will indicate that the next byte of the packet can be received by the module. This direction also accepts a pause of up to four full byte durations (32 bit) delay between two successive bytes before discarding received content (without user notification).

7. The command interface

7.1. Overview

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

- Requests: The host requests the module to trigger any action, e.g. in case of the request `CMD_DATAEX_REQ` the host asks the module to send data via radio.
- Confirmations: On each request, the module answers with a confirmation message to give a feedback on the requested operation status. In case of a `CMD_DATAEX_REQ`, the module answers with a `CMD_DATAEX_CNF` to tell the host whether the data was sent successfully or not.
- Indications and Responses: The module indicates spontaneously when a special event has occurred. The `CMD_DATAEX_IND` indicates reception of data via radio.

Start signal	Command	Length	Payload	CS
0x02	1 byte	2 bytes	Length bytes	1 byte

Start signal 0x02 (1 byte)

Command One of the predefined commands (1 byte). The module implements new and modified commands in comparison to other radio compatible modules.

Length Specifies the number of payload data in the following field. The length field (2 bytes) is LSB first.

Payload Variable number (defined by the length field) of bytes containing the options specifying data and parameters.

Checksum Bytewise XOR combination of all preceding bytes including the start signal, i.e. 0x02 ˆ Command ˆ Length ˆ Payload = CS

All commands of type request must obey the following rules:

- Only one request at a time may be active. Wait for confirmation of the previous request and implement a suiting timeout (depends on the command or action that was requested, 500 ms should cover the worst-case time).
- Indications are spontaneous messages. They may occur in between a command request and its confirmation. The host must ensure to receive and handle alliIndications accordingly. We recommend using the Wireless Connectivity SDK provided via GitHub.
- A high *BUSY* line indicates that the module UART is not ready for reception. Thus, any byte(s) sent will be discarded without user notification ("module busy"). If "module busy" occurs while sending a command to the module, it is necessary to resend this entire command again when *BUSY* shows "module idle" again.

The payload of a command always consists of one or more options. Every command has required and optional options. The order of these options is arbitrary.

Option	Length	Value
1 byte	1 byte	Length bytes

Option One of the predefined options.

Length Specifies the number of data in bytes in the following field.

Value Contains the data or value of the option.

7.2. Data transfer and reception in the command mode

This group of commands includes the commands that either are used to request a radio telegram to be sent or indicates a received frame.

7.2.1. CMD_DATAEX_REQ - Transmit data

This command triggers data transfer in a network. Both the wM-Bus mode and the frame format to be used have to be specified along with the command. The TxPower can also be specified but is optional.

This command is only available for wM-Bus role meter.

The host must await the confirmation message of the radio module before the next `CMD_DATAEX_REQ` is sent towards the module.
The host must adhere to the local regulations item "Duty Cycle" , when it commands the module to send data. In S mode that means 1% (36 seconds per 1 hour observation period), in C mode and T mode 0.1 % (3.6 seconds per 1 hour observation period) of duty cycle.

Command:

Start signal	Command	Length	Payload	CS
0x02	0x01	Payload len	Payload len. bytes	1 byte

The payload field consists of required options and also potentionally optional options in arbitrary order.
Required options are:

wMBus_TxMode

wMBus_TxMode
0x04 0x01 <wM-Bus mode value>

The subset of available wM-Bus modes for transmission are shown in the following table:

wM-Bus Tx mode	S mode	T mode	C mode
Option value	0	1	4

wMBus_FrameFormat

wMBus_FrameFormat
0x05 0x01 <frame format value>

Frame format A is available for all wM-Bus modes. Frame format B is only available for C mode. Using frame format B for a different mode than C mode will lead to rejection of the request by the module.

wM-Bus frame format	Frame format A	Frame format B
Option value	1	2

wMBus_data

Option	wM-Bus raw data length (1 byte)	wM-Bus raw data (max 255 byte)
0x06	<data_length>	<wM-Bus-raw-data>

The module expects the wM-Bus raw data without L-field and CRC. Consequently, the data length of the wMBus_data option is not equal to the L-field of the final wM-Bus frame, but only states how many bytes follow as the option value.
The module calculates and adds the CRC and L-field to the wM-Bus frame according to the frame format before transmission.
The relation between the data length of the option and the resulting L-field of the wM-Bus frame is summarized in the following table:

wMBus data length	L-field frame format A	L-field frame format B (data_length <= 126)	L-field frame format B (126 < data_length)
<data_length>	<data_length>	<data_length> + 2	<data_length> + 4

Optional options:

TxPower
0x0B 0x01 TxPower

Valid values for Tx power range from 0 to 14 (decimal). The default Tx power can be set by means of the user setting `RADIO_TxPower`.

Response:

Start signal	Command	Length	Status	CS
0x02	0x41	Statuslength + 2	0x01 statuslength statusbyte	1 byte

Statusbyte:

0x00: Request successfully received and processed. Statuslength = 0x01.

0x01: Request not successful. Statuslength = 0x01.

0x02: The command was not configured correctly, e.g. required options missing. Statuslength = 0x01.

0x03: The command is not supported by this module. Statuslength = 0x01.

0x04: The value specified for this option is not allowed in this context, e.g wM-Bus mode is not suitable for transmitting or TxPower is out of range. Statuslength = 0x02.

0x05: The option is not supported by this command. Statuslength = 0x02.

Example:

Start signal	Command	Length	T mode	Frame format A	...
0x02	0x41	0x33 00	0x04 0x01 0x01	0x05 0x01 0x01	...

...	wM-Bus raw data	CS
...	0x06 0x19 0x4793444433221155378C20758B8877665593445508FF040000	0x65

7.2.2. CMD_DATARX_START_REQ - Start data reception

With this message the module enters receiving mode. The wM-Bus mode will be configured according to the user setting `wMBus_RxMode`. Once a wM-Bus message is received, the module outputs it with the `CMD_DATAEX_IND` command.

This command is only available for wM-Bus role gateway.

Command:

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

Required options: None
Optional options: None

Response:

Start signal	Command	Length	Status	CS
0x02	0x42	Statuslength + 2	0x01 Statuslength Statusbyte	1 byte

Statusbyte:

0x00: Request successfully received and processed. Statuslength = 0x01.

0x01: Request not successful. Statuslength = 0x01.

0x02: The command was not configured correctly, e.g. required options missing. Statuslength = 0x01.

0x03: The command is not supported by this module. Statuslength = 0x01.

0x05: The option is not supported by this command. Statuslength = 0x02.

0x06: The command is not supported by wM-Bus role. Statuslength = 0x01.

7.2.3. CMD_DATARX_STOP_REQ - Stop data reception

With this message the module leaves receiving mode and will enter idle mode. No more messages will be received.

This command is only available for WM-Bus role gateway.
Command:

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

Required options: None
Optional options: None

Response:

Start signal	Command	Length	Status	CS
0x02	0x43	Statuslength + 2	0x01 Statuslength Statusbyte	1 byte

Statusbyte:

0x00: Request successfully received and processed. Statuslength = 0x01.

0x01: Request not successful. Statuslength = 0x01.

0x02: The command was not configured correctly, e.g. required options missing. Statuslength = 0x01.

0x03: The command is not supported by this module. Statuslength = 0x01.

0x05: The option is not supported by this command. Statuslength = 0x02.

0x06: The command is not supported by wM-Bus role. Statuslength = 0x01.

7.2.4. CMD_DATAEX_IND - Receive data

This telegram indicates the reception of data and represents the counterpart to the commands `CMD_DATAEX_REQ` and `CMD_DATAEX_CNF`. It displays the wM-Bus mode and frame format of the received wM-Bus frame. Depending on the user setting `CfgFlags`, RSSI value (given in two's complement notation) and timestamp of reception are also given.
Command:

Start signal	Command	Length	Payload	CS
0x02	0x81	Payload len.	Payload len. bytes	1 byte

Required options are:

wMBus_RxMode

wMBus_RxMode
0x03 0x01 <wM-Bus mode value>

The subset of available wM-Bus modes for reception are shown in the following table:

wM-Bus rx mode	S mode	T mode	C mode
Option value	0	2	5

In the default setting, Metis-e is in C + T mode and can receive both T mode and C mode frames. The `wMBus_RxMode` option will contain the applicable wM-Bus mode of the received frame (either T mode or C mode).

wMBus_FrameFormat

wMBus_FrameFormat
0x05 0x01 <frame format value>

Frame format A is available for all wM-Bus modes. Frame format B is only available for C mode.

wM-Bus frame format	Frame format A	Frame format B
Option value	1	2

wMBus_data

Option	wM-Bus raw data length (1 byte)	wM-Bus raw data (max 255 byte)
0x06	<data_length>	<wM-Bus-raw-data>

The module outputs the wM-Bus raw data without L-field and CRC. Consequently, the data length of the wMBus_data option is not equal to the L-field of the final wM-Bus frame, but only states how many bytes follow as the option value.
The module checks and removes the CRC of wM-Bus frame according to the frame format before transmission.
The relation between the L-field of the wM-Bus frame and the resulting data length of the option is summarized in the following table:

Frame format:	Frame format A	Frame format B (data_length <= 126)	Frame format B (126 < data_length)
data_length:	L-field	L-field - 2	L-field - 4

Optional options:

RSSI
0x0A 0x01 RSSI

The RSSI value is given as two's complement.

Timestamp
0x0B 0x04 Timestamp

The timestamp is given in the LSB first notation.

7.3. Requesting parameters, actions and events

This group includes all commands that will return read-only parameters or request actions in the module.

7.3.1. CMD_RESET_REQ - Reset

This command triggers a software reset of the module. The reset is performed after the acknowledgement is transmitted. All volatile settings are initialized with their defaults.
Command:

Start signal	Command	Length	CS
0x02	0x06	0x00 0x00	0x04

Required options: None
Optional options: None

Response:

Start signal	Command	Length	Status success	CS
0x02	0x46	0x03 0x00	0x01 0x01 0x00	0x47

As soon as the module has restarted a `CMD_RESET_IND` is printed on the UART and the *BUSY* line will show "module idle".

7.3.2. CMD_FACTORYRESET_REQ - FactoryReset

This command restores the default user settings of the module. If this was successful, a software reset of the module is performed in addition.
Command:

Start signal	Command	Length	CS
0x02	0x10	0x00 0x00	0x12

Required options: None
Optional options: None

Response:

Start signal	Command	Length	Status Success	CS
0x02	0x50	0x03 0x00	0x01 0x01 0x00	0x51

7.3.3. CMD_STANDBY_REQ - Standby

This command triggers the standby mode of the chip, a low power mode with RAM retention. The standby mode is entered after the command confirmation message is transmitted. The UART interface is disabled in standby mode. The latency is smaller than the latency caused by a complete restart of the module as done in the shut down mode.

Command:

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

Required options: None
Optional options: None

Response:

Start signal	Command	Length	Status Success	CS
0x02	0x47	0x03 0x00	0x01 0x01 0x00	0x46

To wake-up from standby mode, a falling edge has to be applied to the *WAKE-UP* pin. Note that in standby mode, the *WAKE-UP* pin has an internal pull-down to ensure the wake-up is not performed accidentally due to a floating pin. When a falling edge is detected, the module wakes up but does not revert to factory settings as the RAM content is retained and all volatile settings are kept. Upon being idle again, a `CMD_STANDBY_IND` message is printed on the UART and the *BUSY* pin will show a low level.

7.3.4. CMD_SHUTDOWN_REQ - Shutdown

This command triggers the shut down mode of the chip, which is the mode with lowest power consumption. The shut down is performed after the command confirmation message is transmitted. The UART interface is disabled in shut down mode.

