



THALASSA REFERENCE MANUAL

AMB2524 / 2606031x2100x

VERSION 4.10

MARCH 25, 2021

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 in the customer system design, the possibility for a firmware update of the product.

Revision history

Revision history

Manual version	FW version	HW version	Notes	Date
1.0 - 4.2	-	-	<ul style="list-style-type: none"> Initial version 	December 2017
4.3	3.4.0	1.2	<ul style="list-style-type: none"> New corporate design and structure 	November 2018
4.4	3.4.0	1.2	<ul style="list-style-type: none"> Update Declaration of Conformity after change of standard and retesting Update 2.4 GHz antenna accessory 2600130021 Correction module height 	December 2018
4.5	3.4.0	1.2	<ul style="list-style-type: none"> Added chapter Reference design Added chapter Information for explosion protection 	February 2019
4.6	3.4.0	1.2	<ul style="list-style-type: none"> Corrected Figure Module dimensions [mm] 	March 2019
4.7	3.4.0	1.2	<ul style="list-style-type: none"> Updated label in chapter General labeling information Updated address of Division Wireless Connectivity & Sensors location 	October 2019
4.8	3.4.0	1.2	<ul style="list-style-type: none"> Updated the firmware update chapter. 	June 2020
4.9	3.4.0	1.2	<ul style="list-style-type: none"> Updated the European declaration of conformity. 	January 2021
4.10	3.4.0	1.2	<ul style="list-style-type: none"> Updated the European declaration of conformity. 	March 2021

Abbreviations and abstract

Abbreviation	Name	Description
ACK	Acknowledgement	Acknowledgement pattern confirming the reception of the transmitted data packet.
CS	Checksum	
DC	Duty cycle	Transmission time in relation of one hour. 1% means, channel is occupied for 36 seconds per hour.
FSE	Field Sales Engineer	
0xhh [HEX]	Hexadecimal	All numbers beginning with 0x are stated as hexadecimal numbers. All other numbers are decimal.
HIGH	High signal level	
LOW	Low signal level	
LPM	Low power mode	Operation mode for reduced power consumption.
LSB	Least significant bit	
MSB	Most significant bit	
PL	Payload	The real, non-redundant information in a frame/packet.
RF	Radio frequency	Describes everything relating to the wireless transmission.
UART	Universal Asynchronous Receiver Transmitter	Universal Asynchronous Receiver Transmitter allows communicating with the module of a specific interface.
US	UserSettings	Any relation to a specific entry in the UserSettings is marked in a special font and can be found in the respective chapter.
VDD	Supply voltage	

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1. Introduction

1.1. Operational description

The Thalassa module was designed as a radio submodule for wireless communication between devices like controls, remote controls, sensors etc. It offers several addressing modes and relieves the host system of radio-specific tasks such as

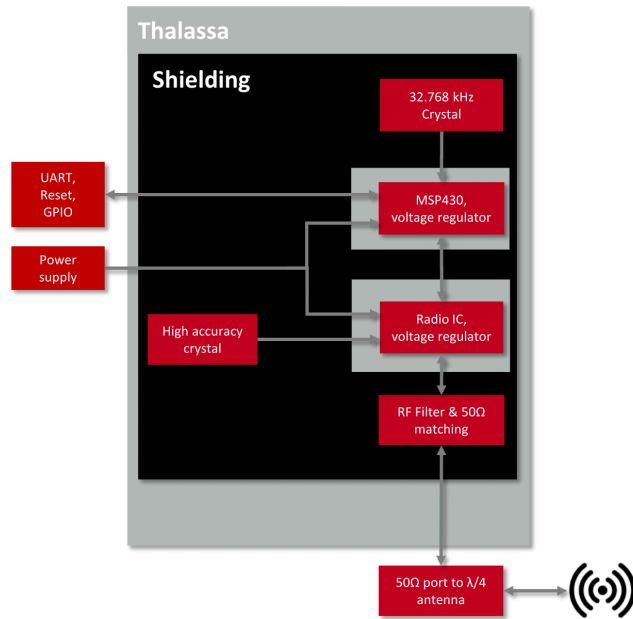
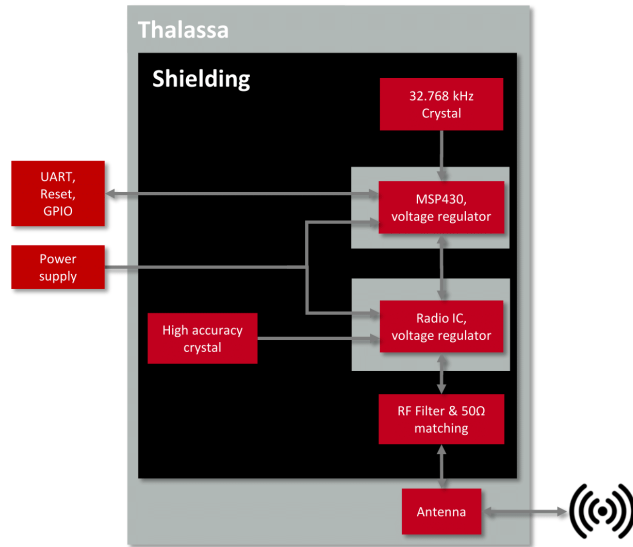
- checksum calculation,
- address resolution and
- repetition of unacknowledged telegrams.

It can be deployed wherever the wireless exchange of small data packets (up to 128 bytes) 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.

Thanks to its small size and the integrated antenna, the module can easily be installed in existing systems without any external circuits.

1.2. Block diagram



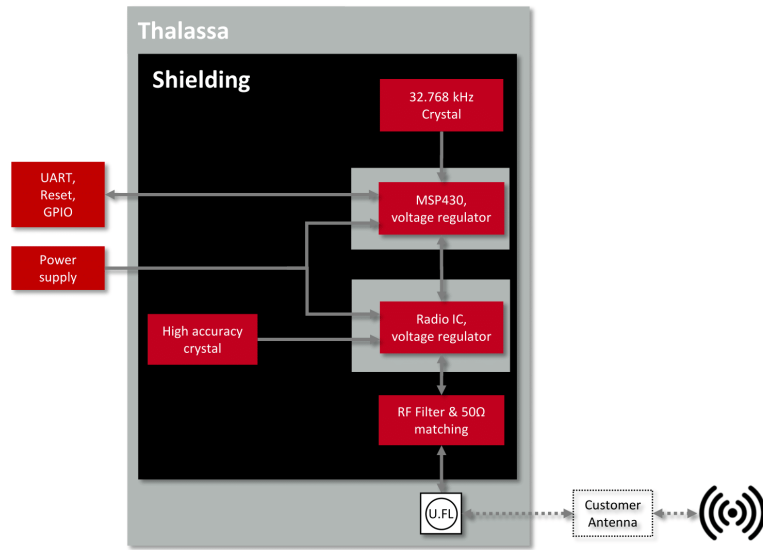


Figure 1: Block diagram of the 3 module variants

1.3. Ordering information

WE order code	Former order code	Description
2606031021000	AMB2524-TR	AMB2524 on Tape & Reel, Reflow solderable, packing unit 400pcs
2606031121000	AMB2524-1-TR	AMB2524-1 on Tape & Reel, Reflow solderable, packing unit 400pcs
2606031321000	AMB2524-2-TR	AMB2524-2 on Tape & Reel, Reflow solderable, packing unit 400pcs

Table 1: Ordering information Thalassa

2. Electrical specifications

In order to ensure a constant processor frequency (and UART clock rate) over the entire voltage range, the clock rate is continuously readjusted on the basis of the available watch crystal. Voltage changes during the reception or output over the serial interface can result in a change of the clock rate between two characters.



Caution: A clean supply voltage is needed for the module to function correctly. Using a 100 μ F blocking capacitor close to the VCC pin is a useful measure (especially when using RS232 converters or clocked DC-DC converters).

2.1. Recommended operating conditions

Description	Min.	Typ.	Max.	Unit
VCC	2.7	3	3.6	V
Temperature range	-30	20	85	$^{\circ}$ C

Table 2: Recommended operating conditions

2.2. Absolute maximum ratings

Description	Min.	Typ.	Max.	Unit
VCC	-0.3		3.9	V

Table 3: Absolute maximum ratings

2.3. Power consumption

2.3.1. Static

Description	Min	Typ.	Max	Unit
TX current consumption at max output power		25		mA
RX current consumption		21		mA
Low power mode		6		μ A

Table 4: Power consumption

2.4. Radio characteristics

Description	Min	Typ.	Max	Unit
Max output power (e.i.r.p)			-6	dBm
Max output power (@ 50 Ω)			0	dBm
Input sensitivity	-98			dBm
Input sensitivity (@ 50 Ω)	-102			dBm
Frequencies	2400.0		2483.5	MHz

Table 5: Radio characteristics

2.5. Pin characteristics

Property	Min	Typ.	Max	Unit
Pin input voltage	-0.3		VCC+0.3	V
Pin output current sunk by any I/O and control pin ¹			6	mA
Pin output current sourced by any I/O and control pin ¹			6	mA
Pin total output current sunk by sum of all I/Os and control pins ¹			48	mA
Pin total output current sourced by sum of all I/Os and control pins ¹			48	mA

Table 6: Pin characteristics

¹Pin characteristics when VCC equals 3V.

3. Pinout

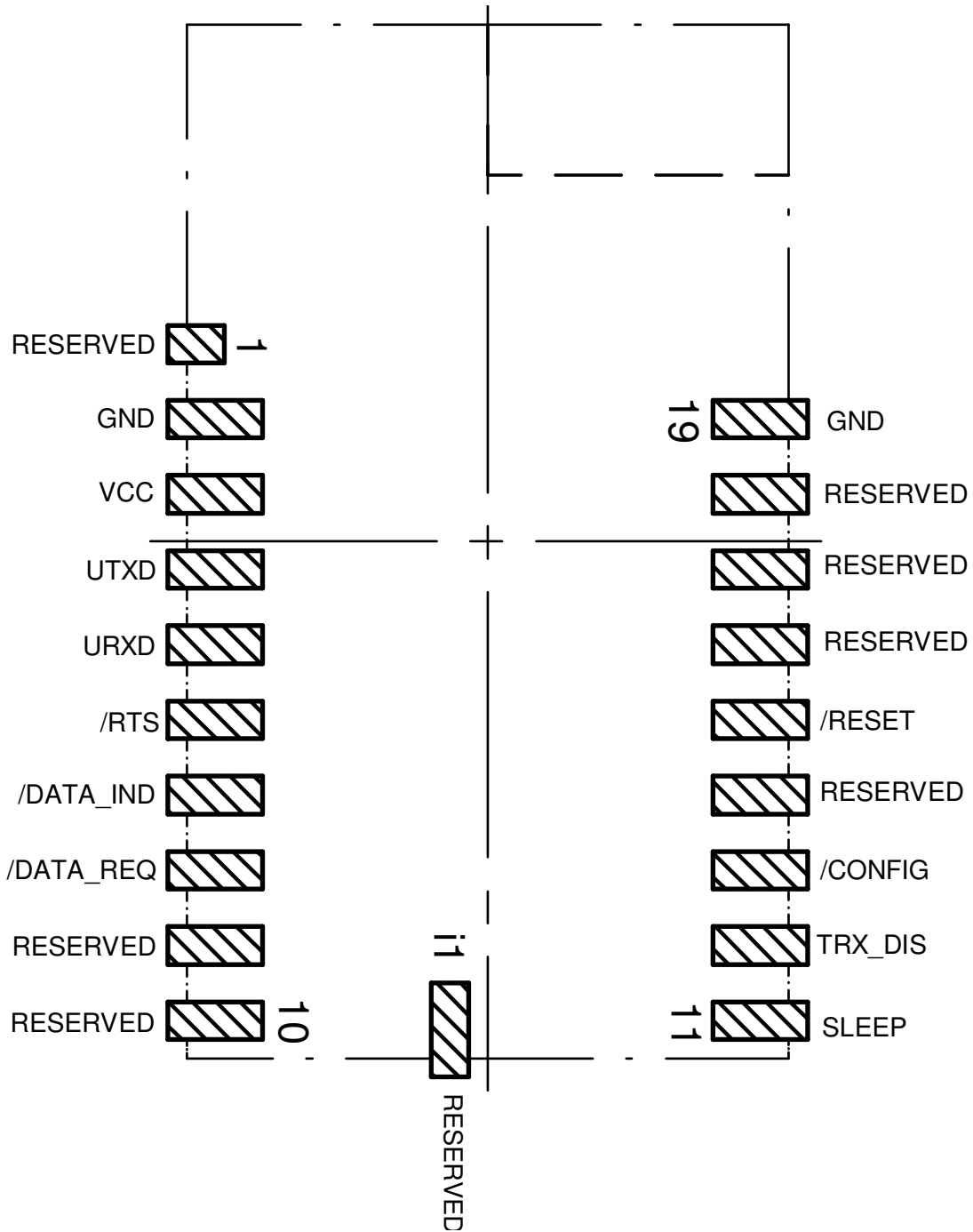


Figure 2: Pinout, internal antenna

No	Designation	I/O	Description
1	<i>ANT</i> or <i>RESERVED</i>	I/O	Antenna connection, 50Ω when module provides ext. antenna connector, reserved otherwise
2	<i>GND</i>	Supply	Ground
3	<i>VCC</i>	Supply	Supply voltage
4	<i>UTXD</i>	Output	UART TX (module transmission)
5	<i>URXD</i>	Input	UART RX (module reception)
6	<i>/RTS</i>	Output	UART ready to send. HIGH level signalizes a busy module UART buffer. While HIGH, all received UART bytes will be discarded.
7	<i>/DATA_IND</i>	Output	Packet receive indication. Goes LOW as soon as a valid packet with correct address is received via radio, stays LOW for an additional <code>UART_DIDelay</code> and remains LOW as long as the output via UART continues.
8	<i>/DATA_REQ</i>	Input	Prompts the wireless transmission of the data received via the UART (falling edge). As long as no new data is received via UART or wireless transmission, the buffer content remains valid and can be resent by means of a new signal. Connect to GND if not needed. The function can be disabled (see chapter 8.31). Without function in the command mode.
9	<i>RESERVED</i>	Output	Reserved. Do not connect.
10	<i>RESERVED</i>	Output	Reserved. Do not connect.