Command:

Start signal	Command	Length	CS
0x02	0x08	0x03 0x00	0x0A

Required options: None
Optional options: None

Response:

Start signal	Command	Length	Status Success	CS
0x02	0x48	0x03 0x00	0x01 0x01 0x00	0x49

To wake-up from shut down mode, a falling edge has to be applied to the *WAKE-UP* pin. In this case, the module restarts such that all volatile settings are lost. As soon as it has restarted, a `CMD_RESET_IND` message is printed on the UART. Note that in shut down mode, the *WAKE-UP* pin has an internal pull-down to ensure the wake-up is not performed accidentally due to a floating pin.

7.3.5. CMD_RESET_IND - Reset

The `CMD_RESET_IND` is sent by the module after a reset. This is done as reaction of a reset command or after a wake-up from shut down mode. Volatile settings are lost after a reset and set to their default values.

Start signal	Command	Length	CS
0x02	0x86	0x00 0x00	0x84

7.3.6. CMD_STANDBY_IND - Standby

The `CMD_STANDBY_IND` is sent by the module after a wake-up from standby. Volatile settings are kept and still the same as before the standby mode.

Start signal	Command	Length	CS
0x02	0x87	0x00 0x00	0x85

7.3.7. CMD_SET_REQ - Modify user settings

This command enables direct manipulation of the parameters in the module's non-volatile user settings. The respective parameters are accessed by means of the corresponding option. Parameters with size of two or more bytes have to be transferred with the LSB first, unless otherwise specified.

The modified parameters only take effect after a restart of the module. This can be done by a `CMD_RESET_REQ` or using the */RESET* pin.

STOP

The validity of the specified parameters is not verified. Incorrect values can result in device malfunction up to a scenario where the firmware of the module needs to be re-flashed to get it operating again!

Any use of CMD_SET_REQ will consume one flash erase/write cycle. Flash erase/write cycles are limited through hardware (guaranteed minimum 100k cycles). For frequently changing parameters use the volatile parameters "runtime settings", see chapter 7.3.9 .

To store the parameters in the flash memory of the module, the particular memory segment must be buffered into RAM, then to be erased entirely and then restored from RAM.
If a reset occurs during this procedure (e.g. due to supply voltage fluctuations), the entire memory area may be destroyed and the module can only be resurrected by means of the JTAG or bootloader firmware update.
Recommended procedure: First verify the configuration of the module with CMD_GET_REQ and only apply a CMD_SET_REQ if required. Make sure the VCC is stable and no reset occur during this procedure.

Format:

Start signal	Command	Length	Payload	CS
0x02	0x04	2 bytes	Length bytes	1 byte

Required options:

Option
Option_byte Option_length Option_value

Response:

Start signal	Command	Length	Status	CS
0x02	0x44	Statuslength + 2	0x01 Statuslength Statusbyte	1 byte

Statusbyte:

0x00: Request successfully received and processed. Statuslength = 0x01.

0x01: Request not successful. Statuslength = 0x01.

0x02: The command was not configured correctly, e.g. required options missing. Statuslength = 0x01.

0x03: The command is not supported by this module. Statuslength = 0x01.

0x04: The value specified for this option is not allowed in this contxt, e.g read-only setting . Statuslength = 0x02.

0x05: The option is not supported by this command. Statuslength = 0x02.

Example:

Start signal	Command	Length	TxPower 10	CS
0x02	0x04	0x03 0x00	0x0B 0x01 0x0A	0x05

Response:

Start signal	Command	Length	Status Success	CS
0x02	0x44	0x03 0x00	0x01 0x01 0x00	0x45

7.3.8. CMD_GET_REQ - Read user settings

This command can be used to query the user settings. The respective parameters are accessed by using the option ParameterIndex with the corresponding option as parameter.

Parameters with size of two or more bytes will be transmitted LSB first, unless noted otherwise.

Format:

Start signal	Command	Length	Payload	CS
0x02	0x05	2 bytes	Length bytes	1 byte

Required options:

Option
0x09 0x01 Option_to_get

Response:

Start signal	Command	Length	Status	Options	CS
0x02	0x45	2 bytes	0x01 Statuslength Statusbyte	Option_to_get	1 byte

Example:

Start signal	Command	Length	ParameterIndex TxPower	CS
0x02	0x05	0x03 0x00	0x09 0x01 0x0B	0x07

Response:

Start signal	Command	Length	Status success	TxPower +10db	CS
0x02	0x45	0x06 0x00	0x01 0x01 0x00	0x0B 0x01 0x0A	0x41

7.3.9. CMD_SETRAM_REQ - Modify runtime settings

This command enables direct manipulation of the parameters in the module's volatile runtime settings. The respective parameters are accessed by means of the corresponding option. Parameters with size of two or more bytes have to be transferred with the LSB first, unless otherwise specified.

The modified parameters will be reset to their respective default values upon a restart of the module.

Format:

Start signal	Command	Length	Payload	CS
0x02	0x12	2 byte	Length bytes	1 byte

Required options:

Option
Option_byte Option_length Option_value

Response:

Start signal	Command	Length	Status	CS
0x02	0x52	Statuslength + 2	0x01 Statuslength Status	1 byte

Statusbyte:

0x00: Request successfully received and processed. Statuslength = 0x01.

0x01: Request not successful. Statuslength = 0x01.

0x02: The command was not configured correctly, e.g. required options missing. Statuslength = 0x01.

0x03: The command is not supported by this module. Statuslength = 0x01.

0x04: The value specified for this option is not allowed in this context, e.g read-only setting. Statuslength = 0x02.

0x05: The option is not supported by this command. Statuslength = 0x02.

Example:

Start signal	Command	Length	TxPower 10	CS
0x02	0x12	0x03 0x00	0x0B 0x01 0x0A	0x13

Response:

Start signal	Command	Length	Status Success	CS
0x02	0x52	0x03 0x00	0x01 0x01 0x00	0x53

7.3.10. CMD_GETRAM_REQ - Read runtime settings

This command can be used to query the runtime settings. The respective parameters are accessed by using the option ParameterIndex with the corresponding option as parameter.

Parameters with size of two or more bytes will be transmitted LSB first unless noted otherwise.

Format:

Start signal	Command	Length	Payload	CS
0x02	0x13	2 bytes	Length bytes	1 byte

Required options:

Option
0x09 0x01 Option_to_get

Response:

Start signal	Command	Length	Status	Options	CS
0x02	0x53	2 bytes	0x01 Statuslength Statusbyte	Options_to_get	1 byte

Example:

Start signal	Command	Length	ParameterIndex TxPower	CS
0x02	0x13	0x03 0x00	0x09 0x01 0x0B	0x11

Response:

Start signal	Command	Length	Status Success	TxPower +10db	CS
0x02	0x53	0x06 0x00	0x01 0x01 0x00	0x0B 0x01 0x0A	0x57

7.4. Message overview

7.4.1. Commands

CMD	Message name	Short description	Chapter
0x01	CMD_DATAEX_REQ	Trigger data transmission	7.2.1
0x02	CMD_DATARX_START_REQ	Enter receive mode	7.2.2
0x03	CMD_DATARX_STOP_REQ	Leave receive mode	7.2.3
0x04	CMD_SET_REQ	Change the user settings	7.3.7
0x05	CMD_GET_REQ	Read the user settings	7.3.8
0x06	CMD_RESET_REQ	Reset the module	7.3.1
0x07	CMD_STANDBY_REQ	Enter standby mode	7.3.3
0x08	CMD_SHUTDOWN_REQ	Enter shutdown mode	7.3.4
0x10	CMD_FACTORYRESET_REQ	Reset the module to factory settings	7.3.2
0x12	CMD_SETRAM_REQ	Change the runtime settings	7.3.9
0x13	CMD_GETRAM_REQ	Read the runtime settings	7.3.10
0x41	CMD_DATAEX_CNF	Data transmission was triggered	7.2.1
0x42	CMD_DATARX_START_CNF	Enter receive mode	7.2.2
0x43	CMD_DATARX_STOP_CNF	Leave receive mode	7.2.3
0x44	CMD_SET_CNF	User settings have been updated	7.3.7
0x45	CMD_GET_CNF	Return the requested user setting values	7.3.8
0x52	CMD_SETRAM_CNF	Runtime settings have been updated	7.3.9
0x53	CMD_GETRAM_CNF	Return the requested RuntimeSetting value	7.3.10
0x81	CMD_DATAEX_IND	Data has been received	7.2.4
0x86	CMD_RESET_IND	Reset has been applied	7.3.5
0x87	CMD_STANDBY_IND	Wake up from standby mode	7.3.6

Table 12: Command overview

7.4.2. Options

Option	Message name
0x01	Status
0x02	Reserved
0x03	wMBus_RxMode
0x04	wMBus_TxMode
0x05	wMBus_FrameFormat
0x06	wMBus_Data
0x07	wMBus_Role
0x08	Reserved
0x09	ParameterIndex
0x0A	UART_BaudrateIndex
0x0B	TXPower
0x0C	CfgFlags
0x0D	RSSI
0x0E	Timestamp
0x81	FWVersion
0x82	ProductName

Table 13: Option overview

8. User settings - Module configuration values

8.1. Difference between volatile and non-volatile settings

The so-called user settings are stored permanently into the internal flash of the module. At start-up, these user settings are loaded as start values into the volatile settings ("runtime settings"). Some of the runtime settings can be modified using the CMD_SETRAM_REQ (see chapter 7.3.9). These runtime settings are lost and replaced by the user settings content when the module is restarted.

See chapters 7.3.9 and 7.3.7 for methods to change volatile and/or non-volatile settings.

The non-volatile user settings can be modified by means of specific commands in the configuration mode (CMD_SET_REQ) of the module. These parameters are stored permanently in the module's flash memory. All settings are described on the following pages. After changing those parameters, a reset will be necessary to make use of the new settings.

The validity of the specified parameters given with a CMD_SET_REQ is not verified. Incorrect values can result in device malfunction and may even result in the need of re-flashing the entire module firmware!

8.2. Modifying the user settings

The following chapters will give examples for the modification for many parameters using the commands CMD_SET_REQ and CMD_GET_REQ.

8.2.1. UART_Baudrate: Configure the UART speed

Option Index	Designation	Permissible values	Default value	Permissions	Number of bytes
10	UART_Baudrate	See description	1	read/write	1

This parameter defines the baud rate used by the modules UART. The permissible values are listed in the following table:

Index	0	1 (default)	2	3	4
Baudrate	9600	115200	230400	460800	921600

After changing the baud rate using the CMD_SET_REQ, the module uses the new baud rate after the next reset. Thus, update the baud rate of the connected host controller to be able to use the module's UART further on.

8.2.1.1. Example 1

Set the baud rate of the module to 115200 Baud using the CMD_SET_REQ with UART_Baudrate index 0:

Start signal	Command	Length	UART_Baudrate 115200	CS
0x02	0x04	0x03 0x00	0x0A 0x01 0x01	0x0F

Response CMD_SET_CNF: Successfully modified the setting.

Start signal	Command	Length	Status success	CS
0x02	0x44	0x03 0x00	0x01 0x01 0x00	0x45

8.2.1.2. Example 2

Request the baud rate of the module using CMD_GET_REQ:

Start signal	Command	Length	ParameterIndex UART_Baudrate	CS
0x02	0x05	0x03 0x00	0x09 0x01 0x0A	0x06

Response CMD_GET_CNF: Successfully read out the baud rate index 1 (115200 Baud).

Start signal	Command	Length	Status success	UART baudrate of 115200	CS
0x02	0x45	0x06 0x00	0x01 0x01 0x00	0x0A 0x01 0x01	0x4B

8.2.2. wMBus_RxMode: wM-Bus mode used for receiving

Option index	Designation	Permissible values	Default value	Permissions	Number of bytes
3	wMBus_RxMode	See description	3	read/write	1

This parameter defines the wM-Bus mode to receive wM-Bus frames. This setting only applies to the role "Gateway" and is not applied to the role "Meter". Only a subset of wM-Bus modes is allowed for the wMBus_RxMode. The permissible values are listed in the following table:

Index	0	2	3 (default)	5
wMBus_RxMode	S	T	C + T	C

8.2.2.1. Example 1

Set the wMBus_RxMode of the module to wM-Bus mode S using the CMD_SET_REQ with wMBus_RxMode 0:

Start signal	Command	Length	wMBus_RxMode S	CS
0x02	0x04	0x03 0x00	0x03 0x01 0x00	0x07

Response CMD_SET_CNF: Successfully modified the setting.