No	Designation	I/O	Description
11	<i>SLEEP</i>	Input	Activates the Sleep Mode (high level). Connect to GND if not needed. The function can be disabled (see chapter 8.31).
12	<i>TRX_DISABLE</i>	Input	Switches the HF part off (high level) as long as no data is to be sent. Connect to GND if not needed. The function can be disabled (see chapter 8.31).
13	<i>/CONFIG</i>	Input	Used to switch the module to the command mode (falling edge). Alternatively, this can be done by means of a UART break signal. Connect to GND if not needed. The function can be disabled (see chapter 8.31).
14	<i>RESERVED</i>	Output	Reserved Do not connect.
15	<i>/RESET</i>	Input	Module internal pull-up, a rising edge will release module from reset, LOW will hold module in reset state.
16	<i>RESERVED</i>	Output	Reserved Do not connect.
17	<i>RESERVED</i>	Output	Reserved Do not connect.
18	<i>RESERVED</i>	Output	Reserved Do not connect.
19	<i>GND</i>	Supply	Ground
i1	<i>RESERVED</i>	Output	Reserved Do not connect.

Table 7: Pinout

4. Quickstart

4.1. Minimal pin configuration

The following pins are required in the minimal configuration: *VCC*, *GND*, *UTXD*, and *URXD*.

If the module is to be connected to a PC, a level converter (TTL to RS232 or USB) must be used. The development tool Thalassa-EV provides the interface on-board.

In the default configuration of the Firmware, all module inputs (*SLEEP*, *TRX_DISABLE*, */CONFIG*, and */DATA_REQUEST*) are activated and must be connected to *GND* if they are not to be used (see table 1).

The */RTS* signal is recommended to be used by the host.

4.2. Power up

Recommended procedure for starting the module:

After supply voltage is applied to the module, the */RESET* pin shall be hold to LOW level for another Δt of at least 2ms after the *VCC* is stable to ensure a safe start-up.

If the module is used on a battery-powered system, using a matching reset-IC (or a discrete RC block for an according delay) is highly recommended to ensure a correct power up and stable behavior towards a battery getting empty.

4.3. Quickstart example

Sending and receiving: Hello World

Connect your pair of modules, EV-boards or USB-sticks with the PC as explained in chapter 4. Please make sure you have a minimum distance of 3 meters between the two modules or devices to avoid overmodulation. When short distances are needed, you could reduce the transmission power to a minimum.

When the connection to the PC is established, please use a terminal tool of your choice. For convenience we assume you selected the tool "hterm". Select the two corresponding COM ports and open them with the right configuration (Thalassa: 38.4 kBaud 8n1)

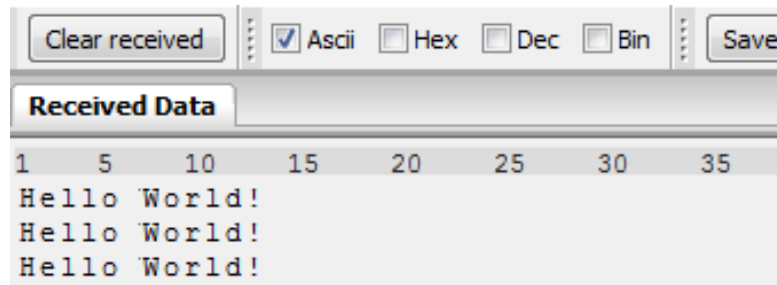
Baud 38400 Data 8 Stop 1 Parity None

Enter the string "Hello World" into the input line of hterm and use the "ASend" button followed by pushing the "start" button to send the data once.

Type ASC Hello World! ASend

This data will be received by the second module and shows up as received data in the second hterm instance. You may send any string of size 1 to 128 characters from one module to the other.

You just used the so called "transparent mode" of the modules to send your data. The address mode that was used is "0". Thus all radio frames are broadcasts that can be received



by any other device using the same radio settings. The frame you send was generated using the timeout method.

Besides the transparent mode, that is suited for transparent data transmission, the so called "command mode" allows both, the module configuration and the data transmission, using a predefined command interface (see chapter 5).

5. Functional description

5.1. Operating modes

The device can be used in the following operating modes:

1. Transparent mode (transparent data transmission)
2. Command mode (module configuration and data transmission using the predefined command interface)

The operating mode after power-up can be configured by means of the `OpMode` parameter. By default, the module operates in transparent mode. Starting in the command mode, the module responds with a `CMD_SET_MODE_CNF` telegram.



Würth Elektronik eiSos highly recommends using the command mode.

5.1.1. Switching from transparent to command mode

The command mode can be entered by applying a falling edge on the `/CONFIG` pin or when a break signal is detected on the UART. A break condition exists if the RX input of the module is kept low for at least 10 more bits after an absent stop bit. Detection of both the falling edge on the `/CONFIG` pin and of the break signal can be disabled using the UserSetting `CfgFlags`. The successful switchover is acknowledged by a `CMD_SET_MODE_CNF` telegram. The switchover can only occur when no data is being received by wireless transmission or UART interface (approximately 100 μ s after `/RTS` goes low and indicates readiness).

5.1.2. Switching from command to transparent mode

The transparent mode can be entered by applying a falling edge on the `/CONFIG` pin, by using the command `CMD_SET_MODE_REQ` or on detection of another break signal on the UART. Detection of both the falling edge on the `/CONFIG` pin and of the break signal can be disabled using the UserSetting `CfgFlags`.

The successful switchover is acknowledged by a `CMD_SET_MODE_CNF` telegram. The switchover can only occur when no data is being received by wireless transmission or UART interface (approximately 100 μ s after `/RTS` goes low and indicates readiness).

5.1.3. Transparent mode

In this mode, data is received via the serial interface and initially buffered. As soon as a specific condition is met (see table 8), the RF telegram is generated with a preamble, checksum, and address information (optional).

The number of characters transmitted in the wireless telegram in addition to the actual payload data depends on the selected addressing method and the data rate, and varies between 12 and 16 bytes (packet overhead).

If required, the RF telegram can be acknowledged by the recipient module (see chapter 8.14). If no acknowledgement is received, the telegram will automatically be repeated upon expiry of a timeout (see chapter 8.20).

The buffer size at the UART interface is 128 bytes, i.e. the maximum size of transmitted data packets is 128 bytes (payload data only, without packet overhead).

To initiate an RF transmission, several options are available, listed in table 8

Start	Condition Description:	Dependent usersettings
Timeout	Transmission starts if no new character is detected within a configurable time period after receiving a character via UART. The timeout is reset every time a new character is received.	UART_Timeout UART_PktMode
End-Of-Text-Character	Transmission begins when the preconfigured character is transmitted via UART.	UART_PktMode UART_ETXChar
Fixed Packet Size	Transmission starts when the preconfigured number of bytes is reached in the RX buffer of the UART.	UART_PktSize UART_RTSLimit UART_PktMode
/Data Request Pin	The transmission starts as soon as a falling edge is detected on the <i>/DATA_REQUEST</i> pin.	CfgFlags

Table 8: Communication in transparent mode

The `UART_PktMode` parameter (see chapter 8.8) can be used to determine which of the listed combinations is to be used.



As long as the receiver module is busy sending characters via the serial interface, wireless data reception is not possible. For example, this effect is noticeable when sending a long data packet and subsequently a short data packet. In this case, the receiver module may still be busy sending the first packet via UART or SPI, and the second packet may be lost.

5.1.3.1. /RTS signal, busy processor

/RTS signals a busy UART buffer which means, when */RTS* is set, no more UART bytes will be neither accepted nor processed. */RTS* is set when any of the events in the prior chapter has occurred.

5.1.4. Command mode

This operating mode primarily serves module configuration. The module acts as a slave and can be fully controlled by an external host using the commands of the command interface (see chapter 7).

It can also be used for wireless transmission of payload data providing a feedback dependent on the transmission success.

5.2. Adopting parameters to fit your application

The non-volatile parameters (see chapter 8) can only be changed in the command mode by using the `CMD_SET_REQ` command. This command will need the following parameters:

- memory position of the parameter
- the new value that shall be applied to this parameter

Furthermore, there are volatile settings that can be accessed by explicit commands for each parameter. All available commands are introduced in chapter 7.

5.3. Device addressing and wireless monitoring

To connect several modules to networks or to send data to specific devices, the module supports the so called address mode. The corresponding UserSetting parameter `MAC_AddrMode` determines whether all modules in range, or all modules in a network or a single module with a fixed address is supposed to receive a certain message.

The address resolution can be disabled ("packet sniffer") with bit 7 in the `CfgFlags`. A module configured in this way will receive all data packets and forward them to the serial interface, regardless of the addressing mode. In sniffer mode, the module does not send any acknowledgement.

Settings like the module address can only be modified in the command mode. Thus we recommend to permanently operate in command mode by setting the UserSettings parameter `OpMode` to the value of 0x10 (16).

To use non-broadcast transmissions you need to adopt the following non-volatile settings:

- `MAC_AddrMode` (mode 1 or 2 should be used depending on the number of addresses you need)
- `MAC_SourceAddrLSB` as the local address for each device of your network, each member of the network will need an unique address. A value of 255 is invalid.
- `MAC_SourceNetID`, as the local network address for each device of your network, each member of the network will need an unique address. A value of 255 is invalid.

In command mode, the command `CMD_DATAEX_REQ`, that has the destination address as an own parameter, can be used to send your data to the specified address. A broadcast message can still be achieved when using 0xFF (255) for both destination address LSB and destination net ID.

6. Host connection

6.1. Serial interface: UART

The configuration in factory state of the UART is 38400 baud with data format of 8 data bits, no parity and 1 stop bit ("8n1"). The baud rate is adjusted by directly configuring the respective registers of the utilized microprocessor. In this way, the data rate can be adjusted freely from 0.5 to 115200 baud. The following data formats are supported:

- 7 or 8 bits
- No, even, or odd parity
- 1 or 2 stop bits



As the UART speed is derived from a digitally calibrated oscillator, there may be variations of up to $\pm 5\%$ over the entire temperature and supply voltage range.

When using the PC program "ACC V3", common data rates can be selected directly via drop-down menu. With this selection, the registers mentioned above are automatically set to the optimum value.

Moreover, the "ACC V3" program also provides a dialog for calculating arbitrary baud rates. The output of characters on the serial interface takes place with secondary priority. For this reason, short interruptions may occur between the output of individual characters (e.g. in the event of an interrupt).

7. The command interface

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

The commands of the command interface can be divided into 3 groups:

- **Requests:** The host requests the module to trigger any action, e.g. in case of the request `CMD_RESET_REQ` the host asks the module to perform a reset.
- **Confirmations:** On each request, the module answers with a confirmation message to give a feedback on the requested operation status. In case of a `CMD_RESET_REQ`, the module answers with a `CMD_RESET_CNF` to tell the host when the reset will be performed.
- **Indications and Responses:** The module indicates spontaneously when a special event has occurred. The `CMD_DATAEX_IND` indicates for example that data was received via radio.

Start signal	Command	Length	Payload	CS
0x02	1 byte	1 byte	length byte	1 byte

Table 9: Telegram format in the command mode

Start signal: 0x02 (1 byte)

Command: One of the predefined commands according to Table 11

Length: Specifies the number of payload data in the following field of variable length and is limited to 128 in order to prevent buffer overflow

Payload: Variable number of data or parameters (maximum 128 byte, LSB first)

CS: Bitwise XOR (exclusive-OR, "^") combination of the preceding bytes, including start sign, which means: `0x02 ^Command ^Length ^Payload Byte0 ...`



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

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, 500ms should cover the worst-case time).
- If no new signal is received for `UART_Timeout` milliseconds (see chapter 8.12) after receiving the `STX` signal the module will wait for a new start signal.

7.1. Data transfer & reception in the command mode

This chapter describes the commands to directly control the module, particular the data transmission and reception over the radio link when the module is in the command mode.

7.1.1. CMD_DATA_REQ

This command serves the simple data transfer in the command mode. Transmission takes place on the configured channel (see chapter 7.3.2) to the previously parameterised destination address (see chapter 7.3.3 and chapter 7.3.4).

This command is especially suitable for transmission on a point-to-point connection. The number of payload data bytes is limited to 128 in order to prevent buffer overflow.