Start signal	Command	Length	Status success	CS
0x02	0x44	0x03 0x00	0x01 0x01 0x00	0x45

8.2.2.2. Example 2

Request the wMBus_RxMode of the module using CMD_GET_REQ:

Start signal	Command	Length	ParameterIndex wMBus_RxMode	CS
0x02	0x05	0x03 0x00	0x09 0x01 0x03	0x0F

Response CMD_GET_CNF: Successfully read out the wMBus_RxMode index 0 (S mode).

Start signal	Command	Length	Status Success	wMBus_RxMode S	CS
0x02	0x45	0x06 0x00	0x01 0x01 0x00	0x03 0x01 0x00	0x43

8.2.3. wMBus_Role: wM-Bus role

Option index	Designation	Permissible values	Default value	Permissions	Number of bytes
7	wMBus_Role	See description	0	read/write	1

This parameter defines the wM-Bus role of the module. The permissible values are listed in the following table:

Index	1	2
Role	Meter	Gateway

As mentioned in the introductory chapter on intended use cases, the Metis-e with integrated firmware offers the meter role as transmitter only and the gateway role as receiver only. Other use cases can be realized with this radio module as well but may require a custom firmware. Please contact your Business Development Manager (BDM) or WCS@we-online.com for quotes regarding these topics.

8.2.3.1. Example 1

Set the wMBus_Role of the module to Meter using the CMD_SET_REQ with wMBus_Role 1:

Start signal	Command	Length	wMBus_Role Meter	CS
0x02	0x04	0x03 0x00	0x07 0x01 0x01	0x02

Response CMD_SET_CNF: Successfully modified the setting.

Start signal	Command	Length	Status Success	CS
0x02	0x44	0x03 0x00	0x01 0x01 0x00	0x45

8.2.3.2. Example 2

Request the wMBus_Role of the module using CMD_GET_REQ:

Start signal	Command	Length	ParameterIndex wMBus_Role	CS
0x02	0x05	0x03 0x00	0x09 0x01 0x07	0x0B

Response CMD_GET_CNF: Successfully read out the wMBus_Role index 1 (Meter).

Start signal	Command	Length	Status Success	`wMBus_Role` Meter	CS
0x02	0x45	0x06 0x00	0x01 0x01 0x00	0x07 0x01 0x01	0x46

8.2.4. RADIO_TxPower: Configure the RF TX-power

Settings index	Designation	Permissible values	Default value	Permissions	Number of bytes
2	RADIO_TxPower	0 - 14	14 (0x0E)	read/write	1

This user setting defines the radio output power of the module.

The user is responsible for adhering to the statutory regulations for the maximum power output when using this module.

8.2.4.1. Example 1

Set the radio output power to 0 using the CMD_SET_REQ:

Start signal	Command	Length	TxPower 0	CS
0x02	0x04	0x03 0x00	0x0B 0x01 0x00	0x0F

Response CMD_SET_CNF: Successfully modified the setting.

Start signal	Command	Length	Status Success	CS
0x02	0x44	0x03 0x00	0x01 0x01 0x00	0x45

8.2.4.2. Example 2

Request the radio output power using CMD_GET_REQ:

Start signal	Command	Length	ParameterIndex TxPower	CS
0x02	0x05	0x03 0x00	0x09 0x01 0x0B	0x07

Response CMD_GET_CNF: Successfully read out the radio as 0 dBm.

Start signal	Command	Length	Status Success	TxPower 0	CS
0x02	0x45	0x06 0x00	0x01 0x01 0x00	0x0B 0x01 0x00	0x4B

8.2.5. CfgFlags: Configure the configuration flags of the module

Settings index	Designation	Permissible values	Default value	Permissions	Number of bytes
12 (0x0C)	CfgFlags	See description	1 (0x01)	read/write	1

This parameter is used for the general module configuration. Per default, the RSSI output (Bit 0) for received radio frames is enabled.

Bit no.	Description
0	Set this bit to 1 to enable RSSI output for CMD_DATAEX_IND
1	Set this bit to 1 to enable timestamp output for CMD_DATAEX_IND
2 - 7	Reserved, must be 0

8.2.5.1. Example 1

Enable the RSSI value output by setting the CfgFlags parameter value to 0x01 using the CMD_SET_REQ.

Start signal	Command	Length	CfgFlags Enable_RSSI	CS
0x02	0x04	0x03 0x00	0x0C 0x01 0x01	0x09

Response CMD_SET_CNF: Successfully modified the setting.

Start signal	Command	Length	Status Success	CS
0x02	0x44	0x03 0x00	0x01 0x01 0x00	0x45

8.2.5.2. Example 2

Request the configuration flags using CMD_GET_REQ:

Start signal	Command	Length	ParameterIndex CfgFlags	CS
0x02	0x05	0x03 0x00	0x09 0x01 0x0C	0x00

Response CMD_GET_CNF: Successfully read out the value of CfgFlags. A parameter value 0x01 indicates that the RSSI value is enabled.

Start signal	Command	Length	Status Success	CfgFlags RSSI_Enable	CS
0x02	0x45	0x06 0x00	0x01 0x01 0x00	0x0C 0x01 0x01	0x4D

8.2.6. Firmware Version: Read out the firmware version

Option index	Designation	Permissible values	Default value	Permissions	Number of bytes
129 (0x81)	`FirmwareVersion`	-	-	read	3

This parameter defines the version of the firmware currently running on the module.

8.2.6.1. Example 1

Request the firmware version of the module using `CMD_GET_REQ`:

Start signal	Command	Length	ParameterIndex FirmwareVersion	CS
0x02	0x05	0x03 0x00	0x09 0x01 0x81	0x8D

Response `CMD_GET_CNF`: Successfully read out the firmware version as 0.9.1. The sequence inside the field "Parameter" is Patch, Minor, Major.

Start signal	Command	Length	Status Success	FirmwareVersion 0.9.1	CS
0x02	0x45	0x08 0x00	0x01 0x01 0x00	0x81 0x03 0x01 0x09 0x00	0xC5

9. Timing parameters

9.1. Reset behavior

Following a reset, a CMD_RESET_IND and a stable low level on the *BUSY* pin signalize that the module is ready for operation. During restart, the *BUSY* may be pulled to GND level for a short time (<100 µs, see figure 7) until it is configured accordingly by the application on the module.

9.1.1. Reset via /RESET pin

To force a module restart by means of the */RESET* pin, it must first be drawn to low for at least 100 µs. After the pin is released, the module will reboot and indicate a CMD_RESET_IND. Note that the selected UART baud rate will introduce a latency for transmitting the 5-byte packet at module start-up.
Recommended procedure: After the */RESET* pin is released, wait for up to 2 ms + UART transmission time for the CMD_RESET_IND packet (value is to be adopted for the selected UART baud rate) and for the stable low level on the *BUSY* pin.

This section applies only to a situation where the VDDS is stable and the module was already running. Additional timings may be needed when VDDS was just applied to the module, see chapter 4.2

9.1.2. Reset as result of a serious error condition

If the module runs in a serious error condition, a software reset is executed. In this case, the module starts up (this includes sending a CMD_RESET_IND) automatically and can be used again. The volatile RuntimeSettings are reset to default. Therefore, the host needs to detect the start-up indication and implement reconfigure the module's volatile settings.

9.2. Latencies when leaving standby or shutdown

The indication CMD_RESET_IND or CMD_STANDBY_IND (5 bytes in total) are written before the *BUSY* pin is pulled back to low level. Therefore, the start-up time is dependent on the UART baud rate. The time presented here was measured with the UART default setting of 115200 Baud, 8n1.

9.2.1. Wake-up latency from standby

The wake-up time is 1.1 ms.

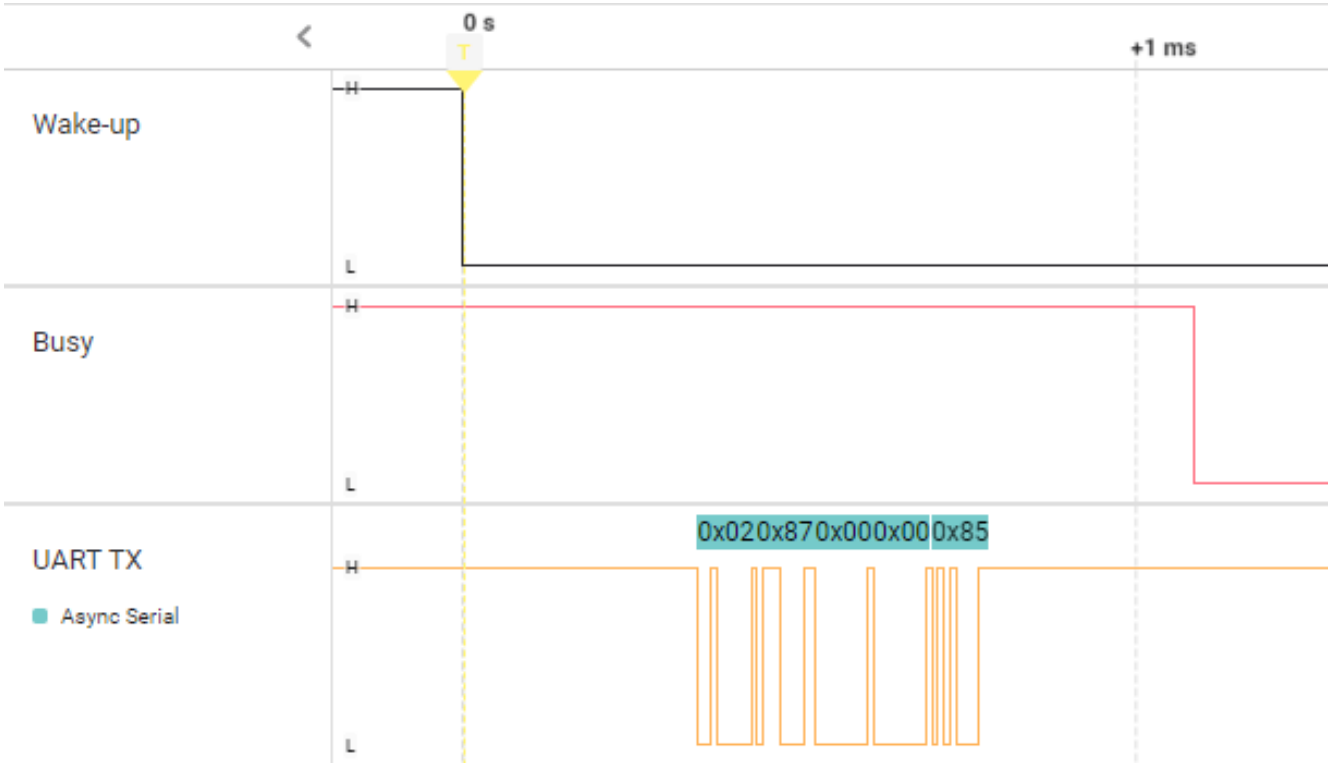


Figure 7: Wake-up from standby

9.2.2. Wake-up latency from shutdown

The wake-up time is 5.4 ms.