Format (limit 128 payload data bytes):

Start signal	Command	Length	Payload	CS
0x02	0x00	1 Byte	Length Bytes	1 Byte

Response:

Start signal	Command	Length	Status	CS
0x02	0x40	0x01	1 Byte	1 Byte

Status:

0x00: ACK received, only possible if MAC_NumRetrys is not 0; see chapter 8.14

0x01: no ACK received or requested

7.1.2. CMD_DATAEX_REQ

This command serves data transfer in a network with several parties. Both the channel to use and the destination address (depending on the parameterised addressing mode) are specified along with the command. The number of payload data bytes is limited to 127, 126, or 125 in order to prevent buffer overflow.

Format in addressing mode 0 (limit 127 payload data bytes):

Start signal	Command	Length	Channel	Payload	CS
0x02	0x01	1 Byte	1 Byte	(Length-1) Bytes	1 Byte

Format in addressing mode 1 (limit 126 payload data bytes):

Start signal	Command	Length	Channel	Dest. address	Payload	CS
0x02	0x01	1 Byte	1 Byte	1 Byte	(Length-2) Bytes	1 Byte

Format in addressing mode 2 (limit 125 payload data bytes):

Start signal	Command	Length	Channel	Dest. network ID	Dest. address	Payload
0x02	0x01	1 Byte	1 Byte	1 Byte	1 Byte	(Length-3) Bytes

Response:

Start signal	Command 0x40	Length	Status	CS
0x02	0x40	0x01	1 Byte	1 Byte

Status:

0x00: ACK received, only possible if MAC_NumRetrys is not 0; see chapter 8.14

0x01: no ACK received or requested

0x02: invalid channel selected

7.1.3. CMD_DATAEX_IND

This telegram indicates the reception of data bytes and represents the counterpart to the commands CMD_DATA_REQ and CMD_DATAEX_REQ. Apart from the RX field strength (RSSI value), this telegram also specifies the sender address (depending on the parameterised addressing mode).

Format in addressing mode 0 (maximum 127 bytes payload data):

Start signal	Command	Length	Payload	Field strength	CS
0x02	0x81	1 Byte	(Length-1) Bytes	1 Byte	1 Byte

Format in addressing mode 1 (maximum 126 bytes payload data):

Start signal	Command	Length	Sender address	Payload	Field strength	CS
0x02	0x81	1 Byte	1 Byte	(Length-2) Bytes	1 Byte	1 Byte

Format in addressing mode 2 (maximum 125 bytes payload data):

Start signal	Command	Length	Sender network id	Sender address	Payload	Field strength
0x02	0x81	1 Byte	1 Byte	1 Byte	(Length-3) Bytes	1 Byte

Concerning the interpretation of the field strength, see chapter 7.2.4

7.1.4. CMD_DATARETRY_REQ

This command relaunches the transmission of the data submitted earlier on with CMD_DATA_REQ or CMD_DATAEX_REQ. Thus, the data does not need to be transmitted again via the serial interface.

The buffered data is lost as soon as new data is sent via UART or data is received via wireless transmission.

Format:

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

Response:

Start signal	Command 0x40	Length	Status	CS
0x02	0x40	0x01	1 Byte	1 Byte

Status:

0x00: ACK received, only possible if MAC_NumRetrys is not 0; see chapter 8.14

0x01: no ACK received or requested

0x03: no data available (e.g., overwritten by wireless data reception)

7.2. Requesting parameters and actions

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

7.2.1. CMD_FWRELEASE_REQ

This command is used to get the firmware version of the module.

Format:

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

Response:

Start signal	Command 0x40	Length	firmware version	CS
0x02	0x4C	0x03	3 Bytes	1 Byte

The major version number is returned first, followed by the minor version number and the revision number.

7.2.2. CMD_SERIALNO_REQ

This command can be used to query the individual serial number of the module.

Format:

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

Response:

Start signal	Command 0x40	Length	Serial number	CS
0x02	0x4B	0x04	4 Bytes	1 Byte

Contrary to most other multi-byte parameters this function returns MSB first. Which means that the first returned byte of the Serial number is the Product-ID (PID).

Let's imagine the 4-byte return value was "0x11 0x00 0x31 0x01" then the corresponding decimal serial number is (as printed on the label of the module): 017. 012545.

The conversion will use PID 0x11 to create the decimal 17 with a prepended 0. Followed by 0x003101 which is 12545 in decimal. A "0" is prepended as the label is always using 6 decimal places for the second part of the serial number and 3 decimal places for the PID.

7.2.3. CMD_RESET_REQ

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

Format:

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

Response:

Start signal	Command 0x40	Length	Status	CS
0x02	0x45	0x01	1 Byte	1 Byte

Status:

0x00: Request successfully received and processed

7.2.4. CMD_RSSI_REQ

This command delivers the current RX level determined by the transceiver IC in the form of a two's complement.

Format:

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

Response:

Start signal	Command 0x40	Length	RX level	CS
0x02	0x4D	0x01	1 Byte	1 Byte

The value obtained in this way delivers the RX level $RSSI_{dBm}$ in dBm as follows:

1. Conversion of the hexadecimal value to a decimal $RSSI_{dec}$
2. If $RSSI_{dec} \geq 128$: $RSSI_{dBm} = (RSSI_{dec} - 256) / 2 - RSSI_{Offset}$
3. Otherwise ($RSSI_{dec} < 128$): $RSSI_{dBm} = RSSI_{dec} / 2 - RSSI_{Offset}$

$RSSI_{Offset}$ is a data-rate-dependent correction factor according to table 10

The relation between the calculated value and the physical RX level in dBm is not linear across the entire operating range and is displayed in figure 3.

Data rate	RSSI offset
2.4 kbps	71
10 kbps	69
250 kbps	72
500 kbps	72

Table 10: Data rate-dependent RSSI offset for Thalassa

7.2.5. CMD_ERRORFLAGS_REQ

This command returns internal error states.

Format:

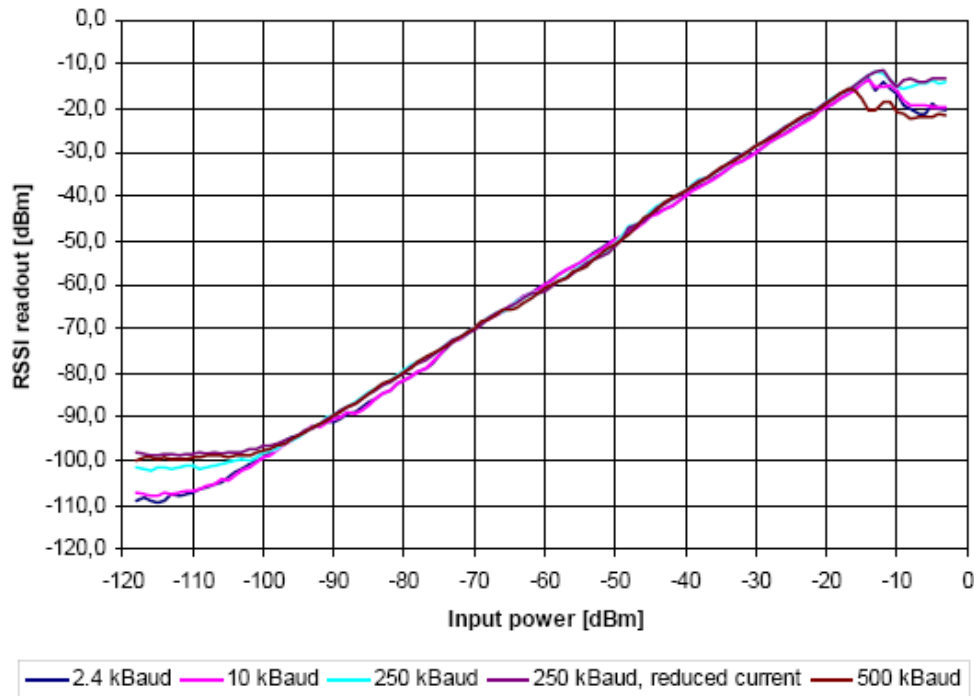


Figure 3: Relation between the RX level and the RSSI value read out for Thalassa

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

Response:

Start signal	Command	Length	error flags	CS
0x02	0x4E	0x02	2 Bytes	1 Byte

An error flag return value of "0" indicates that no error has occurred. The value is set back after the query and in the event of a reset. The meaning of the error flags is not described in detail in this context.

7.3. Modification of volatile parameters

This group contains all functions that will modify runtime settings while the module is running. These settings are all volatile and will be reset to defaults on a reset of the module.

7.3.1. CMD_SET_MODE_REQ

This command is used to toggle the operating mode, e.g. to exit the command mode (this is currently the only application). The return value will also be used as a start up indication if OpMode is set to 0x10 or if a change of the mode using the */config* pin was requested (when changing into command mode).

Format:

Start signal	Command	Length	Operating mode	CS
0x02	0x04	0x01	1 Byte	1 Byte

Response:

Start signal	Command	Length	New operating mode	CS
0x02	0x44	0x01	1 Byte	1 Byte

The following operating modes are defined:

- Mode 0 (0x00): transparent data transfer
- Mode 16 (0x10): command mode

7.3.2. CMD_SET_CHANNEL_REQ

This command is used to toggle the wireless channel. Unlike the non-volatile parameter `PHY_DefaultChannel` (see chapter 8.23), this is a volatile runtime parameter.

Format:

Start signal	Command	Length	Channel	CS
0x02	0x06	0x01	1 byte	1 Byte

Response:

Start signal	Command	Length	New channel	CS
0x02	0x46	0x01	1 Byte	1 Byte

The number of the newly set channel is returned. If the permissible frequency range is exceeded, the lowest and highest permissible channels are configured and returned.

7.3.3. CMD_SET_DESTNETID_REQ

This command serves to configure the destination network ID in addressing mode 2. Unlike the non-volatile parameter `MAC_DestNetID`, this is a volatile runtime parameter.

Format:

Start signal	Command	Length	Dest. NetID	CS
0x02	0x07	0x01	1 Byte	1 Byte

Response:

Start signal	Command	Length	Status	CS
0x02	0x47	0x01	1 Byte	1 Byte

Status:

0x00: Request successfully received and processed

7.3.4. CMD_SET_DESTADDR_REQ

This command serves to configure the destination address in addressing modes 1 and 2. Unlike the non-volatile parameter `MAC_DestAddrLSB` (see chapter 8.17), this is a volatile run-time parameter.

Format:

Start signal	Command	Length	Dest.addr	CS
0x02	0x08	0x01	1 Byte	1 Byte

Response:

Start signal	Command	Length	Status	CS
0x02	0x48	0x01	1 Byte	1 Byte

Status:

0x00: Request successfully received and processed

7.4. Modification of non-volatile parameters

The non-volatile parameters are also called UserSettings and are stored in a special flash location.

7.4.1. CMD_SET_REQ

This command enables direct manipulation of the parameters in the module's non-volatile memory. The respective parameters are accessed by means of the memory position described in table 12. Access outside these memory positions is not possible by means of this function.

You can modify individual or multiple consecutive parameters in the memory at the same time.

Parameters of 2 or more bytes have to be transferred LSB first. The list and description of all accessible non volatile parameters follows in chapter 7.4.2.

A `CMD_SET_REQ` shall always be preceded by a `CMD_GET_REQ` to check whether any parameter needs a change. This is recommended to reduce the number erase-cycles on the flash which are as a matter of fact limited.



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



Caution: To save the parameters in the flash memory of the module, the particular memory segment must first be flushed entirely and then restored from the RAM. If a reset occurs during this procedure (e.g. due to supply voltage fluctuations), the entire memory area may be destroyed. In this case, the module may no longer be operable, which means that the firmware must be re-installed via "ACC". Recommendation: First verify the configuration of the module with CMD_GET_REQ; write only if necessary.

Format:

Start signal	Command	Length	Memory Position	Number of bytes	Parameter	CS
0x02	0x09	1 Byte	1 Byte	1 Byte	(Number of bytes) Bytes	1 Byte

Response:

Start signal	Command	Length	Status	CS
0x02	0x49	0x01	1 Byte	1 Byte

Status:

0x00: Request successfully received and processed

0x01: Invalid memory position (write access to unauthorised area > 79 / 0x4F)

0x02: Invalid number of bytes to be written (write access to unauthorised area > 0x4F)

Example 1: Setting the number of wireless retries (parameter MAC_NumRetrys, memory position 20 according to table 12):

Start signal	Command	Length	Memory Position	Number of bytes	MAC_NumRetrys	CS
0x02	0x09	0x03	0x14	0x01	1 Byte	1 Byte

Example 2: Setting the 3 registers for the baud rate configuration (UART_MCTL, UART_BR0, and UART_BR1). According to table 12, UART_MCTL has the memory position 2:

Start signal	Command	Length	Memory Position	Number of bytes	UART MCTL	UART BR0	UART BR1	CS
0x02	0x09	0x05	0x02	0x03	1 Byte	1 Byte	1 Byte	1 Byte

7.4.2. CMD_GET_REQ

This command can be used to query individual or multiple non-volatile parameters (see chapter 7.4). The requested number of bytes starting from the specified memory position are returned.

You can query individual or multiple consecutive parameters in the memory at the same time. Parameters consisting of 2 or more bytes will typically be transferred LSB first order.

Format:

Start signal	Command	Length	Memory Position	Number of bytes	CS
0x02	0x0A	0x02	1 Byte	1 Byte	1 Byte

Response:

Start signal	Command	Length	Memory Position	Number of bytes	Parameter	CS
0x02	0x4A	1 Byte	1 Byte	1 Byte	(Number of bytes) Bytes	1 Byte

Write or read access to the memory area after the parameters documented in tabel 12 is blocked. The memory position and the number of bytes are limited accordingly. Thus, the last memory position that can be read out is 79 (0x4F).

7.5. Message overview

CMD	Message name	Short description	Chapter
0x00	CMD_DATA_REQ	Send data to configured address	7.1.1
0x01	CMD_DATAEX_REQ	Send data to specific address	7.1.2
0x02	CMD_DATARETRY_REQ	Resends data sent earlier with a CMD_DATA_REQ or CMD_DATAEX_REQ	7.1.4
0x04	CMD_SET_MODE_REQ	Set operation mode of module	7.3.1
0x05	CMD_RESET_REQ	Reset module	7.2.3
0x06	CMD_SET_CHANNEL_REQ	Change the RF channel	7.3.2
0x07	CMD_SET_DESTNETID_REQ	Set the destination network id	7.3.3
0x08	CMD_SET_DESTADDR_REQ	Set the destination address	7.3.4
0x09	CMD_SET_REQ	Change the UserSettings	7.4.1
0x0A	CMD_GET_REQ	Read the UserSettings	7.4.2
0x0B	CMD_SERIALNO_REQ	Read the serial number of the module	7.2.2
0x0C	CMD_FWRELEASE_REQ	Read the firmware version of the module	7.2.1
0x0D	CMD_RSSI_REQ	Request RSSI of last packet	7.2.4
0x0E	CMD_ERRORFLAGS_REQ	Read internal error states	7.2.5
0x40	CMD_DATA_CNF	Data has been sent	7.1.1
0x44	CMD_SET_MODE_CNF	operation mode of module has been updated	7.3.1
0x45	CMD_RESET_CNF	Reset request received	7.2.3
0x46	CMD_SET_CHANNEL_CNF	Channel has been updated	7.3.2
0x47	CMD_SET_DESTNETID_CNF	Destination network id has been updated	7.3.3
0x48	CMD_SET_DESTADDR_CNF	Destination address has been updated	7.3.4
0x49	CMD_SET_CNF	UserSettings have been updated	7.4.1
0x4A	CMD_GET_CNF	Return the requested UserSetting values	7.4.2
0x4B	CMD_SERIALNO_CNF	Return the serial number of the module	7.2.2
0x4C	CMD_FWRELEASE_CNF	Return the firmware version of the module	7.2.1
0x4D	CMD_RSSI_CNF	Return the requested RSSI value	7.2.4
0x0E	CMD_ERRORFLAGS_CNF	Return internal error states	7.2.5
0x81	CMD_DATAEX_IND	Data has been received	7.1.3

Table 11: Message overview

8. UserSettings - Module configuration values

8.1. Difference between volatile and non-volatile settings

The so-called UserSettings are stored permanently into the internal flash of the module. At start-up, these UserSettings are loaded as start values into the volatile settings ("RuntimeSettings"). Some of the RuntimeSettings can be modified by special commands (see chapter 7.3). These RuntimeSettings are lost and replaced by the UserSettings content when the module is restarted.



See chapter 7.3 and 7.4 for methods to change volatile and/or non-volatile settings.

The non-volatile UserSettings 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 UserSettings

The following chapters will give examples for the modification for many parameters using the commands `CMD_SET_REQ` and `CMD_GET_REQ`. The PC software ACC (version 3.4.3 or newer) can also be used to change non-volatile parameters.



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

Designation <small>Designation in ACC</small>	Summary	Permissible values	Default Tarvos	Memory position	Number of bytes
UART_CTL <small>Data format</small>	Control register for UART data format	See description	16	0	1
UART_TCTL	Control register for the baud rate (change only after consultation)	32	32	1	1
UART_MCTL <small>MCTL</small>	Control register for fine-adjusting the UART baud rate; concerning the calculation, see [1]	0 - 255	68	2	1
UART_BR0 <small>BR0</small>	Prescaler for setting the baud rate (LSB); concerning the calculation, see [1]	0 - 255	156	3	1
UART_BR1 <small>BR1</small>	Prescaler for setting the baud rate (MSB); concerning the calculation, see [1]	0 - 255	0	4	1
UART_PktMode <small>Packetizing mode</small>	Selects the packet generation method	0 or 1	0	5	1
UART_PktSize <small>Packet size</small>	Number of characters for transmission start with set packet size	1 - 128	128	7	1
UART_RTSLimit <small>/RTS limit</small>	Number of received characters after which /RTS responds	1 - 128	112	8	1
UART_ETXChar <small>ETX character</small>	End-of-text character used to mark data packets; reception of this character triggers wireless transmission	0 - 255	10	9	1
UART_Timeout <small>Timeout</small>	Timeout after the last character before the data received via UART are transmitted via wireless transmission (in milliseconds)	0 - 65535	5	12	2

Table 12: Overview of non-volatile configuration parameters - Part 1

Designation Designation in ACC	Summary	Permissible values	Default Tarvos	Memory position	Number of bytes
UART_DIDelay Data indication delay	Delay between the signalling by the /DATA_INDICATION pin and the start of the output via UART	0 - 65535	0	14	2
MAC_NumRetrys Retrys	Number of wireless retries	0 - 255	0	20	1
MAC_AddrMode Addressing mode	Addressing mode to use	0/1/2	0	21	1
MAC_DestNetID Dest. net ID	Default destination network ID	0 - 255	0	24	1
MAC_DestAddrLSB Dest. device address	Default destination address (LSB)	0 - 255	0	25	1
MAC_SourceNetID Local net ID	Own network ID	0 - 254	0	28	1
MAC_SourceAddrLSB Local device address	Own address (LSB)	0 - 254	0	29	1
MAC_ACKTimeout ACK timeout	Waiting time for wireless acknowledgement in milliseconds	0 - 65535	10	32	2
PHY_FIFOPrecharge FIFO precharge	Fill level of the FIFO before the transmission is launched (change only after consultation)	8 - 64	8	40	1
PHY_PAPower PA power	transmission output; value range depends on HF configuration	0 - 255	255	41	1
PHY_DefaultChannel Default channel	Utilised wireless channel after reset; value range depends on HF configuration	0 - 255	79	42	1
PHY_CCARSSILevel CCA RSSI level	Field strength level for "channel free" detection (not yet supported)	0 - 255	0	43	1
OpMode Mode	Operating mode	0.16	0	60	1

Table 13: Overview of non-volatile configuration parameters - Part 2

Designation Designation in ACC	Summary	Permissible values	Default Tarvos	Memory position	Number of bytes
MSP_RSELx DCO resistor sel.	Start value for control loop DCO calibration after system reset (change only after consultation)	0 - 7	7	61	1
MSP_DCOCTL DCO control	Start value for control loop DCO calibration after system reset (change only after consultation)	0 - 255	110	62	1
WOR_Prescaler Prescaler	Duration of a wake-up cycle for periodic wake-ups in WOR mode	0 - 65535	4096	64	2
WOR_Countdown Countdown	Number of wake-up cycles before waking up in WOR mode	0 - 65535	5	66	2
WOR_RXOnTime RX on time	Duration of RX readiness in WOR mode	0 - 65535	1000	68	2
CfgFlags Configuration flags (hex.)	Flags for setting various properties; see 10.29	0 - 65535	0 (0x0000)	72	2
Synch1 Synch1	Synch word MSB for transceiver (change only after consultation!)	0 - 255	211	76	1
Synch0 Synch0	Synch word LSB for transceiver (change only after consultation)	0 - 255	145	77	1

Table 14: Overview of non-volatile configuration parameters - Part 3

8.3. UART_CTL

The UART data format can be configured with the help of the upper 4 bits in this register. The meaning of these bits is described in table 15.

Bit no.	Description
0 to 3 (0x0F)	Reserved, must always be set to 0.
4 (0x10)	If this bit is set, the character length will be 8 bits, if not, it will be 7 bits.
5 (0x20)	This bit selects the number of stop bits . If this bit is set, 2 stop bits will be used, if not, 1 will be used.
6 (0x40)	If this bit is set, even parity will be used, if not, odd parity will be used. This bit is only used if bit 7 is set to '1'.
7 (0x80)	This bit enables the use of parity (if set).

Table 15: Setting the data format

8.4. UART_TCTL

This register selects the source for generating the UART clock speed. Currently, the only permissible value is 32.

8.5. UART_MCTL

The registers UART_MCTL, UART_BR0, and UART_BR1 can be used to set the UART baud rate. Concerning the calculation of the corresponding settings, see chapter *References*.

8.6. UART_BR0

The registers UART_MCTL, UART_BR0, and UART_BR1 can be used to set the UART baud rate. Concerning the calculation of the corresponding settings, see *References*.

8.7. UART_BR1

The registers UART_MCTL, UART_BR0, and UART_BR1 can be used to set the UART baud rate. Concerning the calculation of the corresponding settings, see *References*.

8.8. UART_PktMode

Selects the method used for generating packets for the transparent operating mode. Two methods have been implemented:

Mode 0: Sends when

- a. the timeout defined with UART_Timeout is reached, or
- b. the number of bytes defined with UART_PktSize is reached, or

- c. the transmission of the data is requested by means of the `/DATA_REQUEST` pin.

Mode 1: Sends when

- a. the character defined with `UART_ETXChar` is detected, or
- b. the number of bytes defined with `UART_PktSize` is reached, or
- c. the transmission of the data is requested by means of the `/DATA_REQUEST` pin.

Not used in the command mode.

8.9. UART_PktSize

Maximum number of bytes after which the wireless transmission of the data received via UART starts. Used in packet mode 0 as well as in packet mode 1.

Not used in the command mode.

8.10. UART_RTSLimit

Number of bytes after which the host system is prompted to interrupt the data transfer over `/RTS`. Necessary, because an immediate response to the `/RTS` signal may not take place (UART FIFO), depending on the host system.

8.11. UART_ETXChar

End-of-text character that triggers the transmission of the data received via UART. Only used in packet mode 1. During the wireless transmission, the ETX character is treated like a normal character.

Not used in the command mode.

8.12. UART_Timeout

Timeout in milliseconds after the last character has been received on UART before the wireless transmission of the data received via UART starts. Only used in packet mode 0.

In command mode, start of transmission is triggered by the well defined end of the command. The parameter `UART_Timeout` is used in this case to define the maximum delay between two consecutive characters. If this delay is reached (after detection of the STX character), the input buffer will be flushed.

8.13. UART_DIDelay

This parameter determines the delay in milliseconds between the signalling of incoming wireless data over the `/DATA_INDICATION` pin and the output of the data via UART. For example, this delay can be used to prepare a "sleeping" host system for receiving the data. From firmware version 3.2 also valid in the command mode.

8.14. MAC_NumRetrys

This UserSetting determines the maximum number of wireless transmission retries. If this parameter is set to a value other than zero, the receiver module will automatically be prompted to send a wireless acknowledgement ("ACK").

8.15. MAC_AddrMode

This setting defines the address mode of the module. The following modes have been implemented:

No addressing (mode 0): Each module receives the transmitted RF telegram and delivers the received data to the host system via UART. No address information is transmitted in the radio telegram.

1-byte address (mode 1): The receiving module only delivers the data to the host system via UART,

- if the 1 Byte destination address configured at the sender (MAC_DestAddrLSB, see chapter 8.17) corresponds to the 1 Byte source address of the receiver (MAC_SourceAddrLSB, see chapter 8.19) or
- if the destination broadcast address 255 was specified.

Both, the destination address and the source address, are transmitted in the wireless telegram (total = 2 Bytes).

2-Bytes address (mode 2): The receiving module only delivers the data to the host system via UART,

- if both the destination network id and the 1 Byte destination address configured at the sender correspond to the source addresses of the receiver (MAC_SourceNetID and MAC_SourceAddrLSB, see chapter 8.18 and chapter 8.19) or
- if the destination broadcast address 255 was specified.

A total of 4 Bytes of address information are transmitted in the wireless telegram.



Caution: The receiver and transmitter modules must be operated in the same addressing mode!



Caution: In addressing mode 0, the use of wireless acknowledgement may cause problems if several wireless modules are addressed simultaneously. In this case, all modules will simultaneously acknowledge the reception of the package. Thus, the wireless acknowledgement cannot be received by the sending module due to the collision, and the maximum number of retries will be sent.

8.16. MAC_DestNetID

Destination network address to use in addressing mode 2 after a reset. Can be modified with the command `CMD_SET_DESTNETID_REQ` at runtime (volatile). If the special broadcast ID and the broadcast address are set to 255, the packets will be received by all network participants.

8.17. MAC_DestAddrLSB

Destination address to use in addressing modes 1 and 2 after a reset. Can be modified with the command `CMD_SET_DESTADDR_REQ` at runtime (volatile). If the special broadcast address is set to 255 (in the case of addressing mode 2, broadcast ID also 255), the packets will be received by all network participants.

8.18. MAC_SourceNetID

Source network ID to be used in addressing mode 2. Setting the Source Net ID to Broadcast (255) is not allowed.

8.19. MAC_SourceAddrLSB

Source device address to be used in addressing modes 1 and 2. Setting the Source Address to Broadcast (255) is not allowed.

8.20. MAC_ACKTimeout

Time to wait for a wireless acknowledgement before a wireless retry is triggered. The values are automatically set in "ACC" depending on the configured HF data rate.