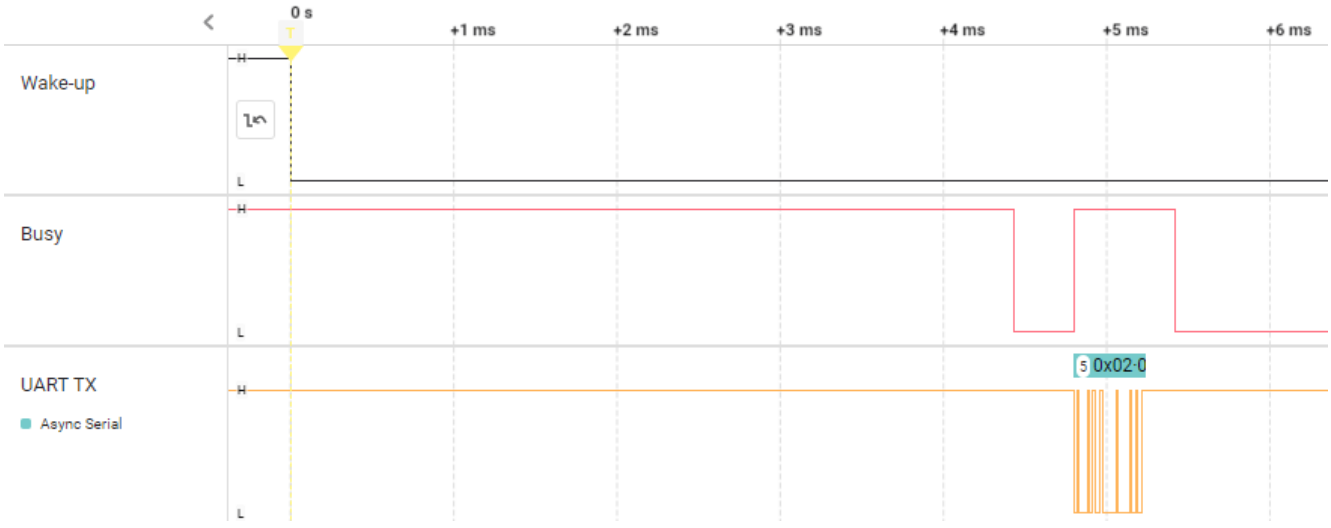


Figure 8: Wake-up from shutdown

9.3. Latencies during data transfer / packet generation

The data transfer is always buffered, i.e. data received via UART is buffered in the module until a specific event occurs. Subsequently, the UART reception is interrupted (flow control with *BUSY* signal) and the payload data is passed to the internal memory of the wireless transceiver (FIFO).
By using several UART buffers, the time during which the UART is not receiving can be minimized.
The wireless transmission starts as soon as the first data is available in the transceiver memory. During the continuous wireless transmission, the remaining payload data is transmitted byte by byte. On the receiver side, the FIFO is read as soon as an incoming packet is detected. If the module detects a packet that requires an ACK, the ACK is sent directly after the packet reception. The channel access method is always deactivated for ACKs.
In combination with a suitable packet generation method, this procedure enables the minimisation of the latencies resulting from buffering.

10. Custom firmware

10.1. Custom configuration of standard firmware

The configuration of the standard firmware includes adoption of the non-volatile user settings (see chapter 8) to customer requirements and creating a customized product based on the standard product.
This variant will result in a customer exclusive module with a unique ordering number. It will also freeze the firmware version to a specific and customer tested version and thus results in a customer exclusive module with a unique ordering number.
Further scheduled firmware updates of the standard firmware will not be applied to this variant automatically. Applying updates or further functions require a customer request and release procedure.

10.2. Customer specific firmware

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

10.3. Customer firmware

A customer firmware is a firmware written and tested by the customer himself or a 3rd party as a customer representative specifically for the hardware platform provided by a module.
This customer firmware (e.g. in form of a Intel hex file) will be implemented into the module's production process at our production site.
This also results in a customer exclusive module with a unique ordering number.
The additional information needed for this type of customer firmware, such as hardware specific details and details towards the development of such firmware are not available for the public and can only be made available to qualified customers.

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

10.4. Contact for firmware requests

Please contact your Business Development Engineer (BDM) or *WCS@we-online.com* for quotes regarding these topics.

11. Firmware update

We highly recommend having the UART accessible for the provided module in any application, in order to have the possibility to perform a firmware update. The customer's host must not access the UART during firmware update. Firmware updates can only be performed through this interface once a module is implemented into a customer PCB.

Flashing a custom or non standard firmware makes all regulatory and conformity information and certificates of chapter 19 invalid.

11.1. Update using the UART interface

Only the *UTDX*, *URXD* and *GND* signals are required for this connection. A suitable adapter/-converter is required for a PC connection (e.g. the FTDI TTL-323R-3V3 UART to USB converter). The customers host must not access the UART during firmware update over the external connection. The boot pin needs to be held for the specified level to enter the bootloader mode during the bootup procedure.

None of the module pins is 5 V TTL compatible. Applying overvoltage to any pin may damage the hardware permanently. Make sure your levels are in the range of the electrical specification shown in chapter 2

11.1.1. ACC Software

As long as our standard firmware is running on the module, the module can be updated with our PC utility ACC via the serial interface. Information on how to obtain the tool, can be found on *our website*.
The module must be reset (`CMD_RESET_REQ` or */RESET* pin) while holding the *BOOT* pin on a LOW level until the bootloader is active.
If the module is not directly connected to a PC, at least the UART should be made accessible, e.g. by means of suitable connectors.
The pin *BOOT* must be connected to a LOW level (while and shortly after a reset) in order to start the bootloader. If the *BOOT* pin is connected to HIGH or left open the application will start. The */RESET* signal shall be connectable to GND for performing a reset of the module (e.g. using a push-button which pulls to *GND* when pressed). The */RESET* pin has an internal pull-up of 100 kΩ.

11.2. Update using JTAG

JTAG is a production interface not intended to be used by the customer or for updating the product in the end application.
Our binary firmware files (production images) are not publicly available and will not be shared with third parties.

12. Firmware history

Version 1.0.0 "Release"

- First released firmware

Version 0.9.x "Prototype"

- Prototype version

13. Design in guide

13.1. 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.).

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.).

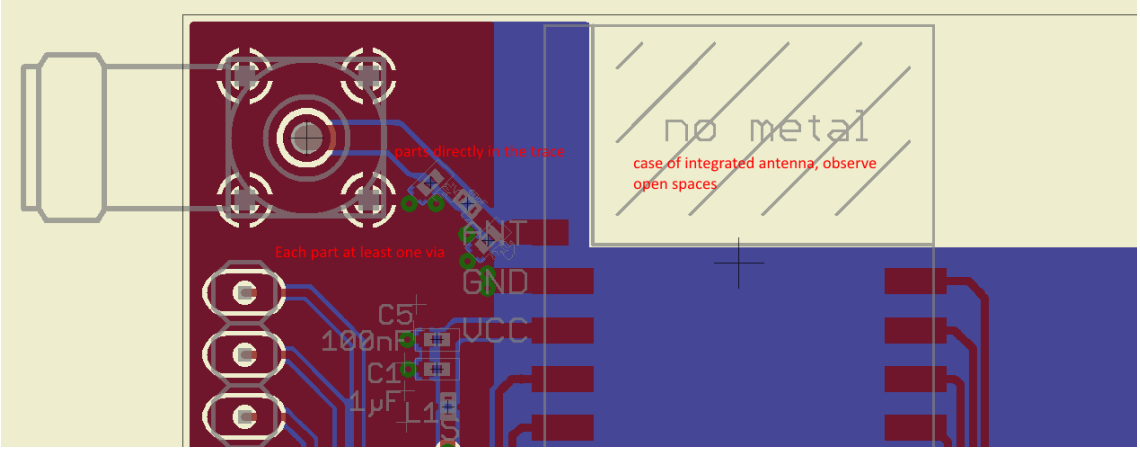


Figure 9: Layout

- 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.

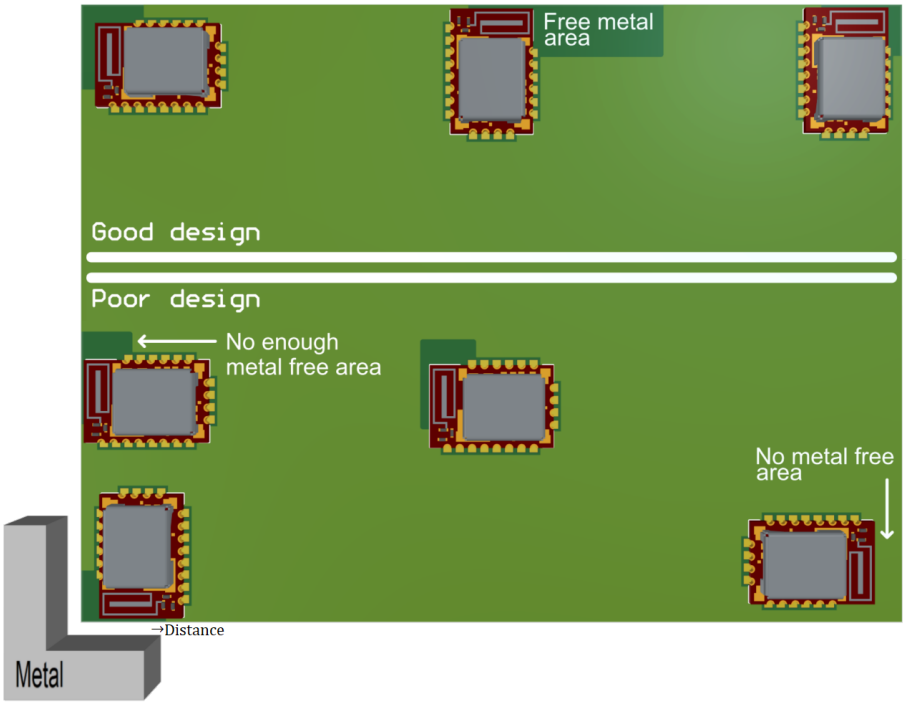


Figure 10: Placement of the module with integrated antenna

13.2. Designing the antenna connection

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

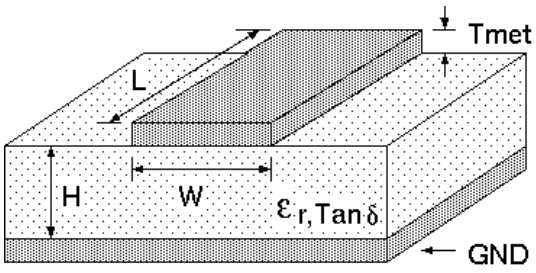


Figure 11: Dimensioning the antenna connection as micro strip

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

$$W = 1.25 \times \left(\frac{5.98 \times H}{e^{\frac{50 \times \sqrt{\epsilon_r} + 1.41}{87}}} - T_{met} \right) \quad (1)$$

Example:
A FR4 material with ε_r = 4.3, a height H = 1000 µm and a copper thickness of T_{met} = 18 µm will lead to a trace width of W ~ 1.9 mm. To ease the calculation of the micro strip line (or e.g. a coplanar) many calculators can be found in the internet.

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

13.3. Antenna solutions

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

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

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

13.3.1. Wire antenna

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

13.3.2. Chip antenna

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

13.3.3. PCB antenna

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

13.3.4. Antennas provided by Würth Elektronik eiSos

13.3.4.1. 2600130086 - Hermippe-III dipole antenna

Well suited for applications where the RF is lead through a metal wall that could serve as ground plane to the antenna.

Figure 12: Hermippe-III dipole antenna

Specification	Value
Frequency range [MHz]	855 – 915
VSWR (free space,without ground plane)	$\leq$ 2.0
Polarisation	Linear
Impedance [Ω]	50±5
Connector	SMA (Male)
Dimensions (L x d) [mm]	50±3 x 7.92±0.2
Weight [g]	4.5
Operating temp. [℃]	-40 – +85

13.3.4.2. 2600130081 - Hyperion-I dipole antenna

Figure 13: Hyperion-I dipole antenna

Ideally suited for applications where no ground plane is available.

Specification	Value
Center frequency [MHz]	868
Frequency range [MHz]	853 – 883
Wavelength	λ /2
VSWR	≤ 2.0
Impedance [Ω]	50
Connector	SMA (Male)
Dimensions (L x d) [mm]	142 x 10
Peak gain [dBi]	-2.3
Operating temp. [℃]	-30 – +80

13.3.4.3. 2600130082 - Hyperion-II magnetic base antenna

Well suited for applications where the RF is lead through a metal wall that could serve as ground plane to the antenna.