HF data rate	ACK timeout recommended
1.2 kbps	85 ms
2.4 kbps	45 ms
4.8 kbps	25 ms
10.0 kbps	15 ms
38.4 kbps	8 ms
76.8 kbps	6 ms
100.0 kbps	5 ms
250.0 kbps	5 ms

Table 16: Recommended timeouts

8.21. PHY_FIFOPrecharge

Number of bytes that are stored in the transceiver FIFO before actual transmission is launched. Required to prevent a buffer underrun for HF baud rates of more than 200 kbps. The values are automatically set in "ACC" depending on the configured HF data rate.

8.22. PHY_PAPower

HF output power of the module. The maximum permissible output depends on the utilised HF configuration. The default value already represents the maximum possible output.

8.23. PHY_DefaultChannel

Determines the wireless channel to use after a module reset. The permissible channels depends on the HF configuration. See chapter 10.

8.24. PHY_CCARSSILevel

Field strength used for "channel-free" detection (not implemented).

8.25. OpMode

Operating mode to be used after power up. Modes 0 (transparent data transfer) and 16 (command mode) can be selected here.

8.26. MSP_RSELx

Start value for a register used to set the processor speed. The speed is controlled continuously in the background. The frequency of the clock quartz is used for the calibration. The system start-up time can be optimised by means of a suitable configuration of this register (change only after consultation).

8.27. MSP_DCOCTL

Start value for a register used to set the processor speed. The speed is controlled continuously in the background. The frequency of the clock quartz is used for the calibration. The system start-up time can be optimised by suitably configuring this register (change only after consultation).

8.28. WOR_Prescaler

Defines the intervals in which the module in the sleep mode wakes up for a countdown (WOR_Countdown) until actual RX readiness. The interval (in seconds) is calculated as follows:

$$T_{\text{Prescaler}} = \frac{\text{WOR_Prescaler}}{4096}$$

8.29. WOR_Countdown

Number of prescaler cycles (countdown) until the module in the WOR mode enters the RX state. The duration until automatic RX readiness is calculated as follows:

$$T_{\text{WOR}} = \frac{\text{WOR_NumCycles} \cdot \text{WOR_Prescaler}}{4096}$$

8.30. WOR_RXOnTime

Defines the duration in milliseconds for which the module in the WOR is RX-ready after waking up before it returns to the sleep mode.

8.31. CfgFlags

16-bit bit field in which the use of individual pins or signals can be disabled. table17 presents a description of the respective flags.

Bit no.	Description
0 (0x0001)	If this bit is set, the function of the <i>/CONFIG</i> pin will be disabled. Subsequently, the unit can no longer be switched to the command mode via this pin.
1 (0x0002)	If this bit is set, the function of the <i>/DATA_REQUEST</i> pin will be disabled. Subsequently, data can no longer be sent using this pin.
2 (0x0004)	If this bit is set, the detection of the break signal on the UART interface will be suppressed. Subsequently, the unit can no longer be switched to the command mode by means of such a signal.
3 (0x0008)	If this bit is set, the status of the <i>SLEEP</i> and <i>TRX_DISABLE</i> pins will be ignored. Thus, the module can no longer be set to the various power-saving modes via these pins.
4 (0x0010)	Reserved
5 (0x0020)	If this bit is set, any character will be accepted as valid checksum in the command mode.
6 (0x0040)	Reserved
7 (0x0080)	If this bit is set, the address will not be resolved. The particular module can be used as packet sniffer to monitor a wireless link (from version 3.2).
9 to 15 (0xFF00)	Reserved

Table 17: Configuration flags



Warning: If both bit 0 and bit 2 are set, the module can no longer be set to the configuration mode. In this case, access to the operating parameters is only possible with the "ACC" program.

9. Timing parameters

9.1. Reset behaviour

Following a reset, a low level on the */RTS* pin signals that the module is ready for operation. However, the level is only valid after the time required for the internal initialisation of the processor (a couple of μs).

After this initialisation, */RTS* is first set to high. Then the processor rate is calibrated on the basis of the watch crystal. Only after this procedure is the module ready for operation.

9.1.1. Power-on reset

After setting the supply voltage and releasing the */RESET* pin (if wired), the period until the module is ready for operation greatly depends on the build time of the clock quartz. This procedure may take up to 1 second; typical values range from 200 to 400 ms.

Recommended procedure: Check for low level on */RTS* pin 2 ms after setting the prescribed supply voltage. Subsequently, an additional 100 μs is required until readiness.

9.1.2. Reset via */RESET* pin

To force a module restart by means of the */RESET* pin, it must first be set to low for at least 10 ms.

After the pin is released, */RTS* will switch to high after 100 μs at the latest. As the build-up time for the clock quartz does not apply in this case, the time until the module is ready for operation is reduced to a couple of ms. During this time, the processor rate will be calibrated, which takes anywhere between 2 and 20 ms depending on the supply voltage and temperature.

Recommended procedure: After the */RESET* pin is released, wait for 2 ms for low level on the */RTS* pin. Subsequently, an additional 100 μs are required until readiness.

9.2. Wake-up from the sleep mode

The switch-over to and from the sleep mode is also acknowledged via the */RTS* signal.

Recommended procedure: After the *SLEEP* pin is released, wait for low level on the */RTS* pin. Subsequently, an additional 100 μs are required until readiness.

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 (see table 8) occurs. Subsequently, the UART reception is interrupted (flow control with */RTS* signal), and the payload data is passed to the internal memory of the wireless transceiver (FIFO).

The wireless transmission starts as soon as the first data is available in the transceiver memory; during the ongoing wireless transmission, the remaining payload data is transmitted piece by piece.

On the receiver side, the FIFO is read as soon as an incoming packet is detected. In combination with a suitable packet generation method, this procedure enables the minimisation of the latencies resulting from buffering.

10. Radio parameters

The RF parameters (data rate, usable frequency range, etc.) can be configured with the PC program "ACC". Depending on the configured data rate, it can also be used to change additional non volatile parameters, e.g. MAC_ACKTimeout, PHY_DefaultChannel, or PHY_FIFOPrecharge. In the factory state, the HF data rate is 250 kbps.

The module Thalassa uses a channel spacing of approximately 500 kHz; the carrier frequency can be determined with the following formula:

$$F_c[\text{MHz}] = 2400.5 + (N_{\text{Channel}} \times 0.500)$$

Here, the channels 0 to 165 are permissible. See table 18 and 19 for an overview of usable frequencies.



Caution: Avoid the channels/frequencies (2405 MHz + n x 13MHz) marked in red, which merely provide a reduced range due to a property of the wireless IC.

Channel no.	Freq. [MHz]	Channel no.	Freq. [MHz]	Channel no.	Freq. [MHz]	Channel no.	Freq. [MHz]
0	2400.5	41	2421.0	82	2441.5	123	2462.0
1	2401.0	42	2421.5	83	2442.0	124	2462.5
2	2401.5	43	2422.0	84	2442.5	125	2463.0
3	2402.0	44	2422.5	85	2443.0	126	2463.5
4	2402.5	45	2423.0	86	2443.5	127	2464.0
5	2403.0	46	2423.5	87	2444.0	128	2464.5
6	2403.5	47	2424.0	88	2444.5	129	2465.0
7	2404.0	48	2424.5	89	2445.0	130	2465.5
8	2404.5	49	2425.0	90	2445.5	131	2466.0
9	2405.0	50	2425.5	91	2446.0	132	2466.5
10	2405.5	51	2426.0	92	2446.5	133	2467.0
11	2406.0	52	2426.5	93	2447.0	134	2467.5
12	2406.5	53	2427.0	94	2447.5	135	2468.0
13	2407.0	54	2427.5	95	2448.0	136	2468.5
14	2407.5	55	2428.0	96	2448.5	137	2469.0
15	2408.0	56	2428.5	97	2449.0	138	2469.5

Table 18: Frequency assignment Thalassa, part 1

Channel no.	Freq. [MHz]	Channel no.	Freq. [MHz]	Channel no.	Freq. [MHz]	Channel no.	Freq. [MHz]
16	2408.5	57	2429.0	98	2449.5	139	2470.0
17	2409.0	58	2429.5	99	2450.0	140	2470.5
18	2409.5	59	2430.0	100	2450.5	141	2471.0
19	2410.0	60	2430.5	101	2451.0	142	2471.5
20	2410.5	61	2431.0	102	2451.5	143	2472.0
21	2411.0	62	2431.5	103	2452.0	144	2472.5
22	2411.5	63	2432.0	104	2452.5	145	2473.0
23	2412.0	64	2432.5	105	2453.0	146	2473.5
24	2412.5	65	2433.0	106	2453.5	147	2474.0
25	2413.0	66	2433.5	107	2454.0	148	2474.5
26	2413.5	67	2434.0	10	8 2454.5	149	2475.0
27	2414.0	68	2434.5	109	2455.0	150	2475.5
28	2414.5	69	2435.0	110	2455.5	151	2476.0
29	2415.0	70	2435.5	111	2456.0	152	2476.5
30	2415.5	71	2436.0	112	2456.5	153	2477.0
31	2416.0	72	2436.5	113	2457.0	154	2477.5
32	2416.5	73	2437.0	114	2457.5	155	2478.0
33	2417.0	74	2437.5	115	2458.0	156	2478.5
34	2417.5	75	2438.0	116	2458.5	157	2479.0
35	2418.0	76	2438.5	117	2459.0	158	2479.5
36	2418.5	77	2439.0	118	2459.5	159	2480.0
37	2419.0	78	2439.5	119	2460.0	160	2480.5
38	2419.5	79	2440.0	120	2460.5	161	2481.0
39	2420.0	80	2440.5	121	2461.0	162	2481.5
40	2420.5	81	2441.0	122	2461.5	163	2482.0
						164	2482.5
						165	2483.0

Table 19: (continue) Frequency assignment Thalassa

11. Battery powered operation

By way of the *SLEEP* and *TRX_DISABLE* pins, the module can be set to various power-saving operating states. These states are described below. Table 20 presents an overview of the available options.

	<i>TRX_DISABLE</i> low	<i>TRX_DISABLE</i> high
<i>SLEEP</i> low	Active mode , wireless and UART communication possible	Stand-by , only UART communication possible
<i>SLEEP</i> high	WOR mode, module wakes up and is ready to receive	Sleep mode, neither UART nor wireless communication possible

Table 20: Power consumption control

11.1. Active mode

In this operating state, the module is permanently ready to receive and forward data via UART or wireless transmission. The module will only switch to one of the other power-saving modes after processing any pending data transmission, i.e. */RTS* must be low.

11.2. Stand-by

In this operating state, the module's transceiver is disabled. Wireless reception is not possible, but transmission of data is possible.

11.3. WOR mode

The module automatically wakes up at configurable intervals and remains ready to receive for a configurable time. In this connection, refer to the parameters *WOR_Prescaler*, *WOR_Countdown*, and *WOR_RXOnTime*.

11.4. Sleep mode

This is the module state with the lowest power consumption. Wireless and UART communication are not possible. The module switches to one of the other operating modes when it detects a falling edge on the *SLEEP* pin.

12. Custom firmware

12.1. Custom configuration of standard firmware

The configuration of the standard firmware includes adoption of the non-volatile Usersettings (see chapter 8) to customer requirements and creating a customized product on base of 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.

12.2. 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 I²C 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.

12.3. 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 side.

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.

12.4. Contact for firmware requests

Please contact your local field sales engineer (FSE) or wireless-sales@we-online.com for quotes regarding this topics.

13. Firmware updates

All products will experience maintenance, security and/or feature updates from time to time. For the standard products these maintained via the PCN process.

Customers can request the creation of a customized product including a "firmware freeze" to ensure that they will receive their verified product even if the standard product is updated.

13.1. Firmware flashing using the production interface

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

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

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



Any certification, declaration, listing and qualification becomes invalid if the production interface is used by a customer. Some products, in their documentation, state exceptions to this invalidation under certain conditions.

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

13.2. Update via ACC Software and UART

Only the *UTDX*, *URXD* and *GND* signals are needed for this connection. A suitable adapter/converter is required for a PC connection (e.g. the FTDI TTL-323R-3V3 UART to USB converter).



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



Users must make sure that their host is not accessing the Thalassa RX line (i.e. pulling it HIGH or LOW) as that will prevent ACC to access the module.

As long as our standard firmware is running on the module, it can be updated with the PC utility "ACC" via the serial interface. If the module is not directly connected to a PC, then at least the UART should be made accessible, e.g. by means of a suitable connector. ACC can be downloaded from the Würth Elektronik eiSos homepage: ACC.

14. Firmware history

Version 3.0 "Production"

- First product release

Version 3.1 "Production"

- Bug fix "break detection"

Version 3.2 "Production"

- Bug fix UART_DIDelay in command mode
- Sniffer mode via CfgFlags

15. Design in guide

15.1. Advice for schematic and layout

For users with less RF experience it is advisable to closely copy the relating evaluation 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 VCC 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.).