Figure 14: Hyperion-II magnetic base antenna with 1.5 m antenna cable

The 2600130082 is an antenna in form of $\lambda/4$ and therefore needs a ground plane at the feeding point.

Specification	Value
Frequency range [MHz]	824 – 894
VSWR	$\leq$ 2.0
Polarisation	Vertical
Impedance [Ω]	50±5
Connector	SMA (Male)
Dimensions (L x d) [mm]	89.8 x 27
Weight [g]	50±5
Operating temp. [°C]	-30 – +60

14. Reference design

14.1. Receiver Sensitivity

The module reacts with reduced receiver sensitivity if coupling between radio and Pin 4, Test2 occurs. The following points can be used to suppress this coupling:

- 68 pF capacitor on Pin4.
- 4-Layer PCB with Signal/GND - GND - Power/GND - Signal/GND layer and routing.
- Ground in between the signal lines properly connected to GND plane.

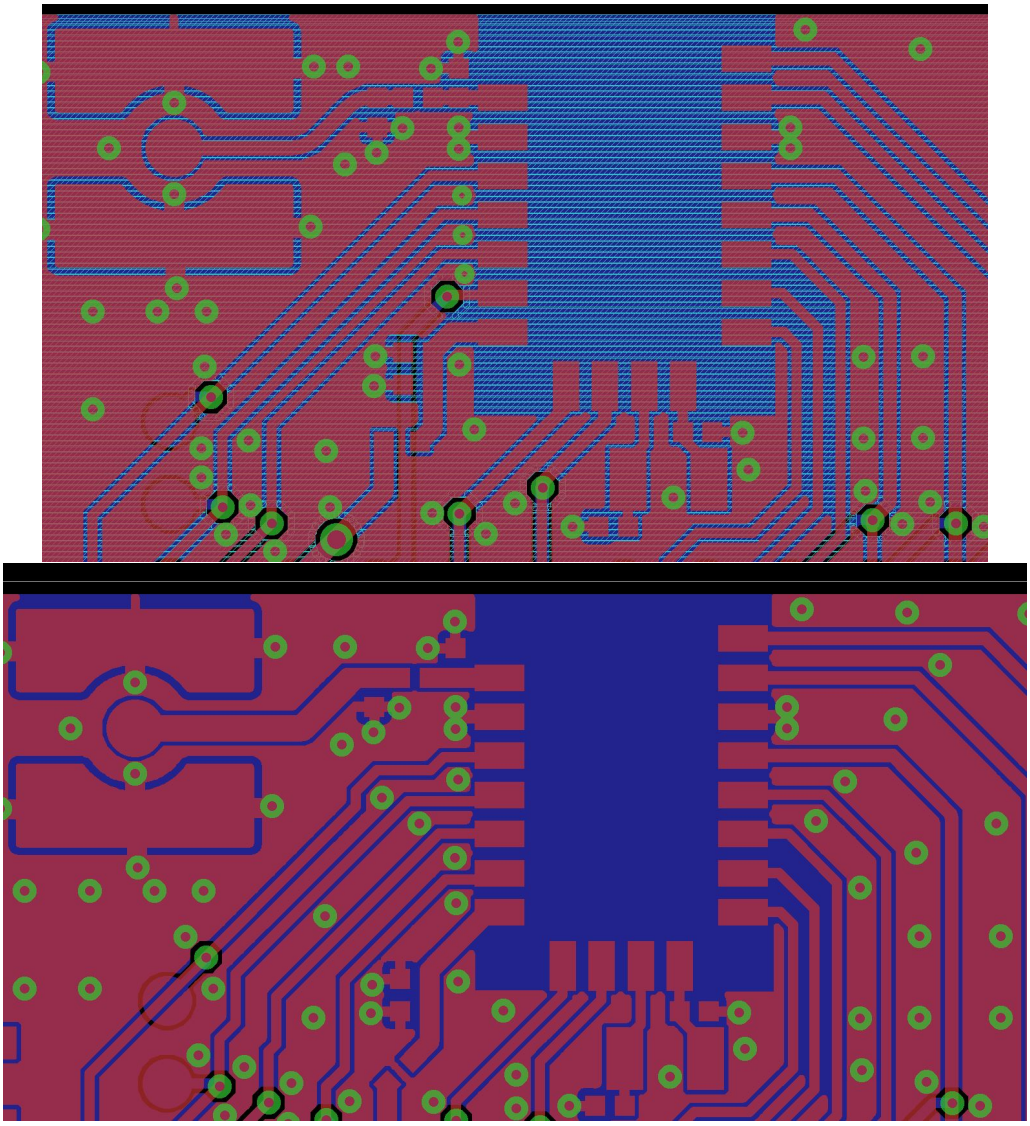


Figure 15: Examples for good decoupling

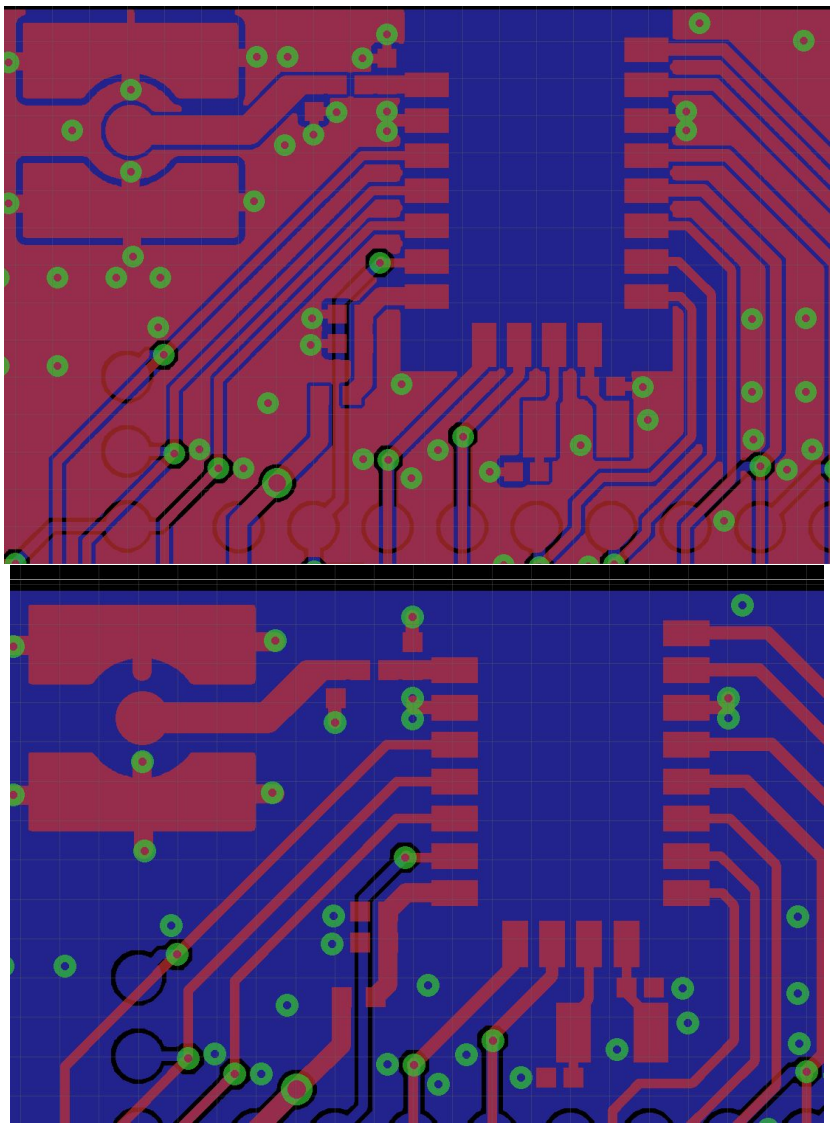
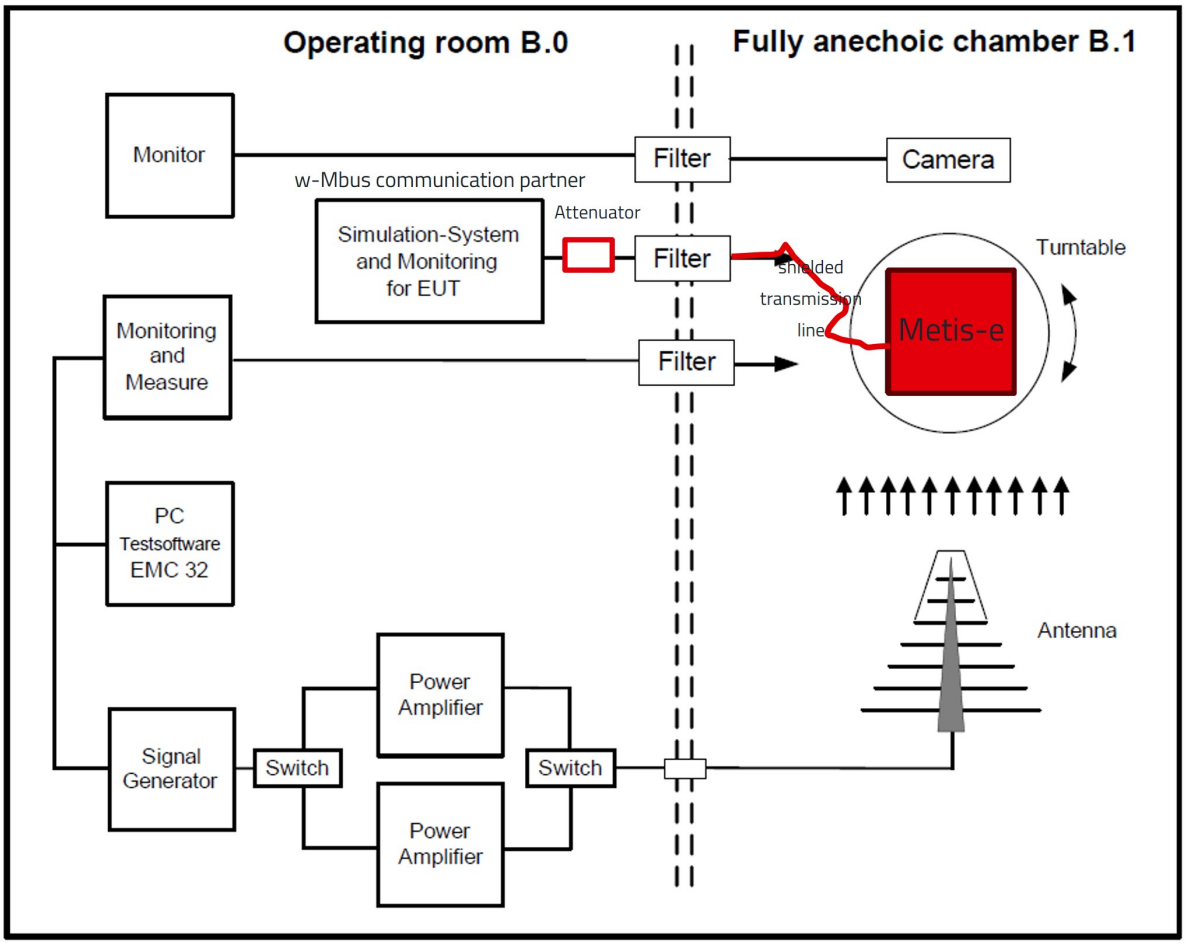


Figure 16: Examples for poor decoupling

14.2. EMC immunity behavior

For a radio device following the "Radio Equipment Directive", the multi-part EMC standard EN 301 489 is applicable, referencing the EMC basic standards of the EN 6100-* series.
Part of the EMC test is the radio immunity. The goal of this test is to verify the device's proper functioning within a radio frequency electromagnetic field, which could be present in any environment.
Everything connected to PIN1 of Metis-e itself is within the scope of the test for the spectrum aspects. In case of Metis-e, an 868 MHz product, the EN 300 220 is applied for the spectrum aspects.
Therefore the EMC test for the Metis-e, as a stand alone radio module, and according to standard EN 301 489, shall include everything but exclude these spectrum aspects.
In the standard this is described in the specification of the arrangements of test signals:
"For transmitters with an antenna connector, the wanted RF output signal to establish a communication link shall be delivered from the antenna connector to the monitoring equipment (AE) by a shielded transmission line, such as a coaxial cable."



As the Metis-e has no integrated antenna but a connector, the compliance test were performed this way.

Furthermore, tests that are not mandatory have been performed including an attached antenna. Depending on the antenna and its ability to absorb energy of specific frequencies of the RF electromagnetic field, the RSSI value is influenced and loss of packets can occur. The phenomenon of lost packets is observed with both tested antennas, the Hermippe-III and Hyperion-I.
This means that special care has to be taken and if:

- The antenna is integrated and the communication link is not delivered by a shielded transmission line.
- The loss of packets is critical.
- The device is used in an environment where EMC disturbances are most likely present.

The evaluation board includes the reference design for an optional filter path. Using narrow band SAW filters eliminates this phenomenon completely. Tests might be needed to decide whether, filtering is needed or not, as the behavior on an antenna outside the used frequency range is usually not specified.
Table 14 give guidance about the implementation depending on the abbility of the antenna to absorb energy of the specific frequencies of the RF electomagnetic field, the requirements on packet errors and the probability of EMC disturbance.

Application and environmental conditions	**Integrated** narrow band **antenna**	**Integrated** wide band **antenna**	Radio **connector**
Packet loss uncritical (PER < 10 %) Or High risk of EMC disturbance	SAW filter small likely needed	SAW filter likely needed	SAW filter small likely needed Hermippe-III suitable
Packet loss critical (PER > 10 %) Or Low risk of EMC disturbance	SAW filter unlikely needed	SAW filter small likely needed	SAW filter unlikely needed Hermippe-III or Hyperion-I suitable

Table 14: Implementation

For the EMC test the acceptable PER (packet error rate) for the end device has to be defined

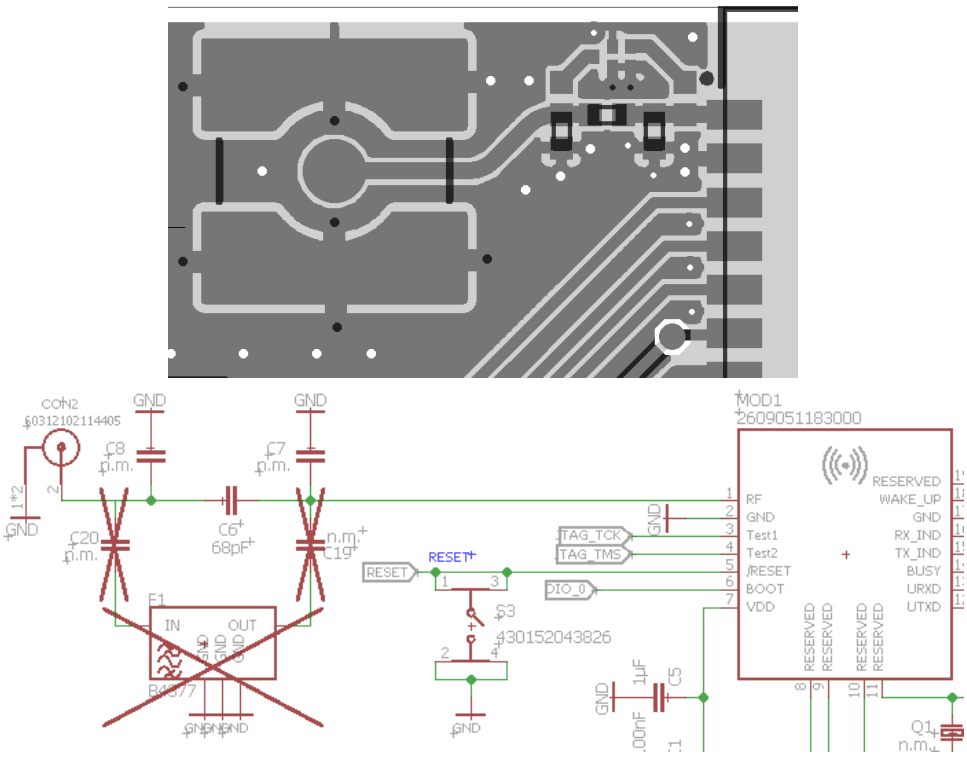


Figure 17: Example without filter

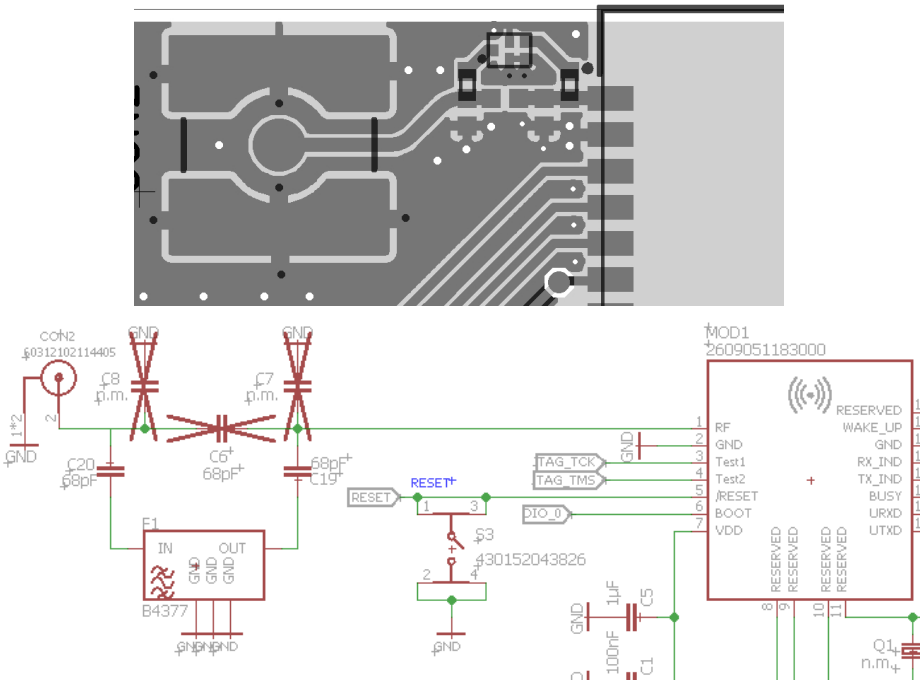
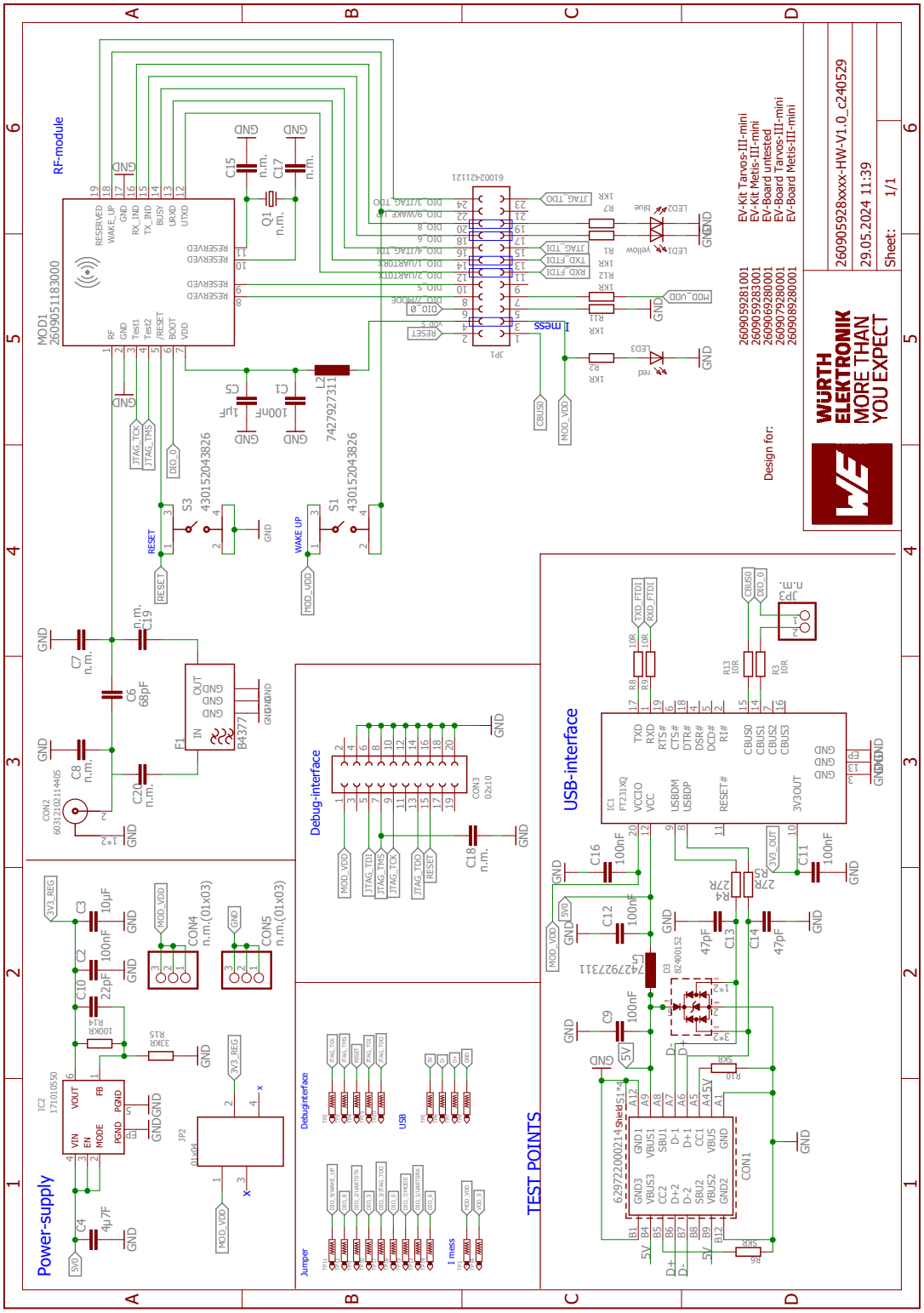