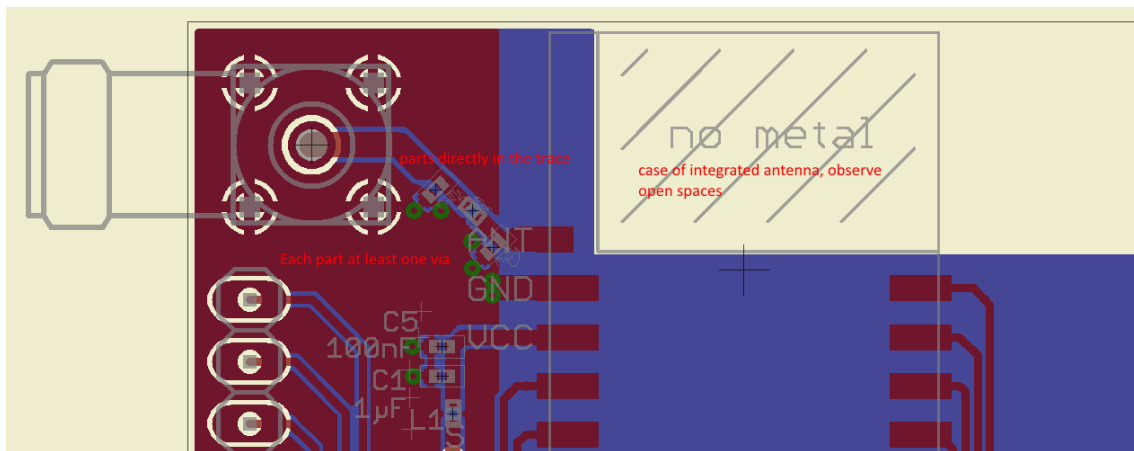


Figure 4: Layout

- 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 evaluation 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.

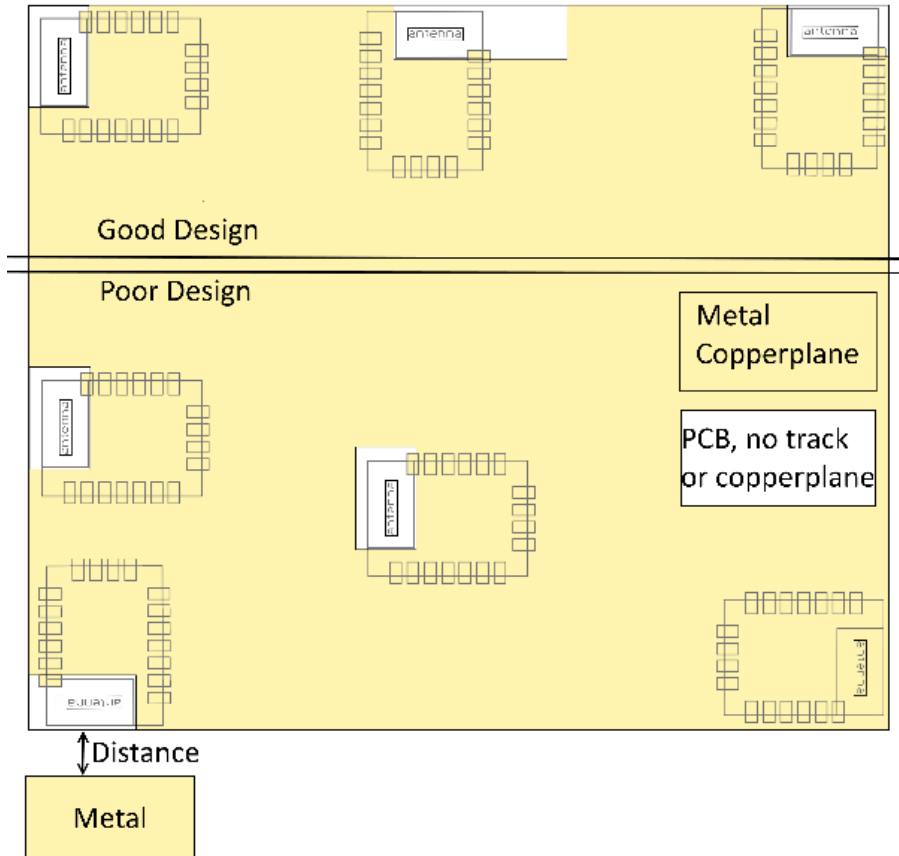


Figure 5: Placement of the module with integrated antenna

15.2. Dimensioning of the micro strip antenna line

The antenna track has to be designed as a 50Ω feed line. The width W for a micro strip can

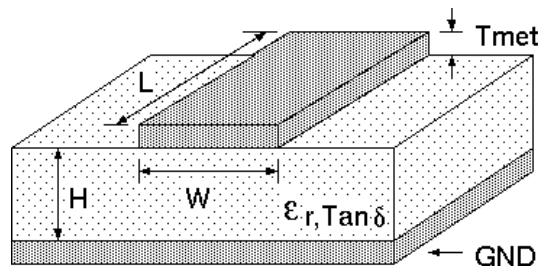


Figure 6: Dimensioning the antenna feed line as micro strip

be calculated using the following equation:

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

Example:

A FR4 material with $\epsilon_r = 4.3$, a height $H = 1000 \mu\text{m}$ and a copper thickness of $T_{\text{met}} = 18 \mu\text{m}$ will lead to a trace width of $W \sim 1.9 \text{ mm}$. 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 $3 \times W$ 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.

15.3. 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 $\lambda/10$ (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 behaviour of the antenna, but will anyway produce shadowing.



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



The choice of antenna might have influence on the safety requirements.

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

15.3.1. Wire antenna

An effective antenna is a $\lambda/4$ 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 $\lambda/4$ radiator has approximately 40Ω input impedance. Therefore, matching is not required.

15.3.2. 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.

15.3.3. 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 evaluation 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.

15.3.4. Antennas provided by Würth Elektronik eiSos

15.3.4.1. 2600130021 - Himalia - 2.4 GHz dipole antenna



Figure 7: 2.4 GHz dipole-antenna

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

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

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

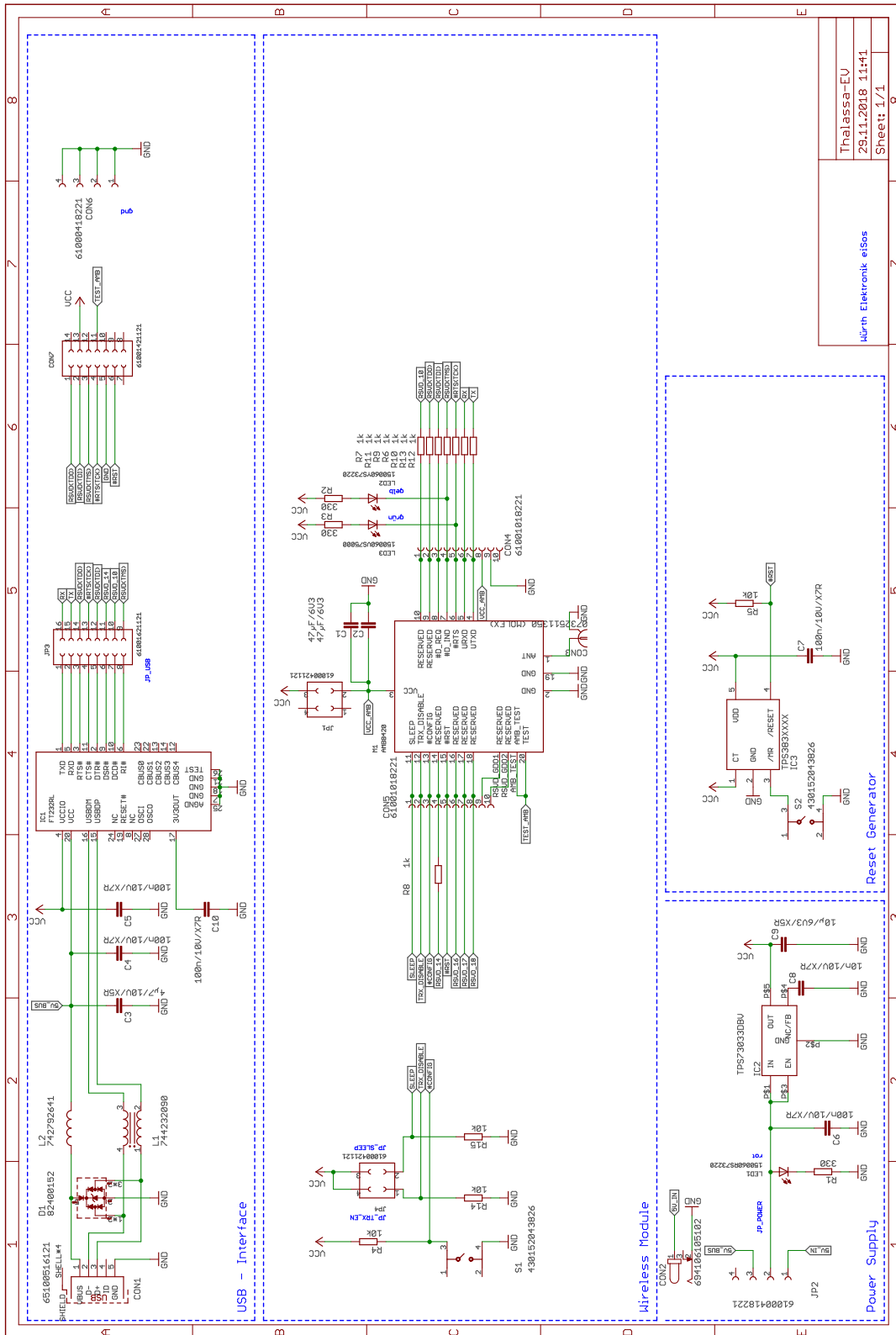
16. Reference design

Thalassa was tested and certified on the corresponding Thalassa evaluation board. For the compliance with the EU directive 2014/53/EU Annex I, the evaluation board serves as reference design.

This is no discrepancy due to the fact that the evaluation board itself does not fall within the scope of the EU directive 2014/53/EU Annex I as the module is tested on the evaluation board, which is also the recommended use.

Further information concerning the use of the evaluation board can be found in the manual of the Thalassa evaluation board.

16.1. Schematic



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Würth Elektronik eiSos

Figure 8: Circuit diagram

16.2. Layout

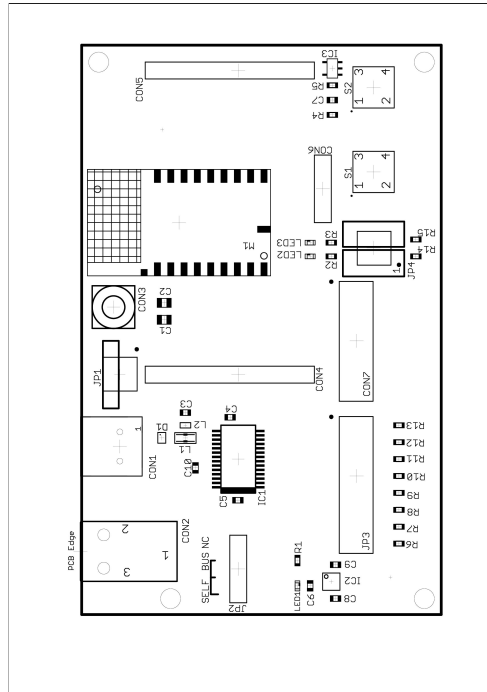


Figure 9: Assembly diagram

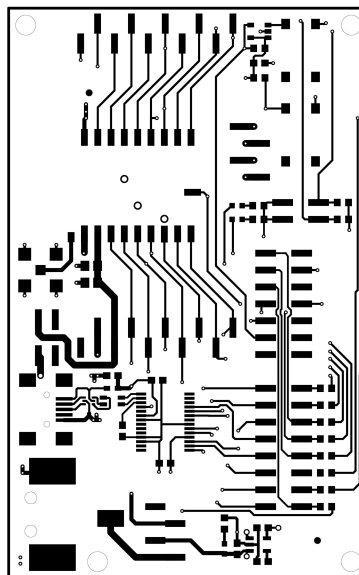


Figure 10: Top Layer

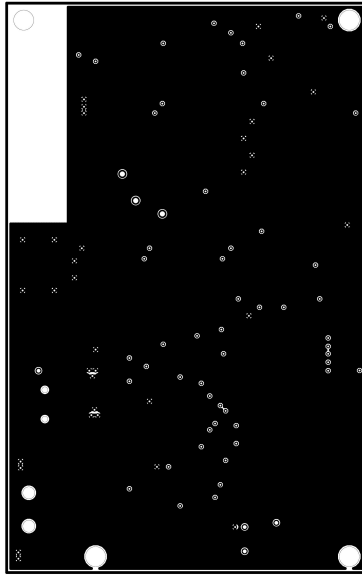


Figure 11: Internal Layer 2

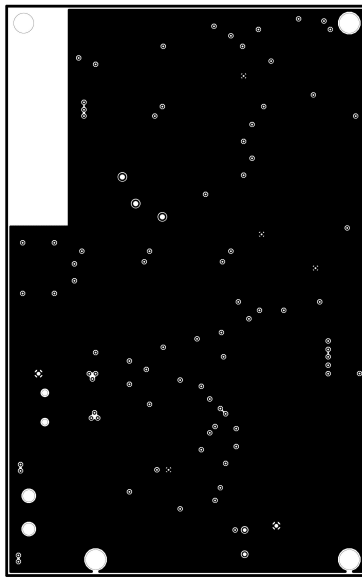


Figure 12: Internal Layer 3

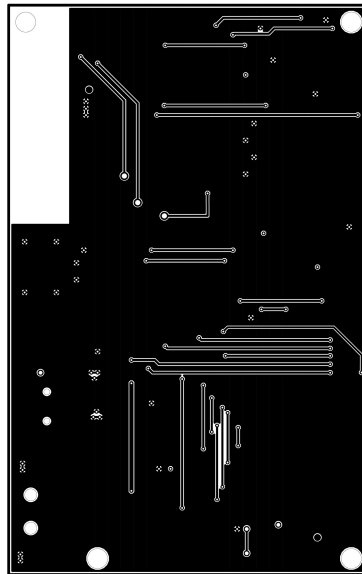


Figure 13: Bottom Layer

17. Manufacturing information

17.1. 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.

17.2. Soldering

17.2.1. 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	$T_{S \text{ Min}}$	150 °C
Preheat temperature Max	$T_{S \text{ Max}}$	200 °C
Preheat time from $T_{S \text{ Min}}$ to $T_{S \text{ Max}}$	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	see table below
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 21: Classification reflow soldering profile, Note: refer to IPC/JEDEC J-STD-020E

Package thickness	Volume mm ³ <350	Volume mm ³ 350-2000	Volume mm ³ >2000
< 1.6 mm	260 °C	260 °C	260 °C
1.6 mm - 2.5 mm	260 °C	250 °C	245 °C
> 2.5 mm	250 °C	245 °C	245 °C

Table 22: Package classification reflow temperature, PB-free assembly, 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.

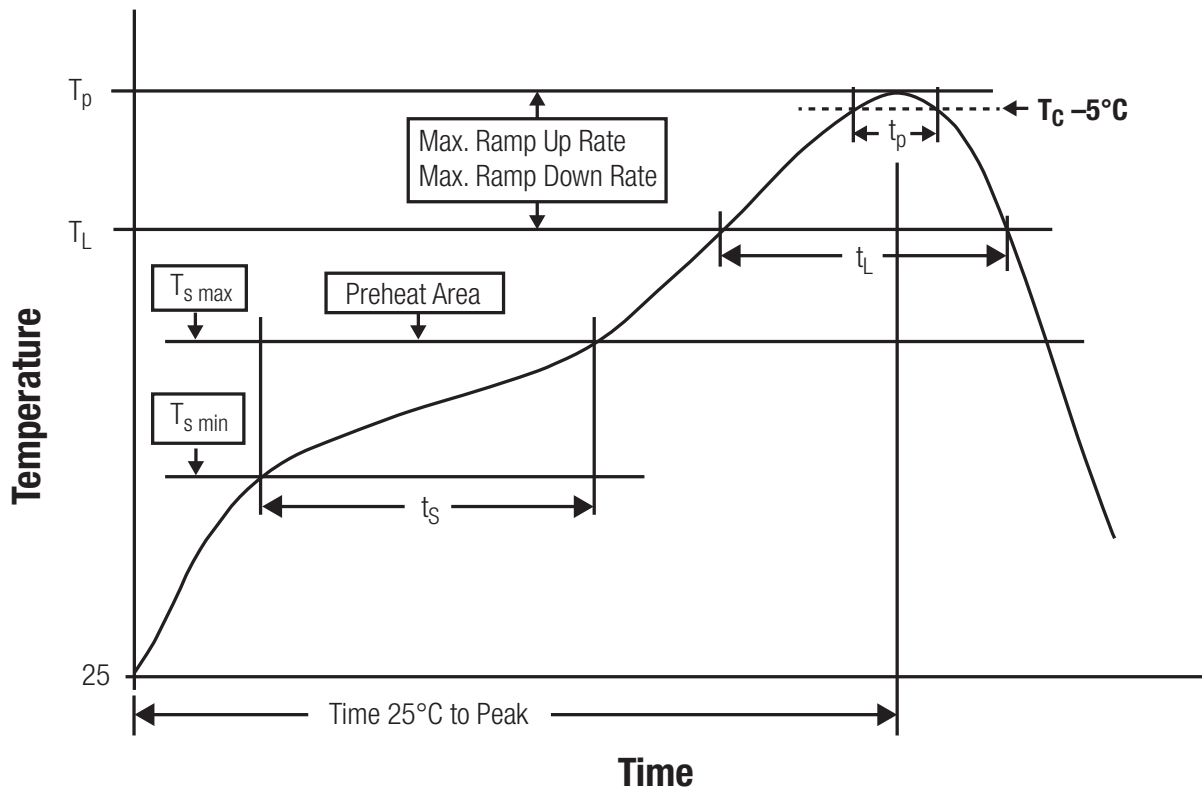


Figure 14: Reflow soldering profile

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

17.2.2. 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.

17.2.3. Other notations

- Conformal coating of the product will result in the loss of warranty. The RF shields will not protect the part from low-viscosity coatings.
- 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.

17.3. 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.

17.4. 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, as for example the radio module Thebe-II, generate a high amount of warmth while transmitting. The manufacturer of the end device must take care of potentially necessary actions for his application.

18. Physical dimensions

18.1. Dimensions

Dimensions
16 x 27.5 x 3.2 mm

Table 23: Dimensions

18.2. Weight

Weight
<2g

Table 24: Weight

18.3. Module drawing

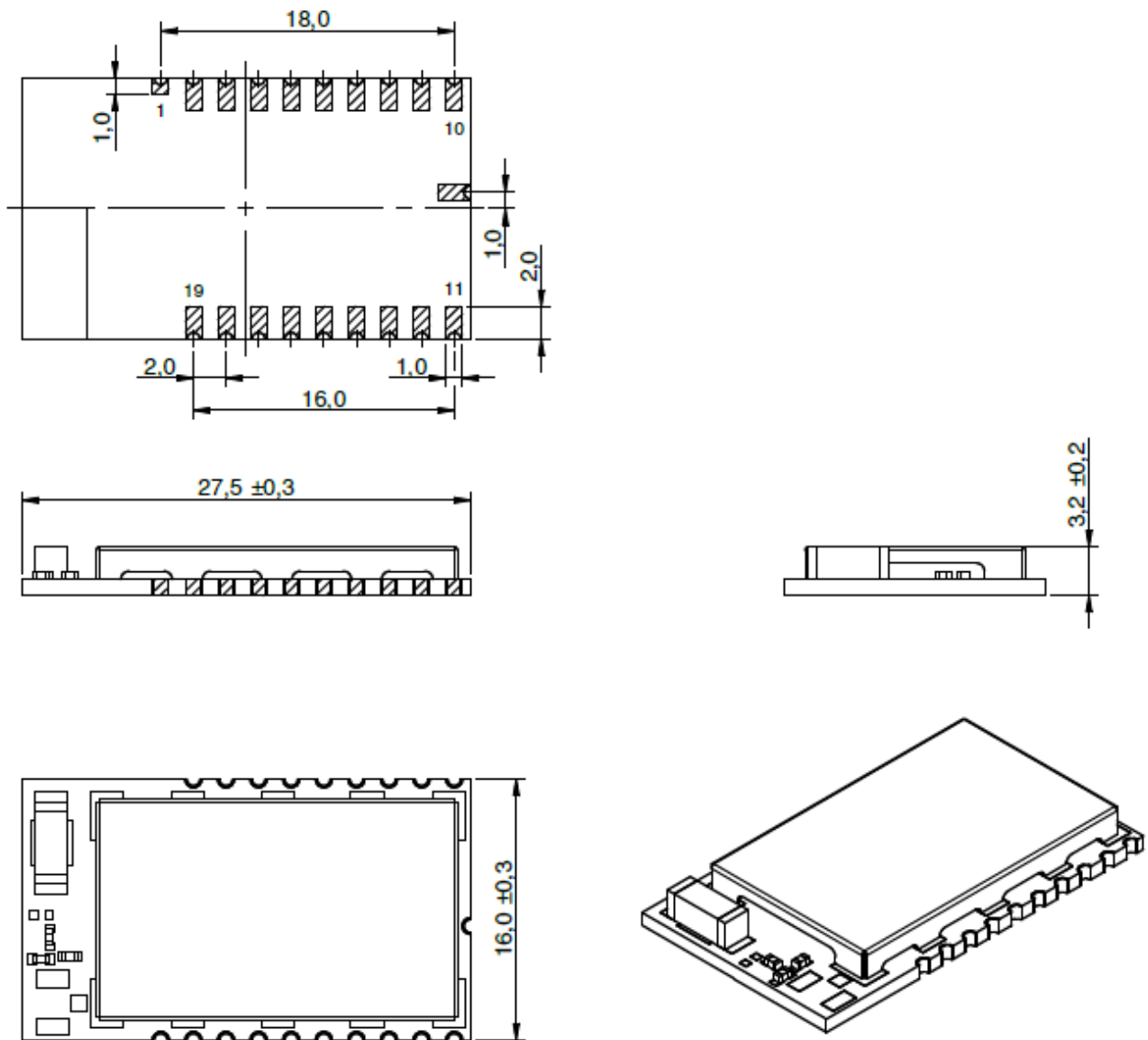


Figure 15: Module dimensions [mm]

18.4. Footprint

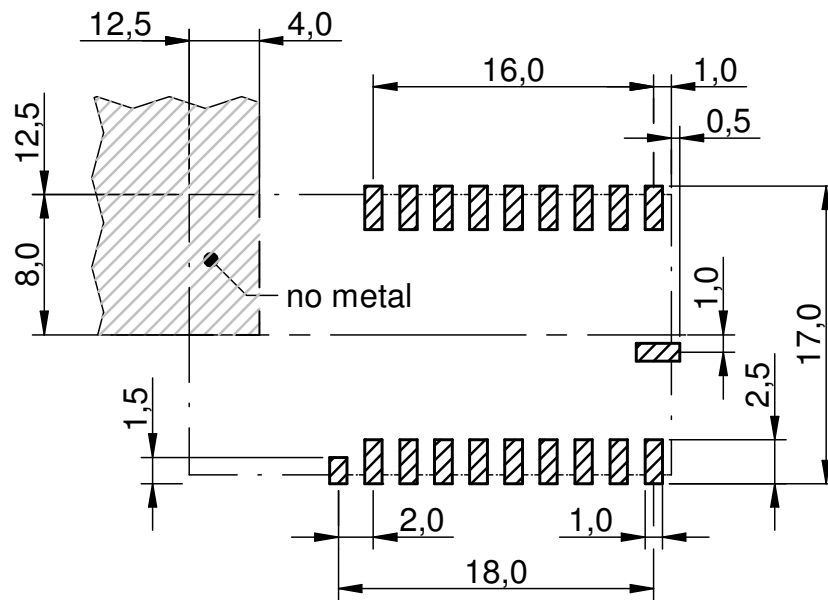


Figure 16: Footprint and dimensions [mm]

When designing the carrier board layout for Tarvos/Thalassa the following must be taken into consideration:

- As shown in Figure 7, avoid having any ground or metal in the ceramic antenna area (none at all on the right side and at least 10 mm distance above if it cannot be avoided).
- The top layer of the carrier board should be kept free of tracks/vias underneath the Thalassa, as it is merely coated with solder mask (unspecified insulation properties) and the bottom of the Thalassa has uncovered vias.
- Tracks should only be laid under the Tarvos in multi-layer structures in which layer 2 serves as ground layer that shields the underlying layers.



Caution: If the spacing of 12 mm between the pad rows is not complied with, there will be a substantial short-circuit risk of VCC against *GND*!



Caution: The not described Pads, the Pad at the Thalassa facing away from the antenna are only for manufacturing process and must not be connected.

18.5. Antenna free area

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

19. Marking

19.1. 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.

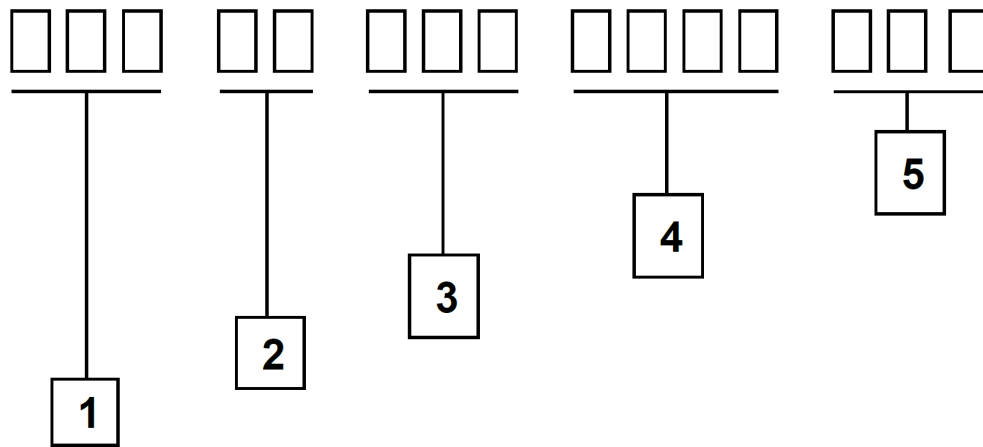


Figure 17: Lot number structure

Block	Information	Example(s)
1	eiSos internal, 3 digits	439
2	eiSos internal, 2 digits	01
3	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	Firmware version, 3 digits	V3.2 = 302, V5.13 = 513

Table 25: 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.

19.2. General labeling information

The module labels may include the following fields:

- Manufacturer identification WE, Würth Elektronik or Würth Elektronik eiSos
- WE Order Code and/or article alias
- Serial number or MAC address
- Certification identifiers (CE, FCC ID, IC, ARIB,...)
- Bar code or 2D code containing the serial number or MAC address

If the module is using a Serial Number, this serial number includes the product ID (PID) and an 6 digit number. The 6 rightmost digits represent the 6 digit number, followed by the product ID (2 or 3 digits). Some labels indicate the product ID with a "." as marker in-between the 2 fields. The PID and the 6 digit number form together a unique serial number for any wireless connectivity product.