Figure 18: Example with filter

14.3. Schematic



14.4. Layout

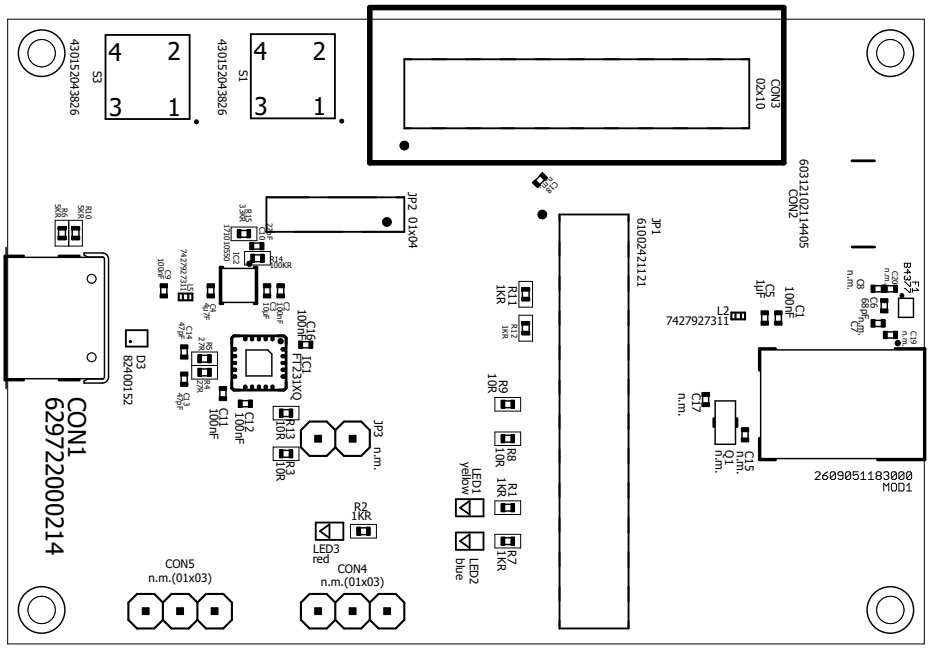


Figure 19: Assembly diagram

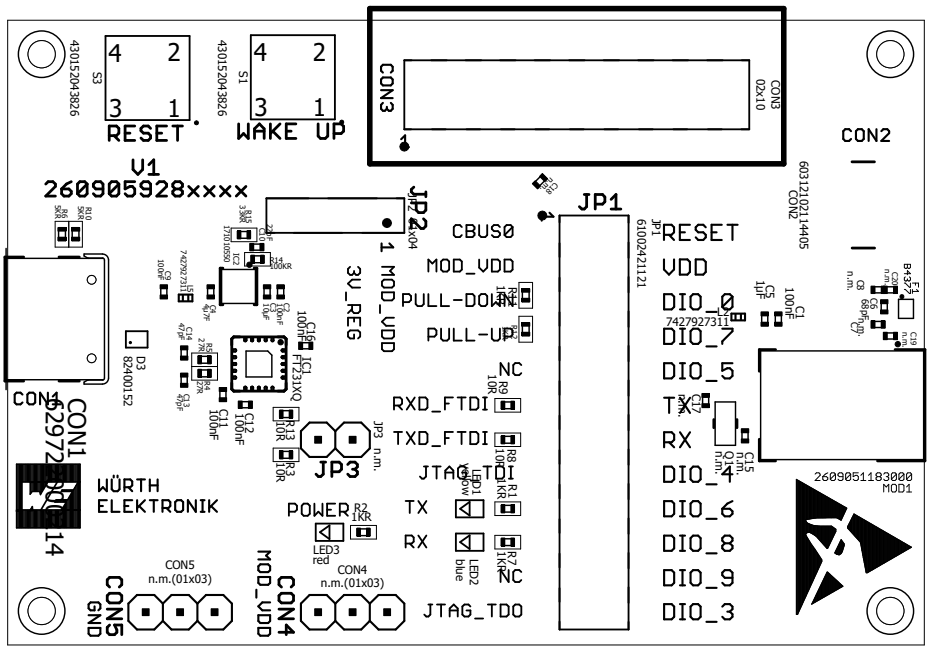


Figure 20: Silkscreen and assembly

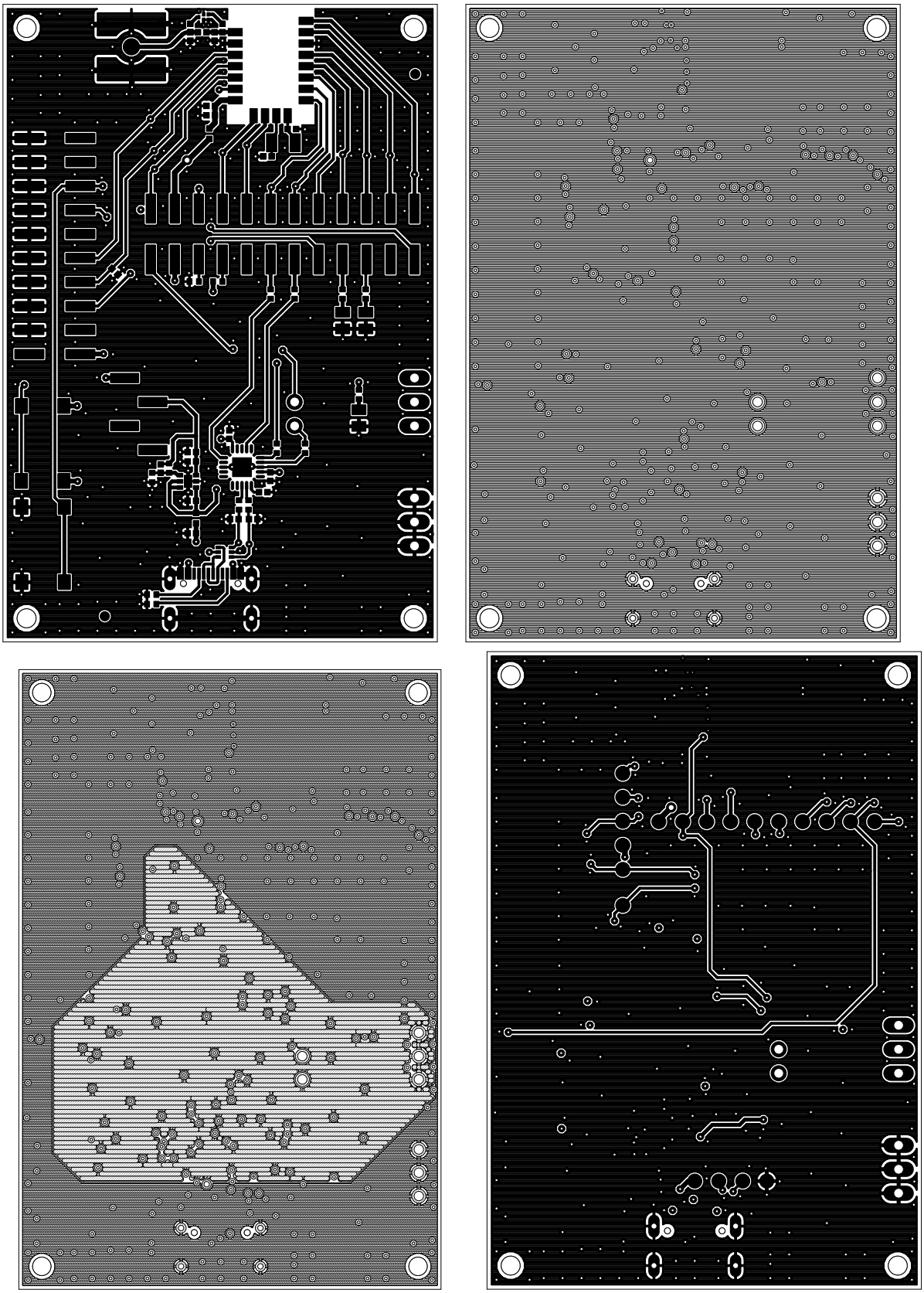


Figure 21: Top, Layer 2, Layer 3 and Bottom Layer

15. Manufacturing information

15.1. 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*.

15.2. Soldering

15.2.1. 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.

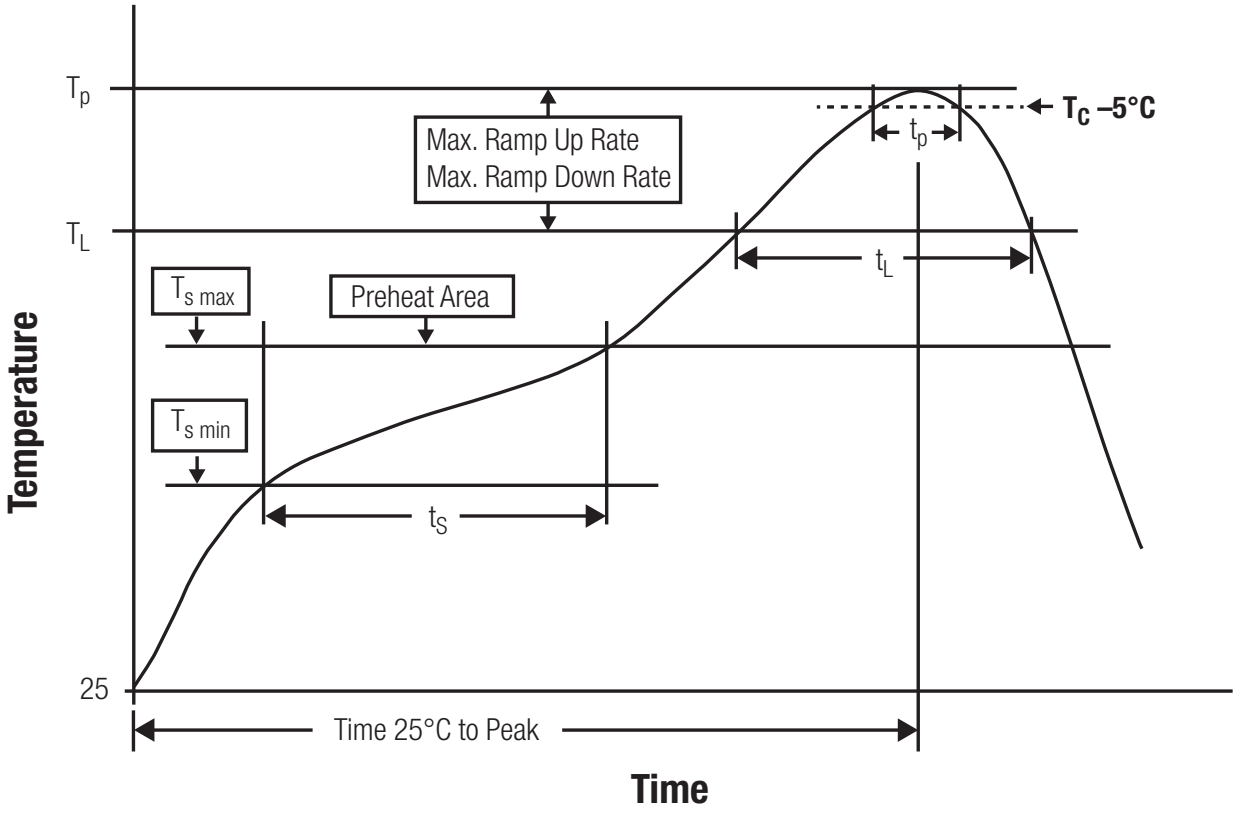


Figure 22: Reflow soldering profile

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

15.2.2. 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.

15.2.3. 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.

15.2.4. 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.

15.3. 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.

15.4. 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.