In case of small labels, the 3 byte manufacturer identifier (0x0018DA) of the MAC address is not printed on the labels. The 3 byte counter printed on the label can be used with this 0018DA to produce the full MAC address by appending the counter after the manufacturer identifier.



Figure 18: Label of the Thalassa

20. 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 0dBm for external antenna and -6dBm for internal antenna.
- The total amount of capacitance of all capacitors is 501.41nF.
- The total amount of inductance of all inductors is 9.9nH.

21. References

- [1] To calculate the baud rate registers UART_MCTL, UART_BR0, and UART_BR1, the "Baud Rate Calculator" tool is integrated in ACC. To configure a standard baud rate, ACC provides a drop-down field with automatic calculation and parameterisation of the baud rate registers.
- [2] "CC1101 Single-Chip Low-Cost Low-Power RF Transceiver (Rev. B)", Texas Instruments
- [3] "CC2500 Single-Chip Low-Cost Low-Power RF Transceiver (Rev. B)", Texas Instruments
- [4] "Tarnos Data Sheet", Würth Elektronik eiSos
- [5] "Thalassa Data Sheet", Würth Elektronik eiSos

22. Regulatory compliance information

22.1. Important notice EU

The use of RF frequencies is limited by national regulations. The Thalassa has been designed to comply with the R&TTE directive 1999/5/EC and the RED directive 2014/53/EU of the European Union (EU).

The Thalassa can be operated without notification and free of charge in the area of the European Union. However, according to the R&TTE / RED directive, restrictions (e.g. in terms of duty cycle or maximum allowed RF power) may apply.

22.2. Important notice FCC

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

The Thalassa can be operated without notification and free of charge in the area of the United States of America. However, according to the FCC Part 15, restrictions (e.g. in terms of maximum allowed RF power and antenna) may apply.

22.3. Conformity assessment of the final product

The Thalassa is a subassembly. It is designed to be embedded into other products (products incorporating the Thalassa are henceforward referred to as "final products").

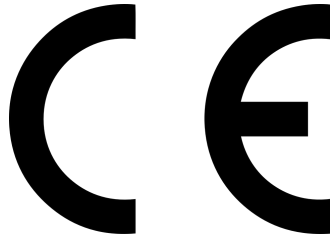
It is the responsibility of the manufacturer of the final product to ensure that the final product is in compliance with the essential requirements of the underlying national radio regulations. The conformity assessment of the subassembly Thalassa carried out by Würth Elektronik eiSos does not replace the required conformity assessment of the final product.

22.4. 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.

22.5. EU Declaration of conformity



EU DECLARATION OF CONFORMITY

Radio equipment: 2606031021000 & 2606031121000

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: 2606031021000, 2606031121000 & 2606031321000

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 2015/863.. Following harmonised norms or technical specifications have been applied:

EN 300 440 V2.1.1 (2017-03)
EN 301 489-1 V2.2.3 (2019-11)
EN 301 489-3 V2.1.1 (2019-03)
EN 62479 : 2010
EN 62368-1: 2014/AC: 2015/A11: 2017

i.A. G. Eslerdt

Trier, 25th of March 2021
Place and date of issue

22.6. FCC Compliance Statement

FCC ID: R7TAMB2524

This device complies with Part 15 of the FCC Rules.

Operation is subject to the following two conditions:

- (1) this device may not cause harmful interference, and
 - (2) this device must accept any interference received, including interference that may cause undesired operation.
- (FCC 15.19)

Modifications (FCC 15.21)

Caution: Changes or modifications for this equipment not expressly approved by Würth Elektronik eiSos may void the FCC authorization to operate this equipment.

22.7. IC Compliance Statement

Certification Number: 5136A-AMB2524

PMN: AMB2524

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

22.8. FCC and IC requirements to OEM integrators

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

The host product with the module installed must be evaluated for simultaneous transmission requirements.

- The users manual for the host product must clearly indicate the operating requirements and conditions that must be observed to ensure compliance with current FCC/IC RF exposure guidelines.
- To comply with FCC/IC regulations limiting both maximum RF output power and human exposure to RF radiation, the maximum antenna gain including cable loss in a mobile-only exposure condition must not exceed 2dBi.
- A label must be affixed to the outside of the host product with the following statements:
This device contains FCCID: R7TAMB2524
This equipment contains equipment certified under ICID: 5136A-AMB2524

- The final host / module combination may also need to be evaluated against the FCC Part 15B criteria for unintentional radiators in order to be properly authorized for operation as a Part 15 digital device.
- If the final host / module combination is intended for use as a portable device (see classifications below) the host manufacturer is responsible for separate approvals for the SAR requirements from FCC Part 2.1093 and RSS-102.

OEM requirements:

The OEM must ensure that the following conditions are met.

- End users of products, which contain the module, must not have the ability to alter the firmware that governs the operation of the module. The agency grant is valid only when the module is incorporated into a final product by OEM integrators.
- The end-user must not be provided with instructions to remove, adjust or install the module.
- The Original Equipment Manufacturer (OEM) must ensure that FCC labeling requirements are met. This includes a clearly visible label on the outside of the final product. Attaching a label to a removable portion of the final product, such as a battery cover, is not permitted.
- The label must include the following text:
Contains FCC ID: R7TAMB2524
The enclosed device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:
(i.) this device may not cause harmful interference and
(ii.) this device must accept any interference received, including interference that may cause undesired operation.

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

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

22.9. Thalassa

The module variants HVIN AMB2524 and AMB2524-1 collected in the PMN AMB2524 are identical in enclosure, appearance, PCB design and bands/technologies. The only difference is, that in AMB2524 an integrated chip antenna is used and for the AMB2524-1 an external $\lambda/4$ antenna is used.

23. Important notes

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

23.1. General customer responsibility

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

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

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

23.3. Best care and attention

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

23.4. Customer support for product specifications

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

23.5. 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 field sales engineer, the internal sales person or the technical support team in charge should be contacted. The basic responsibility of the customer as per section 23.1 and 23.2 remains unaffected. All wireless connectivity module driver software "wireless connectivity SDK" and its source codes as well as all PC software tools are not subject to the Product Change Notification information process.

23.6. 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 field sales engineer 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.

23.7. Property rights

All the rights for contractual products produced by Würth Elektronik eiSos GmbH & Co. KG on the basis of ideas, development contracts as well as models or templates that are subject to copyright, patent or commercial protection supplied to the customer will remain with Würth Elektronik eiSos GmbH & Co. KG. Würth Elektronik eiSos GmbH & Co. KG does not warrant or represent that any license, either expressed or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, application, or process in which Würth Elektronik eiSos GmbH & Co. KG components or services are used.

23.8. 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.

24. Legal notice

24.1. Exclusion of liability

Würth Elektronik eiSos GmbH & Co. KG considers the information in this document to be correct at the time of publication. However, Würth Elektronik eiSos GmbH & Co. KG reserves the right to modify the information such as technical specifications or functions of its products or discontinue the production of these products or the support of one of these products without any written announcement or notification to customers. The customer must make sure that the information used corresponds to the latest published information. Würth Elektronik eiSos GmbH & Co. KG does not assume any liability for the use of its products. Würth Elektronik eiSos GmbH & Co. KG does not grant licenses for its patent rights or for any other of its intellectual property rights or third-party rights.

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The customer bears the responsibility for compliance of systems or units, in which Würth Elektronik eiSos GmbH & Co. KG products are integrated, with applicable legal regulations. Customer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of Würth Elektronik eiSos GmbH & Co. KG components in its applications, notwithstanding any applications-related information or support that may be provided by Würth Elektronik eiSos GmbH & Co. KG. Customer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences lessen the likelihood of failures that might cause harm and take appropriate remedial actions. The customer will fully indemnify Würth Elektronik eiSos GmbH & Co. KG and its representatives against any damages arising out of the use of any Würth Elektronik eiSos GmbH & Co. KG components in safety-critical applications.

24.3. Trademarks

AMBER wireless is a registered trademark of Würth Elektronik eiSos GmbH & Co. KG. All other trademarks, registered trademarks, and product names are the exclusive property of the respective owners.

24.4. Usage restriction

Würth Elektronik eiSos GmbH & Co. KG products have been designed and developed for usage in general electronic equipment only. This product is not authorized for use in equipment where a higher safety standard and reliability standard is especially required or where a failure of the product is reasonably expected to cause severe personal injury or death,

unless the parties have executed an agreement specifically governing such use. Moreover, Würth Elektronik eiSos GmbH & Co. KG products 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. Würth Elektronik eiSos GmbH & Co. KG must be informed about the intent of such usage before the design-in stage. In addition, sufficient reliability evaluation checks for safety must be performed on every electronic component, which is used in electrical circuits that require high safety and reliability function or performance. By using Würth Elektronik eiSos GmbH & Co. KG products, the customer agrees to these terms and conditions.

25. License terms

This License Terms will take effect upon the purchase and usage of the Würth Elektronik eiSos GmbH & Co. KG wireless connectivity products. You hereby agree that this license terms is applicable to the product and the incorporated software, firmware and source codes (collectively, "Software") made available by Würth Elektronik eiSos in any form, including but not limited to binary, executable or source code form.

The software included in any Würth Elektronik eiSos wireless connectivity product is purchased to you on the condition that you accept the terms and conditions of this license terms. You agree to comply with all provisions under this license terms.

25.1. Limited license

Würth Elektronik eiSos hereby grants you a limited, non-exclusive, non-transferable and royalty-free license to use the software and under the conditions that will be set forth in this license terms. You are free to use the provided Software only in connection with one of the products from Würth Elektronik eiSos to the extent described in this license terms. You are entitled to change or alter the source code for the sole purpose of creating an application embedding the Würth Elektronik eiSos wireless connectivity product. The transfer of the source code to third parties is allowed to the sole extent that the source code is used by such third parties in connection with our product or another hardware provided by Würth Elektronik eiSos under strict adherence of this license terms. Würth Elektronik eiSos will not assume any liability for the usage of the incorporated software and the source code. You are not entitled to transfer the source code in any form to third parties without prior written consent of Würth Elektronik eiSos.

You are not allowed to reproduce, translate, reverse engineer, decompile, disassemble or create derivative works of the incorporated Software and the source code in whole or in part. No more extensive rights to use and exploit the products are granted to you.

25.2. Usage and obligations

The responsibility for the applicability and use of the Würth Elektronik eiSos wireless connectivity product with the incorporated Firmware in a particular customer design is always solely within the authority of the customer. Due to this fact, it is up to you to evaluate and investigate, where appropriate, and to decide whether the device with the specific product characteristics described in the product specification is valid and suitable for your respective application or not.

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.

25.3. Ownership

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

25.4. 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.

25.5. Disclaimer of warranty

THE FIRMWARE IS PROVIDED "AS IS". YOU ACKNOWLEDGE THAT WÜRTH ELEKTRONIK EISOS MAKES NO REPRESENTATIONS AND WARRANTIES OF ANY KIND RELATED TO, BUT NOT LIMITED TO THE NON-INFRINGEMENT OF THIRD PARTIES' INTELLECTUAL PROPERTY RIGHTS OR THE MERCHANTABILITY OR FITNESS FOR YOUR INTENDED PURPOSE OR USAGE. WÜRTH ELEKTRONIK EISOS DOES NOT WARRANT OR REPRESENT THAT ANY LICENSE, EITHER EXPRESS OR IMPLIED, IS GRANTED UNDER ANY PATENT RIGHT, COPYRIGHT, MASK WORK RIGHT, OR OTHER INTELLECTUAL PROPERTY RIGHT RELATING TO ANY COMBINATION, MACHINE, OR PROCESS IN WHICH THE WÜRTH ELEKTRONIK EISOS' PRODUCT WITH THE INCORPORATED FIRMWARE IS USED. INFORMATION PUBLISHED BY WÜRTH ELEKTRONIK EISOS REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE A LICENSE FROM WÜRTH ELEKTRONIK EISOS TO USE SUCH PRODUCTS OR SERVICES OR A WARRANTY OR ENDORSEMENT THEREOF.

25.6. Limitation of liability

Any liability not expressly provided by Würth Elektronik eiSos shall be disclaimed. You agree to hold us harmless from any third-party claims related to your usage of the Würth Elektronik eiSos' products with the incorporated Firmware, software and source code. Würth

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25.7. Applicable law and jurisdiction

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25.9. Miscellaneous

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We recommend you to be updated about the status of new firmware and software, which is available on our website or in our data sheet and manual, and to implement new software in your device where appropriate.

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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 26: CRC8 Test Vectors

B. Example codes for host integration

The following code is an example implementation of a function to transmit data using a 1 Byte length field in the command frame. For demonstration reasons the Tarvos-III has been taken. The full function codes of all radio modules are available in the Wireless Connectivity SDK (www.we-online.de/wco-SDK).

```
#define CMD_PAYLOAD_MAX 224
typedef struct {
    uint8_t Stx;
    uint8_t Cmd;
    uint8_t Length;
    uint8_t Data[CMD_PAYLOAD_MAX+1]; /* +1 for CRC8 */
} CMD_Frame_t;
#define CMD_OFFSET_TO_DATAFIELD 3
#define CMD_OVERHEAD (CMD_OFFSET_TO_DATAFIELD+1)

bool TarvosIII_Transmit(uint8_t *PayloadP, uint8_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 = TarvosIII_CMD_DATA_REQ; /* 0x00 */
    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, TarvosIII_CMD_DATA_CNF, CMD_Status_Success,
        true);
}
```

Code 2: Example function implementation for radio modules with 1 byte length field



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