16. Physical specifications

16.1. Dimensions

Dimensions
12 mm x 8 mm x 2 mm

Table 16: Dimensions

16.2. Weight

Weight
<1g

Table 17: Weight

16.3. Module drawing

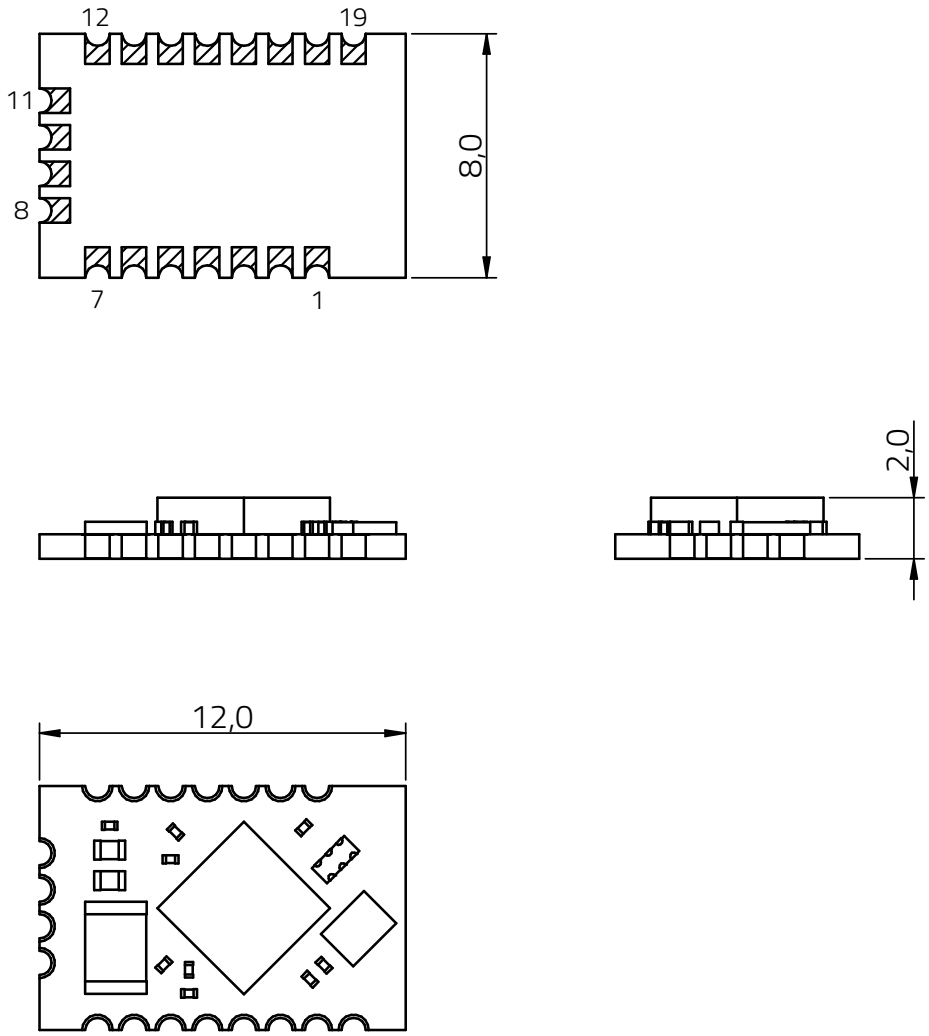


Figure 23: Dimensions [mm]

16.4. Footprint

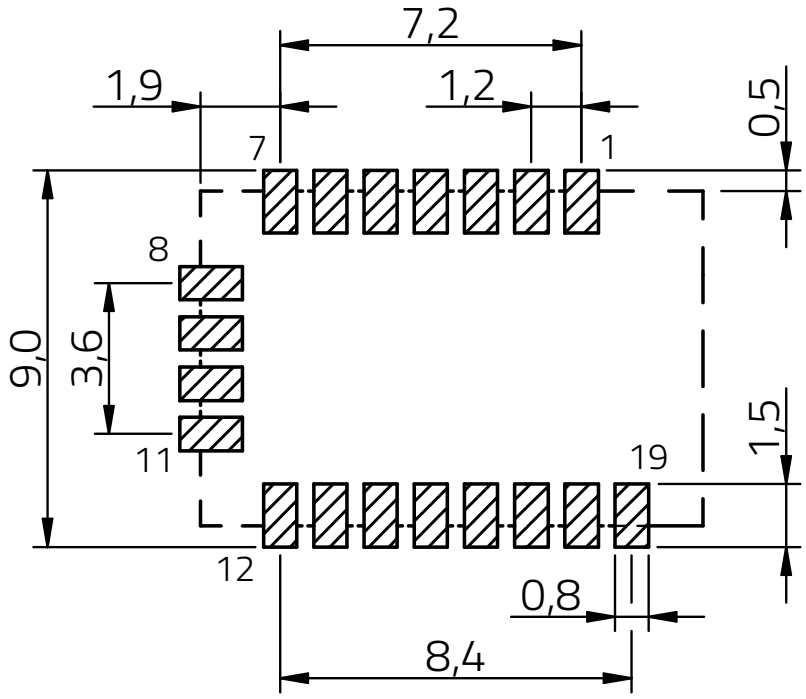


Figure 24: Footprint [mm]

The following points have to be considered:

- To avoid the risk of short circuits, a minimum clearance of at least 14 mm between the opposing pad rows has to be maintained! No Routing on the top layer of a carrier PCB (i.e. "under" the module) shall be performed.
- For the module variant with integrated antenna the marked corner area of 7.3 x 13.8 mm has to be kept free from metal, on any layer.
- The four bottom side pads are optionally for the firmware update using JTAG can be left open when JTAG update is not needed in the customer's application.
- This footprint is also compatible to AMB8626, AMB8426, AMB4426 and AMB3626.

17. Marking

17.1. Lot number

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

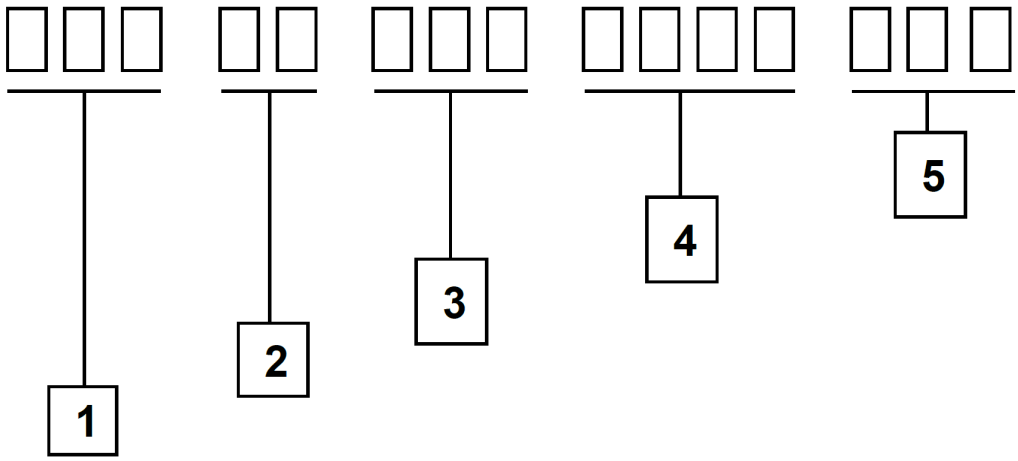


Figure 25: Lot number structure

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

Table 18: Lot number details

As the user can perform a firmware update the printed lot number only shows the factory delivery state. The currently installed firmware can be requested from the module using the corresponding product specific command. The firmware version as well as the hardware version are restricted to show only major and minor version not the patch identifier.

17.2. General labeling information

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

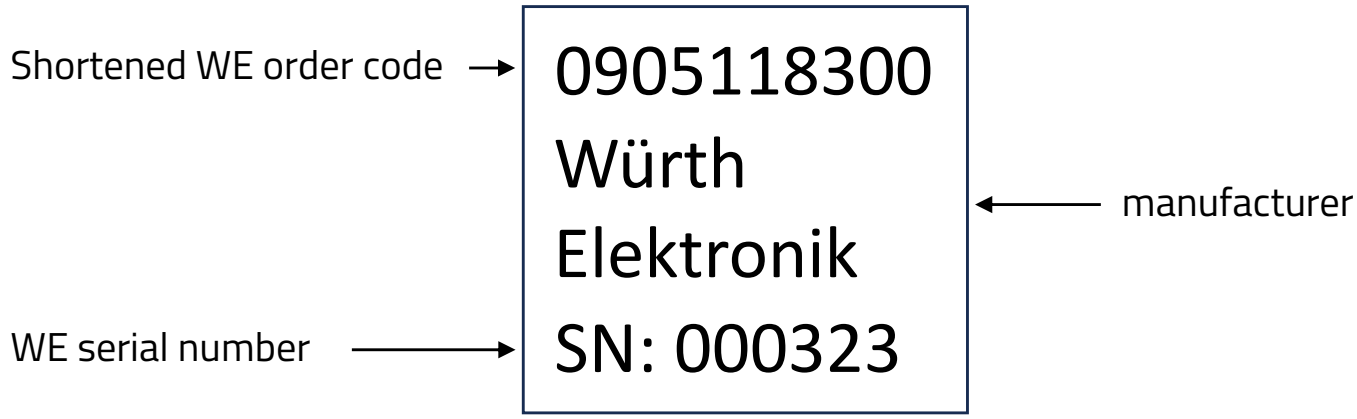


Figure 26: Label of the Metis-e

18. 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 25 mW.
- The total amount of capacitance of all discrete capacitors is 45.6 μF.
- The total amount of inductance of all discrete inductors is 6.81 μH.

19. Regulatory compliance information

19.1. Important notice EU

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

Since the module itself is not fused the voltage supply shall be fed from a power source which is class PS2 according to EN 62368-1.

19.3. Conformity assessment of the final product

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

19.4. 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.

19.5. EU Declaration of conformity

CE

EU DECLARATION OF CONFORMITY

Radio equipment: **2609051183000**

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: 2609051183000

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

EN 300 220-1 V3.1.1 (2017-02)
EN 300 220-2 V3.1.1 (2017-02)
EN 301 489-1 V2.2.3 (2019-11)
EN 301 489-3 V2.1.1 (2019-03)
EN 62311 : 2008
EN 62368-1: 2014/AC: 2015/A11: 2017

i.A. G. Eckhardt

Trier, 15th of July 2024, Gudrun Eckhardt, Teamleader Hardware Development
Place and date of issue

19.5.1. Additional information on EU conformity

- The module is specified as Receiver Category 2.
- The test reports are available upon request.

20. 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 20 and 20 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
Unless otherwise agreed in individual contracts, all orders are subject to the current version of the "General Terms and Conditions of Würth Elektronik eiSos Group", last version available at *www.we-online.com*.

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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.

Ownership

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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A. Additional CRC8 Information

This Annex gives an example CRC8 implementation and test vectors.

A.1. Example CRC8 Implementation

```
#include <stdint.h>

uint8_t Get_CRC8(uint8_t * bufP, uint16_t len)
{
    uint8_t crc = 0x00;
    for (uint16_t i = 0; i < len; i++)
    {
        crc ^= bufP[i];
    }
    return crc;
}
```

Code 1: Example CRC8 Implementation

A.2. CRC8 Test Vectors

Input data	Data length	Resulting CRC8
Null	0	0x00
0x02 0x01 0x00 0x00	4	0x03
0x02 0x87 0x01 0x00 0x16	5	0x92
0x02 0x04 0x04 0x00 0x41 0x42 0x43 0x44	8	0x06
0x02 0x88 0x07 0x00 0x00 0x55 0x00 0x00 0xDA 0x18 0x00	11	0x1A

Table 19: CRC8 Test Vectors

B. Example code for host integration

The following code is an example implementation of a function to transmit data using a 2 byte length field in the command frame. For demonstration reasons, the Proteus-III has been taken. The full function codes of all radio modules are available in the Wireless Connectivity SDK (*www.we-online.com/wco-SDK*).

```
#define CMD_PAYLOAD_MAX 964
typedef struct {
    uint8_t Stx;
    uint8_t Cmd;
    uint16_t Length;                /* LSB first */
    uint8_t Data[CMD_PAYLOAD_MAX+1]; /* +1 for CRC8 */
} CMD_Frame_t;
#define CMD_OFFSET_TO_DATAFIELD 4
#define CMD_OVERHEAD (CMD_OFFSET_TO_DATAFIELD+1)

bool ProteusIII_Transmit(uint8_t *PayloadP, uint16_t length)
{
    /* fill request message with STX, command byte and length field */
    CMD_Frame_t CMD_Frame;
    CMD_Frame.Stx = CMD_STX; /* 0x02 */
    CMD_Frame.Cmd = ProteusIII_CMD_DATA_REQ; /* 0x04 */
    CMD_Frame.Length = length;

    /* fill request message with user payload */
    memcpy(CMD_Frame.Data, PayloadP, length);

    /* fill request message with CRC8 */
    CMD_Frame.Data[CMD_Frame.Length] = Get_CRC8(&CMD_Frame, CMD_Frame.Length +
        CMD_OFFSET_TO_DATAFIELD);

    /* transmit full message via UART to radio module */
    UART_SendBytes(&CMD_Frame, (CMD_Frame.Length + CMD_OVERHEAD));

    /* wait for response message from radio module */
    return UART_Wait_for_Response(CMD_WAIT_TIME, ProteusIII_CMD_TXCOMPLETE_RSP,
        CMD_Status_Success, true);
}
```

Code 2: Example function implementation for radio modules with 2 byte length field

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